Lightning Protection and Insulation Coordination

SDI 520

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Endeavour Energy

Revision History

This standard replaces amendment no 3. All changes are highlighted in this document with grey colouring.

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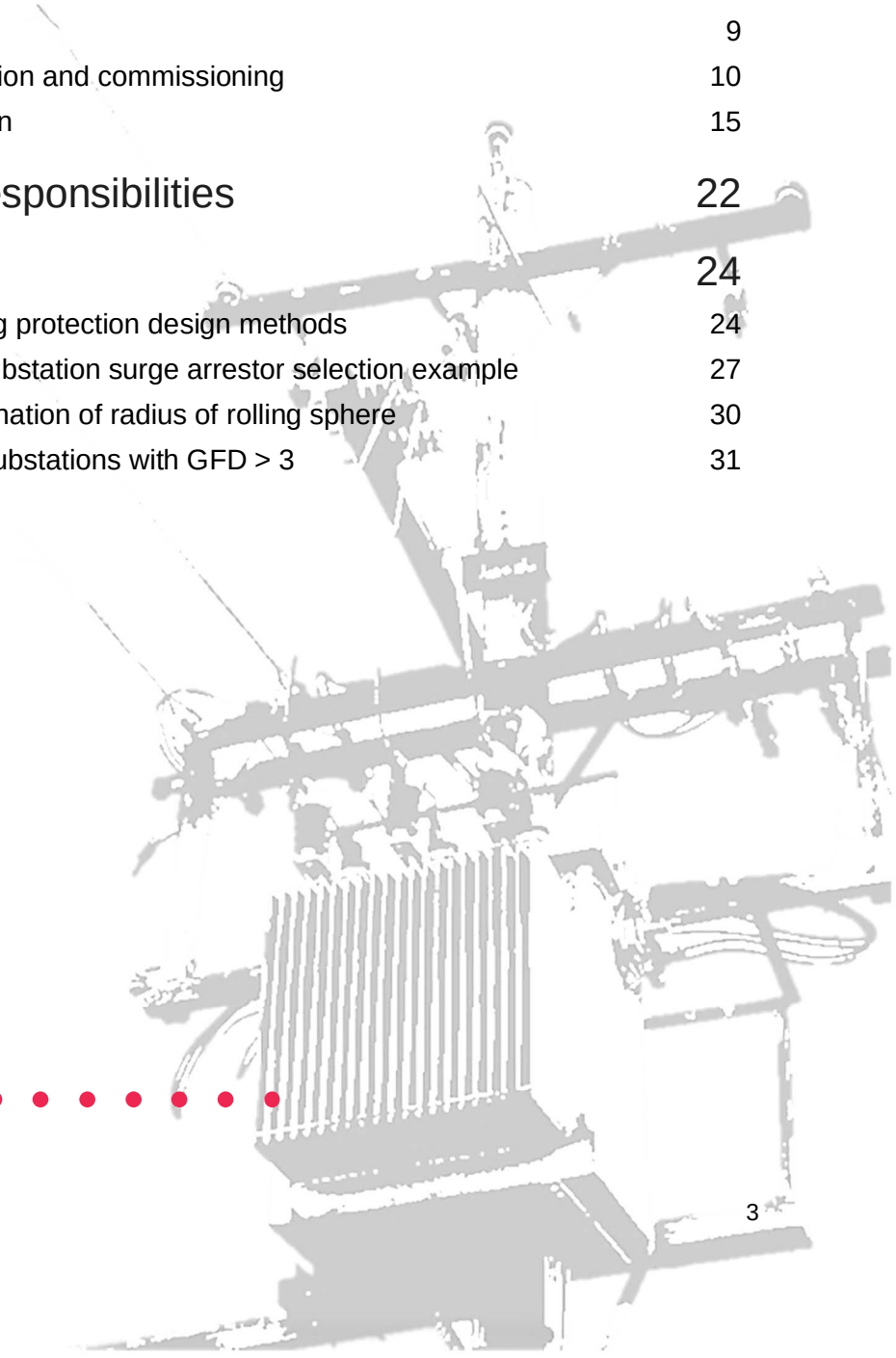


1 Documentation Scope

This instruction defines the minimum requirements for:

1. design of insulation coordination for the network;
2. design, construction and commissioning of lightning protection systems (LPS) for major substations; and
3. selection of surge arrestors.

Design, construction and commissioning of earthing systems associated with LPS are not covered in this instruction. Reference must be made to EDI 516 - *Major substation earthing design, construction and commissioning*, for complete instructions applicable to earthing systems.

Reference must be made to MDI 0031 - *Overhead line design*, for instructions applicable to lightning protection and insulation coordination design for overhead transmission mains.

It is not the intention of this instruction to define the full process of design, construction and commissioning of lightning protection systems and design of insulation coordination and selection of surge arrestors in detail. It is the responsibility of the designer and the project manager to carry out the design and construction that meets the minimum performance requirements of this instruction.

Distribution assets are protected using surge arresters, refer to Section 4.2.3 for more information.

2 References

External Regulations
Electricity Supply Act 1995 (NSW)
Electricity Supply (Safety and Network Management) Regulation 2014
Work Health and Safety Act 2011
Work Health and Safety Regulation 2017

External Standards
ENA National Electricity Network Safety Code (Doc 01-2008)
IEEE 998:2012-Guide for direct lightning stroke shielding of substations
IEC 60071-1:2011-Insulation Coordination-Part 1: Definitions, principals and rules
IEC 60071-2 2018-Insulation coordination - Part 2: Application guidelines
IEC 60099-4:2014-Metal Oxide Surge arresters without gaps for a.c. systems
BS EN 62561-2:2012-Lightning protection system components (LPSC)-Requirements for conductors and earth electrodes
AS 1170.2:2011 (R2016) - Structural design actions Part 2: Wind actions
AS 1307.2:1996 (R2015) - Metal oxide surge arresters without gaps for a.c. systems
AS 1768:2007 - Lightning Protection
AS 2067:2016 – Substations and high voltage installations exceeding 1kV a.c

Company Policies and Procedures
Company Policy 9.2.2 - Network Protection
Company Policy 9.2.5 - Network Asset Design
Electrical Safety Rules
Company Procedure GNV1119 - Quantitative determination of reasonably practicable risk control measures when assessing health and safety risks

Company Standards
Earthing Design Instructions EDI 516 Major substation earthing design, construction and commissioning
Equipment Technical Specification ETS 0011-132kV/66kV/33kV/22kV/11kV transmission surge arrestors
Automation Design Instructions ADI0006-Substation Communication Systems
Mains Design Instruction MDI 0031 - Overhead line design
Mains Design Instruction MDI 0045 -Cable sheath bonding design

3 Definitions and Abbreviations

Abbreviation	Meaning
BIL	Basic Insulation Level expressed in terms of the crest value of the standard lightning impulse.
BSL	The conventional Basic Switching impulse Level expressed in terms of the crest value of the standard switching impulse for which the insulation does not exhibit disruptive discharge when subjected to a specific number of application of this impulse. Statistical BSL (applicable to self-restoring insulation) is the crest value of a standard switching impulse for which the insulation exhibits a 90% probability of withstand, a 10% probability of failure.
CFO	The Critical Flash Over to insulation results in a 50% probability of flashover.
FOS	Factor of Safety
GIS	Gas Insulated Switchgear/Substation
LPS	Lightning Protection System
MCOV	Maximum Continuous Operating Voltage
NER	Neutral Earth Resistor
NEX	Neutral Earth Reactor
r.m.s	Root mean squared
RSM	Rolling Sphere Method
SA	Surge arrestor. Also called surge diverter, used to limit the overvoltages that may occur due to lightning or switching surges.
SPD	Surge Protective Device
SWER	Single Wire Earth Return
Uc	The root mean square (r.m.s) value of a surge arrester's MCOV.
UGOH	Underground to overhead

Term	Definition
Air terminal	A vertical or horizontal conductor of an LPS, positioned so as to intercept a lightning discharge, which establishes a zone of protection. (Ref AS/NZS 1768)
Continuous operating voltage of an arrester (Uc)	The continuous operating voltage is the designated permissible r.m.s. value of power frequency voltage that may be applied continuously between the arrester terminals. Ref AS1307.2
Direct lightning stroke	A lightning discharge composed of one or more strokes that strike the structure or its LPS directly.
Down conductor	A conductor that connects an air terminal network with an earth termination. Ref AS/NZS 1768

