IMP/007/011 - Code of Practice for the Application of Lightning Protection

1. Purpose

The purpose of this document is to ensure the company achieves its requirements with respect to the Electricity Act 1989 (as amended) (the Act), the Electricity Safety, Quality, and Continuity (ESQC) Regulations 2002, the Electricity at Work (EAW) Regulations 1989, the Distribution Licences and The Distribution Code, by laying out the way in which Northern Powergrid will develop efficient, co-ordinated and economical networks.

This document specifies the type of lightning protection and the locations at which it is to be installed on the Northern Powergrid 11kV, 20kV, 33kV, 66kV and 132kV networks.

This document supersedes the following document, all copies of which should be destroyed;

Document Reference	Document Title	Version	Published Date
IMP/007/011	Code Of Practice for the Application of Lightning Protection	2.0	March 2020

2. Scope

This document covers the requirements, application, and installation of lightning protection on 11kV, 20kV, 33kV, 66kV and 132kV networks in Northern Powergrid; it is not intended for this policy to be applied retrospectively with the exception of locations suffering from poor performance under lightning conditions.

All new networks shall be equipped with Lightning Protection in accordance with this Document.

3. Policy

3.1. Assessment of Relevant Drivers

The key internal business drivers relating to Lightning Protection policy are:

- Customer Service

This Code of Practice contributes toward quality of supply to customers by defining the application of lightning protection so as to minimise the damage to equipment and prevent interruption of supply.

- Employee Commitment

This Code of Practice contributes toward safety by specifying the requirements, application, and installation of lightning protection so as to prevent danger.

- Financial Strength

This Code of Practice contributes to financial strength through the correct selection of Withstand Impulse Voltage Level rating for particular equipment.

- Environmental Respect

This Code of Practice contributes toward the environment by defining the application of lightning protection so as to minimise the damage to equipment from lightning.

- Regulatory Integrity

This Code of Practice ensures that Northern Powergrid complies with current legislation relating to lightning protection.

- Operational Excellence

This Code of Practice ensures that Northern Powergrid adopt current best practice relating to lightning protection through referencing national level working groups.

The external business drivers relating to the Application of Lightning Protection are detailed in the following sections.

3.1.1. Requirements of the Electricity Act 1989 (as amended)

The Electricity Act 1989 (as amended) ('the Act') lays down the core legislative framework for the Northern Powergrid operations as a distributor. Specifically, it gives force to the ESQC Regulations 2002, and in section 9 creates the key obligation to develop and maintain an efficient, co-ordinated and economical system of electricity distribution. Discharge of this obligation shall be supported in this document by providing guidelines on efficient application of lightning protection to the wider network.

3.1.2. Requirements of The Electricity Safety, Quality and Continuity (ESQC) Regulations 2002.

The ESQC Regulations 2002 impose a number of obligations on the business, mainly relating to quality of supply and safety. All the requirements of the ESQC Regulations that are applicable to the application of lightning protection shall be complied with, specifically:

Reg. No	Text	Application to this policy
3(1)(b)	…distributors…shall ensure that their equipment is so constructed…as to prevent danger…or interruption of supply, so far as is reasonably practicable	In this policy installation of lightning protection will prevent lightning events from causing damage to the network.
6	A…distributor shall be responsible for the application of such protective devices to his network as will, so far as is reasonably practicable, prevent any current, including any leakage to earth, from flowing in any part of his network for such a period that that part of his network can no longer carry that current without danger.	this will be achieved by installation of lightning protection equipment to prevent lightning induced voltages overstressing the network as far as is reasonably practicable
23(1)	…[the] network shall be: (a) so arranged; and (b) so provided, where necessary, with fuses or automatic switching devices, appropriately located and set; as to restrict, so far as is reasonably practicable, the number of consumers affected by any fault in [the] network	this will be achieved by installation of lightning protection equipment to prevent lightning events causing permanent faults on the network as far as is reasonably practicable

3.1.3. The Health and Safety at Work Act 1974

Section 2(1) states that 'It shall be the duty of every employer to ensure; so far as is reasonably practicable, the health, safety and welfare at work of all his employees'. Section 3(1) also states that 'It shall be the duty of every employer to conduct his undertaking in such a way as to ensure, so far as is reasonably practicable, that persons not in his employment who may be affected thereby are not thereby exposed to risks to their health or safety'.
This is addressed in this policy through prescribing permissible locations for lightning protection.

