IMP/001/912 - Code of Practice for the Economic Development of the HV System

1. Purpose

The purpose of this document is to state the Northern Powergrid policy for the economic development of the HV system. The document states the requirements to achieve a robust, economical and efficient HV system, taking into account the initial capital investment, system losses and the maintenance and operation costs over the life of the assets forming the system. It also takes into account the continuing commitment to improve the quality and reliability of supply to customers. The document applies to the distribution systems of both Northern Powergrid Northeast and Northern Powergrid Yorkshire, the licensed distributors of Northern Powergrid.

This Code of Practice also helps to ensure the company achieves its requirements with respect to the Electricity Act 1989 (including amendments)[1], the Electricity Safety, Quality and Continuity (ESQC) Regulations 2002 (including amendments)[2], the Health and Safety at Work Act 1974, the Electricity at Work Regulations 1989, Electricity Distribution Licences and the Distribution Code.

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

Document Reference	Document Title	Version	Published Date
IMP/001/912	Code of Practice for the Economic Development of the HV System	4.0	July 2018

2. Scope

This document applies to:

- The HV distribution systems of Northern Powergrid Northeast and Northern Powergrid Yorkshire;
- All HV distribution system development including, new connections, system reinforcement and asset replacement; and
- All assets with a nominal operating voltage between 1kV and 20kV, including the HV circuit breakers at 132kV to HV substations[3], HV circuit breakers at EHV to HV substations, HV switchgear at HV to LV substations and HV to LV transformers at HV to LV substations.

It is not intended to apply this Code of Practice retrospectively, but when work is being done on the HV system, the opportunity shall be taken to improve sections of network to comply with the Code of Practice when it is practicable and economic to do so.

Where distributed generation is embedded within an HV system, or embedded in a lower or higher voltage system and may have an impact on the HV distribution system, this Code of Practice should be read in conjunction with the Code of Practice for the Economic Development of Distribution Systems with Distributed Generation, IMP/001/007.

1 Amended by the Utilities Act 2000.

2 This includes The ESQC (Amendment) Regulations 2006 (No. 1521, 1st October 2006) and The ESQC (Amendment) Regulations 2009 (No. 639, 6th April 2009).

3 This Code of Practice applies to HV systems associated with 132kV to HV substations and EHV to HV substations, however, for brevity, reference in this document is made only to EHV to HV substations.

2.1. Table of Contents

3. Policy

3.1. Assessment of Relevant Drivers

The key internal business drivers relating to the economic development of the HV system are:

- Employee commitment - achieved by developing a safe HV system to ensure that employees are not exposed to risks to their health as far as reasonably practicable;
- Financial strength - achieved by developing an integrated distribution system having minimum overall lifetime cost;
- Customer service - achieved by minimising customer disruption arising from interruptions;
- Regulatory integrity - achieved by designing a robust system that meets mandatory and recommended standards;
- Environmental respect - achieved through due consideration being given to the environmental impact of new developments including the impact on system losses and carbon footprint; and
- Operational excellence - achieved through improving the quality, availability and reliability of supply.

In support of the environmental respect business driver and as the UK transitions towards a low-carbon economy, new technology and digitisation are driving unprecedented change in the way energy is generated and used. As an electricity infrastructure provider, it is important to make sure that the Northern Powergrid distribution system is able to facilitate these changes economically and efficiently whilst maintaining high standards of customer service.

The industry is responding to this change by transitioning from a traditional Distribution Network Operator (DNO) to a Distribution System Operator (DSO) model. The transition to a DSO will require changes to the way in which distribution systems are designed and operated.[4] One of the changes relates to the use of flexibility services contracted directly or indirectly with customers as an alternative to traditional reinforcement. Initial guidance on the application of flexibility services is provided in this Code of Practice.

The external business drivers relating to the development of the HV system are detailed in the sections below.

3.1.1. Requirements of the Electricity Act 1989 (including amendments)[5]

Section 9 (1) of the Electricity Act 1989 (as amended) places an obligation on Distribution Network Operators (DNOs) to develop and maintain an efficient, co-ordinated and economical system of electricity distribution and to facilitate competition in the supply and generation of electricity.

Discharge of this obligation is supported by the implementation of these guidelines on the efficient development of the HV system.

3.1.2. The Health and Safety at Work Act 1974

Section 2(1) of The Health and Safety at work Act 1974 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 Code of Practice by:

- Providing guidance on substation location;

4 Further details are set out in the Northern Powergrid DSO v1.1 Development Plan and subsequent updates.

5 The Utilities Act 2000 and The Energy Act 2004 and The Energy Act 2004 (Amendment) Regulations 2012 (No. 2723, 2012).

- Requiring consideration to be given to the level of risk to which employees and the public are exposed by a proposed overhead line route; and
- Requiring that circuits and plant have appropriate continuous, cyclic and short circuit ratings.

3.1.3. Requirements of the Electricity Safety, Quality and Continuity (ESQC) Regulations

The ESQC Regulations 2002 (No.2665, 31st January 2003) and its amendments[6] impose a number of obligations on the business, mainly relating to safety and quality of supply. All the requirements of the ESQC Regulations that are applicable to the design and development of the HV system shall be complied with.

Table 1: Table showing the requirements of the ESQC Regulations relevant to IMP/001/912

Reg. No	ESQCR text	Application to this Code of Practice (CoP)
3(1)(a)	…distributors…shall ensure that their equipment is sufficient for the purposes for and the circumstances in which it is used.	This CoP will contribute to compliance with the ESQC Regulations by requiring that analysis is carried out to ensure that the continuous and short circuit duties to which equipment is exposed are within its capability.
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.	This CoP will contribute to compliance with the ESQC Regulations by a) providing guidance on the routing of overhead lines, in particular the need to avoid the construction of overhead lines in high-risk areas, and b) requiring protection, and switching equipment to limit the impact of interruption of supplies.
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 part of his network can no longer carry that current without danger.	This CoP requires that appropriate protection is fitted to HV circuits in accordance with Northern Powergrid policy.
23(1)	A distributor shall ensure that his network shall be (a) so arranged… as to restrict, so far as is reasonably practicable, the number of consumers affected by any fault in his network.	This CoP provides guidance on circuit configuration such that protection can be implemented to disconnect the minimum section of network reasonably practicable, and on the maximum number of customers connected to sections of HV circuit between isolation points.
27(3)	For the purposes of this regulation, unless otherwise agreed in writing… the permitted variations are- …(c) in the case of a high voltage supply operating at a voltage below 132,000 Volts, a variation not exceeding 6 per cent above or below the declared voltage at the declared frequency.	This CoP states the acceptable limits of voltage variation experienced by customers connected to an HV system and describes the means of controlling the HV system voltage within these limits.

6 This includes The ESQC (Amendment) Regulations 2006 (No. 1521, 1st October 2006) and The ESQC (Amendment) Regulations 2009 (No. 639, 6th April 2009).

3.1.4. Requirements of the Electricity at Work Regulations 1989

Regulation 5 of The Electricity at Work Regulations 1989 states: 'No electrical equipment shall be put into use where its strength and capability may be exceeded in such a way as may give rise to danger' and places obligations on the business relating to the safety of plant and equipment used on the distribution system. It requires that plant and equipment is designed and operated within the limits of its capability.

Compliance with this Code of Practice will help to ensure that the relevant requirements of the Electricity at Work Regulations are satisfied.

3.1.5. Requirements of Northern Powergrid's Distribution Licences

Additional external business drivers relating to the development of the HV system are the Distribution Licences applicable to Northern Powergrid Northeast and Northern Powergrid Yorkshire. These Distribution Licence obligations include:

Standard Licence Condition 7A (Whole Electricity System Obligations) requires the licensee to coordinate and cooperate with other electricity distribution and transmission licensees to achieve optimal efficiency across the whole of the electricity distribution and transmission system.

Standard Licence Condition 20 (Compliance with core industry documents) requires the licensee to comply with the core industry documents relevant to the design of distribution systems:

- Standard Licence Condition 20.1 requires the licensee to comply with the Grid Code;
- Standard Licence Condition 20.2 requires the licensee to at all times have in force, implement, and comply with the Distribution Code;
- Standard Licence Condition 20.3 requires the licensee to be a party to and comply with the Connection and Use of System Code (CUSC). The Connection and Use of System Code (CUSC) defines the contractual framework for connection to and use of Great Britain's high voltage transmission system; and
- Standard Licence Condition 20.3 requires the licensee to be a party to and comply with the Distribution Connection and Use of System Agreement (DCUSA). The DCUSA is a multi-party contract between the DNOs, Suppliers and Generators that deals with the use of distribution system to transport electricity.

Standard Licence Condition 24 (Distribution System planning standard and quality of performance reporting) includes requirements relating to system planning:

- Standard Licence Condition 24.1 requires that the distribution system is planned and developed to a standard of security not less than that laid down in Engineering Recommendation P2 of the Energy Networks Association or set out in any subsequent Engineering Recommendation in the EREC P2 series of the Energy Networks Association, as may be directed by the Authority, so far as that standard is applicable to it'. This Code of Practice requires that the distribution system is designed to at least the standard required by Engineering Recommendation P2.

Standard Licence Condition 31E.1 (Procurement and use of Distribution Flexibility Services) requires the licensee to coordinate and direct the flow of electricity onto and over its Distribution System in an efficient, economic and coordinated manner. This includes:

- Procuring and using Distribution Flexibility Services where it is economic and efficient to do so; and
- Procuring Distribution Flexibility Services in the most economic manner possible.

Standard Licence Condition 49 (Electricity Distribution Losses Management Obligation and Distribution Losses Strategy) requires the licensee to ensure that distribution losses from its distribution system are as low as reasonably practicable, and to maintain and act in accordance with its Distribution Losses Strategy[7]. In particular:

- Standard Licence Condition 49.2 requires the licensee to design, build, and operate its distribution system in a manner that can reasonably be expected to ensure that distribution losses are as low as reasonably practicable; and
- Standard Licence Condition 49.3 requires that in designing, building and operating its distribution system the licensee must act in accordance with its Distribution Losses Strategy, having regard to the following:
  - The distribution losses characteristics of new assets to be introduced to its distribution system;
  - Whether and when assets that form part of its distribution system should be replaced or repaired;
  - The way that its distribution system is operated under normal operating conditions; and
  - Any relevant legislation that may impact on its investment decisions.

The Distribution Licences also facilitate an incentive scheme for overall network performance known as the Interruption Incentive Scheme (IIS). This scheme is a driver to reduce Customer Minutes Lost (CML) and Customer Interruptions (CI), which may incentivise network investment or the use of flexibility services beyond that needed to meet the requirements of Engineering Recommendation P2. This requirement is supported by this Code of Practice by requiring a level of interconnection and/or transfer capacity and/or flexibility services above that required by Engineering Recommendation P2 where this can be provided economically.

Compliance with this Code of Practice will help to ensure that the relevant requirements of the Distribution Licence are satisfied.

3.1.6. Requirements of the Distribution Code

As a Distribution Licence holder, Northern Powergrid is required to have in force, implement and comply with the Distribution Code of Licensed Distribution Network Operators of Great Britain.

The Distribution Code covers all material technical aspects relating to connections to and the operation and use of the distribution systems of the Distribution Network Operators. The Distribution Code is prepared by the Distribution Code Review Panel and is specifically designed to:

- Permit the development, maintenance and operation of an efficient co-ordinated and economic system for the distribution of electricity;
- Facilitate competition in the generation and supply of electricity;
- Efficiently discharge the obligations imposed upon DNOs by the distribution licence and comply with the Regulation (where Regulation has the meaning defined in the distribution licence) and any relevant legally binding decision of the European Commission and/or Agency for the Co-operation of Energy Regulators. This objective was particularly relevant in relation to the recent introduction of a suite of European Network Codes which will place additional obligations on Generators and DNOs.

The Distribution Planning and Connection Code (DPC) specifies the technical and design criteria and the procedures which shall be complied with in the planning and development of the distribution systems. It also applies to users of the distribution systems in the planning and development of their own systems in so far as they affect Northern Powergrid systems.

7 Losses Strategy, Oct 2023. https://www.northernpowergrid.com/losses.

The Distribution Planning and Connection Code (DPC) also sets out principles relating to the design of equipment and its operating regime. Equipment on the Northern Powergrid systems and on users' systems[8] connected to them shall comply with relevant statutory obligations, international and national specifications and Energy Networks Association technical specifications and standards.

Compliance with this Code of Practice will help to ensure that the relevant requirements of the Distribution Code are satisfied.

3.1.7. Requirements of the Distribution Connection and Use of System Code

As a Distribution Licence holder, Northern Powergrid is required comply with the Distribution Connection and Use of System Code (DCUSA) which is a multi-party contract between licensed electricity distributors, suppliers and generators in Great Britain concerned with the use of the electricity distribution system. DCUSA is generally concerned with the commercial and contractual relationship between suppliers, DNOs and customers, but there are some aspects of DCUSA that have technical implications for the design of connections to distribution systems. For example:

- Schedule 22 (Common Connection Charging Methodology) Clause 1.1 defines the Minimum Scheme associated with a connection request which links to the requirements of Engineering Recommendation P2 and hence to the potential requirement to increase the capacity of the distribution system to accommodate new / additional import from the distribution system.
- Schedule 2D (Curtailable Connections) relates to the provision of a Curtailable Connection offer which may require an import and / or export management scheme to be installed as an interim arrangement until the capacity of the distribution system has been increased where necessary.

Compliance with this Code of Practice will help to ensure that the relevant requirements of the Distribution Connection and Use of System Code are satisfied.

3.2. Key Policy Requirements

The general objective in developing the HV system is to obtain a simple and robust system having minimum overall cost, taking into account:

- the initial capital investment;
- the annual cost of any flexibility services[9], expressed in net present value for the duration of the service;
- system losses; and
- the maintainability and operability over the life of the asset.

Any development of the HV system should seek to improve the quality and reliability of the supply provided i.e., reduce the number of potential Customer Interruptions (to improve reliability) and Customer Minutes Lost (to improve availability).