Term	Definition
Earthing Enquiries	Earthing Enquiries mail box: <earthingenquiry@endeavourenergy.com.au>
Electrogeometric Model (EGM):	A geometrical representation of a facility that, together with suitable analytical expressions correlating its dimensions to the current of the lightning stroke, is capable of predicting if the first return stroke of a lightning flash will terminate on the shielding system, the earth, or the element of the facility being protected. Ref IEEE998
Energy capability	The ability of the arrestor to safely discharge surge energy while remaining thermally stable.
Ground flash	Earth discharge. A lightning flash in which at least one lightning discharge channel reaches the ground.
Impulse wave	The first value describes the time taken for the impulse to reach a peak (crest) value from the origin and the second value is the time taken for the peak value to decay to half of its peak value. The duration of the second value is also measured from the origin.
Insulation coordination	The selection of the dielectric strength of equipment in relation to the voltages which can appear on the system for which the equipment is intended and taking into account the service environment and the characteristics of the available protective devices. Ref AS1824.1
Leader	The first part of a lightning stroke current.
Lightning flash	An electrical discharge in the atmosphere involving one or more electrically charged regions, most commonly in a cumulonimbus cloud, taking either of the following forms: Ground flash (earth discharge) Cloud flash
Lightning stroke	Individual current impulse in a ground flash.
Major Substation	Zone substations, transmission substations and switching stations with transmission voltages (including and above 33kV).
Overvoltage	Any voltage between one phase conductor and earth or between phase conductors having a peak value exceeding the corresponding peak of the highest voltage for equipment. Ref AS1824.1 According to their shape and duration, voltages and overvoltages are divided in the following classes: a) continuous (power frequency) voltage: Power-frequency voltage, considered having constant r.m.s. value, continuously applied to any pair of terminals of an insulation configuration. b) temporary overvoltage: Power frequency overvoltage of relatively long duration. c) transient overvoltage: Short-duration overvoltage of few milliseconds or less, oscillatory or non-oscillatory, usually highly damped.
Rated voltage (Ur)	The TOV withstand voltage of a surge arrestor for 10 second duration.
Residual voltage/ discharge voltage	The peak value of the voltage that appears between the terminals of an arrestor during the passage of discharge current through it. This value is often used to describe the protection level of the arrestor - Up
Rolling Sphere Method	A simplified technique for applying the electro-geometric theory to the shielding of substations. The technique involves rolling an imaginary sphere of prescribed radius over the surface of a substation. The sphere rolls up and over (and is supported by) lightning masts, shield wires, fences, and other grounded metal objects intended for lightning shielding. A piece of equipment is protected from a direct stroke if it remains below

Term	Definition
	the curved surface of the sphere by virtue of the sphere being elevated by shield wires or other devices. Equipment that touches the sphere or penetrates its surface is not protected. (Ref IEE998)
Standard lightning impulse wave	The standard lightning impulse wave shape is 1.2/50 microseconds.
Standard switching impulse wave	The standard switching impulse wave shape is 250/2500 microseconds.
Standard short-duration power-frequency voltage	A sinusoidal voltage with frequency between 48Hz and 62 Hz, and duration 1 minute.
Temporary overvoltage (TOV)	Temporary overvoltages are oscillatory power frequency overvoltages of relatively long duration from a few cycles to hours. The most common form of TOV occurs on the healthy phases of a system during an earth fault involving one or more phases.

4 Action

The designer of lightning protection and insulation coordination must meet following functioning requirement.

High voltage equipment of major substations must be protected against overvoltages resulting from switching operations and lightning that could exceed the withstand equipment insulation levels.

Equipment insulation levels must be selected from the standardised ratings provided in this standard. The equipment installed in the network must meet these minimum insulation levels.

4.1 General requirement

4.1.1 Earthing Compliance

Design, construction and commissioning of the earthing system associated with LPS for major substations must be in accordance with EDI 516.

4.1.2 Over voltage protection methods

The following overvoltage protection methods must be incorporated to the major substation lightning protection and insulation coordination designs.

- Shielding of the major substation outdoor live equipment from direct lightning strikes.
- Shielding of the overhead transmission lines entering or leaving the major substation. Refer to 4.3.2.
- Shielding of the overhead transmission lines exiting the major substation, at least for a limited distance.
- Provision of surge arrestors to protect selected major substation equipment.
- Provision of surge arrestors at all overhead line entry/exit points into the major substation.
- A consideration of the duration of overvoltage on the system that is based on the protection detection and clearing times of the major substation equipment.

4.1.3 Lightning protection and insulation coordination design

A new or review of the lightning protection and insulation coordination design is required as follows:

1. all new major substations LPS design is required to comply with this standard.
2. for existing major substations due to change of structure height and location of other equipment or building upgrades or installation or removal, all require a review of LPS design to comply with this standard if proposed works are cost risk justified.
3. an existing major substation where the LPS is damaged or there is no LPS installed.

Note: For existing substations that have been designed, constructed and approved to an older version of this standard, there is no requirement to alter the LPS to comply with the most current version of this standard unless some changes have occurred which affects the original design of the LPS.

All lightning protection and insulation coordination design for major substations must be approved by the Substation Design Manager.

4.2 LPS design construction and commissioning

4.2.1 Equipment and structures to be protected from lightning protection system

The outdoor live high voltage equipment including busbars, transformers, circuit breakers, voltage transformers, current transformers, reactors, capacitor banks, isolators and earth switches in major substations must be protected from direct lightning strikes by installing properly designed LPS using lightning intercepting points.

4.2.2 Lightning intercepting points in LPS design

The following conductive items can be selected for the substation LPS as lightning intercepting points:

1. Roof of the control and amenity building. Refer to section 4.2.9
2. Lightning masts. Refer to section 4.2.10.
3. Steel columns for light, security camera etc. Refer to section 4.2.11
4. Metallic fencing. Refer to section 4.2.12
5. Overhead earth wires. Refer to section 4.2.13
6. Transformer fire walls. Refer to section 4.2.14
7. Overhead line terminating structures with air terminals. Refer to section 4.2.15

Location of lightning intercepting points must be determined by the LPS design. Lightning intercepting points must be provided with sufficient earth connections to the earth grid as specified in the above sections relevant to each item.

4.2.3 Distribution assets in the substation switchyard excluded from LPS design

Distribution assets (eg, enclosed capacitor banks and auxiliary transformers) within major substations are not considered in the LPS design. This is due to distribution assets having a much lower insulation level compared to transmission assets and using the rolling sphere method will result in a non-feasible solution. However, distribution assets are protected by surge arresters.

4.2.4 Design inputs

Equipment insulation level:

Impulse withstand voltage (BIL/BSL) specified in Table 2 must be used for the LPS design for major substations. The equipment used in major substations and transmission lines will have BIL equal or above these specified values.

Average annual lightning ground flash density (GFD):

The GFD within Endeavour Energy's franchise area given in AS/NZS1768 is 3 strikes per km^2. A study carried out shows some Endeavour Energy substation sites have received significantly more than 3 strikes per km^2, for a 3-year period ending December 2015. The substation sites with GFD more than 3 strikes per km^2 are provided in Annexure 6.4.

For all LPS designs carried out as required in section 4.1.3, GFD values as outlined below must be used.

1. For existing substations, GFD values provided in Annexure 6.4 must be used.
2. For existing substations, if GFD values are not provided in Annexure 6.4, the GFD value of 3 strikes per km^2 must be used.
3. For new substations, the GFD value must be obtained from Earthing Enquiries.

4.2.5 LPS levels and design method

Lightning protection system (LPS) design for major substations must be carried out using the rolling sphere method (RSM) as outlined in Annexure 6.1.

Applicable radius of the rolling sphere for LPS design must be determined as outlined in Annexure 6.3. Information specific to the site must be used for the determination of the radius of the rolling sphere.

4.2.6 Risk/efficiency evaluation

Risk evaluation for LPS for major substation is required to be carried out as outlined in Annexure D of IEEE 998. The annual expected number of equipment failures due to direct lightning strikes is required to be less than $1x10^{-4}$. This value is based on one failure over 50 years for total of 200 major substations.

