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INTERNATIONAL STANDARD

colour inside

Lightning and surge voltage protection for photovoltaic (PV) power supply systems

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CONTENTS

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IEC TR 63227:2020
https://standards.iteh.ai/catalog/standards/sist/36857bdf-1870-4427-96b0-a05f14c02591/iec-tr-63227-2020

iTeh STANDARD PREVIEW
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IEC TR 63227:2020
https://standards.iteh.ai/catalog/standards/sist/36857bdf-1870-4427-96b0-a05f14c02591/iec-tr-63227-2020

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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LIGHTNING AND SURGE VOLTAGE PROTECTION FOR PHOTOVOLTAIC (PV) POWER SUPPLY SYSTEMS

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IEC TR 63227 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is a Technical Report.

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

Draft	Report on voting
82/1501/DTR	82/1554A/RVDTR

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 Technical Report 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.

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LIGHTNING AND SURGE VOLTAGE PROTECTION FOR PHOTOVOLTAIC (PV) POWER SUPPLY SYSTEMS

1 Scope

This document deals with the protection of PV power supply systems against detrimental effects of lightning strikes and surge voltages of atmospheric origin. In the event that a lightning and/or surge voltage protection is required to be erected, this document describes requirements and measures for maintaining the safety, functionality, and availability of the PV power supply systems.

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 60364-4-44:2007/AMD1:2015, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

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IEC 60364-7-712:2017, *Low voltage electrical installations – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems*

IEC TR 63227:2020
https://standards.iteh.ai/catalog/standards/sist/36857bdf-1870-4427-96b0-a05f14c02591/iec-tr-63227-2020

IEC 61643-11:2011, *Low-voltage surge protective devices – Part 11: Surge protective devices connected to low-voltage power systems – Requirements and test methods*

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

IEC 61643-31, *Low-voltage surge protective devices – Part 31: Requirements and test methods for SPDs for photovoltaic* installations

IEC 62305-1, *Protection against lightning – Part 1: General principles*

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

IEC 62305-3:2010, *Protection against lightning – Part 3: Physical damage to structures and life hazard*

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

IEC 62561-1, *Lightning Protection System Components (LPSC) – Part 1: Requirements for connection components*

IEC 62561-2, *Lightning Protection System Components (LPSC) – Part 2: Requirements for conductors and earth electrodes*

IEC 62561-3, *Lightning Protection System Components (LPSC) – Part 3: Requirements for isolating spark gaps (ISG)*

IEC 62561-4, *Lightning protection system components (LPSC) – Part 4: Requirements for conductor fasteners*

3 Terms and definitions

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

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
photovoltaic
PV
relating to the conversion of light directly into electrical energy

[SOURCE: IEC 62109-1:2011, 3.55]

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3.2
PV module
smallest complete and environmentally protected assembly of interconnected PV cells

[SOURCE: IEC 60364-7-712:2017, 712.3.2]

IEC TR 63227:2020
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3.3
PV inverter
device which converts DC voltage and DC current into AC voltage and AC current

3.4
PV string
circuit in which PV modules are connected in series to a PV sub-generator in order to achieve the specified output voltage

3.5
PV sub-generator
mechanically and electrically assembled combination of PV modules and other necessary components in order to form a DC power supply unit

3.6
PV generator
combination of PV sub-generators

3.7
surge protective device
SPD
device that contains at least one non-linear component and 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: IEC 61643-11:2011, 3.1.1]

3.8
voltage switching type SPD
SPD that has a high impedance when no surge is present, but can have a sudden change in impedance to a low value in response to a voltage surge

Note 1 to entry: Common examples of components used in voltage switching type SPDs are spark gaps, gas tubes, and thyristors. These are sometimes called “crowbar type” components.

[SOURCE: IEC 61643-11:2011, 3.1.4]

3.9
voltage limiting type SPD
SPD that has a high impedance when no surge is present, but will reduce it continuously with increased surge current and voltage

Note 1 to entry: Common examples of components used in voltage limiting type SPDs are varistors and avalanche breakdown diodes. These are sometimes called “damping type” components.

