



Novaris

Lightning and Surge  
Protection

---

# Lightning and Surge Protection for PV Systems

---

Application Note (AU)

---

Phillip Tompson

---

Introduction

Like all electrical equipment photovoltaic systems can be damaged by both direct and indirect lightning strikes and other overvoltage disturbances caused by electrical switching operations, load switching and so on.

Photovoltaic systems are designed to have an operational life of 20 or more years so the chances of an electrical disturbance causing damage over this time can be quite high. Protection against these disturbances will help to ensure that a long operational life is achieved.

Statistics on damage due to lightning induced overvoltages have shown that electronic installations up to about one kilometre from the strike point may be susceptible to induced or line-carried overvoltages<sup>1</sup>. In a region with a lightning ground flash density of just one flash per square kilometre per year this equates to potentially 60 disturbances over a 20 year period.

For comparison a typical domestic dwelling in the same region has about 1 chance in 100 of taking a direct lightning strike over that 20 year period. Therefore protection against indirect strikes assumes a greater importance.

Figure 1 shows the ground flash density in Australia, reproduced from AS1768-2007. Ground flash density varies from 0.5 to over 8 flashes per square kilometre per year throughout Australia.

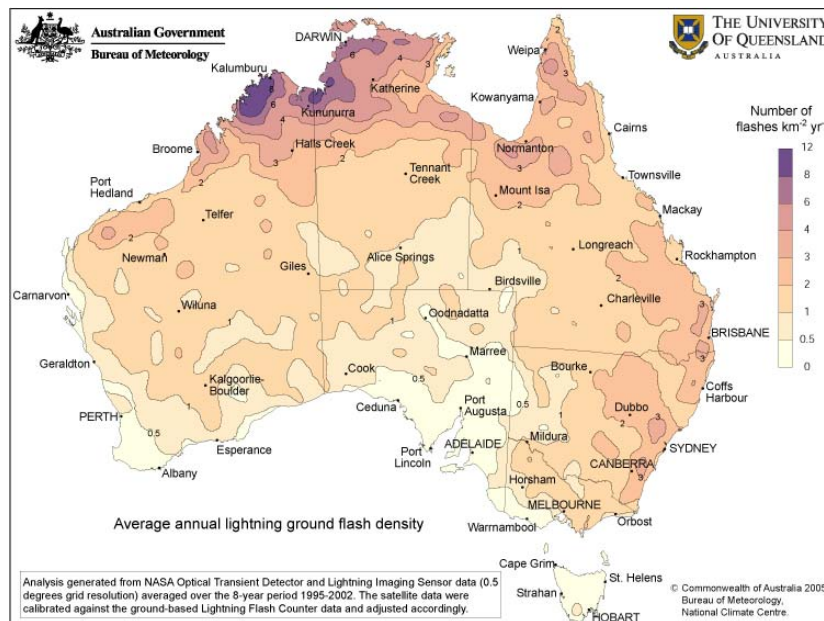


Figure 1. Australia ground flash density from AS1768-2007

This application note applies specifically to grid connect PV systems but the general principles are equally applicable to remote area standalone PV systems. Remote area systems are obviously not prone to line carried overvoltages but comments about induction due to remote lightning strikes equally apply.

## Sources of Lightning Damage

Equipment may be damaged by either direct lightning strikes to the structure, direct lightning strikes to the power line or from indirect strikes caused by cloud to ground or cloud to cloud strikes. These latter events cause induction and earth potential rises. It should be noted that transient electrical disturbances similar to lightning may be caused by power switching operations and power line faults.