This Code of Practice is written to help ensure that all HV system developments are made in such a way as to:

- prevent danger to members of the public and Northern Powergrid staff and its contractors;
- optimise network reliability, availability and losses;
- maintain the power quality experienced by customers;
- discharge the obligation under section 9 of the Electricity Act 1989 (including amendments), specifically to have due regard to future network requirements and performance;

8 DPC 4.4 refers specifically to the requirements of User's Systems.

9 Flexibility services may be provided by HV connected customers to resolve a constraint on the EHV or 132kV system.

- facilitate the use of standardised plant and equipment to reduce capital and operating costs;
- minimise environmental pollution and statutory nuisance; and
- satisfy all other relevant obligations.

3.3. HV System Development

3.3.1. Background

The main purpose of the HV system is to distribute electricity in localised urban and rural areas in an economic, efficient, safe and secure manner, meeting the needs of the current and possible future electricity supply customers. The HV system supplies HV to LV substations, larger demand and generation customers at HV and increasingly systems owned and operated by Independent Distribution Network Operators (IDNOs).

Urban HV systems normally comprise underground cables and looped, ground-mounted substations. Rural HV systems normally comprise overhead lines and teed, pole-mounted HV to LV substations.

The Northern Powergrid Yorkshire HV systems operate at 11kV, with a small number of 6.6kV assets associated with specific customer supplies.[10] The Northern Powergrid Northeast HV systems predominantly operate at 11kV or 20kV, with the majority of 20kV systems serving the northern and western rural areas of the region and 11kV systems serving urban areas and most parts of North Yorkshire. Northern Powergrid Northeast has a small proportion of HV assets operating at other nominal voltages, for example 6.6kV, mainly serving older, industrialised areas.[11]

3.3.2. Application

It is not a requirement to apply this Code of Practice retrospectively, but when design schemes are produced for the HV system, the opportunity shall be taken to improve existing sections of the system to comply with this Code of Practice when it is practicable and economic to do so.

Detailed guidance relating to individual HV system design proposals to ensure that work on the HV system complies with this Code of Practice is outside the scope of this document. HV system design proposals shall be produced on an individual basis, following the principles set out in this document.

The policy requirements outlined in this document will apply to the majority of situations where the HV system is developed. However, there will be a small number of cases where special arrangements, which are not strictly in accordance with the documented policy, may be more appropriate and these can be considered where there are benefits to both Northern Powergrid and its customers. Any such deviations, which shall be broadly in line with the principles described in this document, shall be agreed with the Design Manager[12] at an early stage of the planning process. Any such deviations relating to strategic network development shall be agreed with the relevant Planning Manager[13] at an early stage of the design process.

This Code of Practice shall be read in conjunction with relevant Engineering Recommendations and other Northern Powergrid documents including the following:

- Code of Practice for the Economic Development of Distribution Systems with Distributed Generation, IMP/001/007;
- Code of Practice for Standard Arrangements for Customer Connections, IMP/001/010;
- Code of Practice for the Methodology of Assessing Losses, IMP/001/103;

10 As of 2016, Grimsby Docks 33/6.6kV substation in Northern Powergrid Yorkshire.

11 Darlington 132/6.6kV; Hebburn 66/6.6kV; Rise Carr 33/6.6kV & Wardley 66/6.6kV substations in Northern Powergrid Northeast.

12 The Design Manager is a defined term – see section 5.

13 The Planning Manager is a defined term – see section 5.

- Code of Practice Guidance for assessing Security of Supply in accordance with Engineering Recommendation P2/7, IMP/001/206;
- Code of Practice for Distribution System Parameters, IMP/001/909;
- Code of Practice for the Economic Development of the LV System, IMP/001/911; and
- Code of Practice for the Economic Development of the EHV System, IMP/001/913.

The design of the HV system shall ensure that the technical characteristics associated with:

- voltage levels;
- voltage and waveform quality;
- neutral earthing;
- system phasing, rotation and vector groups; and
- short circuit levels,

comply with the requirements of the respective sub-sections below.

3.3.3. Voltage Levels

The HV system shall be designed to operate at the nominal voltages set out in the Code of Practice for Distribution System Parameters, IMP/001/909. To achieve this, the HV busbars at EHV to HV substations will be controlled by means of Automatic Voltage Control (AVC) relays controlling the tap-changers of the transformers feeding that busbar. The operating voltage of the HV system directly influences the operating voltage of the LV system where de-energised tap-changers (DETC)[14] are installed on HV to LV transformers. Where an on-load tap-changer (OLTC) is installed on a HV to LV transformer the operating voltage of the HV system is less important, as the OLTC will control the LV voltage within its tapping range.

The Electricity Safety, Quality and Continuity Regulations 2002 (including amendments) require that the voltage is declared to customers connected to the distribution system. In the case of customers connected to a high voltage supply operating at a voltage below 132kV, the variation must not exceed 6 per cent above or below the declared voltage at the declared frequency. The HV system shall therefore normally be designed to limit the maximum voltage variation to ±6% of the nominal voltage in order to accommodate any future customer connections to the HV system.

Under normal feeding arrangements and under all planned and fault outage scenarios involving a single event on a given part of the HV system, all customers shall receive a supply within statutory voltage limits. For HV circuits which connect or could be connected to HV to LV substations this shall be achieved by ensuring that the voltage on the HV system does not fall below the nominal voltage by less than 4.5% under first circuit outage conditions.[15] [16] This should leave sufficient margin for LV voltage drop to ensure that customers connected to the LV system receive a voltage within the statutory voltage limits, i.e., 230V +10%/-6%.

HV voltage regulators can be used to maintain voltages on HV systems under system intact and first circuit outage conditions. In this case system studies will be required to ensure that the required settings can be applied for the normal operating condition and credible outage scenarios. It is likely that the regulator will need to have bi-directional capability to achieve this. Voltage regulators shall be specified in accordance with the Technical Specification for 11kV and 20kV Voltage Regulators, NPS/003/020. When

14 DETC is the correct IEC terminology for a tap-changer that is only rated to operate when de-energised. The term 'off-load tap-changer' implies the tap changer can be operated when energised, but this is not the case.

15 As defined in Engineering Recommendation P2.

16 Where the HV voltage drop under first circuit outage conditions is more than 4.5%, this may be acceptable providing the LV systems supplied from the HV system has a suitably small voltage drop.

considering whether a voltage regulator could provide an economical means of system reinforcement, consideration shall be given to the following factors:[17]

- The current rating of the regulator compared to that of the HV circuit;
- Whether any existing regulators have bi-directional capabilities;[18]
- The voltage regulation on the circuit under normal and outage conditions;
- The physical location of the unit including access requirements;
- The choice of pole-mounted vs ground-mounted regulators; and
- Whether an open or closed-delta arrangement for pole mounted regulators would be acceptable.[19]

Voltage regulators should not need to be used on urban systems with low impedance circuits, where voltage regulation is less of an issue. Voltage regulator installations should include a means of communication to allow remote control and monitoring.

Where the use of a voltage regulator would have an adverse effect on circuit loading, shunt capacitor banks may be a more suitable alternative and should be considered.

3.3.4. Voltage and Waveform Quality

New connections provided at HV shall meet the requirements of:

- Engineering Recommendations P28, Voltage fluctuations and the connection of disturbing equipment to transmission systems and distribution networks in the United Kingdom;
- Engineering Recommendation P29, Planning Limits for Voltage Unbalance in the UK for 132kV and Below;
- Engineering Recommendation G5, Harmonic voltage distortion and the connection of harmonic sources and/or resonant plant to transmission systems and distribution networks in the United Kingdom, and
- Engineering Recommendation G99, Requirements for the connection of generation equipment in parallel with public Distribution Networks on or after 27 April 2019.[20]

In respect of fluctuations, voltage unbalance and harmonic voltage distortion, whilst there is no requirement for the HV system itself to operate within the parameters set out in these Engineering Recommendations it shall generally be designed to do so.

Detailed design studies to assess the impact of potentially disturbing loads and generation such as large motors, welders, inverters and other harmonic producing equipment shall be carried out as part of the application process for connecting such loads or generation and when modifications to the systems are being considered. In some cases, a proposed HV connection of a large abnormal load can only be accepted if its point of common coupling is on the EHV system.

Single-phase distribution transformers and overhead line spurs shall be connected to a three-phase HV circuit so that the load on the circuit is balanced across all three phases as far as reasonably practicable. This will minimise voltage unbalance, voltage regulation, and reduce losses.

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17 Further guidance on voltage regulation is included in the Code of Practice for Voltage Management, IMP/001/915.

18 All new regulators, in accordance with NPS/003/020, have bidirectional capabilities.

19 The use of open delta regulators should be limited to overhead line spurs with little chance of being interconnected in the future.

20 Engineering Recommendation G99 permits some relaxation of voltage step changes in defined operational scenarios associated with generation connections.

Where there are power quality issues associated with existing distribution system, the methodology described in Engineering Recommendations P28, P29 and G5 can be used in association with measured values to diagnose and rectify any issues.[21]

3.3.5. System Phasing and Vector Groups

The phase vector relationship and phase connections on the HV system shall be in accordance with the Code of Practice for Distribution System Parameters, IMP/001/909. Standard three-phase HV to LV transformers shall be of vector group Dy11.

3.3.6. Short Circuit Levels

The Code of Practice for Distribution System Parameters, IMP/001/909, states the present design maximum prospective short circuit current and the minimum break rating for new switchgear.

Design short circuit current levels on the HV system are those which can be expected at or close to EHV to HV substations. The impedance of cables and overhead lines causes the short circuit current to reduce significantly at points on the system which are remote from such substations.

Because of earthing arrangements on the source EHV transformer, the prospective short circuit currents on the HV system will generally be higher for phase-to-phase faults than for phase-to-earth faults, thus the short circuit ratings of circuits and switchgear shall be chosen with particular care to avoid overstressing under phase-to-phase fault conditions. When assessing the capability of HV switchgear, consideration shall be given to the X/R ratio of the system.

In order to facilitate future uprating of the short circuit capability of the distribution system, for example to permit connection of additional generation, all new ground mounted switchgear installed on the HV system shall be specified with a minimum three-phase symmetrical short circuit breaking rating as shown in section 3.6.3. As higher rated plant becomes available on the market, then this shall be specified where economical and subject to the approval of the Smart Grid Development Manager.

Where a fault level study is being undertaken an assessment should be made to confirm that all HV equipment being considered in the study is suitably rated. This is particularly important when a system has distributed generation connected to it, as this can cause a localised increase in short circuit current.

Equipment used on overhead lines often has a rating below the design short circuit level. This may be acceptable in two situations:

- Where equipment is deployed on a part of the system where its short circuit rating is greater than the short circuit level of the system at that point.[22] It will be necessary to confirm that such equipment is sufficiently rated under normal operational configurations and credible outage configurations.[23]
- Where equipment, such as un-ganged pole mounted disconnectors or fuses, has an inadequate short circuit rating in relation to the either the normal operational configurations or credible outage configuration[24] but where an Operational Restriction, in accordance with Code of Practice for the Management of Short Circuit Currents in Distribution Switchgear, IMP/001/104 can be implemented. When considering whether an Operational Restriction can be reasonably

21 Such assessment may be easier than for a new customer connection as there is certainty about the customer equipment proposed to be connected to the network and its impact can be measured directly.

22 Pole-mounted auto-reclosers (PMARs) which conform to the requirements of ENA TS 41-36 have a short circuit rating of 12.5kA, meaning that there is only likely to be an issue where they are deployed on 11kV circuits (as the 20kV design short circuit level is 10.1kA). Expulsion fuses are typically rated at 8kA, and hence their suitability needs to be assessed on a site-specific basis. Old, manually dependent air break switch disconnectors (ABSDs) are only rated to break load current, but typically have a make rating of 3kA and hence their suitability needs to be assessed on a site-specific basis. Opportunities should be taken to replace such units with new units with an increased make rating.

23 As part of the design process the relevant Northern Powergrid Control Centre should be consulted to agree the credible outage configurations that should be considered.

24 As part of the design process the relevant Northern Powergrid Control Centre should be consulted to agree the credible outage configurations that should be considered.

implemented any adverse implications on customer supplies shall be considered. All such Operational restrictions shall be agreed with the relevant Northern Powergrid Control Centre.

3.3.7. Losses

The cost of electrical losses in the system is significant and shall be taken into account when procuring assets to be used on the HV system and when designing HV systems, using the methodology set out in the Code of Practice for the Methodology of Assessing Losses, IMP/001/103. A losses assessment shall be carried out as part of the bulk procurement process and on a bespoke basis where the specification of equipment required is outside that of the equipment procured via the bulk purchasing process.

For most routine design work on the HV system, the use of minimum circuit conductor sizes (as per section 3.6.5 and 3.6.7) and the selection of transformers based on the economic loading, set out in the Code of Practice for the Economic Development of the LV System, IMP/001/911, will be sufficient to ensure adherence to Northern Powergrid's losses strategy. However, when assessing options for connecting to or modifying high-loss[25] HV systems, there is a requirement to assess losses on a bespoke basis to compare the merits of different reinforcement configurations.

3.4. System Design Criteria

When designing new, or modifying existing HV systems, care shall be given to ensure that any development is consistent with known proposals for new connections, authorised asset replacement or system reinforcement schemes, and that consideration is given to the longer-term future system requirements. Reference should be made to the Northern Powergrid Investment Plan, Network Development Strategies, Distribution Load Estimates and Northern Powergrid Distribution Future Energy Scenarios[26] to ensure that HV system designs take account of demand growth and generation plant connections that can reasonably be expected within the ten-year planning period[27] and facilitates the transition towards the Government's 2050 net greenhouse gas emissions target. The sub-sections below set out key design criteria for the HV system.

3.4.1. Design Co-ordination

The Northern Powergrid HV systems are developed primarily through the incorporation of new connections or connections to an IDNO system and shall, where practicable, be designed such that the Northern Powergrid system including the interface with the customers systems form part of an economic, co-ordinated and efficient system with flexibility to facilitate any future load or generation increase that can be reasonably anticipated. This is achieved by applying consistent design approaches and the use of standard connection arrangements, switchgear and buildings.

The design of customer connections or connections to IDNO systems shall be such that the capacity available at an EHV to HV substation, i.e., electrical capacity and space to install additional equipment, to meet future customer requirements is not unduly restricted. This is a particular concern at EHV to HV substations where there is limited space to install additional circuit breakers. In such situations dedicated circuit breakers should not be used to provide a new connection if their use would limit the capability of Northern Powergrid to discharge its legal obligation to develop an efficient and coordinated system by preventing the use of any unutilised electrical capacity to supply future customers due to the lack of space to install further circuit breakers or other equipment.