[SOURCE: IEC 61643-11:2011, 3.1.5]

3.10
combination type SPD
SPD that incorporates both voltage switching components and voltage limiting components

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Note 1 to entry: The SPD can exhibit voltage switching (e.g. spark gap), voltage limiting (e.g. varistor) or both. These components can be connected in series as well as in parallel.

[SOURCE: IEC 61643-11:2011, 3.1.6, modified – Second sentence of definition moved to the note to entry. Second sentence of note to entry has been added.]

IEC TR 63227:2020
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4 Design principles

4.1 Causes of damage and damages

The lightning current of a lightning discharge can be injected into PV power supply systems in different ways:

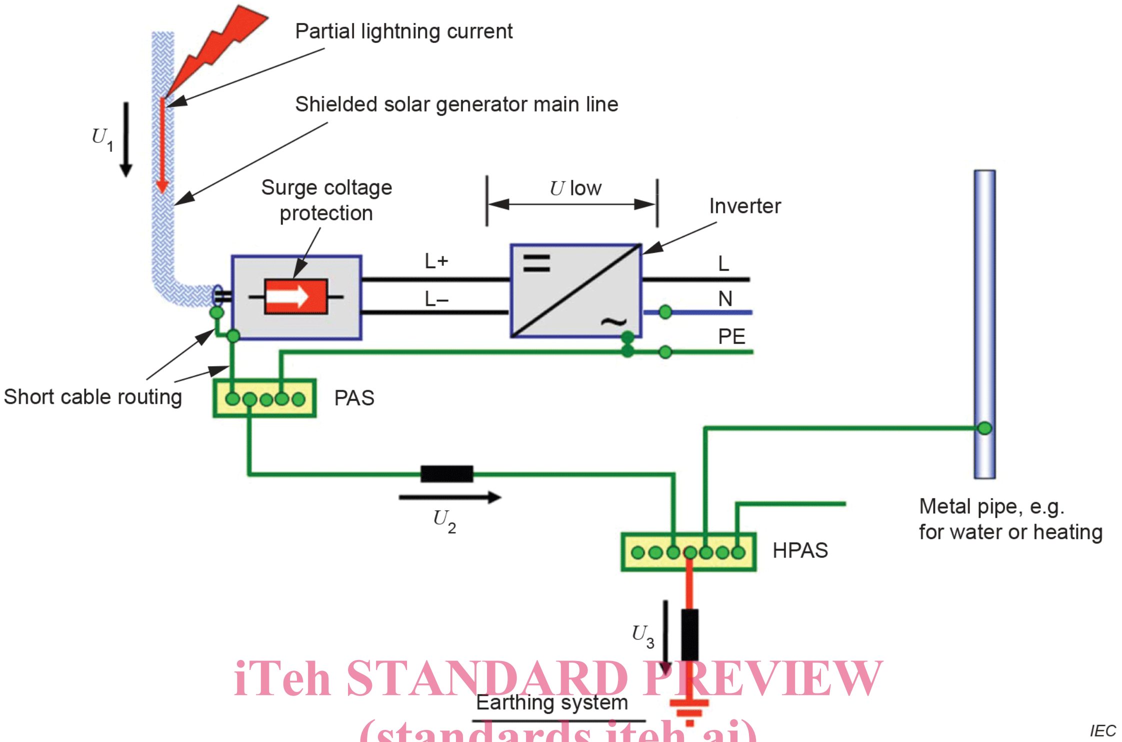
- by galvanic coupling;
- by magnetic field coupling;
- by electric field coupling.

The respective type of coupling is influenced by lightning protective measures (e.g. earthing, equipotential bonding, shielding of the structure, shielding of the electric lines as well as layout and type of these lines).

4.2 Galvanic coupling

A prerequisite for galvanic coupling is for the lightning current or at least part of it to be injected directly. The (partial) lightning current generates a direct-axis component of voltage at the impedances of the lines it passes through. When a structure is struck by lightning, the current flowing to earth normally generates a voltage magnitude of some hundred kilovolts at the effective conventional earth impedance.