4.2.7 Substations with two or more voltage levels

The major substations, however, might have outdoor busbars with two or more voltage levels. The rolling sphere method is applied in the same manner in such cases, except that the sphere radius would increase or decrease appropriate to the change in voltage at a transformer. Ref 6.3.5 of IEEE998.

4.2.8 Standard materials used in the LPS

Materials used for LPS must be highly conductive (copper) and resistant to corrosion resulting from the environment in which they are installed. The metallic components of the LPS must be compatible with the metals used in the structures.

Insulated materials should be used where a risk of anodic or cathodic corrosion exists.

Standard materials listed in Table 1 along with other materials specified in EDI 516 must be used for the design and construction of LPS. The standard materials specified in Table 1 are based on the same materials specified for the earthing system of the major substation and should also comply with the electrical and mechanical strength requirements for lightning protection components specified in BS EN 62561-2:2012.

Table 1 – Standard materials for LPS

Stock Code	Drawing Number	Item description	Component
1566355	397978	Steel lightning masts-15m	Air terminals
1566348	397978	Steel lightning masts-20m	Air terminals
SC18393	N/A	50mmx3mm copper strip- tinned	Air terminals and down conductors
1087850	N/A	95 mm^2 Cu stranded PVC insulated earth cables	Down conductors
1552090	N/A	120 mm^2 Cu stranded PVC insulated earth cables	Down conductors mainly for Transmission substations
1020936	010637	M15x2400mm steel copper clad earth rods	Electrode and Air terminals (cut lengths to suit design)

Stock Code	Drawing Number	Item description	Component
N/A	518253	CRITEC DIN Rail Surge Filter-for AC supply-DSF20A275V (701020) or equivalent	Surge Protection Device

4.2.9 Design of control buildings

Metal roofing of the control buildings of major substations can be designed to incorporate into the lightning interception point of the LPS.

The ridges, corners, and edges of building roof attachment points, which coincide with the metal roofing sheeting, capping or guttering, must be fixed by multiple screws, rivets or clips directly to the supporting steel purlins, beams and trusses below. Roof steelwork must be directly connected to the substation earthing grid using dedicated down conductors or steel reinforcement of the building designed to carry surge current. Minimum of two earth connections from roof steelworks to different sections of the earth grid or steel reinforcement is required.

Buildings with concrete roofs will require placing metal air terminals on the uppermost parts of the building or its projections, with conductors connecting the air terminals to each other and to earth. For reinforced concrete buildings, the reinforcement should be made electrically continuous in all concrete elements. Reference must be made to embedded earthing section in EDI 516.

When installing earth bars to building walls, they must be placed away from lightning down conductors and insulated between the walls to avoid lightning current flashes into the sensitive electronic equipment and auxiliary supply system through earth bars. The earth bars must be insulated from walls using insulators. Refer to EDI 516.

4.2.10 Lightning masts installation and clearance

Lightning masts must be positioned according to the LPS design provided they are away from any equipment or structures that are connected to live parts through insulators to reduce the likelihood of side flashes to adjacent equipment. The closer to the lighting mast increases probability of lightning flash from lightning mast to live equipment. Minimum five meters clearance must be maintained if the amount of clearance is not determined in the design. Five metres clearance is an industry standard, which is based on practical experience rather than theory. Cost benefit analysis for health and safety related risks must be carried out as outlined in company procedure GNV1119 if this clearance cannot be achieved.

Lightning mast footing installation must be designed and constructed as set out in AS 1170 to withstand wind speeds of 48m/s of three second gusts.

Lightning masts must be provided with one earth connection to the substation earth grid and another connection to a 2.4m earth rod installed adjacent to footing of the mast.

Restrictions of other equipment mounting on lightning masts:

Radio antenna, light fittings, security cameras and other equipment which are connected via cables, eventually enter the major substation and connect to either auxiliary power supply or sensitive electronic equipment and must not be mounted on the lightning mast as this could lead to lightning surges entering the substation and damaging the equipment. Refer to section 4.2.20 for protection of communication antenna and radio towers.

4.2.11 Steel columns used for yard lighting and security cameras

There is a risk for damaging sensitive equipment powered from auxiliary AC supply from a lightning surge as a result of a lightning strike to a yard light column. Surge protection devices

(SPD) must be installed to lighting circuits at the Auxiliary AC supply panel. Refer to Table 1 for details of SPD.

Consideration of yard lighting columns and security camera columns as items to be protected by the LPS is not required in the design.

If these columns are specially designed to have two earth connections connected to different section of the earth grid, these columns may be considered as lightning intercepting points in the LPS design if required.

4.2.12 Metallic Security Fence

If the metallic security fence earthing installation is constructed to comply with EDI 516, the fence can be considered part of lightning intercepting point.

4.2.13 Overhead earth wires

Overhead earth wires can be considered lightning intercepting point. Overhead earth wires must be designed to avoid crossing over the busbars or other circuits within the substation.

4.2.14 Transformer firewalls and oil deflection walls

Suitable air terminals must be installed on concrete firewalls if they are used as lightning intercepting points in the LPS design. Installation of air terminals may not be required for metallic oil spillage deflection walls if they are used as lightning intercepting points in the LPS design. Firewalls must be specially designed to have two earth connections connected to different sections of the earth grid to consider as lighting intercepting point.

4.2.15 Overhead line landing structures

Overhead wires terminating landing structures can be considered as lightning intercepting points for LPS design. Landing structures must be designed to have two earth connections connected to different sections of the earth grid to consider as lighting intercepting point.

4.2.16 Down conductors and earthing

Down conductors are generally used for brick buildings with concrete roofs. If there are down conductors between the lightning intercepting points and the earth grid, they must be routed in the shortest vertical distance possible to avoid the flashover of lightning to neighbouring components. Down conductors must be located directly below lightning intercepting points.

Sharp bends in the down conductor should be prevented and re-entry loop limits as stated in AS/NZS 1768:2007 must be maintained.

Down conductors must not be grouped with other cables that are sensitive to induction unless the other cables are also bonded to the LPS.

Nonconductive (wood) lightning masts greater than 10 metres above ground, must have at least two down conductors of cross section area over 50mm^2 copper (Ref BS EN 62561-2:2012), with every down conductor being connected to separate locations of the earthing system. This must only be applied to existing installations; all new structures must be metal.

Lattice steel structures, which have more than one continuous conductive current path, do not require additional down conductors.

4.2.17 Minimum earth resistance

Major substation house sensitive electronic equipment including electronic relays and SCADA equipment, hence the earthing system must have an earth resistance not greater than 5Ω (refer 4.14.2.2 of AS/NZS 1768). In most situations, this resistance target is easily achievable as the LPS is connected to the major substation's earthing system, which is much less than 5Ω in resistance.

4.2.18 Joints and fasteners

The LPS must be designed to have as few joints as possible. Bolted joints must be mechanically and electrically effective. Refer to drawing 385821 in EDI 516 for standard bolted joints for down

conductors. Down conductors must be fastened as outlined in EDI 516. Fasteners must be spaced so as to give adequate support to the conductor. All mechanical connections must be visible and accessible for inspections on a regular basis, checking the integrity of connections over time. The measured resistance of the joints must be below 20mΩ.

4.2.19 Test links

Although the requirement for provision of test links is specified in section 4.13 of AS1768 to minimise the number of joints in down conductors, test links are not required.

4.2.20 Protection of communication antenna and radio towers

SCADA and all other wide area network (WAN) communications to some new major substations may use optical fibre and hence an antenna is not installed.

When carrying out new designs, or assessing existing LPS designs, installation of the antenna must be taken in to account. The project manager must provide the location and the height information of this antenna equipment to the LPS designer.

LPS of substations must be designed to cover antenna installations if it is practical and economically viable. However, if the roof of the control building is used as a lightning intercepting point in LPS design, lightning shielding will not cover roof top antenna installations and consideration must be given for relocation.

In some existing substations antennas are installed on lightning intercepting points such as; the roof tops of control building, lightning masts, gantry structures and must also be considered for relocation.

For such installations where antenna installations cannot be relocated, or it is not economically viable, the LPS designer must include SPD to communication installation as outlined in ADI0006-*Substation Communication Systems*.

4.2.21 Commissioning of LPS installation

Commissioning of LPS must be carried out along with the commission of the earthing system. This requires continuity test for all joints where high resistance joints over 20mΩ must be rectified.