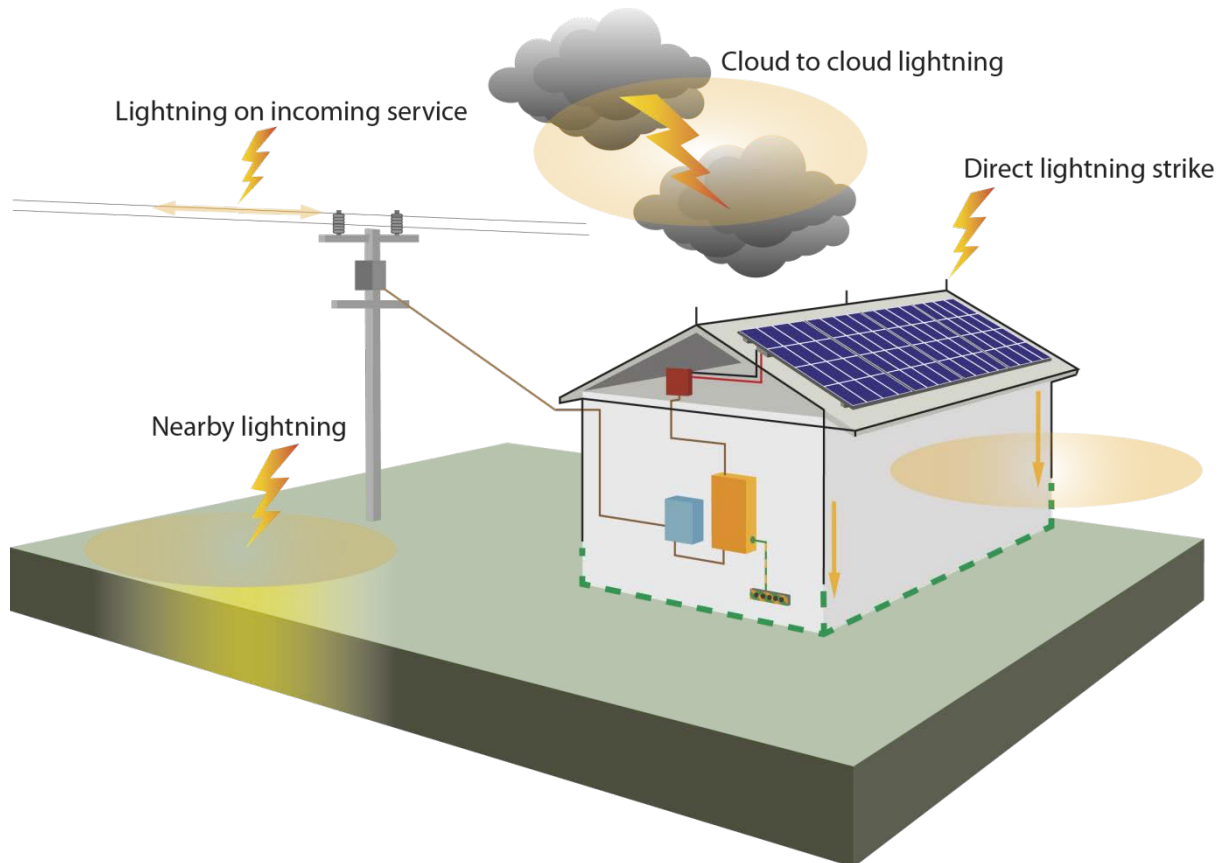


Figure 2. Sources of Lightning Damage

## Protection Options

This application note follows the recommendations for lightning and surge protection set out in AS/NZS1768-2007. There are two options to be considered before lightning and surge protection is applied. Depending upon whether the building has an external lightning protection system (LPS) will determine the choice and placement of surge protection devices (SPDs).

**(a) Building without external LPS**

This is by far the most common case where a building has no external LPS and so the risk of a direct lightning strike is not considered. Figure 3 shows a building with roof mounted solar array and inverter mounted near the main switchboard. Normally the inverter would be mounted close to the main switchboard and in a location that is readily accessible, in accordance with AS/NZS5033.