3.2. Application of Lightning Protection at 132kV Installations

Lightning protection at 132kV installations will be subject to the recommendations of individual studies commissioned at the design stage for any work proposed on the network. The minimum level of impulse voltage withstand on the 132kV system will be 650kV.

Surge arresters will not normally be installed on 132kV networks. Surge protection on 132kV overhead lines of standard construction on steel towers and over-running earth wires will be provided by arcing devices on the insulator sets. The arcing distances for these devices will be set in accordance with NSP/004/127.
In the case of 132kV wood pole overhead lines or overhead lines of unusual construction it will be necessary to consider each circuit on its merits.

Surge arresters will be provided at gas insulated substations in accordance with recommendations of an insulation co-ordination study for the substation.

3.3. Application of Lightning Protection at 11kV, 20kV, 33kV and 66kV Installations

Overhead lines have the greatest exposure to lightning and it is necessary to protect cables, transformers and switchgear against lightning if they are directly connected to overhead lines. This is because they have solid insulation which, if it fails during an over voltage condition, would be extensively damaged by the power-follow current and would require expensive and prolonged repairs. The ability of plant to withstand over

voltages depends on the design of insulation. For economic reasons limits have been placed on the insulation strength and this determines the insulation level or withstand-impulse-voltage level of plant.

The table below shows the minimum withstand-impulse-voltage level of new and recently purchased plant for each system voltage.

Voltage and situation	Withstand Impulse Voltage Level kV		
	Transformers	Switchgear	Cables
11kV	95	95	95
20kV Ground Mounted	125	125	125
20kV Overhead Mounted	145	145	-
33kV Ground Mounted	170	170	194
33kV Overhead Connected	170	-	-
66kV	325	325	345

The magnitude of over-voltages on overhead lines can be far in excess of the withstand-impulse-voltage levels in the above table and thus protection is required for plant at each system voltage. Older plant may have lower values than in the above table but this represents an acceptable risk

3.3.1. Selection of Surge Arresters

Surge Arresters

This Document applies to the gapless metal oxide resistor block type surge arrestor, they are designed for repeated operation to limit surge voltages and divert surge current to earth when a given voltage is exceeded, but interrupt the resulting power frequency current when normal voltage is restored.

The arc gap type of surge arrester shall no longer be fitted on the Northern Powergrid network. The metal oxide type of surge arresters shall comply with the Northern Powergrid Specification for Surge Arresters NPS/001/008.

Rated Voltage of Surge Arresters

The surge arrester rated voltage is the designated maximum permissible rms value of power-frequency voltage at which the arrester is designed to operate correctly. This voltage may be applied to an arrester continuously without altering its operating characteristics. This rating should be near to, but not less than, the highest power frequency line-to-earth voltage to which the arrester may be subjected.

The magnitude of the power frequency line-to-earth voltage which may occur on a system under earth fault conditions is dependent on the means by which the system neutral is earthed.

For the purpose of applying surge arresters, systems are designated either as “effectively earthed” or “none effectively earthed”. A system is effectively earthed only if its neutral is connected to earth via an impedance of less than a certain small value. All Northern Powergrid networks at 11kV, 20kV, 33kV and 66kV are non-effectively earthed and surge arrester types in the Specification for Surge Arresters NPS/001/008 have been selected accordingly.

Rated Discharge Current of Surge Arresters

11kV and 20kV Systems

Surge arresters installed on 11kV and 20kV systems shall have a rated discharge current of 10kA.

33kV and 66kV Systems

Surge arresters installed on 33kV and 66kV systems shall have a rated discharge current of 10kA.

Approved Surge Arresters

Only approved surge arresters purchased to the specification in NPS/001/008 shall be used.

Note:- 11kV and 20kV surge arresters shall not be purchased with an integral earth disconnection device or a moulded pvc cap shroud.

3.4. Protection of Plant

The following sections detail where protective devices are to be installed on high voltage distribution networks. Surge arrestors shall always be connected as close as practical to the equipment they are protecting.

3.4.1. Short Overhead Lines

Plant connected to sections of overhead line less than 5 spans in length do not require protection as the risk of exposure to over-voltage is low.

3.4.2. Underground Cable System

A surge entering a cable from an overhead line is reduced in magnitude because of the mismatch of surge impedances of line and cable which cause part of the surge to be transmitted into the cable and part to be reflected back along the line. But, because of this mismatch, the surge having entered the cable is increased by multiple reflections at its ends. The maximum value to which successive reflections build up is, however, a function of the cable length and the terminating impedances. Above a critical cable length, however, the attenuation and transit times of surge reflections is such that the breakdown level of the cable cannot be attained, and the cable can then be regarded as self-protecting by virtue of its characteristics. For cables that are not self-protecting, fitting a surge arrestor at one end of the cable will only protect the cable within the zone of influence of that surge arrestor.