4.2.22 Construction safety requirements

During construction and commissioning of lightning protection installations, especially in existing substations, there is an increased risk of employees and contractors being exposed to electrical hazards. As a part of the design of a LPS it is essential that the construction safety requirements be identified, and controls are listed in the appropriate safety documents, SAR and safe work method statements (SWMS).

The lightning protection design report must include site specific construction hazards and any special requirements for mitigating risks when working inside or adjacent to the energised substation.

4.2.23 Minimum information in Lightning design report for major substations

While not intending to limit the issues or strategy of design report, the lightning design report should be generally succinct and completed with the following information for review and approval by the Substation Design Manager:

Lightning design report must include minimum information as follows:

1. Lightning interception plan/construction drawing/s showing location of intercepting points and material for the installation covering all critical equipment and earthing requirement for lightning protection system.

2. A three-dimension lightning protection design analysis results if the design was using a software tool or geometric representation of lighting shielding coverage. Analysis must

clearly demonstrate that the required efficiency levels stated in section 4.2.6 has been achieved.

3. Construction hazards and any special requirements for mitigating risks when working inside or adjacent to the energised substation. The company will follow the principles of Safe design. Key information about identified hazards and action to control risks must be recorded and transferred from the design phase to the next stages of the lifecycle. This safety information must be included in the design drawings particularly where designs deviate from this standard.
4. Detail instructions of the SPD installation for items not covered in the lightning shield.
5. Economical justification for proposed works.

4.3 Insulation coordination

Insulation coordination is the selection of insulation strength and protective devices, to match potential over voltages to achieve acceptable service reliability, by minimising risk of equipment failure.

4.3.1 Insulation levels of equipment

The insulation level for equipment for major substations and transmission lines must be chosen according to the established highest system voltage for equipment U_m and impulse withstand voltage (BIL/BSL) as specified in Table 2. These conservative insulation levels are selected from Table 2 of IEC 60071-1.

The insulation level for equipment for distribution networks must be chosen according to the highest established system voltage for equipment U_m and impulse withstand voltage (BIL/BSL) as specified in Table 3. These conservative insulation levels are selected from Table 2 of IEC 60071-1.

Surge arrestors must be used to control the over voltages to below the equipment BIL levels.

Table 2 – Equipment insulation level for major substations and transmission lines

Nominal voltage (kV r.m.s)	Highest system voltage for equipment Um (kV r.m.s)	Standard short duration-one(1) min. power frequency withstand voltage (kV r.m.s)	Impulse withstand voltage (kV peak)
<1	-	1-3	8
11	12	28	95
22	24	50	145
33	36	70	170
66	72.5	140	325
132	145	275	650

Table 3 – Equipment insulation level for distribution network

Nominal voltage (kV r.m.s)	Highest system voltage for equipment U_m (kV r.m.s)	Standard short duration-one(1) min. power frequency withstand voltage (kV r.m.s)	Impulse withstand voltage (kV peak)
<1	-	1-3	8
11	12	28	75
12.7 SWER	-	50	95
22	24	50	125

4.3.2 Reduction of overvoltages to major substation from transmission lines

Measures including, but not limited to, the following must be included in transmission line designs to reduce overvoltages to sufficiently low enough levels so that they can be safely discharged by the surge arrestors located at the entry to the major substations.

- Shielding wires must be designed to achieve reasonably low shielding failure flashover rate.
- Lightning protection of the transmission line may include low structure earthing values, refer to MDI 0031 - Overhead line design for more details.
- Minimum CFO Voltage for equipment for transmission lines must be derived based on the specified BIL/BSL values given in Table 2.

4.3.3 Locations for surge arrestor installations in or near major substations

Surge arrestors must be fitted at the following locations unless a study proves otherwise:

1. At underground to overhead line (UGOH) terminations within or outside the substation, where these overhead lines emanate from the substation. The SA must be located as close as possible to the UGOH termination.
2. On the structure at the substation boundary for any overhead line entering or leaving the substation outdoor busbars.
3. Underground feeder cable entering or leaving the outdoor busbar system in major substations.
4. At terminals of power transformers that are connected to the outdoor busbar system.

Requirements for the installation of surge arrestors for the following equipment must be assessed individually. Required overvoltage protection levels and the suitability of surge arrestors, as specified in ETS 0011 to these specific locations, is required to be assessed by the LPS designer and alternatives, in excess of the standard SA specified in ETS 0011, may be recommended.

- Terminals of power transformers connected with underground cables.
- Terminals of GIS connected with underground cables
- Indoor switchgear connected to aerial lines with a short underground cable with no provision for SA at the switchgear terminal.

4.3.4 Cable sheath voltage limiters (SVL)

Sheath voltage of a single end bonded cable can rise to an unacceptable level during fault conditions. Cable sheath voltage limiters must be installed to single core power cable installations as outlined in MDI 0045 - *Cable sheath bonding design*.

4.3.5 Gas insulated substations (GIS)

The surge impedance of the conductors within the GIS is significantly less than the incoming lines and conductors in an open-air substation. GIS enclosures generally provide very little attenuation of any impulses.

Therefore, installation of SAs must be carried out according to the requirement of the GIS manufacturer.

4.3.6 Power transformers

Where required SAs must be installed as follows for power transformers:

1. The SA must be located as closed as possible to the transformer bushing terminals.
2. The earth of each SA must be connected to an earth bar with the shortest possible lead. The earth bar must be connected directly to the earth grid (refer EDI 516).
3. The SA must be fitted to each phase terminal of the power transformer if an outdoor busbar system is connected. The SA must be fitted to a neutral terminal if specified by the transformer manufacturer.
4. The SA earth lead must be shorter than the distance between the SA terminal and the transformer bushing terminal.
5. The SA earth leads must not be directly connected to the transformer tank or neutral or the SA must not be mounted on the transformer.

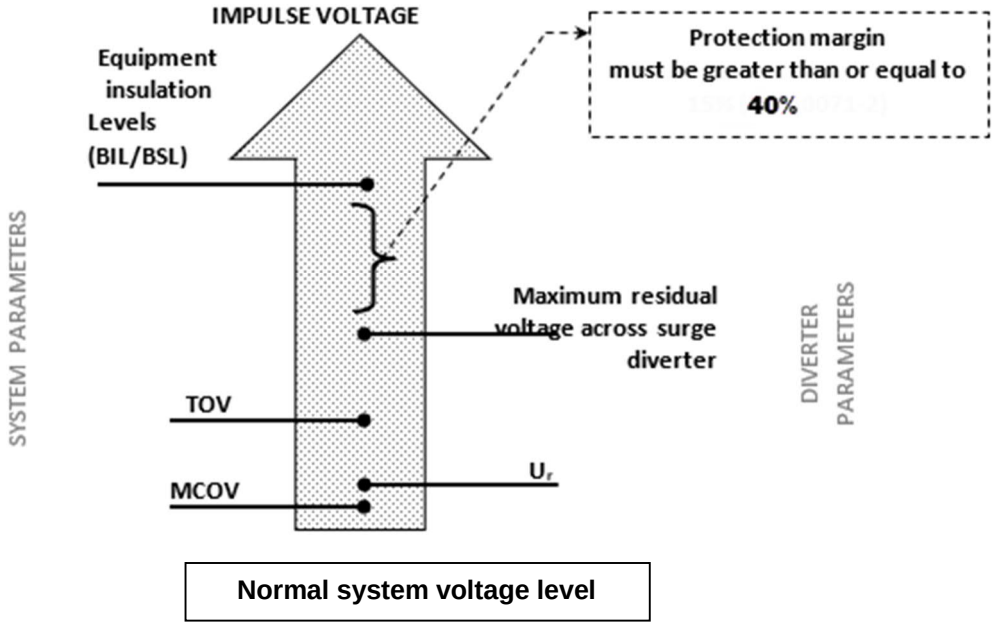
4.3.7 SA for major substations and transmission lines

Surge arrestor selection must be based on:

6. The maximum continuous operating voltage (MCOV) must be greater than the power frequency voltage at the surge arrestor's terminal.
7. Protection level of the surge arrestor must be at least 1.4. The protection level is defined as the ratio between the equipment BIL and the maximum residual voltage across the arrestor with the application of a 10kA (8/20µs) standard lightning impulse wave.
8. The maximum residual voltage must be as low as possible without compromising the MCOV or the TOV limits. Lower residual voltages offer greater zones of protection.

