Choosing Surge Protection

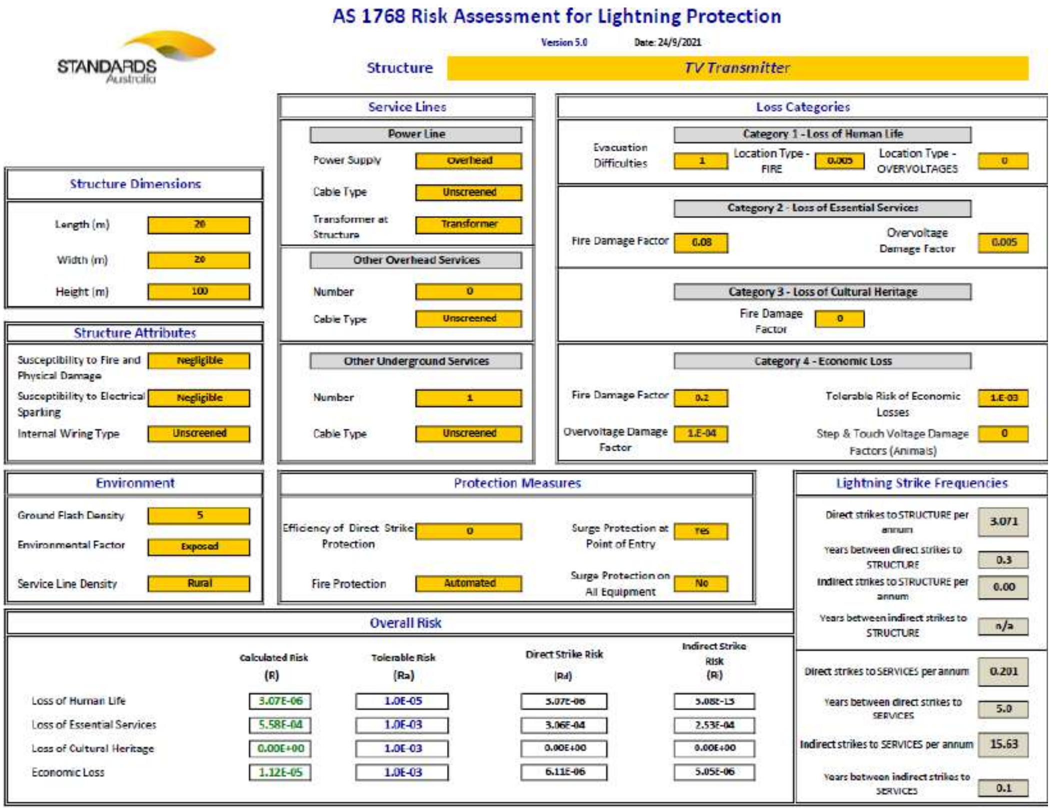
1. Risk Assessment

Historically lightning protection was concerned only with the protection of buildings and structures. Since buildings were constructed of masonry and timber. they constituted a significant fire hazard. Traditional lightning protection comprising air terminals, downconductors and earthing systems were developed.

Today modern structures containing electrically conductive elements such as steel frames, metallic cladding and reinforced concrete are defined as self-protecting and the traditional approach is no longer applicable.

As electrical services were introduced into buildings little thought was given to protecting these services against the indirect effects of a lightning strike even though the effects of an indirect strike could often be more damaging than a direct strike to a modern building.

This situation is now recognised in most of the world's lightning protection standards. The IEC standard (IEC62305-2) presents a risk assessment procedure to assess the need for direct and/or indirect lightning protection. The Australian Standard AS1768 provides an Excel spreadsheet to simplify the risk assessment procedure. A typical cover page of this spreadsheet is shown in figure 1.


AS 1768 Risk Assessment for Lightning Protection

Version 5.0 Date: 24/9/2021

Structure: TV Transmitter

Structure Dimensions

Length (m)	20
Width (m)	20
Height (m)	100

Structure Attributes

Susceptibility to Fire and Physical Damage	Negligible
Susceptibility to Electrical Sparking	Negligible
Internal Wiring Type	Unscreened

Service Lines

Power Line	
Power Supply	Overhead
Cable Type	Unscreened
Transformer at Structure	Transformer
Other Overhead Services	
Number	0
Cable Type	Unscreened
Other Underground Services	
Number	1
Cable Type	Unscreened