For voltages at 20kV or 11kV surge arrestors will be fitted at all cable to overhead line interfaces via combined stand off insulator and surge arrestor units, irrespective of the length of cable installed. The reason for fitting arrestors at both ends of 11kV and 20kV inset cables is mainly due to economic considerations; there is minimal cost difference between a combined stand off insulator and arrestor and a stand off insulator for modern cable terminations (the cost of a set of separate stand of insulator and the logistical considerations for the few occasions when arrestor would not be required from a purely technical consideration have also been considered).

A further consideration was the improvement in reliability of modern polymeric housed arrestors which have a comparable life expectancy to polymeric insulators used for the stand-off arrangement for cable terminations.

Situations arise where a cable is connected to a line at one end and direct to switchgear or a transformer at the other end, and where the length of 11kV or 20kV cable is between 150m and 700m; such situations require the location of surge arresters at both its ends to comply with ENA Engineering Report 134. In such situations and where the manufacture has an option for a termination with a factory fitted integral (or connections for an external) surge arresters this option will be specified. Where the equipment manufacture does not provide facilities for an external surge arrester or provide a factory fitted (approved by the manufacturer for use with their equipment) surge arrester within the termination at the switchgear or transformer end of the cable, surge arresters shall then be located only at that end of the cable connected to the line.

On Networks above 20kV surge arresters shall be provided or not provided in accordance with table 3.4.2. below values are taken from ENA Engineering Report 134.

Table 3.4.2 Location of Surge Arresters in relation to Underground Cable Lengths

System	None (self-protecting) where cable length exceeds:	At one end of cable only, where cable length is less than:	At both ends of cable where length is between:
33kV Systems with overhead lines of earthed construction	250m	150m	150m & 250m
33kV Systems with overhead lines of unearthed construction	1.7km	150m	150m & 1.7km
66kV Systems with overhead lines of earthed construction	150m	150m	
66kV Systems with overhead lines of unearthed construction	700m	150m	150m & 700m

Where an overhead line is of a mixed earthed and unearthed construction then the location of any surge arresters in relation to cable lengths shall be selected in accordance with the type of construction of that part of the line actually connected to the cable.

Where a cable is in the run of a line, and the line connected to one end of the cable is of earthed construction and the line connected to the other end of the cable is of unearthed construction, then the location of any surge arresters in relation to cable lengths shall be selected as for lines of unearthed construction.

Where the cable terminates in a cable box surge arrestors should be fitted in line with table 3.4.2 where practical.

On 33kV Networks where the cable section connects to an underground substation or switching station surge arresters shall always be provided at the overhead line/cable termination and at both ends of the cable in line with guidance in table 3.4.2.

The practice of reducing the gap of arcing horns on the approach to substations shall no longer be followed at 33kV, however this practice shall continue for 66KV and 132kV construction, for further guidance on the appropriate gaps refer to NSP/004/045.

3.4.3. Transformers

11kV and 20kV Transformers

Surge arresters shall not be fitted to pole-mounted transformers, since they are protected by arcing horns, which are considered economically adequate.

Where an overhead line terminates via an underground cable to a transformer (i.e. to a ground-mounted transformer) there is no requirement to fit lightning protection to these transformers subject to 3.4.2 above.

33kV and 66kV Transformer Feeder Substations

The following requirement applies to overhead lines of both earthed and unearthed construction:

Surge arresters shall be fitted at the overhead line termination where lines terminate directly at a transformer.

Where an overhead line terminates via an underground cable to a transformer then the protection arrangements specified in Section 3.4.2 for locating surge arresters in relation to cable lengths shall apply.

Transformers are sometimes directly connected in the run of overhead lines by a short overhead tee-off; say not more than two spans. In such cases surge arresters shall be provided and may be connected at the tee-off point rather than the transformer terminals.

Where arcing horns are provided on 33kV and 66kV transformers they shall be retained in service at the gap distance recommended by the manufacturer.

3.4.4. 11kV, 20kV, 33kV and 66kV Switchgear

Indoor switchgear is invariably connected to overhead lines via an underground cable section, for which the protection arrangements specified in Section 3.4.2 will be applied. At 11kV and 20kV voltage levels no further protection is needed for the switchgear. For switchgear at 33kV and 66kV installations of lightning protection will be subject to the recommendations of individual studies commissioned at the design stage for any work proposed on the network.

