

## LIGHTNING AND SURGE PROTECTION OF PHOTOVOLTAIC SYSTEMS

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## LEUTRON PROTECTS THE FUTURE

Because photovoltaic systems (among other things) are the future. Whether for new buildings or for renovations, for private residences or for office buildings: these systems are being installed on more and more roofs across Germany.

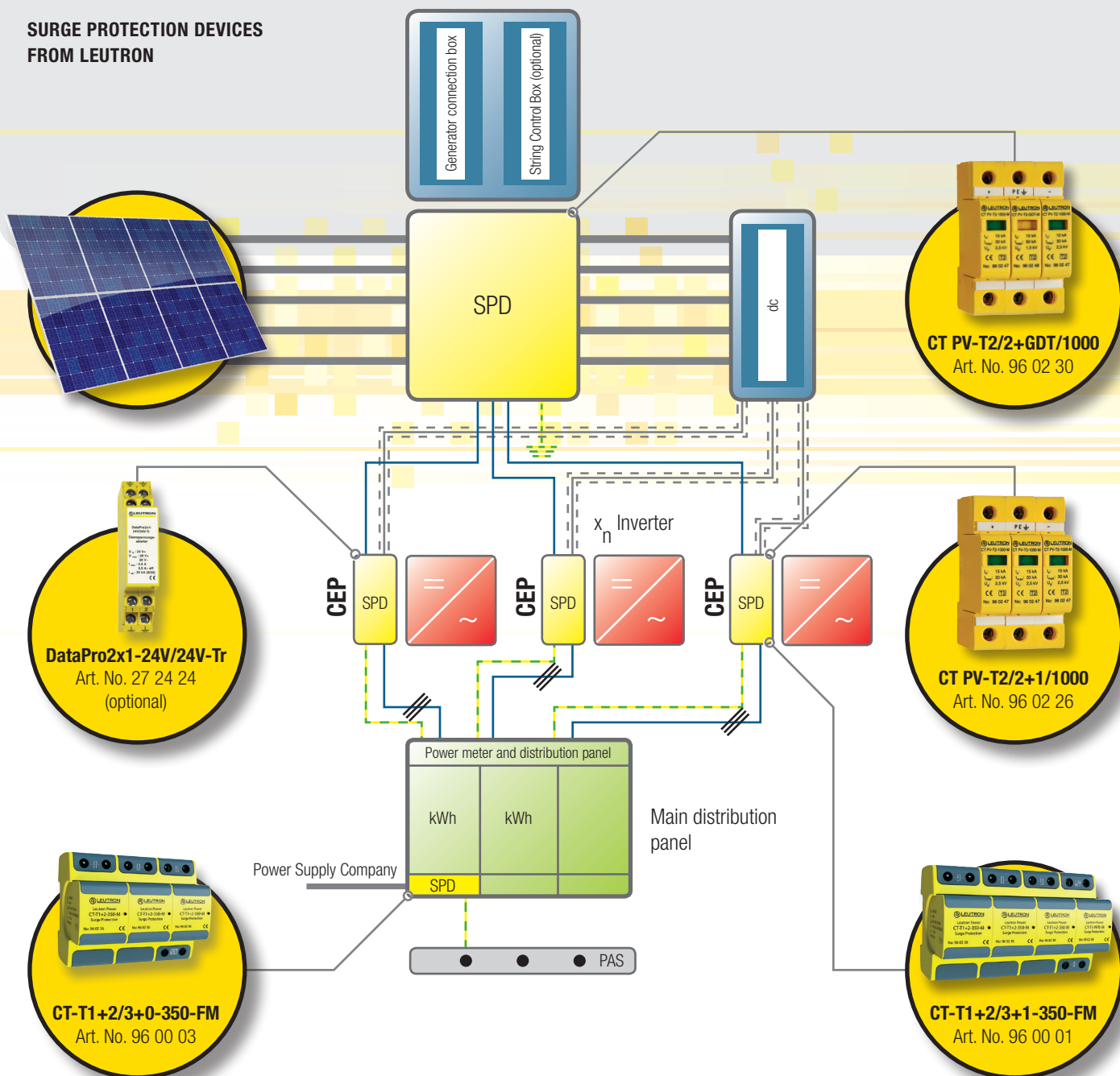
In this sector, the last seven years have witnessed a 30-fold increase in turnover; and

Germany has been the global market leader since 2004. These hi-tech systems provide valuable protection against lightning strikes and power surges thanks to their exposure and large surface area.

In addition to the modules, the photovoltaic system is also integrated into the building's electrical systems, which are necessarily vul-

nerable to direct or indirect lightning strikes. Lightning strikes and power surges have serious consequences: aside from production losses, there are also high repair costs - Costs that Leutron can keep down.