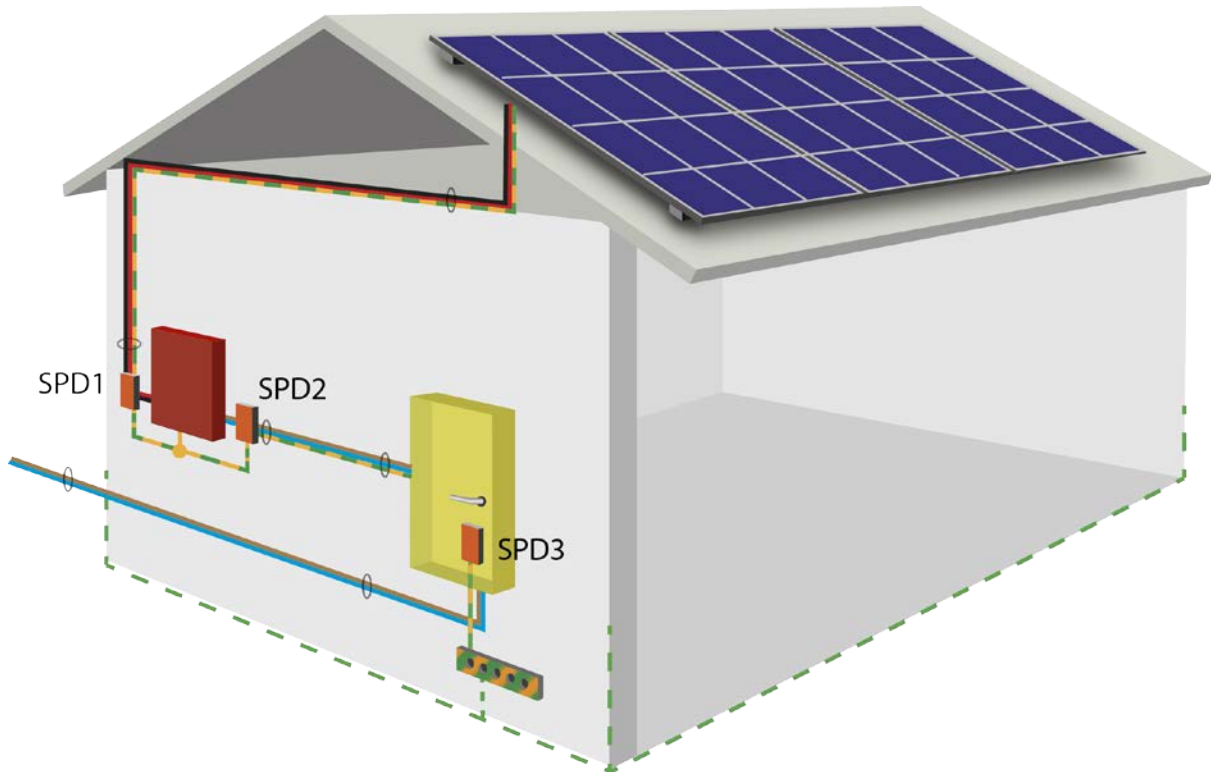


Figure 3. Building without LPS

Protection in this case is required only against indirect lightning. The following is necessary to provide effective protection:

1. The DC cable to the inverter and 4mm<sup>2</sup> earth conductor must be run in the same conduit.
2. Install an SPD on the DC input to the inverter (SPD1 in figure 2). This SPD must be specifically designed for DC PV applications. AC SPDs are unsuitable and could present a hazard under fault conditions. A rating of  $I_{max} = 10kA$  is suitable.
3. Install an SPD on the AC output of the inverter (SPD2 in figure 2). Whilst a shunt type surge diverter is suitable more effective protection can be obtained by using a series connected shunt diverter, like the Novaris SSP, which eliminates the detrimental effects of lead inductance. A rating of  $I_{max} = 10kA$  is suitable.
4. The protective earths of the SPDs and the frame earth of the inverter must be bonded together and in turn connected to the main earth bar as in figure 2. 4mm<sup>2</sup> cable is suitable.
5. Install an SPD on the incoming AC supply in the main switchboard (SPD3 in figure 2). A rating of  $I_{max} = 40kA$  is suitable.

Note: Many twin and earth AC cables of less than 10mm<sup>2</sup> contain an earth conductor less than 4mm<sup>2</sup>. An extra earth conductor should be added. Run this in the same conduit as the twin and earth cable.