Refer to Annexure B - Major substation surge arrestor selection example, for worked examples for selecting surge arrestors.

Insulation and protection level margins for overvoltages are depicted as follows:



VOCABULARY

MCOV	Maximum continuous operating voltage level.
Ur	Surge arrestor rated voltage level.
TOV	Temporary overvoltage level.
Protection levels	Upl - Maximum residual voltage with 10kA current wave (8/20µs) – lightning impulse Ups - Maximum residual voltage with 0.5kA current wave (30/60µs) – switching impulse.
Insulation levels	BIL - Basic Impulse Insulation Level. (8/20µs). BSL – Basic Switching Impulse Insulation Level. (30/60µs).

Figure 1 - Relative magnitudes of system and arrestor parameters

4.3.8 Major substation and transmission line surge arrestor – minimum of selection criteria

Table 4 – Transmission surge arrestor - minimum electrical selection criteria

TYPE-Nominal system voltage (kV rms)	11	22	33	66	132
Nominal system voltage- phase to earth - kV rms	6.35	12.70	19.05	38.11	76.21
Maximum system voltage- phase to phase - kV rms	12	24	36	72.5	145
Maximum system voltage- phase to earth - kV rms	6.93	13.86	20.79	41.86	83.72
Uc- Maximum Continuous Operating Voltage (MCOV) using 5% harmonic content and Maximum system voltage - kV rms phase to earth	7.27	14.55	21.82	43.95	87.90
Ur-minimum surge arrestor rated voltage for effectively earthed neutral systems using factor of safety FOS = 1.25 times (phase to earth)	9.09	18.19	27.28	54.94	109.88
Ur- minimum surge arrestor rated voltage for isolated or resonant earthed neutral systems using FOS = 1.25 times (phase to earth)	15	30	45	90.625	181.25
Temporary over voltage TOV using 1.4x MCOV for effectively earthed neutral systems - kV phase to earth	10.18	20.37	30.55	61.53	123.07
TOV using 1.732 x MCOV for isolated or resonant earthed neutral systems - kV phase to earth	15	30	45	90.625	181.25
Temporary over voltages duration in seconds (TOV duration) Ref Protection Information	2	2	2	2	2
Standard equipment short duration (1 min) power frequency withstand voltage (kV rms phase to phase)	28	50	70	140	275
Standard equipment lightning impulse withstand voltage (kV peak)- (BIL)	95	145	170	325	650
In-Nominal (8/20 µs impulse) discharge current kA	10	10	10	10	10
Maximum allowable residual voltage across surge arrestor to provide 40% protection margin for 10 kA 8/20µs impulse current U_{pl}- (kV peak)	67.86	103.57	121.43	232.14	464.29
Minimum energy capability (2 impulses) in kJ/kV (Ur)	5	5	5	5	5
High circuit pressure relief capability – kA for 0.2 seconds	50	50	50	50	50

*For Distribution assets (eg, enclosed capacitor banks and auxiliary transformers) auxiliary transformers within major substations refer to Table 5 for minimum electrical selection criteria.

4.3.9 Distribution substation and line surge arrestor – minimum of selection criteria

Table 5 - Distribution surge arrestor - minimum electrical selection criteria

TYPE-Nominal system voltage (kV rms)	11	22
Nominal system voltage- phase to earth - kV rms	6.35	12.70
Maximum system voltage- phase to phase - kV rms	12	24
Maximum system voltage- phase to earth - kV rms	6.93	13.86
Uc- Maximum Continuous Operating Voltage (MCOV) using 5% harmonic content and Maximum system voltage - kV rms phase to earth	7.27	14.55
Ur-minimum surge arrestor rated voltage for effectively earthed neutral systems using factor of safety FOS = 1.25 times (phase to earth)	9.09	18.19
Ur- minimum surge arrestor rated voltage for isolated or resonant earthed neutral systems using FOS = 1.25 times (phase to earth)	15	30
Temporary over voltage TOV using 1.4x MCOV for effectively earthed neutral systems - kV phase to earth	10.18	20.37
TOV using 1.732 x MCOV for isolated or resonant earthed neutral systems - kV phase to earth	15	30
Temporary over voltages duration in seconds (TOV duration) Ref Protection Information	2	2
Standard equipment short duration (1 min) power frequency withstand voltage (kV rms phase to phase)	28	50
Standard equipment lightning impulse withstand voltage (kV peak)- (BIL)	75	125
Maximum allowable residual voltage across surge arrestor to provide 40% protection margin for 10 kA 8/20µs impulse current U_{pl}- (kV peak)	53.57	89.29

4.3.10 Network Neutral Earthing Configuration.

For the substations shown in Table 6, the star point of secondary side of the power transformers are earthed via neutral earth resisters (NER) or neutral earth reactors (NEX). For all other substations, the star point of power transformers are effectively (solidly) earthed.

Table 6 - Substations with secondary side of transformer earthed through NER or NEX

Substation	Transformer Voltage (kV)	Earthing through NER or NEX
Arndell Park ZS	132/11	NEX
Broughton Pass HVC	66/11	NER
Denham Court TS	132/33	NER
Guilford TS	132/33	NEX
MT Piper TS	132/66	NER
Mungerie Park ZS	22kV	NER
North Paramatta ZS	132/11	NEX
Parklea ZS	22kV	NER
Ulladulla ZS	33/11	NEX
Warrimoo TS	132/66	NER
West Liverpool ZS	33/11	NEX

4.3.11 Drawings

A list of standard drawings is provided in Table 7. Request for any deviation from Standard construction arrangements must be forwarded to Earthing Enquiry for dispensation approval. The reason for the deviation must be stated clearly and objectively for consideration and assessment.

Table 7 - Standard drawing list

Drawing no.	Amd no.	Subject
385809	A	SUBSTATION SECURITY FENCE, GATE AND GENERAL EARTHING DETAILS
385810	A	SUBSTATION STEEL REINFORCEMENT WELDING AND STANDARD EARTH CONNECTIONS
385821	A	SUBSTATION EARTH BAR, EARTH STRAP MOUNTING AND FABRICATION DETAILS.
397978	A	LIGHTNING PROTECTION MASTS 20m and 15m
397979	A	FOOTING AND EARTHING DETAILS FOR LIGHTNING MASTS 20m and 15m

5 Authorities and Responsibilities

General Manager Operations has the authority and responsibility for approving this instruction.

Manager Delivery Excellence has the delegated authority and responsibility for approving this instruction for minor changes and making recommendations to General Manager Operations for major changes in respect to this instruction.

Substation Design Manager has the authority and responsibility for:

- keeping the contents of this instruction up to date;
- approving lightning protection and insulation coordination designs, drawings; and
- approving the Safety in Design risk report for lightning protection and insulation coordination designs.

Substation Primary Design Manager has the authority and responsibility for:

- maintaining that the content of this instruction is kept up to date based on industry best practice and current research and literature regarding major substation overvoltage risk management;
- reviewing lightning protection and insulation coordination designs, drawings, commissioning, construction safety and test reports for major substations and advising solutions to Substation Primary Design Engineers;
- approving lightning protection and insulation coordination, commissioning, construction safety and test reports for major substations; and

Major Substation Project Managers have the authority and responsibility for:

- providing the necessary design inputs;
- building the lightning protection system in accordance with the approved design and this instruction;
- as built drawings and testing information is uploaded onto Endeavour Energy's network system for the ongoing management of the major substations; and
- Implementing the controls within the Safety in Design report.

Substation Primary Design Engineers have the authority and responsibility for:

- reviewing lightning protection and insulation coordination designs, drawings, commissioning, construction safety and test reports and providing solutions;
- recommending lightning protection and insulation coordination design reports and drawings for approval; and
- undertake a Safety in Design risk assessment and develop a Safety in Design risk report for lightning protection and insulation coordination designs.

Manager Network Connections has the authority and responsibility for lightning protection and insulation coordination designs carried out for contestable network projects are in accordance with this standard.

Regional Service Managers, Manager Projects and Programs and Transmission Managers have the authority and responsibility for lightning protection and insulation coordination designs carried out for network projects are in accordance with this standard.