### SURGE PROTECTION DEVICES FROM LEUTRON



## PV SYSTEMS FOR THE HOME

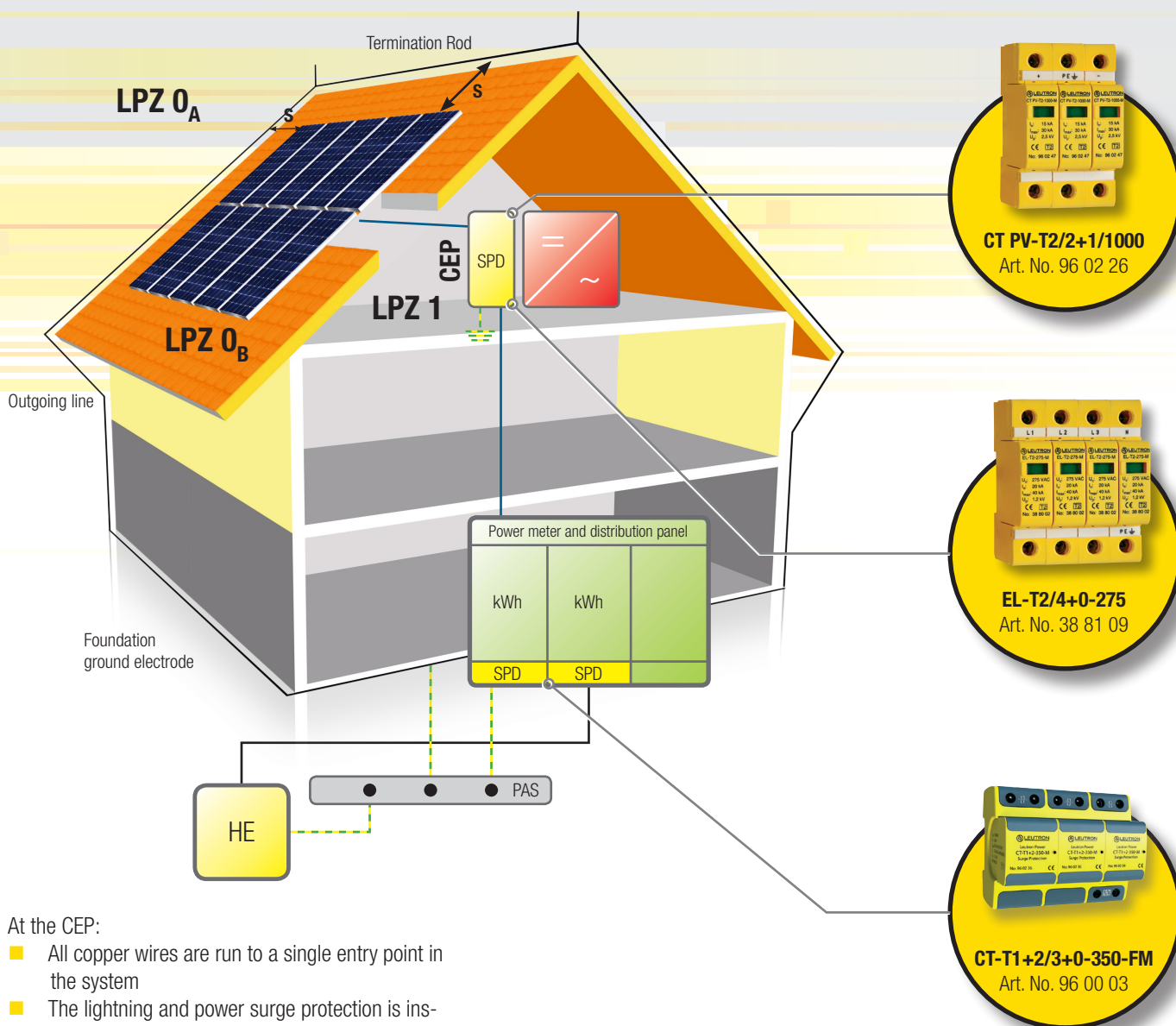
There is one point to bear in mind when installing PV systems in private residences with lightning protection systems:

The lightning rods must be distanced from the PV modul in such way that lightning discharge are prevented, while casting as little shade as possible onto it on the other. The length and place of the air termination rod must also be chosen accordingly. Specifications for adjustment of the protection

area of the lightning rod are given in VDE 0185-305-3. The space (s) between the photovoltaic system and the air termination rod should be greater than 0.5 m.

If it is not possible to leave a buffer space, then a direct electroconductive connection must be installed between the external lightning protection system and the PV module frame.

The purpose of this is to prevent lightning currents from flowing through the module frame construction. Thus, the electrical connection between the air termination rod and the frame construction is made on one side only, preferably on the side of the outgoing lines from the external lightning protection.



At the CEP:

- All copper wires are run to a single entry point in the system
- The lightning and power surge protection is installed
- The only connection to the building's ground connection runs from here.



## LEUTRON PROTECTS PHOTOVOLTAIC SYSTEMS UP TO 1000 V DC

When applying surge protection devices (SPDs) in PV installations some specifics have to be considered. In contrast to the application of SPDs AC systems, PV installations contain a dc generator circuit with specific features. These specific features have an influence on the design of the protection system, and the SPDs have to be selected accordingly.

The SPDs for PV installations have to be laid out to fit the maximum no-load voltage ( $U_{OCSTC}$  = voltage of the no-load circuit at standard test conditions) of the solar generator as well as for a maximum availability and security of the PV installation. Photovoltaic is an essential pillar of energy gen-

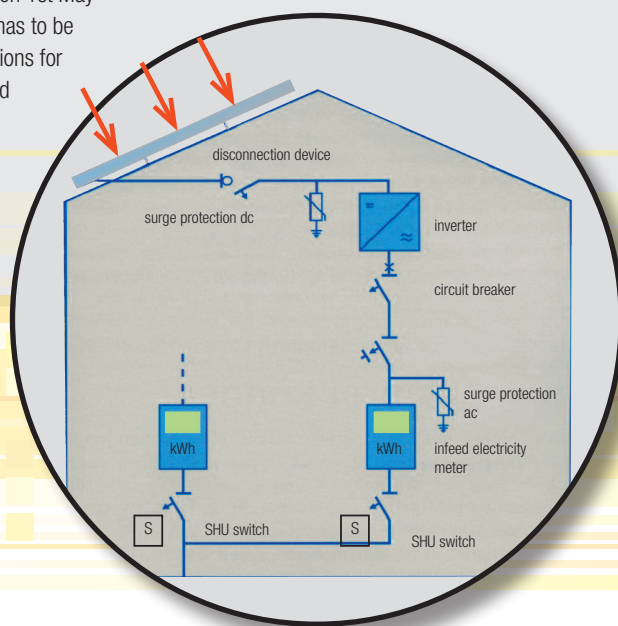
eration in the area of renewable, respectively regenerative energies. This does not only apply to Germany but to important export markets like Southern Europe and North America as well.

The standard DIN VDE 0100 (VDE 0100) part 712 [1] for the erection of PV installations exists since June 2006. This standard is harmonized on a European level, i.e. it is a HD document

Since its transitional period expired on 1st May 2008 the standard is effective and has to be applied. The standard holds instructions for surge-voltage protection devices and lightning protection.