Figure 1 shows examples of galvanic couplings at an equipotential bonding line carrying a (partial) lightning current and at the conventional earth impedance. This type of coupling is also present where a (partial) lightning current passes through a line’s cable screen. In that case, the (partial) lightning current causes a direct-axis component of voltage at the coupling impedance of the cable screen, which appears between the cable screen and the inner conductor. This direct-axis component of voltage U_1 can jeopardize the electric or electronic systems connected at the two line ends.



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Key

U_1 Direct-axis component of voltage at the cable screen the current flows through

U_2 Direct-axis component of voltage at the voltage equalizing cable $U_2 = L\ \mathrm{d}i/\mathrm{d}t$

U_3 Voltage at the conventional earth impedance RE ($U_3 = i\ R_E$)

PAS Equipotential bonding bar

HPAS Main earthing bar

Figure 1 – Examples of direct-axis components of voltage for galvanic coupling

4.3 Magnetic field coupling

The process at which the magnetic field $H(t)$ of a lightning discharge passes through conductor loops is referred to as magnetic field coupling or magnetic induction (see Figure 2). If the conductor loops are open (idle motion), voltages u_{ind} will result in proportion to $\mathrm{d}H/\mathrm{d}t$; however, where the conductor loops are short-circuited currents, i_{ind} will result in proportion to $H(t)$.

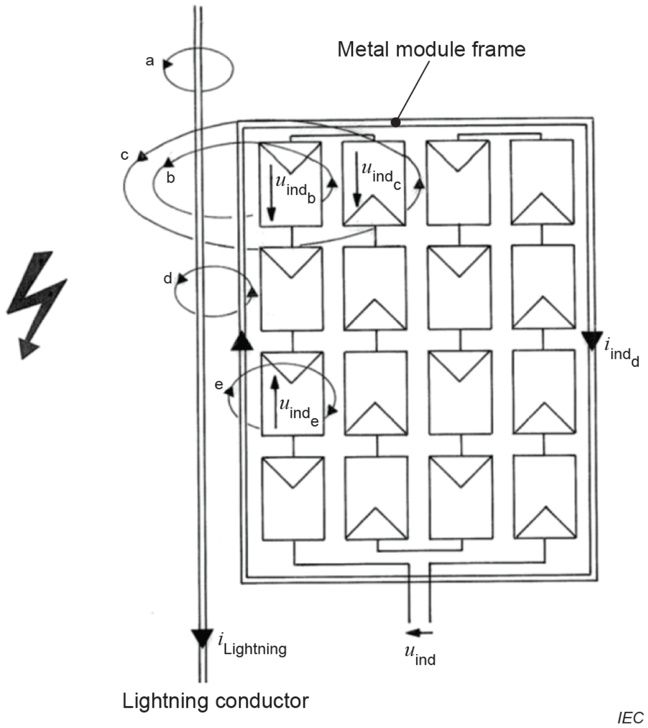

Figure 2 – Voltages induced in loops by the steepness of the lightning current

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Magnetic injections can be reduced considerably by increasing the distance of air-termination systems and down-conductors to the PV modules. A minimum value of 0,5 m is recommended for the distance of air-termination systems and down-conductors to the PV modules. The separation distance s can differ from this value (see Annex C).

IEC TR 63227:2020
https://standards.iteh.ai/catalog/standards/sist/... 870-4427-96b0-a05f14c02591/iec-tr-63227-2020

4.4 Electric field coupling

A prerequisite for electric field coupling is an “electrically effective aerial” (e.g. the module frame). The electric field strength resulting from the leader approaching reaches up to 500 kV/m at a distance of a couple hundred metres to the prospective striking point. As soon as the main discharge starts, the electric field breaks down. During that process, field changes $\mathrm{d}E/\mathrm{d}t$ can appear at a magnitude of 500 (kV/m)/µs.