Such sterilisation of system capacity, which would prevent the efficient connection of future customers, is not permitted by this Code of Practice and all system development shall avoid this situation arising by properly considering this issue at the design stage.

At an EHV to HV substation where the HV switchboard cannot be extended, a new HV switchboard can be installed close to the existing HV switchboard to effectively create additional connection points for HV circuits. The installation of such a HV switchboard should not sterilise the land within an EHV to HV

25 A 'high-loss' system can be characterised by small section conductors, long circuit lengths or high utilisation of assets.

26 https://www.northernpowergrid.com/downloads/4211.

27 The current Distribution Load Estimates cover an eight-year period, and the plan is to extend this period to ten years.

substation making the eventual replacement of the substation plant more expensive.[28] The choice of switchgear and housing for the HV substation shall take into consideration:

- The number of additional HV circuits required;
- Whether the HV substation may be extended in the future;
- The protection requirements of the circuits;
- Whether the HV substation could be used as the basis for a new HV switchboard at a replacement EHV to HV substation.

When undertaking non-discretionary design studies (i.e., those associated with new connections and diversions), opportunities for improving the HV system in accordance with this Code of Practice and the investment criteria laid out in relevant discretionary work programmes shall be identified and considered. This synergy between discretionary and non-discretionary design work assists in the development of an efficient, co-ordinated and economical HV system.

When reinforcing the HV system, consideration shall be given to specific and anticipated load and generation developments such that equipment and circuits are sufficient to meet the requirements of that part of the system for at least 10 years taking into account the:

- likely demand or generation growth in a particular geographic area associated with any agreed development plans or network strategies which have been prepared for that area;
- anticipated load growth in the area being considered as set out in the Distribution Load Estimates.[29]

Where designs involve the reconfiguration of HV circuits on the system, the connection of new or additional demand or distributed generation in excess of 250kVA suitable records shall be kept to catalogue design proposals as they are created in order to co-ordinate design activities.[30] Such records shall be consulted such that authorised and active proposals can be taken into account when developing further proposals.

The physical completion of discretionary and non-discretionary development work on the HV system shall be monitored to ensure that future design proposals take into account authorised and completed work and hence facilitate the development of a co-ordinated, economical and efficient system.

3.4.2. Systems Analysis

The Northern Powergrid recognised electrical power system design tools shall normally be used to ensure that any connection or modification to the HV system does not result in any plant or equipment operating beyond its capability for compliance with this Code of Practice. The requirement to undertake network analysis using these design tools may be relaxed where the design engineer has sufficient competency to take such a decision.[31]

Where system development focussing on improving quality of supply performance is being designed the GROND (Geographical Representation of Network Data) application shall be used to assess the reliability of circuits and to design system and protection arrangements that optimise reliability and customer service benefits. GROND shall also be used where a development scheme could have an adverse impact on circuits previously optimised from a quality of supply perspective.[32]

28 Northern Powergrid Major Projects can be consulted on the feasibility of installing a HV switchboard in the grounds of an EHV to HV substation.

29 Future DLEs will include demand forecasts for individual areas in particular with regards to LCT uptake. In the future the System Planning section will issue more guidance on localised growth trends.

30 In accordance with IMP/001/010 section 3.11.16.

31 Extra care should be taken when making modifications to rural HV circuits where voltage regulation can be difficult to estimate; in such cases the Northern Powergrid design tools should be used.

32 Appendix 1 details the modelling assumptions to be used in GROND.

Information on circuit loading can be obtained from the Northern Powergrid historical load information database, PI[33], which is populated with data from the Northern Powergrid SCADA system and from half-hourly metering transactions.

3.4.3. Increasing System Capability

Where the design feasibility study carried out as part of a new demand connection, a new generation connection or an internally driven assessment (e.g., initiated following an Asset Serviceability Review) indicates that the HV system capacity is insufficient, consideration shall be given to establishing:

- the bespoke rating[34] for the system asset that has been identified as having insufficient capacity, as this may establish that the system is sufficient;
- whether existing customers are exceeding their contracted capacity, as addressing this may establish that the system is sufficient; and
- whether existing customers are operating at an acceptable power factor, as addressing this may establish that the system is sufficient.
- Enhancing the capability of the existing asset creating the insufficiency (i.e., a minimum intervention). For example, increasing the clearance of OHL spans, changing a substation target voltage or application of Load Drop Compensation;
- Enhancing the capability of the system to create additional capacity i.e., system reinforcement;
- A combination of the above.

The Code of Practice for the Economic Development of Distribution Systems with Distributed Generation, IMP/001/007 provides guidance on alternative means of increasing system capability where the insufficiency is associated with generation plant connections. The Code of Practice for Standard Arrangements for Customer Connections, IMP/001/010 provides guidance on alternative means of increasing system capability where the insufficiency is associated with a new demand connection. Where the driver for increasing system capability is internally driven the principles of these Codes of Practices shall be applied.

3.4.4. Flexibility Services

Through the ENA's Open Networks project the long-term roles and responsibilities of DNOs are being redefined as markets for flexibility services open up and expand, offering an alternative to increasing the capability of the distribution system using traditional assets. An outcome of the Open Networks project is Northern Powergrid's commitment to openly test the market to compare reinforcement and flexibility services as a means of increasing system capacity for all new projects of any significance. Northern Powergrid has also committed to developing the ENA's six key steps for delivering flexibility services to ensure the transition is successful.[35]

A flexible service is a commercial service where a customer modifies their generation and/or consumption of electricity in response to an external signal (e.g., change in electricity or Use of System price or on receipt of a specific communication signal) to provide a service to a distribution system operator, a transmission system operator or electricity supplier.

As part of a commitment to transition towards a DSO and as an output of the Open Networks project, Northern Powergrid has published the DSO development plan[36] and has committed to:

33 Prior to PI rollout in Northern Powergrid Northeast the legacy LIPP package should be used.

34 Guidance is provided in IMP/001/011 – Code of Practice for Overhead Line Ratings and Parameters and IMP/001/013 - Code of Practice for Underground Cable Ratings.

35 Available from: https://www.energynetworks.org/publications/

36 Available from: https://www.northernpowergrid.com/asset/0/document/5139.pdf

- use flexibility services as an alternative to system reinforcement where it is practical and economic to do so. Demand Side Response is an example of a flexibility service; and
- providing flexible connection offers for new demand or generation customers, where appropriate.

These options provide customers with more control and choice over how they use their electricity and provides them with new competitive opportunities to participate in the energy market.

The three use cases for contracted customer flexibility services are:

- As an alternative to system reinforcement (Sustain, Secure and Dynamic Flexibility Service Products) – to avoid or defer spending on traditional system reinforcement;
- As a means of managing system risk during construction or maintenance work (Sustain, Secure and Dynamic Flexibility Service Products) – to manage the risk of supply interruption associated with construction work; and
- Emergency Support (Restore Flexibility Service Products) – to provide emergency support during unplanned supply interruption.

As at December 2023 the application of the Flexibility First Policy, INV/007, is focussed on the use of flexibility services as an alternative to discretionary reinforcement related investment on the 132kV and EHV system.[37] Details of the process for deployment of flexibility services in other situations, including to address constraints on the HV system will be developed in due course.

3.5. HV System Configuration

3.5.1. Common Underground and Overhead Configuration

The Code of Practice for the Economic Development of the EHV System, IMP/001/913, sets out the requirements to design an EHV system that establishes EHV to HV substations generally equipped with duplicate EHV to HV transformers and HV busbars. This is the preferred arrangement, which enables demand up to a defined value[38] supplied from the EHV to HV substation to be maintained for a single circuit outage of either of the incoming EHV feeders, either of the EHV to HV transformers or either of the transformer HV circuit breakers. In this case the HV system is not required to ensure Engineering Recommendation P2 compliance of the demand group supplied by the EHV to HV substation. In rural areas, an EHV to HV substation equipped with a single transformer may suffice, however in this case the HV system will need to have sufficient interconnection with other EHV to HV substations to maintain all supplies normally supplied from the substation to ensure compliance with Engineering Recommendation P2.

The Code of Practice for the Economic Development of the EHV System, IMP/001/913, requires that when establishing a new EHV to HV substation, it should be located as far as practicable, at the load centre so as to minimise the extent of the distribution infrastructure (particularly overhead lines and underground cables) required to service the demand and generation plant connected to it, having due regard to the economics of laying new incoming and outgoing feeders, the environmental impact of the development and likely future land development. Development of the HV system over a period of time can result in a situation where the supply zones of adjacent EHV to HV substations encroach upon each other. When designing major extensions to the HV system, particularly new outlets from EHV to HV substations and to supply new material demand and / or generation customer, consideration shall be given to re-establishing natural supply zones where economically viable. This can be achieved by transferring load between EHV

37 As at December 2023 the application of the Flexibility First Policy, INV/007 is focussed on the use of flexibility services as an alternative to discretionary reinforcement related investment. The assessment process is set out in the CoP Flexibility First Decision Making - Use of sustain and secure flexibility service products to address constraints on the 132kV and EHV distribution system , INV/007/001. Details of the process for deployment of flexibility services in other situations will be developed in due course. As at December 2023 INV/007 and INV/007/001 are in the process of being published.

38 This capacity is sometime referred to as the firm capacity.

to HV substations in order to maintain a reasonable balance between the load on adjacent substations, the number of customers supplied from and the length of each HV circuit.

The HV circuits emanating from EHV to HV substations shall either form interconnectors with other EHV to HV substations or open rings connected to the HV busbar either side of the bus coupler (section) circuit breaker. The development of HV interconnection between EHV to HV substations[39] is preferred to rings on the same EHV to HV substation as this will provide improved system reliability, flexibility and security by affording greater capacity to transfer load under outage conditions and to optimise the load on EHV to HV substations. HV circuits shall be configured with sufficient interconnection to maintain supplies under reasonably foreseeable outage conditions. Appendix 2 illustrates the basic HV system configurations.

When considering a scheme to connect demand to a dedicated interconnector [40] between EHV to HV substations, additional consideration shall be given to ensure that the outage plans for both EHV to HV substations are not adversely affected.[41]

HV circuits shall normally be operated as radial circuits with the open point selected for ease of operational access and to minimise the number of Customer Interruptions (CI) and Customer Minutes Lost (CML), whilst taking account of the need to minimise system losses and optimise voltage regulation. When open points are planned to be moved consideration shall be given to primary protection settings with respect to the reconfigured circuit.[42] Opportunities shall be taken to provide remote control facilities at the HV normal open points wherever possible to facilitate post-fault restoration of customer supplies and the application of Automated Power Restoration System (APRS).

The HV system shall be configured such that the number of customers normally supplied from each HV circuit does not exceed 2000. Further restrictions apply to the number of customers connected between switching points as set out in sections 3.5.2 and 3.5.3 below.

A 'firm HV substation' comprises three or more panels of extensible ground mounted switchgear configured to enable two HV circuits from the source EHV to HV substation, equipped with suitable protection, to operate in parallel such that supplies to the HV substation will be uninterrupted for an outage of one of the two circuits from the source substation. Such a configuration improves the security of supply to the HV substation, and the customers supplied from it, when compared to a simple radial system. The use of 'firm HV substations' as a solution to address reliability issues (such as those associated with the worst performing circuits) are unlikely to be cost effective when compared against automation schemes such as APRS where there are one or more alternative HV circuits that could be used to restore supplies to customers affected by a HV outage. Hence, establishing a new 'firm HV substation' should normally only be considered as part of a scheme to provide a HV Point of Supply to a single customer.[43]

Remote control of HV switching points can be achieved by the installation of remotely controlled actuators on ground-mounted switchgear[44] or the installation of remotely controlled pole-mounted auto reclosers (PMARs) or enclosed switch disconnector (ESDs) on overhead lines (OHLs). Guidance on the application of remote-control facilities is provided in An Application Guide for HV System Remote Control, IMP/001/912/002.

Figures 1 and 2 in Appendix 2 illustrate how these requirements should be applied in practice.

39 The use of interconnection between EHV to HV substations supplied from the same Grid Supply Points (GSP) generally does not give rise to excessive circulating currents. Interconnection between EHV to HV substations supplied from different Grid Supply Points can provide increased resilience for the loss of a GSP, but can give rise to excessive circulating currents that can be difficult to model.

40 i.e. a HV circuit with no customers connected to it.

41 Ex-EHV circuits energised at HV and operated as part of the HV system shall only have HV demand connected to them if there is no authorised scheme to re-energise them at their design voltage.

42 In particular second stage protection, HV metered customers, overhead line and long underground cables.

43 This arrangement is shown in Code of Practice for Standard Arrangements for Customer Connections, IMP/001/010.

44 New ring main units are currently specified for at least one switch to be pre-wired for future remote control.

3.5.2. Underground Systems

The preferred ground mounted switchgear used to form urban radial circuits is a non-extensible ring main unit (RMU) equipped with two ring switches and a transformer circuit breaker or a metered circuit breaker where it is used to provide a connection to a HV customer. Extensible equipment can be used where there are economic opportunities to increase the amount of interconnection as an alternative to the use of breeches joints. Such switchgear can be configured to provide combinations of circuit switches / circuit breakers[45] and transformer circuit breakers. Figure 1 in Appendix 2 illustrates how such extensible switchgear may be configured.

Ground-mounted HV to LV substations and HV substations in urban systems (i.e., systems predominantly comprising underground cable) shall be looped into the HV circuits supplying them. Teed connections to substations in urban areas shall be avoided, as the marginal cost of the additional cable for the loop-in is negligible when compared to the quality of supply and operational benefits, particularly considering the cost of deploying temporary generation in the event of planned or fault outages.

Underground HV circuits, comprising ground-mounted substations equipped with RMUs or extensible switchgear inherently provide switching facilities between groups of customers. To maintain the operational benefits that this facility provides only one tee is permitted between switching points.[46] Underground HV circuits shall be configured so that no section of circuit has more than 250 customers between remote controlled switching points.[47] This number may be increased to 500 where the HV circuit is not a 'worst-performing' circuit. If the HV circuit is not classed as a 'worst-performing circuit' i.e., where the 5-year historic (CI/CML) Interruption Incentive Scheme (IIS) cost is less than £30k (2013/14 prices), the application of remote control based on the customer number criteria may be relaxed as follows:

- Remote control facilities shall be provided at HV to LV substations such that no more than 500 (increased from 250) customers are supplied from any part of the HV circuit between remote control switching points; and
- Remote control facilities shall be provided on both the switches of a RMU where the HV to LV substation supplies more than 200 (increased from 150) customers, and which form a group of 250 customers between remote control switching points.