If the length of cable from the inverter to the switchboard is only one or two meters, SPD2 may be omitted and SPD3 provides primary protection for the switchboard and inverter.

By far the vast majority of installations can be successfully protected using this approach.

### (b) Building with external LPS

Figure 4 shows a building with an external lightning protection system (LPS). In accordance with AS/NZS1768-2007 the solar array frame must be bonded to the LPS. In this case the solar array frame and its earthing conductor form part of the LPS. Thus partial lightning current will flow in the array bonding and earthing conductors. These must be sized accordingly and 35mm<sup>2</sup> is recommended in AS/NZS1768-2007.

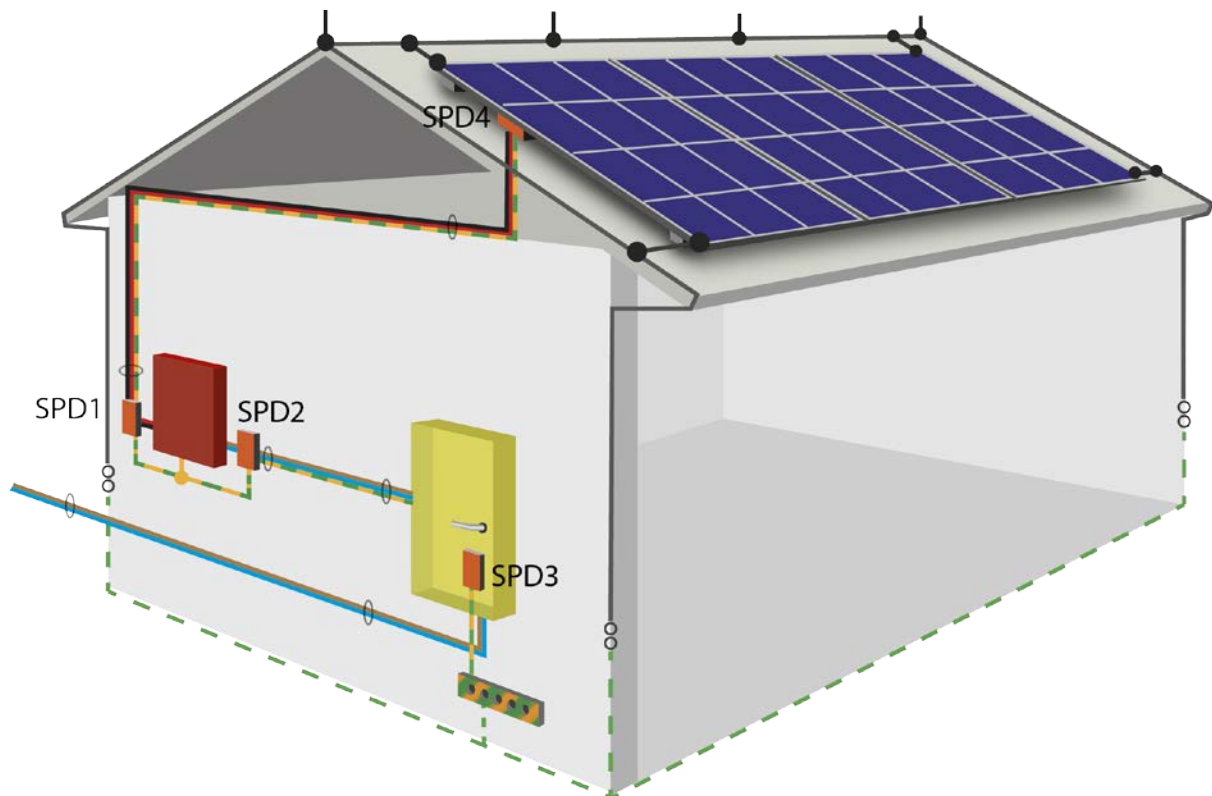


Figure 4. Building with LPS.