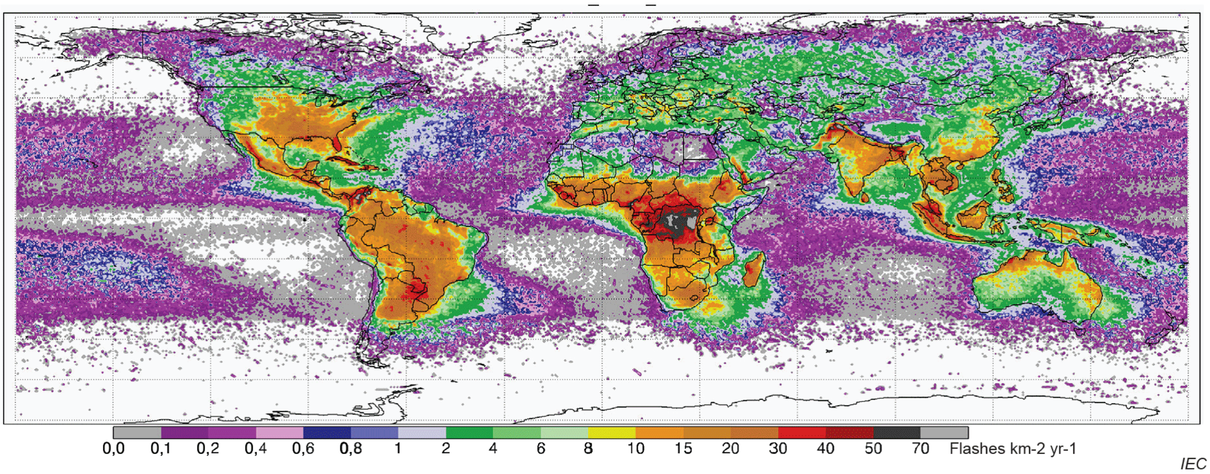
The effect of electric field coupling to equipment installed within and outside a structure is generally very small compared to that of magnetic field coupling.

4.5 Risk management

A lightning protection system (LPS) designed to comply with class III meets the regular requirements for PV power supply systems.

In special cases, e.g. for objects of cultural value or requirements for an increased availability of the system, it should be checked in accordance with IEC 62305-2 whether additional measures or a different LPS class is required.

The lightning protection measures for the PV power supply system are adapted to the LPS class of the structure. The LPS class of the building is determined by factors as its use, values and others as well as the area-specific lightning activity (Figure 3). The area-specific lightning activity should be also taken into account to decide on lightning protection measures for ground-mounted systems.



(Source: https://ghrc.nsstc.nasa.gov/pub/lis/climatology/LIS-OTD/HRFC/browse/HRFC_COM_FR_V2.3.2015.png)

Figure 3 – High resolution full climatology (HRFC)

5 Lightning protection system (LPS)

5.1 General

The erection of conventional PV power supply systems on or at buildings does not change the lightning strike risk. It is recommended to design and harmonize the PV power supply and lightning protection systems before erection.

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IEC TR 63227:2020
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The PV generator delivers current and voltage even at low amounts of solar irradiance. This has to be taken into account for mounting and troubleshooting purposes.

Suitable measures of external lightning protection are supposed to catch direct lightning and feed them into an earthing system such that no galvanically coupled currents can have an effect on metal building installations and the PV power supply system.

In addition to that, measures of internal lightning protection are used to prevent impacts that lightning strikes and potential differences may have onto and inside the building.

The purpose of these measures is to prevent damage to the building (mechanical damages up and including fire and its effects) as well as damage to the PV power supply system (supply networks, controls and electrical protective equipment). Where the legislator requires lightning protective measures as part of the preventive fire protection, these shall not be affected by PV power supply systems.

For lightning protection, the IEC 62305 series applies.

For the erection of PV power supply systems, the IEC 60364 series and, in particular, IEC 60364-7-712 apply.

In order for a lightning protection system to be erected, co-ordination across all trades involved is required.

Design, erection, and inspection are carried out by lightning protection specialists. The requirements for lightning protection specialists are specified in IEC 62305-3. A lightning protection specialist is someone who is able to design, erect or inspect lightning protection systems based on their professional training, knowledge, and experience as well as knowledge of the relevant standards.