A surge voltage protection is not explicitly required, but it is recommended (see figure 1). Likewise, the standard points out that when applying a lightning protection the PV installation has to be protected by an insulated air terminal considering the separation distance.

Figure 1: Extract from DIN VDE 0100-712, exemplary



### External Lightning Protection

Due to their large-area setup and often exposed location PV installations are especially prone to atmospheric discharges like lightning. We have to distinguish between direct lightning impacts and indirect effects of inductive and capacitive character.

On the one hand, the necessity of lightning protection results from the requirements of the standard and on the other hand it is defined by the application itself, i.e. if it is an installation on a building or in the field.

Installations on buildings can be divided into installations on buildings with an existing lightning protection system, e.g. public buildings, or those without one, e.g. barn roofs.

Due to their large modules, field installations have a great potential risk of lightning strokes as well. In this case an external lightning protection is advisable to prevent direct lightning strokes anyway.

Corresponding notes are given in DIN EN 62305-3 (VDE 0185-305-3) supplement 2 (dimensioning according to class of protection and lightning protection level LPL III), as well as in the VdS directive 2010 (for PV installation > 10 kW a lightning protection is necessary).

Additionally measures for surge protection are demanded. Thus, the PV generator is to be protected preferably by a separate air termination. However, if a direct connection to the PV generator can not be avoided, e.g., if it is not possible to maintain the separation distance, the effect of partial lightning currents must be considered.

In order to minimize induced surges only shielded generator main lines should be applied. A shield with a sufficient cross section (minimum of 16 mm<sup>2</sup> Cu) can be used additionally to divert partial lightning currents.

The same applies to closed metal housings. With cables and metal housings the earthing has to be

implemented on both sides. Hence, the generator main line (dc side) lies in an LPZ 1 (lightning protection zone), which allows for an SPD of type 2. Otherwise a type 1 SPD would be necessary.

### Application and correct layout of Surge Protective Devices

The application and design of SPDs in low-voltage installations can be considered as a standard solution on the inverter side, while their application and proper dimensioning on the side of the dc PV generator still is a challenge.

Firstly, the PV generator has some specifics, and secondly, the SPD is placed in a dc circuit. Conventional SPDs are typically designed for ac systems, and not for dc systems.

For several years now appropriate standards exist, which can be transferred to dc applications in principle. However, in the past, relatively low PV system voltages were used, whereas nowadays



they can reach about 1000 V dc at the no-load PV circuit. Such high dc voltages of the system must be controlled by appropriate SPDs.

The locations where to install SPDs in PV systems in a technically wise and reasonable way depend on the type of the PV system, its concept and its spatial dimensions. Figures 2 and 3 illustrate the fundamental difference:

1. A building with an external lightning protection installation and a PV generator mounted on the roof (building installation).
2. A large-area PV generator (field installation) equipped with an external lightning protection installation as well.

In the first case only the dc input of the inverter is protected due to the short cable lengths, whilst in the second case SPDs are placed inside the connection box of the solar generator (to protect the PV modules) as well as at the dc input of the inverter (to protect the inverter).

If the cable length between the PV generator and the inverter exceeds the distance of 10 m SPDs should be placed close to the PV generator and near the inverter, too. The AC side, i.e. the output side of the inverter and the system infeed point, has to be protected by SPD type 2 at the inverter output as a standard and – at building installations with external lightning protection at the system infeed – by a SPD type 1.