Table 2: Customer number criteria for remote control application on underground circuits

	Standard Criteria[48]	Relaxed Criteria[49]
Maximum number of customers between remote control switching points	250	500
Minimum number of customers at a substation to apply remote control on both the switches of the RMU	150	200

Multiple tees are permitted where an underground cable in a rural area provides supplies to several substations[50] along its length with only a small number of customers between switching points. In these situations, a ground mounted substation could be established to sectionalise the network appropriately.

45 The use of second stage protection shall be avoided on new circuits. When replacing switchgear equipped with second stage protection, consideration shall be given to using a switch equipped with automation facilities.

46 Having multiple tees between switching points increases the complexity and time taken to locate faults, isolate the faulty section and hence restore supplies to customers.

47 Where 5-year historic (CI/CML) IIS cost of >£30k (2013/14 prices) the numbers of customers between remote controlled switching points can be relaxed and increased to 500. The historic IIS costs by feeder can be requested from the Reliability Strategy Manager.

48 Standard criteria apply to a 'worst-performing circuit'.

49 Relaxed criteria apply to a circuit which are not classed as 'worst-performing circuit'.

50 i.e., via breeched pole-mounted or pad-mounted HV to LV substations.

Pole-mounted HV to LV substations shall not be established in urban areas where the HV system is predominantly underground, and an HV overhead line would be unacceptable in terms of safety and from a planning permission perspective.

Where there is a need to connect a new HV to LV substation to an underground system in rural or semi-rural areas a pad-mounted HV to LV substation may be considered.[51] In this case the relevant parts of section 3.5.3 shall be applied. Pad-mounted substations should not normally be installed in urban areas as the installation of a ground-mounted HV to LV substations is likely to result in a more economical, efficient and co-ordinated system within the planning period.

3.5.2.1. Fault Passage Indicators on Ground-mounted Switchgear

Fault passage indicators (FPIs) shall comply with the Specification for Fault Passage Indicators and Current Transformers for use with Ground Mounted 11 & 20kV Switchgear, NPS/003/013. FPIs shall be installed on the outgoing switch or circuit breaker of ground mounted distribution switchgear. Where there are more than 250 customers connected to the HV to LV substation or where switchgear is extensible, FPIs shall be fitted on all switches or feeder circuit breakers.

FPIs installed on ground mounted switchgear which is fitted with remote control shall be capable of indicating to the Network Management System (NMS) when they have operated.

3.5.2.2. Long Cables between Switching Points

Where the construction of new overhead lines to connect new customers in remote rural locations is not reasonably practicable, such connections can be made using HV cable. Depending on the length of such cables there can be issues associated with capability of switchgear to cater for the capacitive charging currents when the cable is energised and the ability to carry out fault location and pressure testing using standard test equipment. Current practice is to install intermediate isolation / switching points such that the maximum section length of HV cable is 7km.[52] When choosing the type and configuration of switching points to install, consideration shall be given to auxiliary power requirements, protection requirements and substation earth potential rise implications of the different configuration options.

3.5.3. Overhead Systems

Rural overhead systems shall be developed to follow the same basic system configuration as urban systems, comprising mainly interconnectors between EHV to HV substations. These will normally be supported by strategically-placed cross-ties between adjacent interconnectors in order to provide alternative means of securing and restoring supplies in the event of an outage.

Teed connections shall normally be used to connect pole-mounted or-pad mounted[53] HV to LV substations. Ground mounted HV to LV substations and HV substations in overhead systems shall be looped-in where economic.[54] In overhead systems where a pole mounted HV to LV substation is unacceptable, for example where the location is considered to be high-risk or give rise to safety concerns, and where there is a need for LV capacity of 315kVA or less, a pad-mounted HV to LV substations should be considered. Pad-mounted HV to LV substations can be used in similar manner to pole-mounted HV to LV substations being teed in to an existing cable network via a breeches joint. Being fully enclosed, pad-mounted HV to LV substations address many of the safety issues associated with the installation of a pole-mounted HV to LV substation, however there are a number of factors that need to be considered when

51 As of December 2023, there is an ongoing programme to introduce pad-mounted substations, including developing application drawings, procuring and making available the specialist operational tools, and completing training for operational staff. Pad-mounted substations shall only be included in design projects once the implementation programme is completed.

52 Further background information can be found in EATL STP Report S5243_1: AC Cable Connections: Practical and Electrical Limits to Their Length.

53 Whilst the design of pad mounted substations can accommodate a looped connection into a HV circuits, such a connection arrangement is not permitted in Northern Powergrid. This is due to the additional procedures required to operate a pad mounted substation compared to a ground mounted substation.

54 GROND software can be used to assess benefits of installing a second feed taking into account fault rates, customer numbers and the cost of the additional cable.

locating a pad-mounted HV to LV substation as they are likely to be installed in locations where there is general public access.

As of December 2023, there is an ongoing programme to introduce pad-mounted HV to LV substations, including developing application drawings, procuring and making available the specialist operational tools, and completing training for operational staff. Pad-mounted HV to LV substations shall only be included in design projects once the implementation programme is completed. The following factors are illustrative and will be refined as part of the Pad-mounted HV to LV substation implementation programme.

- Whilst pad-mounted substations are compact compared to a ground-mounted substation, for example a 25kVA unit require an area of 1m x 1m and a 200kVA unit requires an area of 2m x 2m, the sides of a pad-mounted HV to LV substation must be 1m from all objects and 3m from the doors and windows or any building;
- There also needs to be sufficient space around the pad mounted HV to LV substation to allow the equipment to be operated safely, for example when removing the HV fuses using 'hot sticks'; and
- The location should be selected to minimise the risk of vehicle impact (including from vehicles on a public footpath and from agricultural vehicles where a pad mounted substation is installed in a rural area).

Each location where the installation of a pad-mounted HV to LV substation is being considered shall be subject to a risk assessment, which may identify that the location is unsuitable, and a ground-mounted substation should be installed or whether additional security, such as a wooden or metal fence, is required to mitigate a trespass or vandalism risk.

Where installation of a pad-mounted HV to LV substation would result in there being multiple pad-mounted HV to LV substations in close vicinity [55] consideration should be given to the number of tees between switching points in accordance with the criteria set out below.

Tee-connections shall normally be used to connect a pole-mounted or pad-mounted HV to LV substation or customers requiring a HV Point of Supply along the route of the overhead line, with teed spurs added as necessary between switching points to supply customers remote from the main overhead line. Where a section of underground cable is connected to an overhead network to connect a pole-mounted HV to LV substation, the cable shall be connected to the overhead line via an air break switch disconnector (ABSD) so that the cable and substation can be isolated from the overhead line. Where a pad-mounted HV to LV substation is connected to a rural or semi-rural network underground system, it shall be breeched in to the HV cable supplying it.

Overhead HV circuits with teed substations and underground systems with multiple teed connections[56] shall be configured so that no section of circuit has more than 130 customers between switching points and no more than 250 customers between remote controlled switching points, to optimise the benefit of the availability of the switched alternative supply. Where there is no switched alternative, for example on a tail-end spur circuit, the number of connected customers shall not exceed 500. PMARs or ESDs can be used to achieve remote control switching points[57] and ABSDs can be used to achieve manual switching points. In addition to the number of customers between manual switching points, the number of pole-mounted substations between manual switching points shall also be considered as there may be practical implications associated with the installation of temporary generators at a large number of pole mounted transformers in order to restore supplies.

55 Multiple pad-mounted HV to LV substations should not be used in lieu of a ground-mounted HV to LV substation where installing such a substation would result in a more economical, efficient and co-ordinated system within the planning period.

56 Generally, only found in rural areas.

57 Where additional PMARs are added to a circuit to achieve further remote control points, consideration should be given to enabling the auto-reclose features on the new PMAR and disabling the auto-reclose features on an existing PMAR to achieve an optimum solution.

When planning the location of PMARs, consideration should be given to the methods of isolation. As PMARs are not suitable for creating a point of isolation, the use of ABSDs in series with PMARs may be required.

3.5.3.1. Location of Protection Equipment

In general, the provision of auto reclose facilities on an overhead line will result in a reduction in the number of customers per fault and the fault restoration times for that circuit. The optimum number of PMARs to install and their location is dependent upon several factors including, the presence of auto reclose facilities on the source circuit breaker, circuit fault rates, repair and restoration times, and the distribution of customers supplied via the circuit. Operational factors e.g., access arrangements also need to be considered when establishing the number and location of PMARs on an overhead line. An assessment of various combinations of PMAR numbers and locations may be required to establish the optimum overall number and location of PMARs to achieve the following objectives:[58]

- No customer should experience on average more than four HV interruptions per year over a three-year period i.e., 12 of more over three years;[59] and
- A maximum of three auto-reclose devices (including the source circuit breaker) should be used in series on HV circuits.[60]

The provision of auto reclose facilities should be considered at:

- The source HV circuit breaker at the EHV to HV substation;
- Locations along the main line; and
- Spur connections to the main line.

A summary of the design process can be found in Appendix 3.

3.5.3.2. Protection Equipment at Source

All HV circuits comprising more than 1km of overhead line in total (i.e., including spurs) shall be equipped with auto reclose facilities either at the source HV circuit breaker at the EHV to HV substation or a PMAR. Where the source HV circuit breaker has a multi shot capability, this functionality shall be used.

Consideration should be given to disabling any auto reclose functionality on the source HV circuit breaker and installing a PMAR at the beginning of the first main overhead line section where the:

- First leg from the EHV to HV substation comprises entirely underground cable and feeds more than 50 customers; or
- Underground cable section is more than 500m long.

In determining possible locations for a PMAR the following should be considered:

- The continuous current capacity and breaking capacity of the PMAR;
- Staff access requirements; and
- Grading with the protection of any HV customer supplied via the PMAR.

58 For guidance on how to optimise the number and position of PMARs see Appendix 1 and Appendix 4.

59 Ofgem's worst served customer definition from Strategy decision for the RIIO-ED1 electricity distribution price control – Reliability and safety.

60 In rare circumstances consideration can be given to adding four auto-reclosers in series. In these cases advice should be taken from technical services to establish the appropriate settings.

3.5.3.3. Protection Equipment on the Main Line

In addition to the auto reclose facilities installed at the source circuit breaker or PMAR at the start of the first main overhead line section, the installation of further PMARs on the main overhead line shall be to meet the general objectives set out in section 3.5.3.1.

3.5.3.4. Protection Equipment on Spurs

The classification criteria and protection requirements for spurs connected to overhead lines [61] is shown below. The spur type is defined as its length from either the tee position with the mainline or upstream spur.

- Major Spur – Spurs comprising 5km or more of overhead line and more than 130 customers connected. Major spurs should be protected by one or more PMARs provided this does not compromise the main line grading;

- Medium Spur – Spurs comprising between 0.5km and 5km of overhead line or spurs greater than 5km with fewer than of 130 customers connected. Medium spurs should be protected by an auto sectionalising link unless the estimated minimum load current is less than 300mA when the spur should be treated as a minor spur.[62.] If the installed transformer capacity on the spur exceeds 333kVA at 11kV or 500kVA at 20kV the use of ABSDs may be required for switching on the spur;

- Minor Spur – Spur comprising less than 0.5km of overhead and/or spurs with an estimated minimum load current of less than 300mA should be connected with expulsion fuses in Northern Powergrid Northeast or solid in Northern Powergrid Yorkshire, however, the fault risk associated with these spurs is relatively small and it is difficult to justify the costs of retrofitting protection equipment on these spurs. Where there are no existing links, minor spurs should be solidly connected to the main line;

Small section conductors on spurs – If the prospective fault currents coupled with clearance times are too high for the spur conductors,[63] then expulsion fuses should be installed.

Tee connections to substations – Tee connected pole-mounted HV to LV substations shall be protected by expulsion fuses in Northern Powergrid Northeast.[64] In Northern Powergrid Yorkshire teed overhead line connected pole mounted HV to LV substations shall be connected directly and cable connected pole mounted HV to LV substations shall be connected via expulsion fuses.

Within Northern Powergrid Yorkshire the widespread adoption of triggered spark gaps, three shot auto-reclose operation in the source zone and use of non-time graded auto-reclose settings has led to some minor differences in how spurs are to be protected compared with Northern Powergrid Northeast. The following tables show the appropriate protection and/or isolation to be used at the location where a spur connects to the main line or upstream spur for the HV systems in the two licence areas.

61 For HV circuits with a total length of overhead line of ≤ 1km, any minor or medium spurs connected shall be protected by expulsion fuses. For HV circuits with a total length of overhead line >1km then auto-reclose facilities shall be provided and spur the requirements in 3.5.3.4 apply.

62 300mA minimum load can be estimated as 15 customers and/or 2 transformers at 11kV and 30 customers and/or 4 transformers at 20kV.

63 See Appendix 5 of the Code of Practice on Fusing, IMP/001/921.

64 On minor and medium spurs within Northern Powergrid Northeast, pole mounted HV to LV substations can be connected directly.

Table 3: Table showing the 11kV OHL protection requirements in Northern Powergrid Yorkshire

Connected to / Type	Mainline – Source Auto Reclose Zone	Mainline – Middle Auto Reclose Zone	Mainline – Final Auto Reclose Zone	Major Spur	Medium Spur	Minor Spur
Major Spur	PMAR	PMAR	ASLs 2 or 3 shot*	PMAR or ASL (depending on parent mainline AR zone)		
Medium Spur	ASLs 2 shot only	ASLs 2 or 3 shot*	ASLs 2 or 3 shot*	ASLs 2 or 3 shot**	ASLs or Direct Connection (depending on parent mainline AR zone)	
Minor Spur	Direct Connection ***	Direct Connection ***	Direct Connection ***	Direct Connection ***	Direct Connection ***	Direct Connection ***
OHL spur containing small section conductor	Fused	Fused	Fused****	Fused****	Fused****	Fused****
OHL connected Pole mounted HV to LV substation	Direct Connection	Direct Connection	Direct Connection	Direct Connection	Direct Connection	Direct Connection
Cable connected Pole mounted HV to LV substation	Fused	Fused	Fused	Fused	Fused	Fused

* 3 shot ASLs only to be used if there is another protective device downstream.