Loss Categories

Category 1 - Loss of Human Life	
Evacuation Difficulties	1
Location Type - FIRE	0.005
Location Type - OVERVOLTAGES	0
Category 2 - Loss of Essential Services	
Fire Damage Factor	0.08
Overvoltage Damage Factor	0.005
Category 3 - Loss of Cultural Heritage	
Fire Damage Factor	0
Category 4 - Economic Loss	
Fire Damage Factor	0.2
Tolerable Risk of Economic Losses	1.E-03
Overvoltage Damage Factor	1.E-04
Step & Touch Voltage Damage Factors (Animals)	0

Environment

Ground Flash Density	5
Environmental Factor	Exposed
Service Line Density	Rural

Protection Measures

Efficiency of Direct Strike Protection	0
Fire Protection	Automated
Surge Protection at Point of Entry	Yes
Surge Protection on All Equipment	No

Lightning Strike Frequencies

Direct strikes to STRUCTURE per annum	3.071
Years between direct strikes to STRUCTURE	0.3
Indirect strikes to STRUCTURE per annum	0.00
Years between indirect strikes to STRUCTURE	n/a
Direct strikes to SERVICES per annum	0.201
Years between direct strikes to SERVICES	5.0
Indirect strikes to SERVICES per annum	15.63
Years between indirect strikes to SERVICES	0.1

Overall Risk

	Calculated Risk (R)	Tolerable Risk (Ra)	Direct Strike Risk (Rd)	Indirect Strike Risk (Ri)
Loss of Human Life	3.07E-06	1.0E-05	3.07E-06	5.08E-15
Loss of Essential Services	5.58E-04	1.0E-03	3.06E-04	2.53E-04
Loss of Cultural Heritage	0.00E+00	1.0E-03	0.00E+00	0.00E+00
Economic Loss	1.12E-05	1.0E-03	6.11E-06	5.05E-06

Figure 1. Risk Assessment from AS1768

In this example the structure is all steel and therefore self-protecting. The risk assessment determines that only surge protection is required.

2. Lightning Protection Zones

The risk assessment procedure takes into account four sources of lightning damage and the analysis presents the frequency of these events, shown in the bottom right table in figure 1. These four sources are:

- S1 Direct strike to the structure
- S2 Strike near the structure
- S3 Direct strike to a service
- S4 Strike near a service

This is summarised in figure 2 (from both IEC and AS standards)

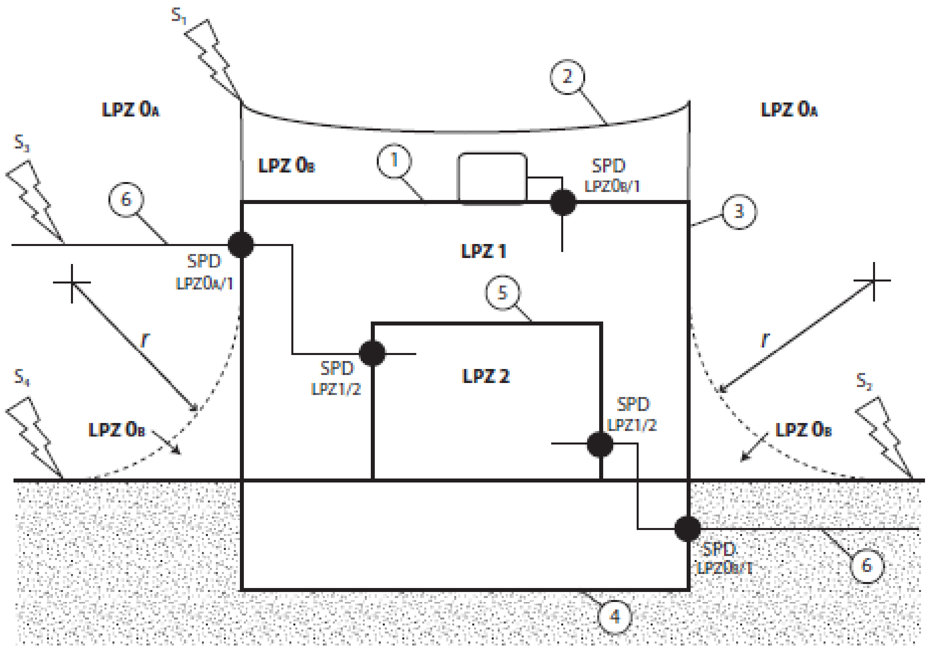


Figure 2. Sources of Lightning Damage and Lightning Protection Zones

The risk assessment indicates the need for surge protection whether at the point of entry of services into the structure or further downstream at distribution boards and final circuits and equipment cabinets. The rating of surge protection devices (SPDs) depends upon their location in the distribution network. Type 1 SPDs are installed in the main switchboard being the boundary of lightning protection zone 0_A ($LPZ0_A$) and the internal distribution wiring in LPZ1. A direct strike to the service or an earth potential rise due to a direct strike to the structure will cause a proportion of the current to flow through the Type 1 SPD.