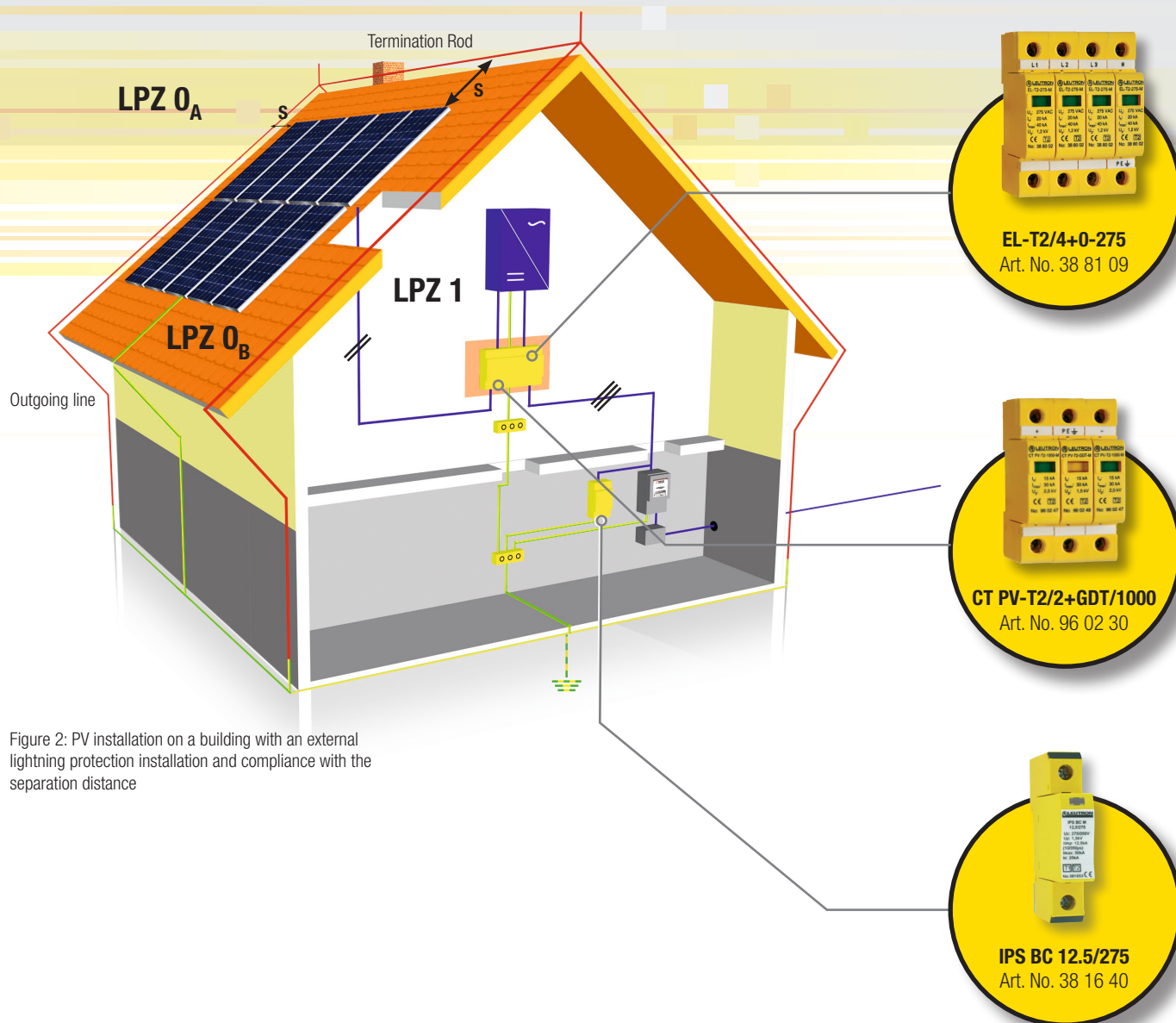


Figure 2: PV installation on a building with an external lightning protection installation and compliance with the separation distance

## LEUTRON PROTECTS PHOTOVOLTAIC SYSTEMS UP TO 1000 V DC

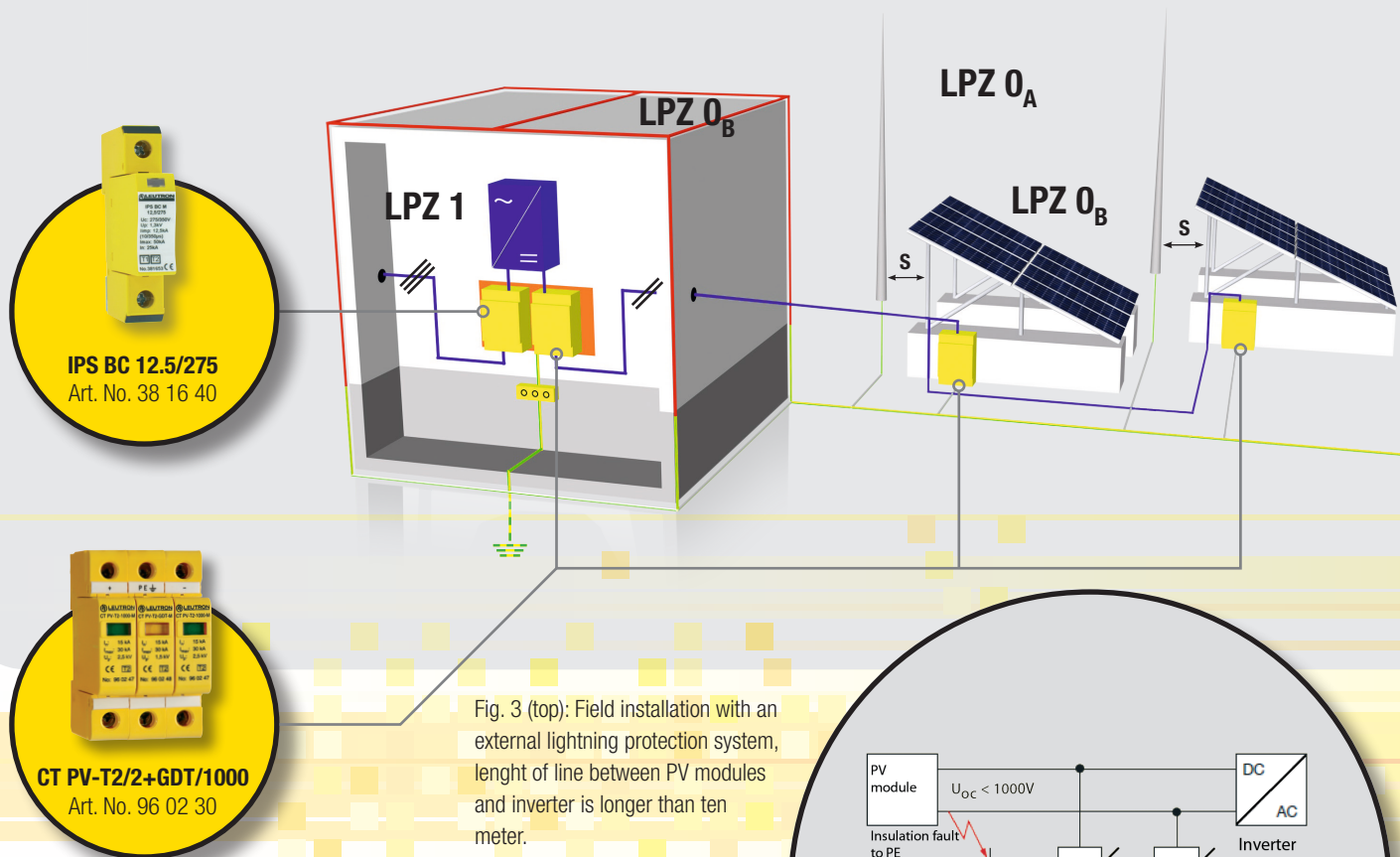


Fig. 3 (top): Field installation with an external lightning protection system, length of line between PV modules and inverter is longer than ten meter.

Fig. 4 (right): Y-connection with three varistors

Fig. 5 (bottom): Y-connection with two varistors and a spark gap

### Specifics on the side of dc solar power generator

Until now, SPDs that had been designed for normal supply voltages were used at the dc side to protect both L+ and L- against ground potential. These SPDs were laid out to at least 50% of the maximum no-load voltage of the PV generator.