** ASL limited to 2 shot if the major spur is ASL protected.

*** Fused spurs to be avoided due to widespread adoption of TSGs in Northern Powergrid Yorkshire.

**** Small section spurs may be protected by fuses in Source or Middle Zone, however the final zone PMAR instantaneous settings mean they may not operate and solid links and FPIs may be more suitable.

Table 4: Table showing the 11kV & 20kV OHL protection requirements in Northern Powergrid Northeast

Connected to / Type	Mainline – Source Auto Reclose Zone	Mainline – Middle Auto Reclose Zone	Mainline – Final Auto Reclose Zone	Major Spur	Medium Spur	Minor Spur
Major Spur	PMAR	PMAR	ASLs 2 or 3 shot*	PMAR or ASL (depending on parent mainline AR zone)		
Medium Spur	ASLs 2 or 3 shot*	ASLs 2 or 3 shot*	ASLs 2 or 3 shot*	ASLs 2 or 3 shot*/**		
Minor Spur	Fused	Fused	Fused	Fused	Fused	Fused
OHL spur containing small section conductor	Fused	Fused	Fused	Fused	Fused	Fused
OHL connected Pole mounted HV to LV substation	Fused	Fused	Fused	Fused	Direct Connection	Direct Connection
Cable connected Pole mounted HV to LV substation	Fused	Fused	Fused	Fused	Fused	Fused

* 3 shot ASLs only to be used if there is another protective device downstream.

** ASL limited to 2 shot if the major spur is ASL protected.

3.5.3.5. Pole-mounted Fault Passage Indicators

Fault passage indicators (FPIs) shall comply with the Technical Specification for Overhead Line Fault Passage Indicators, NPS/001/014. On Overhead HV systems, pole mounted FPIs shall be installed:

- As near as possible to manual switching points;
- As near as possible to both ends of cable sections;
- As near as possible to the point of connection with the main line on major spurs that are not protected with a PMAR;
- To ensure that no more than 250 customers are between FPIs; and
- To ensure that there is no more than 3km of main line without an FPI.

Pole mounted FPIs should not be installed on poles:

- Supporting one or more underground cables;
- Supporting transformers;
- Supporting double circuit lines;

- At overhead line tee-off positions;
- Closer than 300m to a 275 or 400kV overhead line;
- Closer than 150m to a 132kV overhead line;
- Closer than 100m to a 66kV overhead line;
- Closer than 50m to a 33kV overhead line; or
- Closer than 100m to 25kV overhead conductors.

All pole-mounted FPIs installed on main lines shall be capable of indicating to the Network Management System (NMS) when they have operated.

3.5.3.6. Lightning Protection

Lightning protection shall be installed in accordance with the Code of Practice for the Application of Lightning Protection, IMP/007/011. This code of practice includes guidance on the use of Triggered Spark Gaps (TSGs) and Surge Arrestors. TSGs shall comply with the Technical Specification for Insulators for Overhead Lines up to and including 132kV, NPS/001/006. Surge Arresters shall comply with the Technical Specification for Gapless Metal Oxide Surge Arresters, NPS/001/008.

For covered conductor construction Arc Protection Devices (APDs) shall be installed.

3.5.3.7. Location of Switching Equipment

Ferro-resonance is a phenomenon which occurs when a critical combination of capacitance (present where underground cables are installed) and inductance (contributed by transformer windings) exists along with little resistive load (de-loaded transformers). Overvoltage on a system can result from the ferro-resonant state during single-phase switching. The phenomenon is discussed in section OA4 of the Northern Powergrid Operational Practice Manual (OPM).

Ferro-resonance is mainly a concern on spurs which are controlled by non-ganged switching devices such as expulsion fuses, solid links or automatic sectionalising links. Installing underground cable on the main line should not cause ferro-resonance as main lines are usually controlled using three-phase ganged switching devices and generally have a minimum load high enough to dampen any resonance.

Where possible the use of HV underground cable in rural situations should be avoided as ferro-resonance will not occur where the system being energised or de-energised comprises entirely of HV overhead lines.

Where this is impractical, consideration should be given to minimising the risk of ferro-resonance either by the design of the system or providing switching facilities so that the risk of ferro-resonance can be managed by appropriate operation of the system.

Ferro-resonance is unlikely to occur, and no specific design criteria need to be implemented, when:

- Where there are more than 10 transformers in the circuit to be energised (or de-energised). This is shown in Scenario 1 in Appendix 6, or
- The aggregate length of underground cable in a section of HV circuit comprising overhead line and underground cable energised (or de-energised) by a switching operation less than the critical length set out in the tables in Appendix 5. This is shown in Scenario 2 in Appendix 6.

In these cases, the spur from the mainline can be equipped with Expulsion Fuses, Solid Links or Automatic Sectionalising Links i.e., an un-ganged arrangement, where permitted under section 3.5.3.4.

Ferro-resonance may occur in all other scenarios involving switching of circuits comprising underground cable, overhead line and transformers and additional switching facilities shall be provided to manage the risk operationally.

Scenario 3 in Appendix 6 illustrates the situation where a circuit comprising fewer than 10 transformers and an aggregate length of underground cable greater than the critical length set out in the tables in Appendix 5 is energised (or de-energised) by a switching operation. In this case a three-phase ganged switching device, for example an ABSD, should be installed before the start of the cable section in addition to any spur protection such as auto sectionalising links. In exceptional circumstances (e.g., fault level above the rating of auto sectionalising links) a PMAR can be used instead. In this case the PMAR should be set to instantaneous protection with the number of shots to lockout set to mimic a three or two shot auto sectionalising link as appropriate.

Scenario 4 in Appendix 6 illustrates the situation where a circuit comprising fewer than four transformers and an aggregate length of underground cable greater than the critical length set out in the tables in Appendix 5 is energised (or de-energised) by a switching operation. In this case, solid links or pole mounted expulsion fuses may be installed at pole mounted transformers, in accordance with section 3.5.3.4, so that the transformers can be isolated before the spur is switched into or out of service using the un-ganged pole mounted expulsion fuses.[65]

3.5.4. System security and Interconnection

3.5.4.1. Compliance with Engineering Recommendation P2

The HV system shall be designed to provide at least the standard of security required by Engineering Recommendation P2, Security of Supply, for which compliance is a requirement of Northern Powergrid's Distribution Licences of and the Distribution Code. HV circuits can be used to provide system security:

- to other HV circuits supplied from the same or a different EHV to HV substation;
- in conjunction with other HV circuits, to an EHV to HV substation, particularly in the case of an EHV to HV substation equipped with a single transformer.

When making any changes to the HV system, a security assessment shall be undertaken, in accordance with the Guidance for assessing Security of Supply in accordance with Engineering Recommendation P2/7, IMP/001/206, in order to confirm that all the associated HV circuits and, where appropriate, the EHV to HV substation, are compliant with Engineering Recommendation P2.

When a HV circuit is used to provide security, it shall be capable of picking up the full post-fault load of the demand which it is securing, such that all customers supplied from it would receive a supply voltage within statutory limits, without the circuit exceeding its cyclic rating, within the three hour timescale prescribed in Engineering Recommendation P2. Subsequent switching on the HV system may be required to ensure that the circuit remains within its continuous rating.[66] Consideration shall be given to the practicalities associated with the switching operations required to restore supplies within the prescribed timescales.[67] Strategically placed remote control facilities on HV switches and circuit breakers and the application of APRS can be used to facilitate the timely provision of security contribution, and shall be used where necessary to assure three-hour restoration.

In the case of an EHV to HV substation equipped with a single transformer, the interconnecting HV system shall be capable of supplying all the demand supplied from that substation, including the demand on those feeders used to provide interconnection, and it is likely to be the limiting factor on

65 Given the comparable installation costs and operational time penalty of replacing several links relative to operating one ABSD, installing an ABSD is preferred.

66 It may be appropriate, e.g., when confirming compliance with Engineering Recommendation P2 to apply a bespoke continuous or cyclic rating taking into account the load profile of a circuit, although consideration should be given to the possibility that the load profile may change in the future as demand changes / grows. IMP/001/011 and IMP/001/013 give further guidance.

67 Some existing systems may require multiple switching operations to restore supplies within statutory voltage limits; i.e., one or more open points may need to be moved to de-load the circuit to allow supplies to be restored, in addition to the switching required to isolate the faulty section. To comply with Engineering Recommendation P2 the time required to restore supplies will be site specific, however it is normally reasonable to assume that only one authorised person is available for on-site switching that only two manual switching operations and an additional six remote control switching operations, in addition to those required to isolate the fault, can be achieved within three hours.

that substation's ability to accommodate additional demand. To enable supplies to customers supplied from such a substation to be restored as soon as possible[68] in the event of an EHV outage, a combination of APRS facilities (which can be used to restore supplies to individual feeders) and remote control (which can be used to energise the HV busbar at the EHV to HV substation and restore remaining customer supplies via the busbars) shall be provided on the interconnecting HV circuits.

To increase the security of supply to an EHV to HV substation, interconnection to alternative EHV to HV substations shall be provided, where practicable and economic such that a minimum one-third of the substation's demand can be secured in the event of a second circuit outage at an EHV to HV substation equipped with two transformers.

Most HV circuits have a group demand of between 1 and 12MW, i.e., Engineering Recommendation P2 Class of Supply B,[69] and whilst Engineering Recommendation P2 permits 1MW of demand to remain off supply for repair time, Northern Powergrid considers this unacceptable, and provisions shall be made to secure the full demand within three hours. Other HV circuit, such as a minor spur, will have no interconnection with other HV circuits and hence are limited to supplying a group demand of 1MW i.e., Class of Supply A. Where a demand group is supplied by a single HV to LV transformer, provided that the nameplate rating of the transformer is 1MVA or less, the magnitude of the demand group can be greater than 1MW and still be considered to be a Class of Supply A provided that the group demand can be accommodated within the cyclic rating of transformer.[70]

HV to LV substations shall also meet the requirements of Engineering Recommendation P2, although the requirements are minimal where the substation demand is less than 1MW. Guidance on LV interconnection is given in the Code of Practice for the Economic Development of the LV System, IMP/001/911.

3.5.4.2. Interruption Incentive Scheme & Guaranteed Standards

HV systems have historically been designed to provide a security of supply above that required to meet the minimum requirements of Engineering Recommendation P2 where practical and economical to do so. The Interruption Incentive Scheme (IIS) and application of Guaranteed Standards (GS) both reinforce the case to continue with this approach. This section, section 3.5.2, and section 3.5.3 describes the configuration and protection arrangements for the HV system to meet the IIS and GS objectives.

3.5.4.3. Islanded systems

Parts of the HV system within both the Northern Powergrid Northeast and Northern Powergrid Yorkshire areas operate at different voltages to the surrounding system and therefore need to have sufficient interconnection within the islanded system to ensure Engineering Recommendation P2 compliance and deliver an acceptable quality of supply.

These legacy systems have limited capability and will also incur higher losses compared to delivering the same energy from an 11kV of 20kV system. Where the HV system in a geographic area operates at a non-standard HV nominal voltage[71] or a combination of a standard[72] and non-standard nominal voltage, a new connection shall be provided at 11kV (or 20kV where appropriate) unless a connection to a non-standard nominal voltage HV system is significantly more economical. Where a busbar operating at a non-standard nominal voltage is provided only for the benefit of one customer, this shall not be developed to connect other customers. Where the provision of a connection would require the installation of a new EHV to HV substation, the Point of Supply shall normally be provided at 11kV (or 20kV where appropriate) as this provides an economical means of developing the HV system.

68 Supplies should be restored as soon as possible and well within the three hour period required in Engineering Recommendation P2.

69 HV circuits normally supply demand in Class of Supply B as defined in Engineering Recommendation P2.

70 The note relating to Class of Supply A Engineering Recommendation P2/8 Table 1 refers. For example if the demand on a 1MVA transformer increased to 1.2MW, provided that it could be accommodated within the cyclic transformer rating, this would still be a Class of Supply A. This relaxation doesn't apply where the demand group is supplied by multiple HV to LV transformers.

71 E.g., 6kV or 6.6kV.

72 I.e., 11kV and 20kV.

If it is significantly more economical to provide a connection to a non-standard nominal voltage HV system, in order to facilitate future conversion from a to a non-standard nominal voltage HV system to standard nominal voltage HV system, all new HV equipment connected to the non-standard nominal voltage HV system should be capable of operating at a standard nominal voltage. This may require the use of dual ratio transformers.

3.5.5. Active Network Management

Active Network Management (ANM) is a generic term given to techniques for managing distribution systems more actively than would have been the case in the past e.g., managing power flow by actively controlling the current flowing through a circuit by controlling customers' demand or the output from generation plant. ANM schemes are described in the Code of Practice for the application of Active Network Management, IMP/001/016 and the Code of Practice for the Economic Development of Distribution Systems with Distributed Generation, IMP/001/007. Export limitation schemes could also be considered as being a form of ANM, although in this case the monitoring and control functions are installed on the customer's side of the Point of Supply. Engineering Recommendation G100 provides further details. When modifying a HV system which forms part of an ANM scheme careful consideration should be given to prevent unduly restricting the access that a customer has to import from or export to the HV system.

3.5.6. Interfaces with Connected Parties

Arrangements at interfaces with customers and IDNOs shall comply with the relevant obligations of the Distribution Code. Interfaces with IDNOs shall also comply with the relevant obligations of ESQC Regulations and Engineering Recommendation P2. Further guidance on planning the interface to an IDNO system is given in Engineering Recommendation G88.

Guidance on the provision of connections to customers is given in the Code of Practice for Standard Arrangements for Customer Connections, IMP/001/010.

Guidance on the connection of customers' generation is given in the Code of Practice for the Connection of Distributed Generation, IMP/001/007, and in Engineering Recommendation G99.

Care shall be taken to ensure compatibility of plant ratings at interfaces, see section 3.6.9

3.6. Selection, Application and Configuration of Plant

Items of plant that constitute the Northern Powergrid distribution system shall comply with the relevant Northern Powergrid's Network Product Specifications.