Accredited Service Providers (ASPs) and **Lightning Protection Designers** have the authority and responsibility for:

- lightning protection and insulation coordination designs comply with this standard;

- seeking clarification of this instruction, where necessary from the Substation Primary Design Manager, either directly or through the Network Connections;
- work performed is in accordance with local and statutory requirements;
- standard risk management principles and procedures are followed, and public safety is not unduly compromised within their reasonable capability; and
- preparing and advising on associated safe work method statements (SWMS), SAR and risk management plans for construction and commissioning support.

Telecommunications Manager has the authority and responsibility for reviewing antenna installations in Major Substations in accordance with this standard.

6 Annexures

6.1 Annexure A: Lightning protection design methods

If for some reason economically viable LPS design cannot be achieved using RSM, the other lightning protection design methods stated below in the order of preference must be used (Ref IEEE998). The designer must state in the design report the reason for using other methods and the achieved LPS efficiency level.

1. CVM/FIFM collection volume/field intensification factor method Ref 7.1.1 IEEE998 and appendix A
2. EGM–Mousa- Ref 6.4 IEEE998.
3. EGM–Eriksson-Ref 6.5 IEEE998
4. Fixed angle-Ref 5.1 IEEE998
5. Empirical-Ref 5.2 and 5.3 IEEE998
6. LPM- leader progression model-Ref 7.1.2 IEEE998
7. LIT- leader inception theory-Ref 7.1.3 IEEE998

6.1.1 Rolling sphere method:

Use of the rolling sphere method involves rolling an imaginary sphere of radius ***S*** over the surface of a substation. The sphere rolls up and over (and is supported by) lightning masts, shield wires, substation fences, and other earthed metallic objects that can provide lightning shielding. A piece of equipment is said to be protected from a direct stroke if it remains below the curved surface of the sphere by virtue of the sphere being elevated by shield wires or other devices. Equipment that touches the sphere or penetrates its surface is not protected. The basic concept is illustrated in Figure 2.

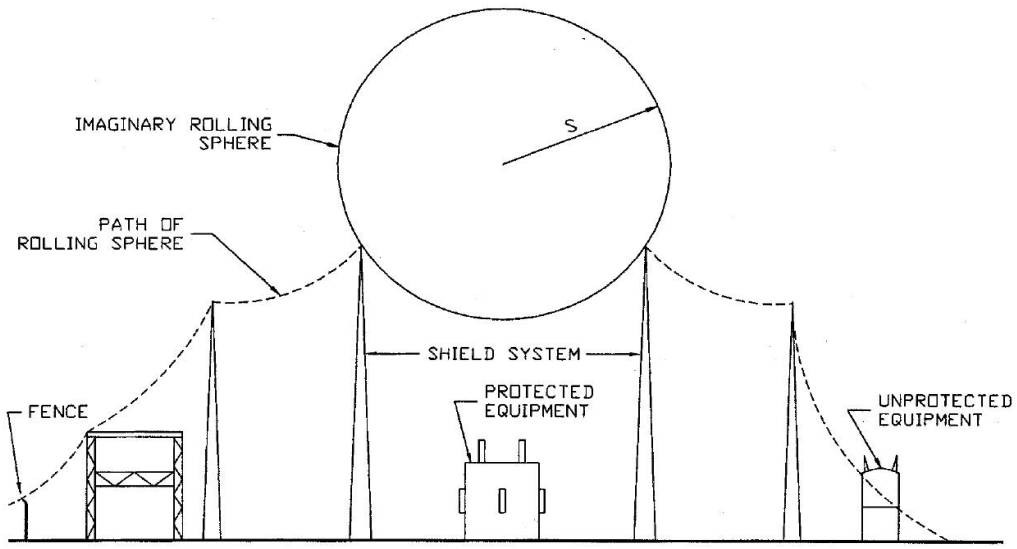


Figure 2: Principle of rolling sphere with multiple shielding electrodes Ref IEE998

6.1.2 Collection volume method (CVM)

The CVM defines lightning capture areas. This model allows computation of parabolic-like lightning “collection volumes” for all potential strike points on a structure. The model takes into account many fundamental physical quantities such as structure height, electric field intensification on the approach of a downward leader, leader velocity ratio, and downward leader charge and site altitude. It uses the concept of “attractive radius” – the capture radius of the

collection volume when viewed in plan. The collection volume assumes all points on a structure are able to launch an intercepting upward leader, but differentiates these points based on the field intensification they create.

This analysis produces a parabolic-like volume above the prospective strike point, as illustrated in Figure . This volume represents the three dimensional “capture” or “collection volume” of that point. For a particular downward leader charge and ratio of propagating leader speeds, the downward leader will only terminate at the nominated point if the striking distance is attained and the leader path is contained within the velocity or propagation related boundary of the collection volume.

Collection volumes are calculated for all points of interest around the substation, i.e., air terminations, structure corners and edges, equipment, busbars, conductors, etc. A simple example is shown in Figure (b).

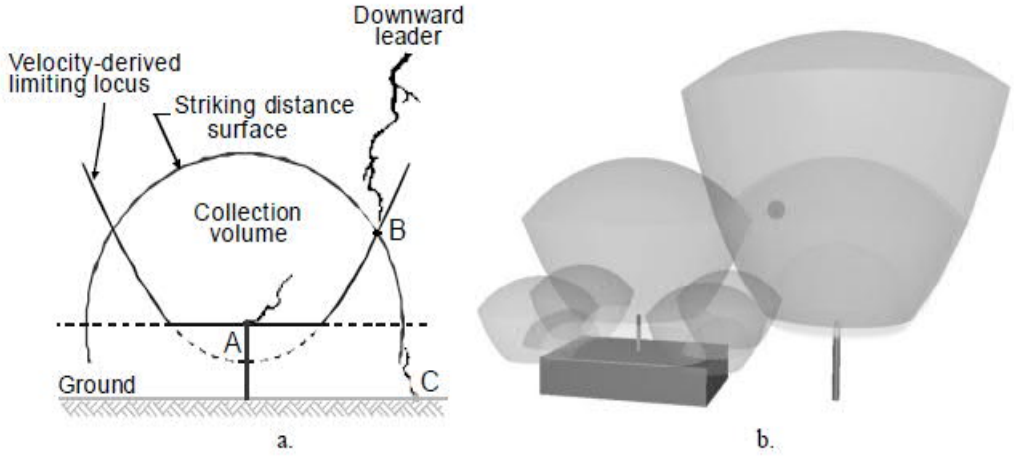


Figure 3: (a) Definition of parabolic-like collection volume for a prospective strike point. (b) A three-dimensional view showing collection volumes computed for various critical points (air terminations and competing features) around a site.

In summary, the procedure for implementing the CVM for protecting substations against lightning strokes is as follows:

a) Specify all elevated object heights, widths, and shapes.

b) Identify the “most probable” competing features (structure perimeters, sharper/more pointed features of substation equipment, busbars etc.).

c) Select the type (lightning mast or shield wire), height, number, and location of the air terminations (using a rough estimate of the attractive area of each—Equation (23-IEEE998) and Equation (24-IEEE998) of the Eriksson EGM can be used for this purpose).

d) Specify the basic physical parameters:

1. BIL or CFO -translate to downward leader charge/prospective peak current as given in Table 2;
2. Cloud base height (typically 3 to 5 km);
3. Site elevation or altitude above sea level, applying the appropriate correction factor to the air break down field if applicable;
4. Leader velocity ratio.

e) Compute the electric field intensification factors for all air terminations and nominated competing features.

f) For all air terminations and nominated competing features, compute the:

   5. Collection volume (striking distance surface and the velocity/leader propagation-based boundary);

   6. Attractive radius from the intersection point of the striking distance surface (for the given leader charge/BIL/CFO) and the propagation-based boundary.

g) Apply the attractive radii or capture areas to their respective air terminations and competing features.

h) Check to see if the air termination capture areas completely overlap the capture areas of all competing features (a plan view is useful here).

i) If not completely overlapped, relocate some of the existing air terminations or increase their height, or use more air terminations. Repeat the above steps until complete overlap is achieved.

6.1.3 Other Methods

Refer to IEEE 998 for other methods stated in section 5.2.3.