IEC standards recognise that a direct lightning strike may be modelled by a current waveform with a rise time of 10us and a decay of 350us (10/350), hence Type 1 SPDs have a 10/350us rating as well as an 8/20us rating. After the LPZ0/1 boundary the subsequent current may be modelled by an 8/20us waveform, hence Type 2 and Type 3 SPDs have an 8/20us rating.

3. Selection of SPDs for LV Power Distribution

Whilst the risk assessment can provide an indication of the rating of the various SPDs, if the structure is self-protecting this can prove difficult. By identifying the relevant lightning protection zone boundary the rating of the surge protection at that boundary can be determined from Table 1.

Zone Boundary	SPD Location	I_{max} rating 8/20us	I_n rating 8/20us	I_{imp} rating 10/350us
LPZ2/…n	Long final subcircuits, electricity supply outlets	3 -10kA	2 -5kA	-
LPZ1/2	Major submains, short final subcircuits and load centres	10 – 50kA	5 – 20kA	-
$LPZ0_B/1$	Service entrance, underground, domestic	50kA	20kA	6.25kA
$LPZ0_A/1$	Service entrance, building fed by long overhead service lines, or is a large industrial or commercial structure	100kA	40kA	12.5kA
$LPZ0_A/1$	Service entrance, building in a high lightning area (N_g greater than 2.5), or fitted with an LPS	100kA	40kA	12.5kA
$LPZ0_A/1$	Service entrance, building in a highly exposed lightning area (N_g greater than 5), and fitted with an LPS eg mountain top site or tropical regions	200kA	80kA	25kA

Table 1. Recommended surge ratings – power derived from AS1768

3.1 Surge protection technology

Use the drawings on page 6 of handbook V5.0

Once the surge rating of the SPD has been determined from table 1, the most appropriate SPD technology can be selected.

a. *Surge Diverters, SD, SDN, SDD, NSP, NXP (Type 1/2)*

Surge diverters are one port shunt connected devices. Novaris surge diverters are voltage clamping devices using metal oxide varistors (MOV). They can be used in all lightning protection zones and have ratings up to 200kA (8/20us) or 25kA (10/350us) per phase.

HRC fuses or preferably Novaris surge circuit breakers, SCB, are recommended for overcurrent protection of surge diverters.

One port surge diverters are most commonly used at main and distribution switchboards in commercial and industrial buildings. Surge diverters are not recommended for installations where sustained overvoltages may be present. Hybrid spark gaps are designed for this purpose.

b. Spark Gaps, SG (Type 1)

Spark gaps have high surge ratings and are suitable for installation in main switchboards with highly exposed overhead LV power lines in high lightning areas. Spark gaps have a crowbar effect that can cause AC current to flow after being triggered. This is called follow on current. For this reason, SCBs cannot be used for overcurrent protection of spark gaps. Fuses or circuit breakers must be used.

c. Hybrid Spark Gaps, HSG (Type 1/2)

A hybrid spark gaps combine the advantages of voltage switching and voltage limiting components. They can withstand temporary overvoltages in excess of the line to line supply voltage whist providing performance almost identical to that of a surge diverter.

They have negligible AC follow on current so may be protected by an SCB.

Hybrid spark gaps can be used in main and distribution switchboards.

d. Series Surge Protector, SSP (Type 1/2/3)

Single port SPDs are compromised by the presence of their connecting leads. Typically, voltage drops of 500V per meter can be expected under impulse conditions.

For circuits that are more sensitive the two port SSP provides a means of eliminating the shunt connected leads by being placed in series with the load.

SSPs are suitable for applications such as UPS inputs, rectifiers, VSDs and motors.

e. Surge Filters, SFH, SFM, SFD (Type 1/2/3)

Surge filters are true two port SPDs offering exceptionally low let-through voltages capable of protecting highly sensitive electronic loads.