3.6.1. Standard Plant

Distribution Licence Condition 20 requires DNOs to comply with a Distribution Code that is designed so as to permit the development, maintenance, and operation of an efficient, coordinated and economical system for the distribution of electricity. The adoption of a standard range of plant and equipment for use on the HV system helps to achieve this requirement by bringing economies of scale and helps to manage network risks by facilitating the ability to interchange plant under emergency situations. A standard range of plant also offers benefits in terms of reducing the range of spares and tools that need to be carried and limits the number of products for which specialist training is required. The range of standard plant defined in the sections below, provides a co-ordinated suite of switchgear, transformers and circuit ratings.

3.6.2. Transformers

HV to LV substations shall be equipped with transformers complying with the Technical Specification for 11 & 20kV Distribution Transformers, NPS/003/011 or Technical Specification for 11kV & 20kV Pad Mounted Transformers, NPS/003/041.

Transformer ratings shall be selected giving consideration to the eventual loading requirement of the LV system which the transformer will supply. The Code of Practice for the Economic Development of the LV System, IMP/001/911, gives further guidance on the selection of the most appropriate transformer for each application.

3.6.2.1. Ground-mounted and Pole-mounted Transformers

The preferred arrangement for 11kV ground-mounted distribution transformers is one that forms an integral part of a unit distribution equipment (UDE), where HV and LV connections are on the same side of the transformer and both HV and LV switchgear can be directly connected (close-coupled) to the transformer, resulting in a compact substation arrangement. This is also the preferred arrangement for 20kV ground-mounted distribution substations but where the switchgear design is such that it cannot be close coupled to a transformer a HV cable connection is permissible.

The Technical Specification for 11 & 20kV Distribution Transformers, NPS/003/011 refers to the Energy Networks Association Technical Specification (ENATS) 35-1 for Distribution Transformers (from 16kVA to 2000kVA).

Table 5 – Table showing typical pole mounted and ground mounted transformer ratings and applications

Rating (kVA)	Phasing	Location	Application
25	Single-phase, 2 wire	Pole mounted	Rural system substation
50	Single-phase, 3 wire	Pole mounted	Rural system substation
100	Single-phase, 3 wire	Pole mounted	Rural system substation
50	Three-phase, 4 wire	Pole mounted	Rural system substation
100	Three-phase, 4 wire	Pole mounted	Rural system substation
200	Three-phase, 4 wire	Pole mounted	Rural system substation
315	Three-phase, 4 wire	Pole mounted	Rural system substation
315	Three-phase, 4 wire	Ground mounted	Urban system substation
500	Three-phase, 4 wire	Ground mounted	Urban system substation
800	Three-phase, 4 wire	Ground mounted	Urban system substation
1000	Three-phase, 4 wire	Ground mounted	Urban system substation
1250	Three-phase, 4 wire	Ground mounted	Single customer connection
1600	Three-phase, 4 wire	Ground mounted	Single customer connection

HV to LV transformers are provided with a DETC as standard, however on-load tap changers can be specified to automatically control the voltage on the LV side of an HV to LV transformer. A transformer equipped with an OLTC can be used where the voltage variations on the HV or LV system are such that using a transformer equipped with a DETC, set on a fixed tap, would result in the voltage at customers' Points of Supply being outside statutory limits and traditional reinforcement, such as reducing the system impedance, proves more costly.

3.6.2.2. Transformers in Pad-mounted Substations

Pad-mounted substations are a single piece of distribution equipment, comprising a transformer, disconnectable HV terminations and an LV cubicle containing between one and three fused LV ways, housed within a compact metal enclosure that can be installed on a relatively small concrete pad.

The Technical Specification for 11 & 20kV Pad Mounted Transformers, NPS/003/041, refers to ENATS 35-1 for Distribution Transformers (from 16kVA to 2000kVA), and includes the specification for the transformers, HV connections and LV switchgear.

Table 6: Table showing typical pad mounted transformer ratings and applications

Rating (kVA)	Voltage (kV)	Phasing	LV Feeder Ways	Application
50	11 & 20	Single-phase, 2 wire	1	Rural / Semi-rural system substation
50	11 & 20	Single-phase, 3 wire	1	Rural / Semi-rural system substation
50	11	Three-phase, 4 wire	1	Rural / Semi-rural system substation
100	11 & 20	Single-phase, 3 wire	1	Rural / Semi-rural system substation
100	11 & 20	Three-phase, 4 wire	2	Rural / Semi-rural system substation
200	11	Three-phase, 4 wire	2	Rural / Semi-rural system substation
315	11 &20	Three-phase, 4 wire	2	Rural / Semi-rural system substation

Transformers in pad-mounted substations are provided with a DETC as standard and there are no provisions for these transformers fitted with an OLTC. The LV incoming transformer disconnector (load break switch) and maximum demand indicator (MDI) CTs shall be equipped on transformer with 200kVA and above. The LV cables for the transformer tails depends upon the transformer rating; 185mm^2 waveform will be used for 100kVA and below, 300mm^2 waveform shall be used for 200kVA and above. There are connection terminals available for the connection of temporary generation on pad mounted transformers rated at 100kVA and above.

3.6.3. Ground-mounted Switchgear

Single busbar, non-oil, metal clad ground-mounted switchgear installed on the HV system shall conform to the Technical Specification for Primary 11kV and 20kV Circuit Breakers, NPS/003/006 or the Technical Specification for Ground Mounted Distribution RMU & Extensible Switchgear for use on 11 & 20kV networks, NPS/003/014 as applicable. These specifications refer to ENATS 41-36.

Switchgear shall be to the specification below:

Table 7: Table showing ground-mounted switchgear ratings

Application	Switchgear	Rating			
		Switching	Busbar	Break Rating at X/R of 14.14	Make Rating[73]
132 to 11kV substations	Feeder CB	630A[74]	2000A[75]	25kA	62.5kA
	Transformer CB	2000A[75]	2000A[75]	25kA	62.5kA
	Bus Section CB	2000A[75]	2000A[75]	25kA	62.5kA
EHV to 20kV substations	Feeder CB	630A[74]	1250A	20kA	50kA
	Transformer CB	1250A	1250A	20kA	50kA
	Bus Section CB	1250A	1250A	20kA	50kA
EHV to 11kV substations	Feeder CB	630A[74]	2000A	25kA	62.5kA
	Transformer CB	2000A[75]	2000A[75]	25kA	62.5kA
	Bus Section CB	2000A[75]	2000A[75]	25kA	62.5kA
20kV switching stations	Feeder Switch	630A	630A	-	40kA
	Feeder CB	630A	630A	16kA	40kA
	Customer CB	200A or 630A	630A	16kA	40kA
11kV switching stations	Feeder Switch	630A	630A	-	50kA
	Feeder CB	630A	630A	20kA	50kA
	Customer CB	200A or 630A	630A	20kA	50kA
20kV to LV substations	Feeder Switch	630A	630A	-	40kA
	Feeder CB	630A	630A	16kA	40kA
	Transformer CB	200A	630A	16kA	40kA
11kV to LV substations	Feeder Switch	630A	630A	-	50kA
	Feeder CB	630A	630A	20kA	50kA
	Transformer CB	200A	630A	20kA	50kA

3.6.4. Pole-mounted Switchgear

Pole-mounted switchgear installed on the HV system shall conform to the following Technical Specifications:

- Technical Specification for Overhead Line Air Break Switch Disconnectors, NPS/001/003;
- Technical Specification for 11kV, 20kV and 33kV Pole Mounted Expulsion Switch Fuse Tube and Solid Link, NPS/001/004; or
- Technical Specification for 11kV, 20kV and 33kV Pole Mounted Auto-reclose Circuit Breakers and Enclosed Switch Disconnectors, NPS/001/009.

Pole mounted switchgear shall be to the specification below:

73 Make rating is based on 2.5 x the break rating at 45ms. Where switchgear is tested at 120ms this factor will increase to 2.7.

74 Higher rated, 800A units can be used to provide supplies to single, large demand or generation customers.

75 Higher rated, 2500A units can be used to facilitate the connection of 20/40MVA primary transformers.

Table 8: Table showing pole-mounted switchgear ratings

Type of Pole Mounted Switchgear	Rating			Minimum Continuous Load Current
	Continuous	Switching	Break Rating at X/R of 14	
Auto recloser	630A	630A	12.5kA	-
ABSD	400A	See Table OB1 in OPM	400A (Load Current)	-
Expulsion fuse	Up to 200A[76]	See Table OB2 in OPM	8kA	-
Auto sectionalising link	Up to 200A	See Table OB2 in OPM	-	300mA
Current Limiting Fuse[77]	Up to 200A	[TBC]	43kA	-

3.6.5. Overhead lines

New overhead lines that form main lines or interconnectors shall be constructed as a three-phase overhead line.

New overhead lines or existing overhead lines that are being rebuilt,[78] which form minor, medium or major spurs shall be constructed as a three-phase overhead line where:

- The overhead line to which it would be connected is a three-phase overhead line, or where it is reasonably likely to be converted to a three-phase overhead line in the foreseeable future;
- Required to meet the existing or new system requirements;
- The total number of HV to LV substation connected to the overhead line is more than 10 or the number of customers supplied from the overhead line is more than 100; or
- Provision of a three-phase supply would facilitate the provision of three-phase services to allow the connection of three-phase equipment, particularly low carbon technology (LCT) equipment that would bring benefits to a rural community.

Where these criterial are not met, a new overhead line or an existing overhead line that is being rebuilt shall be constructed, wherever reasonably practicable, to facilitate future uprating to three-phase operation by the addition of a third conductor.

Bare wire HV overhead lines forming part of a main line, interconnector or spur shall be constructed using AL5 type conductor in accordance with the Technical Specification for HV Wood Pole Lines up to and including 33kV, NSP/004/042.

Single-phase lines shall be limited in conductor size to 50mm^2 AAAC.

Overhead lines comprising bare wire shall be to the specification below:

76 Switching capacity will be less than this value, see Section OB4 within the Operational Practice Manual.

77 For use in pad mounted substations in conjunction with a Bay-O-Net fuse. See Appendix 7.

78 Overhead lines constructed with 2 x 32mm^2 HDBC or 2 x 50mm^2 AAAC conductor can be converted to three phase by adding a third conductor of the same type with minimal work involved if the lines are constructed with medium (or stout and extra stout) grade poles, crossarms with a minimum of 1.2m phase to phase spacing and spans below the design span of 80-90m.

Table 9: Table showing bare wire overhead line ratings

Application	Rating (Summer/Spring & Autumn/Winter)	Design Temperature	Conductor Material and Size
Minor Spur and Medium Spur ≤700kVA[79] [80]	165/191/206A	50°C	50mm² AAAC
Medium Spur >700kVA	345/375/392A	75°C	100mm² AAAC
Main lines and interconnectors	345/375/392A	75°C	100mm² AAAC
Main lines and interconnectors	504/547/572A	75°C	175mm² AAAC

HV overhead lines utilising covered conductor forming part of a main line, interconnector or spur shall be constructed using conductor in accordance with the– Specification for HV Wood Pole Lines of Compact Covered Construction up to and including 33kV, NSP/004/044.

Overhead lines utilising covered conductor shall be to the specification below:

Table 10: Table showing covered conductor overhead line ratings

Application	Rating (Summer/Spring & Autumn/Winter) [81]	Design Temperature	Conductor Material and Size
Minor Spur and Medium Spur ≤700kVA	156/181/195A	50°C	50mm² AAAC (XLPE covered)
Medium Spur >700kVA	360/391/409	75°C	120mm² AAAC (XLPE covered)
Main lines and interconnectors	360/391/409	75°C	120mm² AAAC (XLPE covered)
Main lines and interconnectors	477/518/541	75°C	185mm² AAAC (XLPE covered)

The ratings in the above tables apply to single circuit systems and are 0% excursion ratings. Where HV circuits are operated as multi-circuit systems e.g., when used to supply a firm HV substation, it may be appropriate to use 3% excursion ratings. The Code of Practice for Guidance on the Selection of Overhead Line Ratings, IMP/001/011, gives further guidance on the rating of overhead lines.

All new overhead lines equipped with conductors greater than 50mm² cross section shall be designed to operate at 75°C with clearances in accordance with the Guidance on Overhead Line Clearances NSP/004/011. Overhead lines of 50mm² cross section, whether bare or covered, shall be designed to operate at 50°C.

3.6.6. Underground Cables

Cables used to form the HV system shall comply with Technical Specification for 11 & 20kV Power Cables, NPS/002/020.

11kV cables shall be used on HV systems operating at between 5.25 and 6.6kV. Where there is a credible likelihood of an 11kV cable forming part of a 20kV or 33kV system as part of future system development, 22kV or 33kV cables, as appropriate, shall be used on 11kV systems.

Cables shall be to the specification below:

79 700kVA relates to the largest step up transformer available for use with mobile generation plant and corresponds to approximately 500 customers. The total installed transformer capacity on a spur of 700kVA or less is also appropriate for 50mm² conductors in terms of losses.

80 Where minor spurs are likely to be developed to form main lines or interconnectors in the future they should be built to 100mm² AAAC.

81 Ratings are for XLPE covered AAAC conductor: Conductor Code Name AL3. Further information is provided in NSP/004/044.

Table 11: Table showing underground cable ratings

Application	Conductor Material and Size	Laid Direct Continuous Rating at 65°C (XLPE cable jointed to paper insulated cable)	Laid Direct Continuous Rating at 90°C (XLPE between switching points)
EHV to 11kV transformer to 11kV switchboard connection	400mm^2 Cu XLPE single core	-	691A
11kV feeder	300mm^2 Al triplex	390A	460A
11kV switchgear to 11kV to LV transformer connection (or where 300mm^2 Al is impractical due to space constraints)	185mm^2 Al triplex	300A	355A
Large 11kV demand or generation customers	300mm^2 Cu XLPE Triplex	-	590A
Large 11kV demand or generation customers (where 300mm^2 Cu insufficient)	400mm^2 Cu XLPE Triplex	-	665A
EHV to 20kV transformer to 20kV switchboard connection	400mm^2 Cu XLPE single core	-	670A
20kV feeder or 20kV switchgear to 20kV to LV transformer connection	185mm^2 Al XLPE triplex	295A	355A

The standard 11kV cable shall be 300mm^2 Al Triplex. This cable size has proven economic advantages in terms of losses over 185mm^2 cable in the majority of networks.[82] 300mm^2 Al shall therefore be used for all 11kV circuits unless it is impractical (e.g., where there are tight bending radii and in some older switchgear terminations). In these situations, 185mm^2 Al can be used but the length of this cable shall be kept to a minimum and jointed as close as reasonably practicable to the 300mm^2 Al cable used to form the rest of the circuit.