6.2 Annexure B: Major substation surge arrestor selection example

Example 1: Application of surge arrestor in an effectively earthed network

1. Decide on location of surge arrestor (SA) – in this example the location is to be on the primary winding of a 33kV/11kV two winding transformer of DY1 vector group. SA to be located between each phase and earth.
2. Therefore, maximum system voltage for 33kV system is 36kV - Um.
3. Minimum surge arrestor rated voltage from Table 4 - Ur = 27.28kV.
4. Minimum energy capability must be 5kJ/kV for all arrestors.
5. Lightning impulse rating must be 10kA for all locations within Endeavour Energy substations. The current wave shape to be used must be 8/20 µs.
6. Consider the system earthing configuration – in this example the system is solidly earthed. Therefore the maximum value that the voltage can rise to will be 1.4 times the MCOV value - from Table 2, this is 30.55kV for a maximum of two (2) seconds. This is the TOV value. The above value also includes a 5% harmonic content.
7. Consider maximum continuous voltage (Uc) to which the arrestor will be subjected during normal operation. This is the MCOV value, which in this case will be 21.82kV.
8. Consider BIL level of 33 kV equipment - see table 4 = 170kV
9. Therefore, maximum residual voltage across the surge arrestor is = BIL/1.4 = 121.42kV
10. Mechanical strength - static and dynamic loading is location dependant. Only conductor weight and swing needs consideration as arrestors will not be used to support any other system component.
11. Short circuit pressure relief capability - 50kA symmetrical.

Therefore:

Table 8 - SA criteria

Description	Values
Switching Surge Energy capability – minimum	5 kJ/kV
Maximum system voltage Phase to Phase (Um)	36kV
Minimum rated voltage Phase-Earth (Ur)	27.28kV
Discharge current rating - peak	10kA
Maximum Continuous Operating Voltage Phase to Earth MCOV	21.82kV
Temporary Over Voltage Phase to Earth TOV	30.55kV
TOV duration	2 seconds
Maximum residual voltage after application of 10kA 8/20 us current wave	121.42kV
Short circuit pressure relief capability	50kA symmetrical

Use above criteria to select from manufacturer's catalogue.

Example 2: Application of surge arrestor in a non-effectively earthed network

1. Decide on location of surge arrestor (SA) – in this example the location is to be on the primary winding of a 33kV/11kV two (2) winding transformer of DY1 vector group. SA to be located between each phase and earth.
2. Therefore, maximum system voltage for 33kV system is 36kV - Um.
3. Minimum surge arrestor rated voltage from Table 4 – Ur = 45 kV.
4. Consider line discharge class – in this case it is 2. Minimum energy capability must be 5kJ/kV for all arrestors.
5. Required SA rating must be 10kA line class 2 for all locations within Endeavour Energy substations. The current wave shape to be used must be 8/20us.
6. Consider the system earthing configuration - in this example the system is not effectively earthed. Therefore, the maximum value that the voltage can rise to will be 1.732 times the MCOV value - from Table 2, this is 45kV for a maximum of two (2) seconds. This is the TOV value. The above value also includes a 5% harmonic content.
7. Consider maximum continuous voltage (Uc) to which the arrestor will be subjected during normal operation – this is the MCOV value, which in this case will be 21.82 kV.
8. Consider BIL level of 33 kV equipment - see Table 4 = 170kV
9. Therefore, maximum residual voltage across the surge arrestor is = BIL/1.4 = 121.42kV
10. Mechanical strength - static and dynamic loading is location dependant. Only conductor weight and swing needs consideration as arrestors will not be used to support any other system component.
11. Short circuit pressure relief capability – 50kA symmetrical.

Therefore:

Table 9: SA criteria

Line class	2
Switching Surge Energy capability – minimum	5 kJ/kV
Maximum system voltage – Um	36 kV
Minimum rated voltage – (Ur)	45 kV
Discharge current rating - peak	10 kA
Maximum Continuous Operating Voltage Phase to Earth MCOV	21.82 kV
Temporary Over Voltage Phase to Earth TOV	45 kV
TOV duration	2 seconds
Maximum residual voltage after application of 10kA 8/20 us current wave	121.42 kV
Short circuit pressure relief capability	50 kA symmetrical

Use the above criteria to select from manufacturer's catalogue.

Manufacturers will supply arrestor parameters in a format similar to the following. These values must be used to aid in selection.

Table 10: SA catalogue information

Maximum Duty Cycle Voltage Ur	Maximum Continuous Operating Voltage Phase to Earth MCOV	Switching Surge Energy Rating	Max. residual voltage with current wave (8/20µs)
kV	kV	kJ/kV	U_{pl} (10 kA kV peak)
24	19.5	6	62.4
27	22.0	6	70.2
30	24.4	6	78.0
36	29.0	6	93.6
39	31.5	6	101
45	36.5	6	117

For Example 1, the surge arrestor Duty Cycle Voltage = 36kV was selected to suit TOV=30.55kV

TOV is greater than Ur in this example. This arrestor meets the MCOV, Ur and TOV and maximum residual voltage requirements

Lighting Protection Margin for Example1:

Lightning Impulse Withstand Level (U_{wl}) = 170

Lightning Protection Level (U_{pl}) = 93.6

Lighting Protection Margin (%)= (U_{wl}/U_{pl}-1)*100

=81%

For Example 2, the surge arrestor Duty Cycle Voltage = 45kV was selected to suit TOV=45kV

TOV is equal to Ur in this example. This arrestor meets the MCOV, Ur and TOV and maximum residual voltage requirements.

Lighting Protection Margin for Example2:

Lightning Impulse Withstand Level (U_{wl}) = 170

Lightning Protection Level (U_{pl}) = 117

Lighting Protection Margin (%)= (U_{wl}/U_{pl}-1)*100

=45%

This lightning protection margin over 40% as specified has been achieved for both of these examples.

6.3 Annexure C: Determination of radius of rolling sphere

Table 11: Determination of radius of rolling sphere suitable to acceptable LPS failure rate

Nominal Voltage of Busbar (kV)	BIL (kV) specified in Table-2	Surge impedance of 5m high busbar Ref formula C5 in IEEE998 (Ω)	Allowable stroke current for given BIL Ref formula 18 in IEEE998 (I_1- kA)	Radius of rolling sphere-S for 100% protection level Ref formula 17 in IEEE998 (m)	Selected radius of rolling sphere-S with acceptable risk levels Ref formula 17 in IEEE998 (m)	Acceptable stroke current for selected radius of rolling sphere Ref formula 18 in IEEE998 (I_2-kA)	Probability that a stroke will exceed current I_1 Ref formula 10 in IEEE998	Probability that a stroke will exceed current I_2 Ref formula 10 in IEEE998	Probability that a stroke which descend upon unprotected area	[1]Unprot-ected area (m^2)	[2]Ground Flash Density (GFD) Ref formula 11 in IEEE998	Annual expected Number of Flashes Descend into unprot-ected area	Annual expected number of equipment failures due to direct lightning strokes	Target annual number of equipment failures due to direct lightning strokes
11	95	366	0.57	6.7	26.8	4.9	0.9846	0.9999	0.0154	2118	3	0.00635	9.76E-05	1.00E-04
22	145	351	0.91	9.0	27	4.9	0.9841	0.9998	0.0157	2035	3	0.00611	9.57E-05	1.00E-04
33	170	342	1.09	10.2	27	4.9	0.9841	0.9997	0.0156	1966	3	0.00590	9.17E-05	1.00E-04
66	325	325	2.20	16.0	28.5	5.3	0.9804	0.9980	0.0176	1746	3	0.00524	9.24E-05	1.00E-04
132	650	300	4.77	26.5	33.7	6.9	0.9623	0.9853	0.0230	1364	3	0.00409	9.39E-05	1.00E-04

The lightning protection designer is required to determine applicable radius of rolling sphere using correct information relevant to the site. The information relevant to this determination includes:

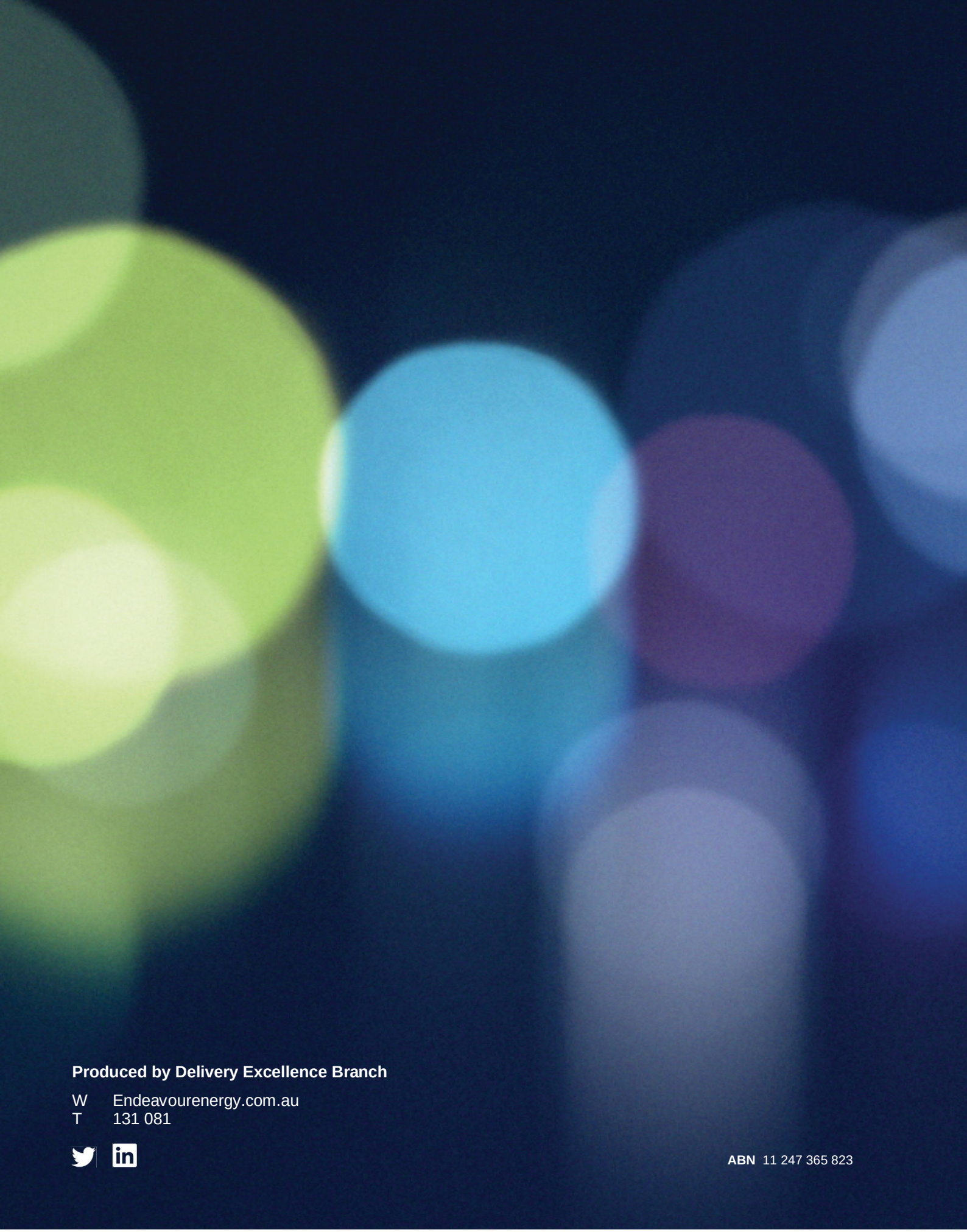
1. Unprotected area: Designer is required to calculate unprotected area based on actual intercepting pints and determine the applicable radius of the rolling sphere. Unprotected area in
2. Table 11 is based on a single mast.
3. Ground flash density (GFD): Refer to section 4.2.4.

6.4 Annexure D: List of substations with GFD > 3

Table 12: List of substations with GFD>3

Substation	GFD	Substation	GFD	Substation	GFD	Substation	GFD	Substation	GFD
ABBOTSBURY	5.94	CAWDOR	5.52	HORSLEY PARK	6.79	NEPEAN TS	6.37	SOUTH LEPPINGTON	3.82
AMBARVALE	7.22	CHERITON AVENUE	3.82	HUNTINGWOOD	3.4	NEWTON	5.52	SOUTH PROSPECT	4.67
APPIN	4.24	CHIPPING NORTON	6.79	INNER HARBOUR	8.49	NORTH RICHMOND	4.67	SOUTH WINDSOR	6.37
ARNDELL PARK	5.94	CLAREMONT MEADOWS	3.4	JASPER RD	5.52	NORTH ROCKS	4.24	SPRINGHILL TS	5.09
BAULKHAM HILLS 11KV	6.79	CORRIMAL	3.4	KANDOS	4.24	NORTHMEAD	3.82	SPRINGWOOD	6.37
BAULKHAM HILLS TS	6.37	CRANEBROOK	4.24	KANGAROO VALLEY	5.09	OAKDALE	7.64	ST MARYS	3.82
BELLA VISTA	5.52	DENHAM COURT	3.4	KATOOMBA NORTH TS	5.52	ORAN PARK	3.4	TAHMOOR	7.64
BELLAMBI TS	3.4	DUNDAS	3.4	KELLYVILLE	8.06	OUTER HARBOUR TS	5.09	THE OAKS	4.24
BERRIMA JUNCTION	3.82	EAST RICHMOND	5.09	KEMBLA GRANGE	4.67	PENRITH 11KV	5.52	TOMERONG	3.82
BLACKHEATH	5.09	E' WALLGROVE SS	5.94	KENNY STREET	5.52	PENRITH TS	5.52	ULLADULLA	7.22
BLACKMANS FLAT	5.09	EASTERN CREEK	7.22	KENTLYN	4.24	PLUMPTON	3.4	UNANDERRA	6.79
BLACKTOWN TS	8.91	EDMONDSON PARK	4.24	KINGSWOOD	3.4	PORT CENTRAL	3.4	WARRIMOO TS	8.49
BLAXLAND	6.79	EMU PLAINS	6.37	KURRAJONG	3.4	PORT KEMBLA	3.4	WENTWORTH FALLS	4.67
BONNYRIGG	4.24	ERSKINE PARK	3.4	LAWSON	11.03	PORTLAND	5.94	WERRINGTON	5.09
BOSSLEY PARK	5.52	FAIRFAX LANE TS	5.09	LAWSON TS	11.03	PRESTONS	5.94	WEST CASTLE HILL	6.79
BOW BOWING	3.4	FAIRFIELD	3.82	LEABONS LANE	4.24	PROSPECT	9.76	WEST LIVERPOOL 11KV	4.24
BRINGELLY	4.24	FIGTREE	5.52	LITHGOW	5.09	QUAKERS HILL	4.67	WEST LIVERPOOL TS	4.67

BULLI	3.82	GERRINGONG	3.82	LUDDENHAM	3.4	RICHMOND	3.82	WEST PARRAMATTA	5.09
CABRAMATTA	6.79	GLENMORE PARK	4.67	MACQUARIE FIELDS	4.24	RINGWOOD	5.94	WEST WETHERILL PARK 11KV	5.09
CAMBRIDGE PARK	4.24	GLOSSODIA	5.52	MAMRE	5.09	RIVERSTONE	4.67	WEST WETHERILL PARK TS	5.09
CAMELLIA TS	3.4	GRANVILLE	6.79	MARAYONG	5.52	ROBERTSON	5.09	WEST WOLLONGONG	3.4
CAMPBELLTOWN	5.09	HARTLEY VALE	3.82	MINTO	5.52	ROOTY HILL	4.24	WETHERILL PARK	4.24
CANLEY VALE	6.37	HAWKESBURY TS	4.67	MITTAGONG	5.94	ROSEHILL	3.4	WHALAN	3.4
CARLINGFORD TS	3.4	HAZELBROOK	4.24	MOOREBANK	5.94	RYDALMERE	4.24	WINDSOR	5.52
CARRAMAR	4.67	HELENSBURGH	4.24	MT DRUITT TS	3.82	SCHOFIELDS	5.09	WISEMANS	5.94
CASTLE HILL	4.67	HINCHINBROOK	5.52	MUNGERIE PARK	3.82	SEVEN HILLS	5.09	WOODPARK	3.4
CASULA	3.4	HOLROYD	5.09	NARELLAN	5.09	SHERWOOD	3.4		
CATTAI	3.4	HOMEPRIDE	6.79	NEPEAN 11KV	5.94	SMITHFIELD	3.82		



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