After years of usage an insulation fault may occur in the PV generator. Due to this error the full voltage of the PV generator would apply to the SPD at the healthy pole, thus, causing an overload. When stressed with permanent high voltages SPDs with metal oxide varistors may break or trigger the disconnection device.

In the worst case, a fire hazard caused by a stationary arc can not totally be excluded when the disconnection device is activated, especially in PV installations with high system voltages.

Even an upstream over-current protection (fuse) presents no solution, since the short-circuit current of the PV generator is only insignificantly higher than the rated current.

Today, PV installations with system voltages of

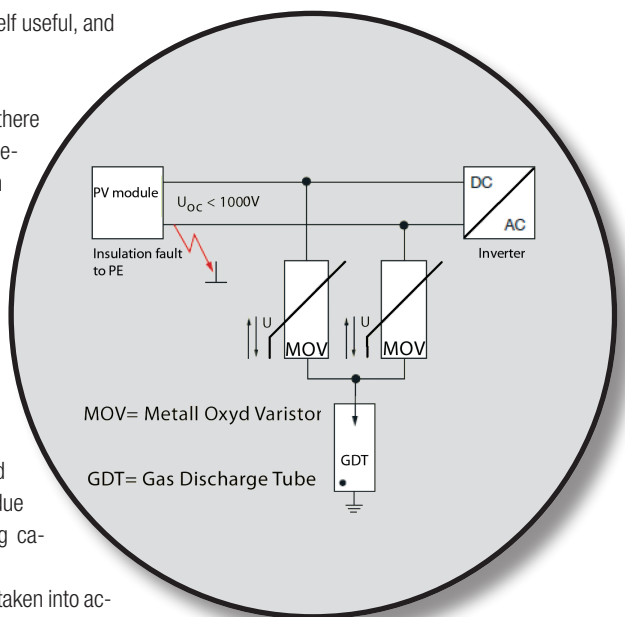
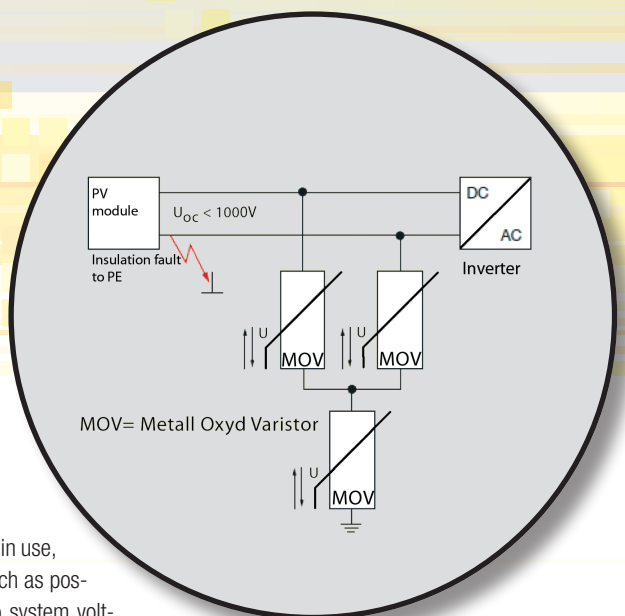
about 1000 V dc are more and more in use, to minimize the power losses as much as possible. In order to adapt the SPDs to system voltages that high the so called Y-connection which consists of three varistors proved itself useful, and is established (see figure 4).

Even in case of an insulation error there are still two varistors connected in series, thus, effectively preventing an overload of the SPDs.

Nevertheless, also in this case the so called leakage current flow through the varistors. The probability of increased leakage currents rises with the age of the varistors and with numerous exposures to surge voltages.

In the worst case, these increased leakage currents may cause a fire due to the absence of any dc switching capacity.

Subsequently, two things have to be taken into ac-



count: the high permanent voltage at the SPD, e.g. caused by an error at the PV installation, and the flow of a high leakage current, e.g. due to frequent exposure to surge voltages.

The solution is provided by an Y-connection consisting of two varistors and a spark gap against ground potential (figure 5). The Y-connection prevents a too high permanent voltage at the SPD

in case an insulation fault occurs in the PV circuit, and the spark gap itself impedes the flow of a leakage current. In other words, in case of an insulation fault the spark gap prevents the disconnection device to be triggered.

Actually, the series connection of a metal oxide varistor and a spark gap (a gas discharge tube in this case) is nothing new – in memory of the old-

established valve arrester. The single difference is the application in a dc circuit.