Copper conductor XLPE insulated 11kV single core cable is available in larger sizes than the table above (400mm^2, 500mm^2 and 630 mm^2 at 11kV and 400mm^2 at 20kV) and can be used where the triplex conductors would have an insufficient rating or excessive impedance, for example to provide supplies to individual customers with a large HV demand and/or generation. The use of these cables shall be restricted to special circumstances, and not used in general network situations. An assessment of network losses should be undertaken in these situations as per section 3.3.7. Care should be taken to co-ordinate the cable rating with the switchgear rating.[83]

Ratings in the above table are based on cables being laid direct at standard depth. De-rating factors will apply where cables are installed in ducting[84] or laid in proximity to other cables. Care should be taken to establish the appropriate rating where cables are installed in long duct banks e.g., those adjacent to EHV to HV substations.

Further guidance on cable ratings is given in the Code of Practice for Guidance on the Selection of Underground Cable Ratings, IMP/001/013. Care should be taken with respect to rating when modifying part of a circuit comprising paper insulating cable with XLPE cable. The new circuit rating will be limited to the operating temperature of the paper cable which is generally 65°C.

82 Its use helps ensure compliance with SLC49 (Electricity Distribution Losses Management Obligation and Distribution Losses Strategy) and Northern Powergrid's RIIO ED1 Business Plan (Strategy for Losses).

83 The majority of outgoing circuit breakers on the system are typically rated at 400A, 630A or in a minority of cases 800A.

84 Increasingly Highways Authorities are restricting the use of long, open cut trenches. This is leading to short ducted sections being laid and cable being pulled through later.

3.6.7. Bespoke and Real-time Thermal Ratings

Where cost-effective, it may be appropriate to carry out a bespoke thermal rating study using measured overhead line clearances for overhead lines, soil thermal resistivity measurements for cables and thermal modelling for transformers. Using such data and modelling it is possible to calculate circuit specific ratings which may release latent thermal headroom.

Where a bespoke assessment does not result in an adequate rating, the use of real time thermal measurements e.g., wind speed as input into an ANM system can also be considered.

3.6.8. Earthing and Bonding

The Northern Powergrid requirements for earthing and bonding, so far as they apply to the design of HV systems, are set out in the Code of Practice for Earthing LV Networks and HV Distribution Substations, IMP/010/011.

3.6.8.1. Arc Suppression Coils

Arc suppression coil (ASC) earthing works in conjunction with the overhead line protection, typically comprising auto-reclose schemes. The inductive reactance of the coil is adjusted to match the capacitive reactance to earth of two phases with the third phase connected solidly to earth. In the event of a transient single-phase-to-earth fault, the resulting lagging current negates the capacitive current from the network conductors. There will therefore be negligible fault current, and customers will consequently experience fewer interruptions and an improved quality of supply. In the event of the detection of a permanent single-phase-to-earth fault, a bypass circuit breaker will operate to short circuit the ASC and allow circuit protection to detect the fault and disconnect the circuit. The time applied to the scheme will be dependent on the original method of system earthing to limit the duration of overvoltages on the healthy phases.

The application of ASCs is covered in the sectional level document, An Application Guide for Arc Suppression Coils, IMP/001/912/001. Modifications to the HV system may affect the ability of an ASC to tune to the cable capacitance and hence reduce the earth fault current. When adding significant lengths of underground HV cable to a system supplied from an EHV to HV substation with an ASC installed, care should be taken to check that the total cable capacitance does not exceed the inductance of the ASC.

Typically, ASCs are fitted at an EHV to HV substation where the HV circuits comprise predominantly overhead lines and where the aggregate length is more than 35km in the Northern Powergrid Northeast area or 50km in the Northern Powergrid Yorkshire area.

ASCs are typically installed at selected EHV to HV substations supplying HV circuits classed as being worst performing circuits. The installation of an ASC is driven purely by quality of supply performance. Installation is only beneficial at substations where the HV circuits comprise a high percentage of overhead line (i.e., cable forms typically no greater than one third of the circuit length). When deciding whether to install an ASC the improvement in the performance of the circuits supplied from EHV to HV substations should be based on an economic assessment. The benefits will be greatest at those substations which have the highest number of overhead line faults and the greatest length of normally connected overhead lines.

When a new ASC is installed, it shall be sized 50% greater than the capacitance of the network. This is to future proof the substation from new cable being added in the future. When a network alteration means an existing coil is greater than the HV network capacitance by a margin of 15% or less the coil should be considered for replacement. This is because a 15% over-tuning is recommended to avoid operating at the resonant point which could occur if extra HV network may be switched in. Any assessments of network capacitance should take all HV network downstream of the EHV to HV substation including Northern Powergrid owned, IDNO and customer owned networks.

3.6.9. Co-ordination of Current Ratings

The distribution system has historically been developed using standard components with co-ordinated ratings for the major items of plant. Over time the standard ratings have increased reflecting the difficulties of securing new substation sites and the opportunities that present themselves when time-expired assets are replaced. Such co-ordination is still the preferred approach to system development and aligns with the requirement of section 9 of the Electricity Act ‘to develop and maintain an efficient, co-ordinated and economical system of electricity supply’.

When increasing the capacity of part of the distribution system consideration shall be given to the rating of associated plant and equipment to ensure that an unacceptable ‘weak link’ is not retained or created. This is especially true on HV circuits whereby unintentional tapering can occur as the circuit sections closest to the EHV to HV substation are replaced with larger sections and the replacement of downstream sections is deferred.

The profile of load on the system is changing particularly in urban areas where peak demand increasingly occurs during summer months. It is important to ensure that the seasonal capability of plant is adequate to cater for the seasonal demand imposed upon it.

Checks shall be made as to the compatibility of plant ratings across a customer connection interface. This is critical to ensure consistent application of seasonal or cyclic ratings where the customer’s plant has a peak demand in the summer months.

3.6.10. Protection and Control

Protection of the HV systems shall be in accordance with the Code of Practice for the Protection of Distribution Networks, IMP/001/014.

The primary rating of CTs and VTs used for protection purposes shall be co-ordinated with the capability[85] of the associated primary plant.

SCADA facilities shall be provided at EHV to HV substations supplied in accordance with the SCADA Code of Practice, IMP/007/003.

Protection and control facilities shall be used to provide information to monitor and manage power flow on the HV system in both real time and planning timescales. This information shall include real and reactive power flows in the forward and reverse direction on all HV circuit breakers at an EHV to HV substation and, where practicable, PMAR and HV regulators. This information should be made available via SCADA to the Northern Powergrid data historian.

3.7. Plant Location and Routing of Circuits

3.7.1. Location of Substations

The Code of Practice for Standard Arrangements for Customer Connections IMP/001/010 and the Code of Practice for the Economic Development of the LV System, IMP/001/911 give details of the requirements for HV substation location, their design capacity and accommodation.

During the design and installation of new substations the guidance contained within the Construction, Design and Management Regulations shall be followed in particular the guidance relating to the future maintenance, renewal and disposal needs of the substation.

All substations and their associated housings shall be installed and arranged in accordance with the guidance set out in the following internal documentation:

- IMP/005 Policy for the renewal of outdoor HV substations;

85 It is worth noting that the capability of a transformer will be in excess of its nameplate rating.

- IMP/009 Policy for the enclosure of ground mounted distribution substations;
- IMP/011 Policy for fire mitigation at operational premises; and
- IMP/001/012 Code of Practice for flood mitigation at operational premises; and
- NSP/007/020 Guidance on substation design: transformer noise.

3.7.2. Routing of Overhead Lines

Overhead line routes shall be selected to minimise the effect on the amenity of the area including following contour lines where possible and avoiding skylines. The Holford Rules for the routing of overhead lines shall be adhered to. The crossing of motorways, high speed dual carriageways and railways shall be achieved with an underground cable route wherever practicable. If an overhead crossing is necessary the additional clearances specified in the Guidance on Overhead Line Clearances, NSP/004/011, shall be used and any failure containment applied in accordance with the Specification for HV Wood Pole Lines up to and including 33kV, NSP/004/042.

In addition, overhead line routes shall be selected taking into account the requirements of the Policy document Guidance on the Risk Assessment of Overhead Lines, NSP/004/012, specifically to ensure that no new high or medium risk sections of overhead line are commissioned. Opportunities shall be taken to modify existing overhead lines so as to reduce the risk rating of existing sections from high or medium risk to low risk.[86] Consideration can be given to the use of covered conductor as a means of reducing such risks if adequate risk mitigation cannot be achieved by other means, e.g., by vegetation management where overhead lines pass through wooded areas or the use of danger signs in recreational areas.

HV overhead line routes in close proximity to or parallel with existing higher voltage lines or electrified railway lines shall be avoided as far as practicable as undesirable induced voltages may arise.

Overhead lines should not be routed across or within the plot boundaries of residential housing estates. If this is unavoidable all poles and stays within plot boundaries shall be secured by an easement. The Code of Practice on Easements for Overhead Lines and Underground Cables, CNS/001/014, provides further details.

Where practicable all pole-mounted switchgear shall be located adjacent to public roads to facilitate convenient access particularly under adverse weather conditions.

In areas of outstanding natural beauty increased consideration should be given to installing underground cable instead of overhead lines. This consideration should be taken into account when either rebuilding an overhead line or installing an entirely new overhead line.

3.7.3. Routing of Underground Cables

The Policy for the Installation of Distribution Power Cables, NSP/002 provides guidance and sets out the Northern Powergrid policy on the procedures that are to be followed when installing distribution power cables. The document covers the excavation of trenches, trench preparation, installation of ducts, installation of safety features and warning signs, laying and pulling in of cables, back filling of trenches, re-making of ground and recording of cable positions.

When routing new HV cables, consideration shall be given to the potential for future network extension to cater for load development as well as to the immediate need. Routes should ideally be simple and direct with the minimum of cross-over particularly in the open trenchwork of substations. Where practical and economic, cables shall be laid on a route that is separate from other cables supplying or providing security to a given group of customers. Opportunities shall be taken to use common excavation with new LV cables. Cable routes shall be accessible by vehicle and preferably be in the public highway where Northern Powergrid has statutory rights. Where this is not practicable cable easements must be sought

86 System designers should refer to the register of overhead line risk assessment that details the high and medium risk sites.

in accordance with the Code of Practice Easements for Overhead Lines and Underground Cables, CNS/001/014.

4. References

4.1. External Documentation

Reference	Title	Version and Date
CDM Regulations	The Construction (Design and Management) Regulations 2015	Statutory Instrument 2015 No. 51
EAW Regulations	The Electricity at Work Regulations 1989	Statutory Instrument 1989 No. 635
Electricity Act	The Electricity Act 1989 (as amended by the Utilities Act 2000, Energy Act 2004)	February 2023
ENA TS 35-1	Distribution Transformers (from 16kVA to 2000kVA)	Multiple Parts with different issue dates
ENA TS 41-36	Switchgear For Service Up To 36kV (Cable and Overhead Conductor Connected)	Issue 3, 2012
Engineering Recommendation G100	Technical Requirements for Customers' Export and Import Limitation Schemes	Issue 2, Amendment 1, 2022
Engineering Recommendation G5	Harmonic voltage distortion and the connection of harmonic sources and/or resonant plant to transmission systems and distribution networks in the United Kingdom	Issue 5, 2020
Engineering Recommendation G98	Requirements for the connection of Fully Type Tested Micro-generators (up to and including 16 A per phase) in parallel with public Low Voltage Distribution Networks on or after 27 April 2019	Issue 1, Amendment 7, 2022
Engineering Recommendation G99	Requirements for the connection of generation equipment in parallel with public distribution networks on or after 27 April 2019	Issue 1, Amendment 10, 2024
Engineering Recommendation P2	Engineering Recommendation P2 Security of Supply	Issue 8, 2023
Engineering Recommendation P28	Voltage fluctuations and the connection of disturbing equipment to transmission systems and distribution networks in the United Kingdom	Issue 2, 2019
Engineering Recommendation P29	Planning limits for voltage unbalance in the UK for 132kV and below	Issue 1, 1990
ESQC Regulations	The Electricity Supply, Quality and Continuity Regulations 2002	31 January 2003 (as amended)
Health and Safety at Work Act	Health and Safety at Work Act	1974
The Distribution Code	The Distribution Code and The Guide to the Distribution Code of Licensed Distribution Network Operators of Great Britain	Issue 56, 2024
The Electricity Distribution License	Standard conditions of the Electricity Distribution Licence	April 2023