They comprise three stages of protection, primary surge protection, series connected low pass filters followed by secondary surge protection. Current ratings range from 6A to 2000A per phase.

They are particularly suited to the protection of data centres, server rooms, communications and cell sites as well as remote telemetry installations.

Type 2/3 surge filters are ideal in equipment cabinets as a final stage of protection.

4. Selection of SPDs for Signal and Data Equipment

Table 2 shows the recommended surge rating for signal and data SPDs related to the lightning protection zone boundary.

Zone Boundary	SPD Location	I_{max} rating 8/20us	I_{imp} rating 10/350us
LPZ2/…n	Internal marshalling cubicle or equipment cabinet	5kA	-
$LPZ0_B/1$	External signal cables shielded from direct lightning strike	10kA	2.5kA
$LPZ0_A/1$	Point of entry, long overhead or underground signal cables	20kA	5kA
$LPZ0_A/1$	Point of entry signal cables, building in a high lightning area (N_g greater than 2.5), or fitted with an LPS	20kA	5kA

Table 2. Recommended surge ratings – signal and data derived from AS1768

Selecting the appropriate SPD requires knowledge of the signal that will pass through the SPD. Generally, signal and data SPDs are two port devices with line and equipment connections.

Insert the diagram from V5 handbook page 28

When selecting SPDs for process control and data applications, it is important that the signal is not attenuated or lost through the SPD. The following procedure should be followed:

a. *Determine the signalling protocol and peak line voltage.*

   Table 3 provides a list of common signalling protocols and the appropriate Novaris SPD for each application. If the protocol is not known, the peak signal voltage must be determined.

b. *Select the Clamping Voltage*

   The clamping voltage of the SPD must be greater than the peak signalling voltage. The following is a guide:

Peak Signal Voltage (V)	Power System (V)	SPD Clamping Voltage (V)
0-6	5	7v5
6-15	12	18
15-30	24	36
30-60	48	68

c. *Determine the signal current*
   - SL models are rated at I_L = 250mA
   - SL2/4 models are rated at I_L = 500mA
   - SLH2 models are rated at I_L = 2.5A
   - SSP6A models are rated at I_L = 6A
   - SSP10A models are rated at I_L = 10A

   For higher current applications, use SFD or IFD surge filters.

d. *Select signal frequency / data rate*

Standard SL/SL2 series will pass signals up to 60MHz. For higher data rates use the SL485 or RJ45 for Ethernet applications.

e. *Earth isolation*

The normal SL DIN rail base, designated -G, connects the protective earth to the DIN rail to provide a low impedance earth path. If the screen earth of the cable must be isolated use the -EC90 base. For the SL2 select the -G or -EC90 version.

Insert the table of page 29 of handbook V5. Call it table 3.

5. Selection of SPDs for RF Applications

a. *Options for RF SPDs*

Inline coaxial SPDs containing a gas discharge tube (GDT) are suitable for a wide frequency range (up to 3GHz or 6GHz) but must be chosen with respect to the power on the line if used for transmitting.

Stub type SPDs are used in specialised applications for example where a high passive intermodulation distortion (PIM) is required. Typically this may be around -150dBc.

Spark gap coaxial protectors provide protection for high powered transmitters used for HF radar, FM and TV broadcasting. Typical connectors are EIA flange type.

b. *Identify the connector*

Novaris manufactures a wide range of coaxial SPDs to suit most common connectors and gender variations.

c. *Select the clamping voltage*

The clamping voltage of the SPD must be greater than the peak line voltage. This is particularly important when used for transmitting applications. Knowing the modulation type is important. For example, a 100% amplitude modulated signal will double the peak line voltage.

Power in 50 ohms (W)	GDT Voltage (V)
0 - 25	90
25 - 125	230
125 - 300	350
300 - 800	600
800 - 2000	1000

Spark gap CEIA protectors can operate up to 100KW.

d. *Identify the maximum operating frequency*

3G (to 3GHz) models are available in all standard small format connector types and feature replaceable GDT. These have 50ohm characteristic impedance. Units with F type connectors have 75ohm characteristic impedance.

6G (to 6GHz) models are available in N type, SMA and 4.3-10 with 50ohm characteristic impedance.

Stub type protectors have specific frequency ranges.

CEIA protectors using EIA flange connectors are 50ohm and can operate to 1GHz.