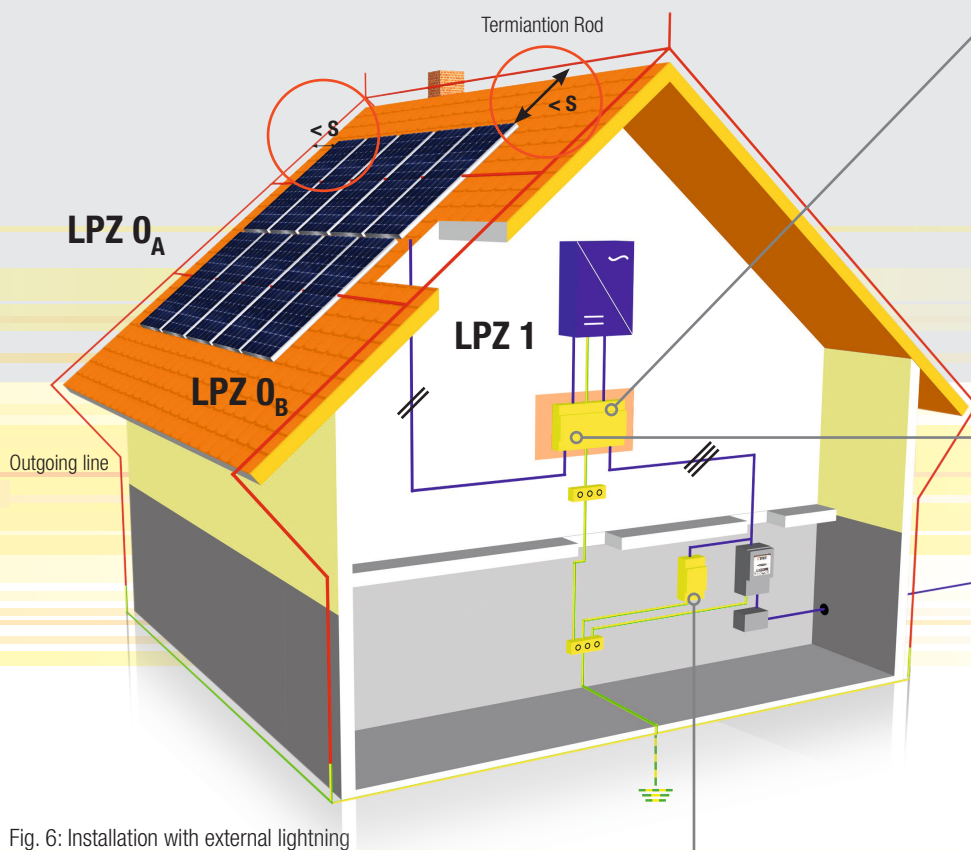


Fig. 6: Installation with external lightning system and no compliance to separation distance



## APPLICATION OF LIGHTNING CURRENT ARRESTER TYPE 1

The application of type 1 SPDs on the dc side of the PV systems is recommended when an external lightning protection system is installed and the necessary separation distance between the lightning protection system and parts of the PV generator can not be kept. (cf. fig. 6).

It is advisable to use SPD type 1 on dc site of PV power supply systems if

- an external lightning protection is realized and
- the required separation distance to elements of the PV power supply systems is not given

The lightning impulse current capability limp per pole of the SPD is selected according to DIN EN 62305-1. The lightning impulse current capability limp of the SPD should be at least 10 kA (10/350µs) for each active line.

This normative minimum requirements for the type 1 SPDs is entirely fulfilled by the newly developed dc type 1 and 2 combined arresters (T1 + T2). The new Leutron SPDs PP PV 800 and PP PV 1000 type 1 combined arresters (cf. fig. 6) are designed for  $U_{OC\ STC}$  voltages up to 800 V dc respectively 1000 V dc at  $I_{imp}$  12.5 kA (waveform 10/350 µs) per pole and therefore for the actual requirements more than sufficiently.

The control is done via special thermal fuses to avoid fire hazard in case of overload. An integrated status display (LED) indicates the actual operation mode. An overload status can also be indicated via an optional remote contact.

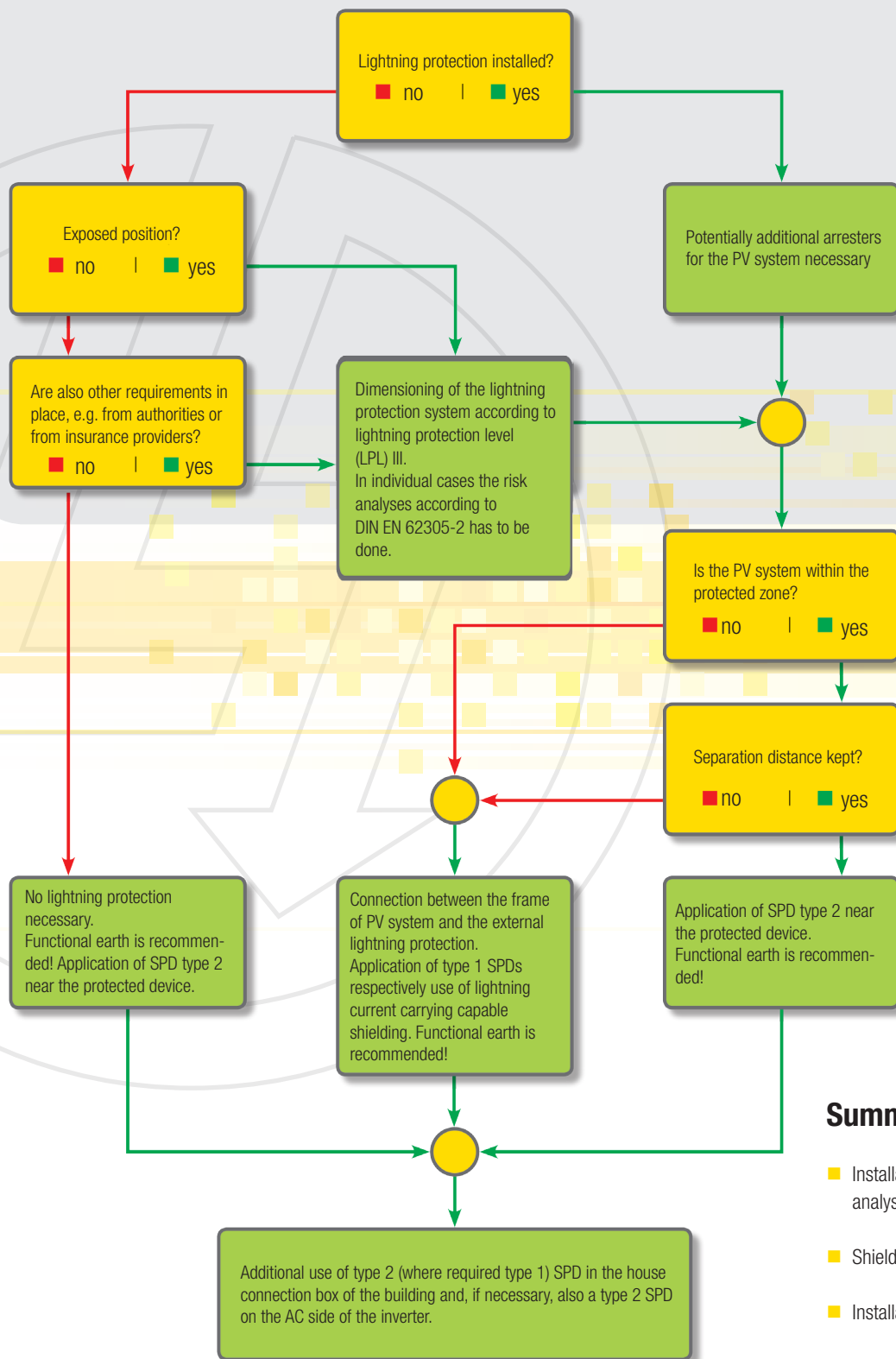
All surge protection devices on the dc side (type 1 and 2) have to be selected in a way that in case of a short circuit they are able to transit into a safe mode and to avoid the risk of fire hazard due to an overload or an electric arc.