For the protection of switchgear and transformers at outdoor substations, surge arresters shall be installed at any overhead line termination to which one, two or three lines are directly connected. If four or more overhead lines are directly connected, then no surge arresters shall be installed. This is because, where several overhead lines meet, the amplitude E of any single incident surge is reduced to 2E/N where N is the number of lines connected to the Substation. A normally open circuit breaker to a line is not included in the number of directly connected lines.

Pole mounted auto re-closers and enclosed disconnecters located at open points shall be fitted with surge arrestors where practical

Where arcing horns are provided on switchgear they shall be retained in service.

3.5. Installation and Earthing of Surge Diverters

Surge arresters shall be installed as closely as practicable to the plant to be protected.
The high voltage and earth connections shall be as short as possible.

The earth connection of the surge arrester shall be bonded direct to the earthed metalwork of the plant to be protected. Where the surge arrester is mounted on a pole carrying a cable termination, the earth connection shall be bonded direct to the cable terminal box or cable Sheath; the earth connection shall not be a separate earth lead bonded to the equipment earth at the foot of the pole or supporting structure, as this practice will increase the surge voltage impressed on the plant to be protected.
Standard arrangements of connections are detailed in the Code of Practice for construction of Overhead Lines NSP/004/042 and NSP/004/120.

The resistance to earth of the equipment to which the surge arrester earth connection is made shall be 10 ohms or less; it can be shown that the effectiveness of surge arresters at any of the system voltages considered is disproportionately decreased as this value of earthing resistance is exceeded.

3.6. Overhead Lines Operating at Reduced Voltage

When an overhead line is being operated, either temporarily or permanently at a system voltage lower than the line design voltage, any surge arresters installed shall be rated for the lower system voltage. Arcing horns if fitted will be changed to those applicable to the lower system voltage for at least 500m from the terminating substations.

3.7. Transformer Duplex Gaps

Pole-mounted transformers are supplied with duplex gaps fitted to the bushings. These gaps are to be set and maintained at 25mm for 11kV networks and 38mm for 20kV networks.

Specially designed arresters are available for tank mounting in parallel with the bushings however they are not the most economical way of protecting the transformers. The unit will therefore be included in the zone of influence of surge arresters or within the zone of influence of a Triggered Spark Gap, i.e. within 0.5km.

3.8. Triggered Spark Gaps

Triggered spark gaps (specified in NPS/001/006) are installed to protect transformers subject to induced over voltages from lightning strikes to the ground near to the line being damaged. Triggered spark gaps will not protect equipment from direct lightning strikes.

Usually, transformers are installed in groups to supply villages or small communities. Such groups of transformers should be protected by a triggered spark gap installed as near as possible to the centre of a circle of diameter 1km which encloses as many transformers as possible.

Where there are single transformers on or near the main line, then triggered spark gaps should be installed approximately every kilometre of the main overhead line. Long sections of line without transformers need no protection.

The triggered spark gaps are connected to the centre phase of three phase lines, and are earthed to driven rods adjacent to the pole. The earth resistance should be less than 20 ohms for the most effective protection of transformers. As resistance above 40 ohms significantly reduces the effectiveness of the triggered spark gaps, reasonable efforts should be used to get a resistance of less than 40 ohms.

Triggered spark gaps should only be fitted to lines without upstream fuses as the operation of the triggered spark gap puts an earth fault onto the system. Before triggered spark gaps are fitted, any upstream fuses should be removed and replaced by auto-sectionalising links where practical. Triggered spark gaps may be installed downstream of an auto-sectionalising link, solid link or switch.

Installation on poles with stays should be avoided if possible, but if not, the triggered spark gaps should be positioned so as to ensure that any arc products cannot reach any pole mounted metalwork (Drawing 1091200014 provides guidance on typical installation requirements).

On single phase lines (i.e. with two conductors) the triggered spark gaps should be installed preferably on the conductor that is the centre phase of the main three phase line of which it is a spur. If a choice of site is possible within the criteria above, then the triggered spark gap should be on the three phase line rather than the single phase line.

Isolated transformers should be protected by a triggered spark gap on the first pole away from the transformer.