The following is recommended:

1. Bond the solar array frame to the LPS using 35mm<sup>2</sup> cable.
2. Install an SPD at the solar array (SPD4 in figure 3). This SPD must be specifically designed for DC PV applications. AC SPDs are unsuitable and could present a hazard under fault

conditions. A rating of  $I_{max} = 40kA$  is suitable. Connect the protective earth of the SPD to the solar array frame.

3. The DC cable to the inverter and  $4mm^2$  earth conductor must be run in the same conduit.
4. Install an SPD on the DC input to the inverter (SPD1 in figure 3). This SPD must be specifically designed for DC PV applications. AC SPDs are unsuitable and could present a hazard under fault conditions. A rating of  $I_{max} = 40kA$  is suitable.
5. Install an SPD on the AC output of the inverter (SPD2 in figure 3). Whilst a shunt type surge diverter is suitable more effective protection can be obtained by using a series connected shunt diverter, which eliminates the detrimental effects of lead inductance. A rating of  $I_{max} = 40kA$  is suitable.
6. The protective earths of the SPDs and the frame earth of the inverter shall be bonded together and in turn connected to the main earth bar via the main switchboard as in figure 3.  $4mm^2$  cable is suitable.

Note: Many twin and earth AC cables of less than  $10mm^2$  contain an earth conductor less than  $4mm^2$ . An extra earth conductor should be added. Run this in the same conduit as the twin and earth cable.

7. Install an SPD on the incoming AC supply in the main switchboard (SPD3 in figure 3). A rating of  $I_{max} = 100kA$  is suitable.

If the length of cable from the inverter to the switchboard is only one or two meters, SPD2 may be omitted and SPD3 provides primary protection for the switchboard and inverter.

If the length of cable from the solar panel array to the inverter or from the inverter to the switchboard containing SPD3 is greater than 40m higher surge ratings for SPD1, SPD2 and SPD4 should be considered. 80kA is suitable.

### (c) Other Considerations

The above examples serve as a basis for most installations. Where a multi string array is installed, multiple DC SPDs will be required depending upon the configuration. Where the solar array is located remote from the building housing the inverter, SPDs will be required at each string and at the inverter.

If the array and inverter system contain monitoring instruments such a temperature, insolation, wind etc. surge protection will be required for these as well. The Novaris application note on PLC and SCADA (Document no. 0015-D17V3) provides detail on this protection.

## SPD Selection

---

### (a) SPD for DC PV

The SPD for the DC input to the inverter and solar array must be designed specifically for DC application. AC SPDs are not suitable because upon failure their disconnect circuitry may not quench the arc. AC SPDs rely upon a voltage zero crossing to quench the arc. This does not occur with DC. So the arc may persist, with the attendant hazard of fire.

At the time of writing this document (early 2013) there exists only one standard relevant to the testing and performance of DC SPDs for PV application. This is prEN50539-11. All Novaris DC PV SPDs comply with this standard. The configuration is shown in figure 5, comprising all mode protection and equal let through voltage,  $U_p$ , from each line to earth and line to line.

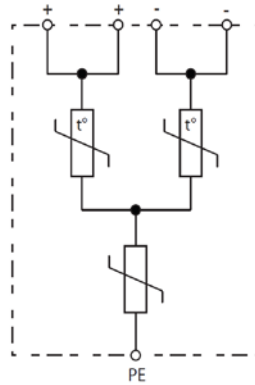


Figure 5. DC PV Configuration

The voltage clamping components are ZnO varistors. These are fitted with thermal disconnects and an arc quenching DC fuse.

Due to the characteristics of PV panels, over current fusing of DC PV SPDs is ineffective. The short circuit current from a typical PV string is limited and so an SPD fault even to a short circuit may not cause the fuse to trip. Figure 6 shows the typical characteristic of a solar panel. The short circuit current is very close to the maximum power point current. It is important to choose a DC PV SPD with a short circuit withstand current,  $I_{SCWSPV}$ , greater than the short circuit current of the solar array string,  $I_{SCPV}$ , to which the SPD is connected.