An overview supporting the SPD selection for PV supply systems is shown in fig. 7.





## SELECTION OF SPDs FOR PV SUPPLY SYSTEMS



### Summary

- Installation of PV module according to risk analysis (VDE 0185-3-4)
- Shielding of primary generator line
- Installation of combined arrester
- Installation of combined arrester after entry building point
- Set-up of suitable protection units
- Installation of protection components at CEP

Fig. 7: Flow chart for selecting SPDs in PV supply systems according to DIN EN 62305-3 supplemental sheet 5

## PP PV

- Two-pole dc lightning current arrester, class I and II.
- Applicable at LPZ transition point OA-1 and higher
- Test standard: IEC 61643-11 / EN 61643-11

- Mounting on 35 mm DIN rail (EN 60715)
- Space required for installation: 36/54 mm
- Optional remote signalling contact (FM)

### PP PV 800 and 1000

When applied in PV installations, these devices are placed inside the connection box of the so-

lar generator and on the dc side of the inverter.

Type	Max. continu. op. voltage dc Uc	Max. imp. discharge current (8/20)	Item no.
PP PV 800	800 V	40 kA	37 44 00
PP PV 800/FM	800 V	40 kA	37 44 01
PP PV 1000	1000 V	40 kA	37 44 02
PP PV 1000/FM	1000 V	40 kA	37 44 03



## CT PV

- Applicable at the boundaries LPZ OB - 1 and higher
- Test standard: IEC 61643-1 / EN 61643-11
- Mounting on 35 mm DIN rail (EN 60715)

- Degree of protection according to IEC EN 60529: IP 20
- Enclosure material: thermoplastic yellow/black
- Inflammability class according to UL 94 V0
- Optional remote changeover contact

### CT PV-T2/2-0

Fully pluggable surge arrester type II for the use in photovoltaic applications. Suitable fuse-free

earthed photovoltaic applications with system voltages up to 600 or 1000V dc.

Type	Max. continu. op. voltage dc Uc	Nominal discharge current (8/20)	Item no.
CT PV-T2/2-0/600	600 V	15 kA	96 02 20
CT PV-T2/2-0/600-FM	600 V	15 kA	96 02 21
CT PV-T2/2-0/1000	1000 V	15 kA	96 02 22
CT PV-T2/2-0/1000-FM	1000 V	15 kA	96 02 23

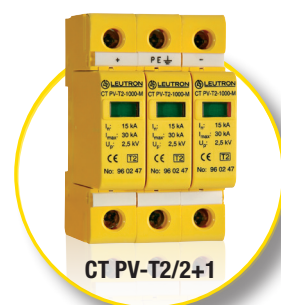


### CT PV-T2/2+1

Fully pluggable surge arrester type II for the use in photovoltaic applications. Suitable fuse-free

earthed photovoltaic applications with system voltages up to 600 or 1000V dc.

Type	Max. continu. op. voltage dc Uc	Nominal discharge current (8/20)	Item no.
CT PV-T2/2+1/600	600 V	15 kA	96 02 24
CT PV-T2/2+1/600-FM	600 V	15 kA	96 02 25
CT PV-T2/2+1/1000	1000 V	15 kA	96 02 26
CT PV-T2/2+1/1000-FM	1000 V	15 kA	96 02 27

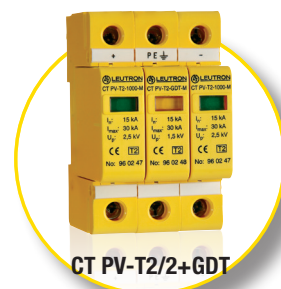


### CT PV-T2/2+GDT

Fully pluggable surge arrester type II for the use in photovoltaic applications. Suitable fuse-free

earthed photovoltaic applications with system voltages up to 600 or 1000V dc.

Type	Max. continu. op. voltage dc Uc	Nominal discharge current (8/20)	Item no.
CT PV-T2/2+GDT/600	600 V	15 kA	96 02 28
CT PV-T2/2+GDT/600-FM	600 V	15 kA	96 02 29
CT PV-T2/2+GDT/1000	1000 V	15 kA	96 02 30
CT PV-T2/2+GDT/1000-FM	1000 V	15 kA	96 02 31





## PROTECTION OF PV SYSTEMS WITH GENERATOR CONNECTION BOXES FROM LEUTRON

### Generator connection boxes with surge protection

With the development of ever more powerful inverters Leutron designed a new generation of generator connection boxes, which satisfy the requirements of PV installations the last generation.

The new generator connection boxes allow for a very efficient installation by collecting several strings of the PV installation at one single point. This type of installation reduces the process of cabling to a minimum.

All terminals of the generator connection boxes are accredited to 1000 V. Up to 12 strings can

be combined and protected with a single generator connection box. Every generator connection box has two output terminals for plus and minus pole, which allows for several generator connection boxes to be connected in parallel.

By this, installation may be expanded to any number of strings. Installation and mounting of Leutron generator connection boxes is an easy and fast process due to their preassembled bridges, busbars and screw connections and dummy plugs.

Generator connection boxes from Leutron contain no dc switch-disconnector, because the manufactures of inverters place them in their units.

String fuses are not a part of the delivery. They can be ordered separately.