Historically within Northern Powergrid (Northeast Ltd) it has sometimes been the practice to remove electrode at one side of the arcing horn on pole transformers within the protection influence of a TSG this was to force the lightning surge to be dissipated through the TSG rather than at the transformer arcing horns, where it would be possible for the fault to develop into phase to phase fault. Experience has shown that a TSG will grade with an arcing horn gap (the TSG operating before the arcing horns for a lightning impulse); as the removal of one side of an arcing horn will impair the operation of the arcing horn and deplete this level of protection this practice shall no longer be implemented.

3.9. Substations fitted with arc suppression coils

Lightning protection at installations where arc suppression coils are fitted in the 11kV or 20kV neutral/earth connection will be subject to the recommendations of individual studies commissioned at the design stage.

3.10. Assumptions

This policy shall be applied in full when designing new HV and EHV overhead feeders, whether from new or existing substations. However, as some of the requirements identified above are qualified by ‘so far as is reasonably practicable’, there is no requirement pro-actively to review the entire network solely for the purpose of bringing it up to the standards laid out here for new build.

3.11. Implementation and Monitoring of this Code of Practice

All business divisions involved in the design or provision of new construction work on the Northern Powergrid Network responsible for the implementation of this code of practice, however, the main accountabilities for implementation and monitoring of this code of practice lie with:

Designation	Role
Design Manager	The manger appropriate to the part of the network where the code of practice is being applied, who is accountable for the implementation of the Code of Practice for the 11kV and 20kV Network They shall ensure responsible persons are appointed to implement this code of practice.
PEP Manager	They shall be accountable for the implementation of the Code of Practice for the EHV Network. They shall ensure responsible persons are appointed to implement this code of practice.
Construction Manager	They shall be accountable for the implementation of the Code of Practice. They shall ensure responsible persons are appointed to implement this code of practice.

3.12. Planned Code of Practice Review

This code of practice shall be proposed for review on a biennial basis or at any time when external or internal influences drive a change in policy e.g. a change in legislation, learning points from the initial implementation stage.

The following responsibilities shall apply to code of practice control and review:

Designation	Responsibility
Publication Manager	Responsible for issuing a quarterly report to the Policy Production Manager (or representative) detailing policies scheduled for biennial review within the next 6 months
Policy Production Manager	Responsible for assessing the continued applicability of this code of practice and for amending this document and communicating any changes in policy.

4. References

4.1. External Documentation

Reference	Title
2002 No. 2665: 2003	The Electricity Safety, Quality and Continuity Regulations 2002
Engineering Report 134 2013	Lightning Protection for Networks up to 132kV
HASAWA: 1974	The Health and Safety at Work Act 1974

4.2. Internal Documentation

Reference	Title
NPS/001/006	Technical Specification for Insulators for Overhead Lines up to and including 132kV
NPS/001/008	Technical Specification for Gapless Metal Oxide Surge Arresters
NSP/004/042	Specification for HV Wood Pole Lines up to and including 33kV
NSP/004/045	Code of Practice for EHV Wood Pole Lines operating up to 132kV with span lengths up to 220m
NSP/004/120	(OHI 20) Guidance on Mounting Overhead Line Plant and Equipment on HV Poles
NSP/004/127	(OHI 27) Guidance on the selection and application of insulators

4.3. Amendments from Previous Version

Reference	Description
Whole Document	Doc approved by email Mark Callum 23/10/2023 Doc republished to grid - LB 31/01/2024

5. Definitions

Term	Definition
EHV	Means a voltage at 33,000V and above
ENA	Energy Networks Association
HV	Means a voltage greater than 1000V, but less than 33,000V

6. Authority for Issue

6.1. CDS Assurance

I sign to confirm that I have completed and checked this document and I am satisfied with its content and submit it for approval and authorisation.

		Date
Liz Beat	Governance Administrator	31/01/2024

6.2. Author

I sign to confirm that I have completed and checked this document and I am satisfied with its content and submit it for approval and authorisation.

Review Period - This document should be reviewed within the following time period;

Standard CDS review of 3 years?	Non Standard Review Period & Reason	
Yes	**Period:** N/A	**Reason:** N/A
Should this document be displayed on the Northern Powergrid external website?		Yes
		Date
Jim Paine	Technical Policy Manager	27/02/2020

6.3. Technical Assurance

I sign to confirm that I am satisfied with all aspects of the content and preparation of this document and submit it for approval and authorisation.

		Date
Ged Hammel	Senior Policy and Standards Engineer	28/02/2020

6.4. Authorisation

Authorisation is granted for publication of this document.

		Date
Mark Callum	Smartgrid Development Manager	23/10/2023