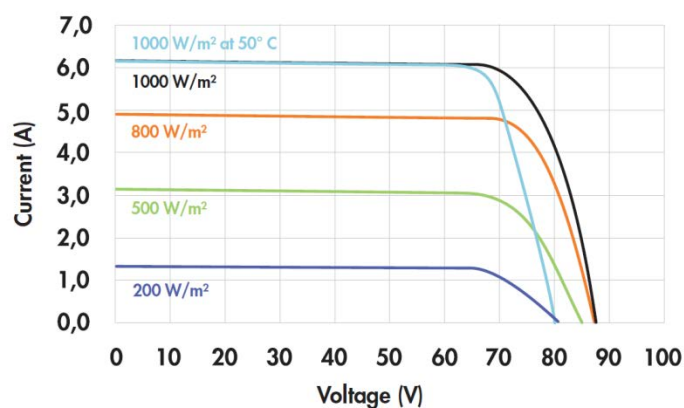


Figure 6. Typical solar panel characteristic (Sunpower E19/425)

Figure 7 provides a specification summary for the Novaris DC PV SPDs.

Model	$U_{CPV}$	$I_{max}$	$I_n$	$I_{scwpv}$	$U_p$
<b>SDPV-40-600</b>	600V	40kA	20kA	63A	<2000V
<b>SDPV-40-1000</b>	1000V	40kA	20kA	63A	<3000V

Figure 7. Novaris DC PV SPDs

$U_{CPV}$  Maximum continuous operating voltage  
 $I_{max}$  Maximum discharge current (8/20us)  
 $I_n$  Nominal discharge current (8/20us)  
 $I_{scwpv}$  Short-circuit withstand  
 $U_p$  Voltage protection level (in accordance with AS/NZS1768-2007)



Figure 8. Novaris DC PV SPD, model SDPV-40-600

**(b) SPD for AC**

SPDs for AC protection may be either SDD, surge diverters or SSP, series surge protectors. Figure 8 summarises some of the options.

Model	$U_c$	$I_L$	$I_{max}$	$I_n$	$I_{SCCR}$	$U_p$
<b>SDD1-50-275</b>	275V		50kA	20kA	25kA	<800V
<b>SDD3-50-275</b>	275V		50kA	20kA	25kA	<800V
<b>SDD1-100-275</b>	275V		100kA	40kA	50kA	<800V
<b>SDD3-100-275</b>	275V		100kA	40kA	50kA	<800V
<b>SSP1-20-50-275</b>	275V	20A	50kA	20kA	25kA	<800V
<b>SSP1-32-50-275</b>	275V	32A	50kA	20kA	25kA	<800V
<b>SSP1-63-50-275</b>	275V	63A	50kA	20kA	25kA	<800V

Figure 9. Novaris AC SPDs

$U_c$  Maximum continuous operating voltage  
 $I_L$  Maximum load current  
 $I_{max}$  Maximum discharge current (8/20us)  
 $I_n$  Nominal discharge current (8/20us)  
 $I_{SCCR}$  Short-circuit current rating  
 $U_p$  Voltage protection level (in accordance with AS/NZS1768-2007)





Figure 10. Novaris AC SPDs SDD1-50-275 & SDD3-100-275

## References

1. Overvoltage Protection of Low Voltage Systems. P. Hasse IEE Power Series 12
2. IEC62305-3. Protection against lightning – Part 3: Physical damage to structures and life hazard
3. IEC62305-4. Protection against lightning – Part 4: Electrical and electronic systems within structures
4. IEC61643-11. Low voltage surge protective devices – Part 11: Requirements and test methods
5. IEC61643-12. Low voltage surge protective devices – Part 12: Selection and application principles
6. prEN50539-11. Low voltage surge protective devices – Part 11: Requirements and tests for SPDs in photovoltaic applications
7. AS/NZS1768-2007. Lightning Protection.
8. AS/NZS5033-2012. Installation and safety requirements for photovoltaic (PV) arrays.