### Generator connection boxes, blocking diodes and string fuses

In case that several strings of the PV generator should be connected together, a generator connection box is often used.

It also includes, if necessary, blocking diodes, string fuses and surge protection devices besides the connection terminals for the PV string cables (cf. fig. 9).

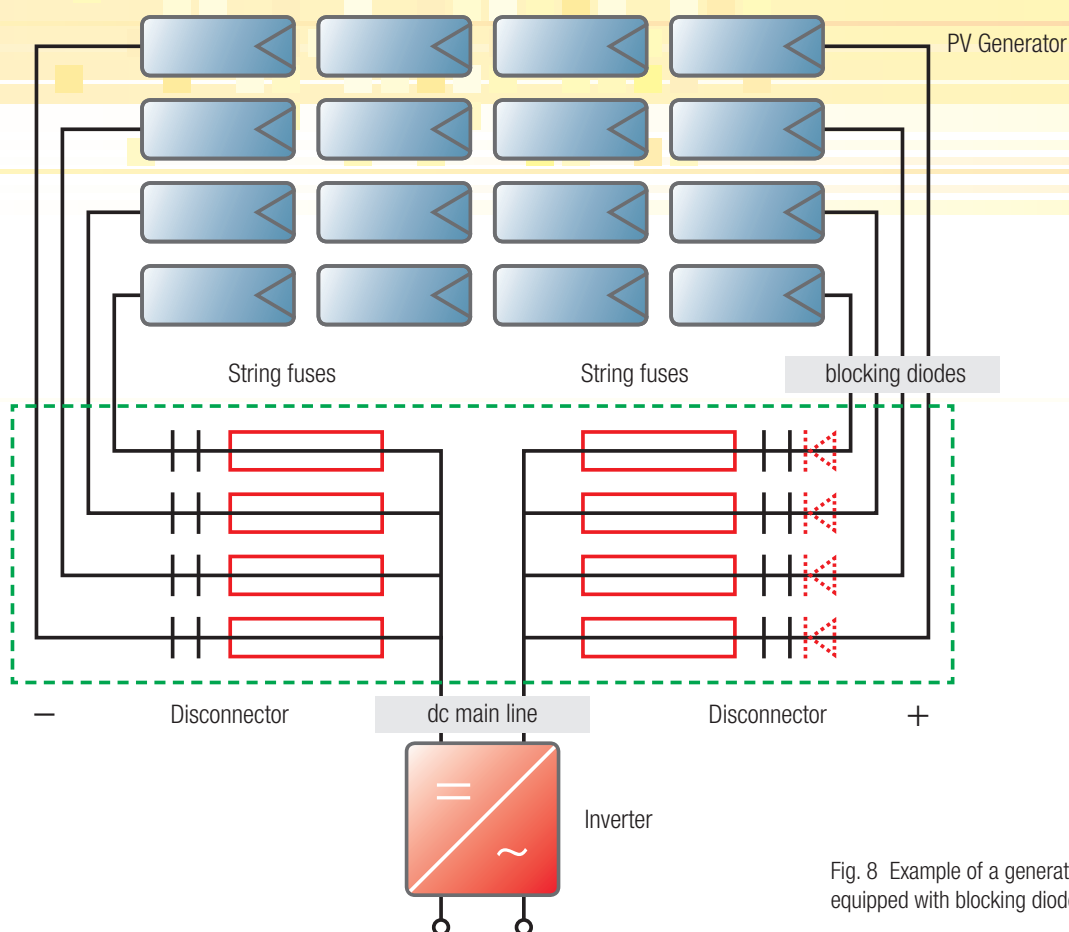


Fig. 8 Example of a generator connection box equipped with blocking diodes and string fuses



The string currents are transferred combined via two main generator lines to the PV generator. These lines have to be dimensioned according to the total string current.

To protect the generator lines also in case of a double earth fault, both lines (+ and -) have to be protected with string fuses. Kick fuses, suitable for dc application and with low power dissipation, are often used in this case.

The rated current of the fuse must be higher than the short-circuit current of the PV modules to ensure a failure-free operation. The generator connection box can also be equipped with disconnect and measurement terminals to enable the control and monitoring of the string currents.

The generator connection box has, according to DIN VDE 0100-712, to be tagged with an appropriate warning label.

To decouple the single module strings from each other, blocking diodes can be used in each string. If a short circuit condition or shadowing effect occurs in one of the strings, all other strings can continue working without disturbances.

Without the blocking diodes current would flow in load direction (back current). If blocking diodes are used, according to VDE 0100 part 712, the reverse voltage must be dimensioned for double voltage of the PV modules (under STC = Standard Test Conditions).

Blocking diodes are applied in conducting direction during normal operation of the PV system. Therefore the full current flows over the blocking diodes (often heat sinks are necessary).

The breakdown of blocking diodes is problematic because the whole PV strings break down. This is often lately detected and fixed, so that today most of the grid-connected photovoltaic systems do not use blocking diodes.

The technical conditions of connecting are to be noted, details are given from manufacturer of inverters.

Please see the manufacturer's requirement about the maximum reverse current in any parallel connection of solar panels.



Fig. 9: Generator connection box with two SPD type 1+2 / class I and II (PP PV 1000)



Fig. 10: Generator connection box with one SPD type 1+2 / class I and II (PP PV 800)

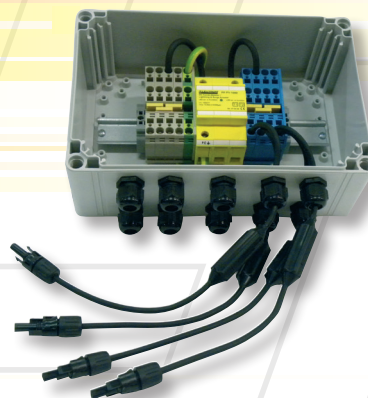


Fig. 11: Generator connection box with one SPD type 1+2 / class I and II (PP PV 1000) and blocking diodes

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