4.2. Internal Documentation

Reference	Title
CNS/001/001	Guidance on the Acquisition of Wayleaves
CNS/001/014	Easements for Overhead Lines and Underground Cables
IMP/001/007	Code of Practice for the Economic Development of Distribution Systems with Distributed Generation
IMP/001/010	Code of Practice for Standard Arrangements for Customer Connections
IMP/001/011	Code of Practice for Overhead Line Ratings and Parameters
IMP/010/011	Code of Practice for Earthing LV Networks and HV Distribution Substations
IMP/001/012	Code of Practice for Flood Mitigation at Operational Premises
IMP/001/013	Code of Practice for Underground Cable Ratings and Parameters
IMP/001/014	Code of Practice for the Protection of Distribution Networks
IMP/001/016	Code of Practice for the Application of Active Network Management
IMP/001/103	Code of Practice for the Methodology of Assessing Losses
IMP/001/104	Code of Practice for the Management of Short Circuit Currents in Distribution Switchgear
IMP/001/206	Guidance for Assessing Security of Supply in Accordance with Engineering Recommendation P2/7
IMP/001/909	Code of Practice for Distribution System Parameters
IMP/001/911	Code of Practice for the Economic Development of the LV System
IMP/001/912/001	An Application Guide for Arc Suppression Coil
IMP/001/912/002	An Application Guide for HV System Remote Control
IMP/001/913	Code of Practice for the Economic Development of the EHV System
IMP/001/921	Code of Practice on Fusing
IMP/005	Policy for the Renewal of Outdoor HV Distribution Substations
IMP/007/003	SCADA Code of Practice
IMP/007/011	Code of Practice for the Application of Lightning Protection
IMP/009	Policy for the Enclosure of Ground Mounted Distribution Substations
IMP/011	Policy for Fire Mitigation at Operational Premises
INV/007	Flexibility First Policy
INV/007/001	Flexibility First Decision Making: Use of Sustain and Secure Flexibility Service Products to Address System Constraints on the 132kV and EHV Distribution System
NPS/001/003	Technical Specification for 11kV, 20kV and 33kV Overhead Line Air Break Switch Disconnectors
NPS/001/004	Technical Specification for 11kV, 20kV and 33kV Pole Mounted Expulsion Switch, Fuse Tube and Solid Link
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
NPS/001/009	Technical Specification for 11kV, 20kV and 33kV Pole Mounted Auto-reclose Circuit Breakers and Enclosed Switch Disconnectors
NPS/001/014	Technical Specification for Overhead Line Fault Passage Indicators
NPS/002/020	Specification for 11 & 20kV Power Cables
NPS/003/006	Technical Specification for Primary 11kV and 20kV Switchgear
NPS/003/011	Technical Specification for Ground Mounted Distribution Transformers up to and including 20kV
NPS/003/013	Specification for Fault Passage Indicators and their associated Current and Voltage Sensing Instruments for use with Ground Mounted 11 & 20kV Switchgear
NPS/003/014	Technical Specification for Ground Mounted Distribution RMU & Extensible Switchgear for use on 11 & 20kV networks

Reference	Title
NPS/003/020	Technical Specification for 11kV and 20kV Voltage Regulators
NPS/003/041	Technical Specification for 11 & 20kV Pad-mounted Transformers
NSP/002	Policy for the Installation of Distribution Power Cables
NSP/004/011	Guidance on Overhead Line Clearances
NSP/004/012	Guidance on the Risk Assessment of Overhead Lines
NSP/004/042	Specification for HV Wood Pole Lines up to and including 33kV
NSP/004/044	Specification for HV Wood Pole Lines of Compact Covered Construction up to and including 33kV
NSP/007/020	Guidance on Substation Design: Transformer Noise
OPM	Operational Practice Manual

4.3. Amendments from Previous Version

Section	Amendment
3.1	Paragraphs added to introduce the role of the DSO.
3.1.5	Reference to SLC7A and SLC31E added.
3.1.5	Reference to Engineering Recommendation P2 in SLC 24.1 clarified.
3.1.5	Updated the section to include flexibility services as a licence condition 31E.
3.1.7	New section added re DCUSA.
3.3.4	References to Engineering Recommendations P28, P29, G5 and G99 added.
3.3.6	Paragraph added to clarify the requirement re inadequately rated plant.
3.4	New paragraph added re the design criteria to include future energy scenarios and Government's 2050 net greenhouse gas emissions target.
3.4.3	New paragraph added related to increasing system capacity.
3.4.4	New paragraph added related flexibility services.
3.5.1	Added requirement to apply remote control to HV normal open points with telecontrol facilities.
3.5.2	Updated section to align with the recently published remote control application guide.
3.5.2	Updated section to install pad-mounted substation to an underground system in rural and semi-rural networks where previously Inverted pole HV to LV substations were allowed to establish (when available).
3.5.3	Added guidance for the establishment of HV to LV pad-mounted substations (when available).
3.5.3	Clarification that EREC G100 has replaced NPg document IMP/001/015.
3.5.4.1	Updated section to align with EREC P2/7.
3.5.4.1	Requirements for remote control and APRS at single transformer primary substations clarified.
3.6.2	Created two subsections i) ground mounted and pole mounted transformers, and ii) transformers in pad-mounted substation.
3.6.2.2	New section added regarding pad mounted transformer.
3.6.3	Enhanced 11kV switchgear added in relation to 132/11kV substations.
3.6.4	Added current limiting fuse ratings.
3.6.5	Added notes to develop overhead line networks with three-phase lines and uprate the existing single-phase networks.
3.6.7	New section added re bespoke and real time ratings.
4.1	General update.
4.2	General update.
5	New definitions added for pole-mounted substation, pad-mounted substation and flexibility service.

Section	Amendment
All	Minor editorial changes to improve legibility.
Appendix 2	Updated figure 2 to incorporate guidance on the application of remote control.
Appendix 7	Added Appendix on Pad mounted substations to provide a brief overview description of design and functionality of pad mounted transformers.

5. Definitions

Term	Definition
AAAC	All-Aluminium Alloy Conductor.
ABSD	Air Break Switch Disconnector.
ANM	Active Network Management.
APRS	Automated Power Restoration System.
ASC	Arc Suppression Coil.
AVC	Automatic Voltage Control.
CI	The number of customers interrupted per year (CI). This is the number of customers whose supplies have been interrupted per 100 customers per year over all incidents, where an interruption of supply lasts for three minutes or longer, excluding re-interruptions to the supply of customers previously interrupted during the same incident.
CML	The duration of interruptions to supply per year (CML). This is the average customer minutes lost per customer per year, where an interruption of supply to customer(s) lasts for three minutes or longer.
CoP	Code of Practice.
Design Manager	The manager responsible for tactical decisions associated with implementing this Code of Practice who can be the Design Manager for discretionary new connection schemes, non-discretionary HV reinforcement schemes and other designs.
DETC	De-energised tap changer.
DINIS	Distribution Network Information System. System studies software used in Northern Powergrid.
DNO	Distribution Network Operator. The person or legal entity named in Part 1 of the Distribution Licence and any permitted legal assigns or successors in title of the named party.
Dyn11	Delta (HV), Star (LV), 11 o'clock (+30° phase displacement). Northern Powergrid standard vector group of HV to LV transformer.
EHV	Means voltages equal to or greater than 33kV and less than 132kV.
Embedded Generation	Generating stations which are connected to a distribution system, rather than to the transmission system. Sometimes referred to as Distributed Generation.
ENATS	Energy Network Association Technical Specification.
Flexibility Service	A commercial service where a customer modifies their generation and/or consumption of electricity in response to an external signal (e.g., change in electricity or Use of System price or on receipt of a specific communication signal) to provide a service to a distribution system operator.
FPI	Fault Passage Indicator.
GROND	Geographical Representation of Network Data. Reliability assessment software used in Northern Powergrid.
GS	Guaranteed Standard
GSP	Grid Supply Point
HV	Means voltages greater than 1kV and less than 33kV.
HV substation	A set of electrical equipment used to connect the HV systems. Typically, HV Metered Switchgear for a dedicated customer and HV switching stations fall into this category.

Term	Definition
HV to LV substation	A set of electrical equipment including a HV to LV transformer. For example, a pole mounted substation, a pad mounted substation or a UDE.
IDNO	Independent Distribution Network Operators develop, operate and maintain local electricity distribution network. IDNO networks are directly connected to the Distribution Network Operator (DNO) networks or indirectly to the DNO via another IDNO.
IIS	Interruption Incentive Scheme.
LV	Low Voltage (less than 1,000 Volts)
NMS	Network Management System. Software used to manage the Northern Powergrid distribution network.
Northern Powergrid	Northern Powergrid (Northeast) plc and Northern Powergrid (Yorkshire) plc
Northern Powergrid Northeast	Northern Powergrid (Northeast) plc
Northern Powergrid Yorkshire	Northern Powergrid (Yorkshire) plc
OLTC	On Load Tap Changer
Pad-mounted substation	A substation where a HV to LV transformer and associated HV and LV terminations is housed in a metal enclosure mounted on a concrete pad. The substation can be supplied via an underground cable.
PI	Software used in Northern Powergrid to view SCADA data.
Planning Manager	The manager responsible for strategic decisions who can be i) the System Planning Manager for issues relating to the strategic planning and development of the system ii) the Smart Grid Development Manager.
PMAR	Pole mounted Auto-reclosing Circuit Breaker
Pole-mounted substation	A substation where a HV to LV transformer and any associated HV switchgear and/or LV switchgear is mounted on a single or double wood pole structure. The substation can be supplied via an overhead line or underground cable.
Power Quality	The term 'power quality' is used to describe how near to a sinusoid waveform the power supply is. This term is often used to encompass both flicker and harmonic distortion.
Quality of Supply	The term Quality of Supply is used to describe how well Northern Powergrid Northeast and Northern Powergrid Yorkshire satisfy those customers connected to its distribution system, using minimum targets and standards agreed with Ofgem on their behalf. One aspect is Supply Performance, which is measured against the following targets. Availability – Average minutes lost per connected customer. Security – Number of Supply interruptions per 100 connected customers. Reliability – Number of faults per 100km of distribution system mains.
SCADA	Supervisory Control and Data Acquisition (often referred to as telecontrol).
UDE	Unit Distribution Equipment. A close coupled unit comprising of HV Switchgear, Transformer and LV Board.

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
Deb Dovinson	Governance Administrator	25/03/2024

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
Alan Creighton	Senior Smart Grid Development Engineer		24/04/2024

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
Mark Callum	Smart Grid Development Manager	24/04/2024

6.4. Authorisation

Authorisation is granted for publication of this document.

		Date
Mark Nicholson	Director of Engineering	01/05/2024

Appendix 1 – Summary of modelling assumptions for use in reliability calculations

This appendix sets out the generic parameters that should be applied when using GROND for CI & CML performance assessments.

All studies should be carried out using the Light, Medium & Heavy fault rate per km per annum for both Underground cable and Overhead Lines as follows:

Table 12: Table showing fault rates per annum for GROND modelling

	Light	Medium	Heavy
Underground	0.05	0.05	0.05
Overhead	0.1	0.08	0.07

All transient fault rates per km are set at zero.

Value per CI and CML to be set as follows:

Table 13: Table showing CI/CHL costs for GROND modelling

Type	Value (£) (2016-17 prices[87])
CI	£11.51
CHL	£17.10

Restoration times to be set as follows:

Table 14: Table showing Restoration times for GROND modelling

Switching	Time (Mins)
Manual	80
Manual/FFI	80
Telecontrol	10
Automatic	2
Recloser	1

Repair times to be set as follows:

Table 2 Table showing repair times for GROND modelling

Type	Time (Mins)
Underground	480
Overhead	480

87 For up to date CI/CHL figures confirm with System Reliability Manager.

Appendix 2 – Illustrative HV System Configurations

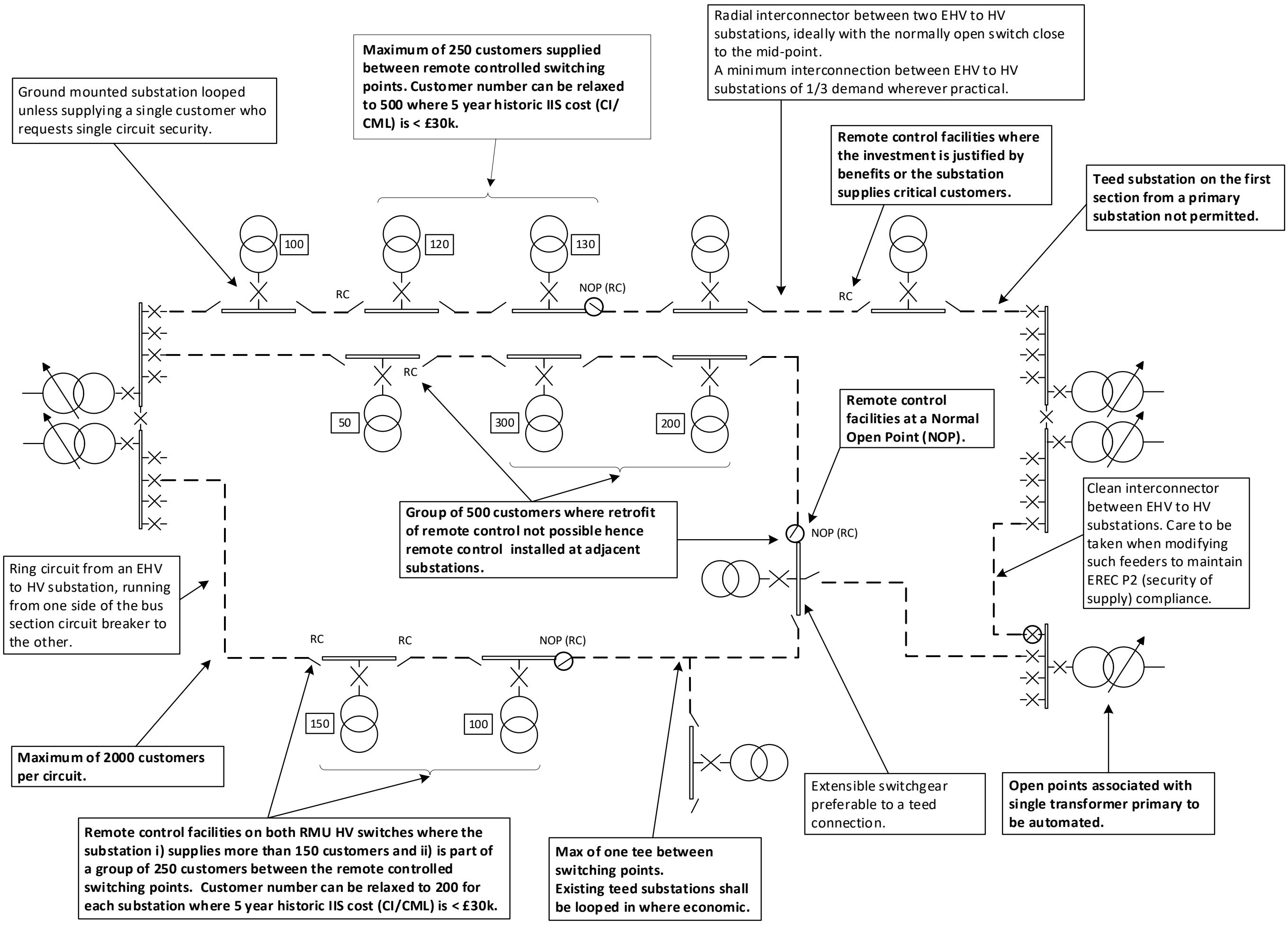

Figure 1: HV underground cable configuration

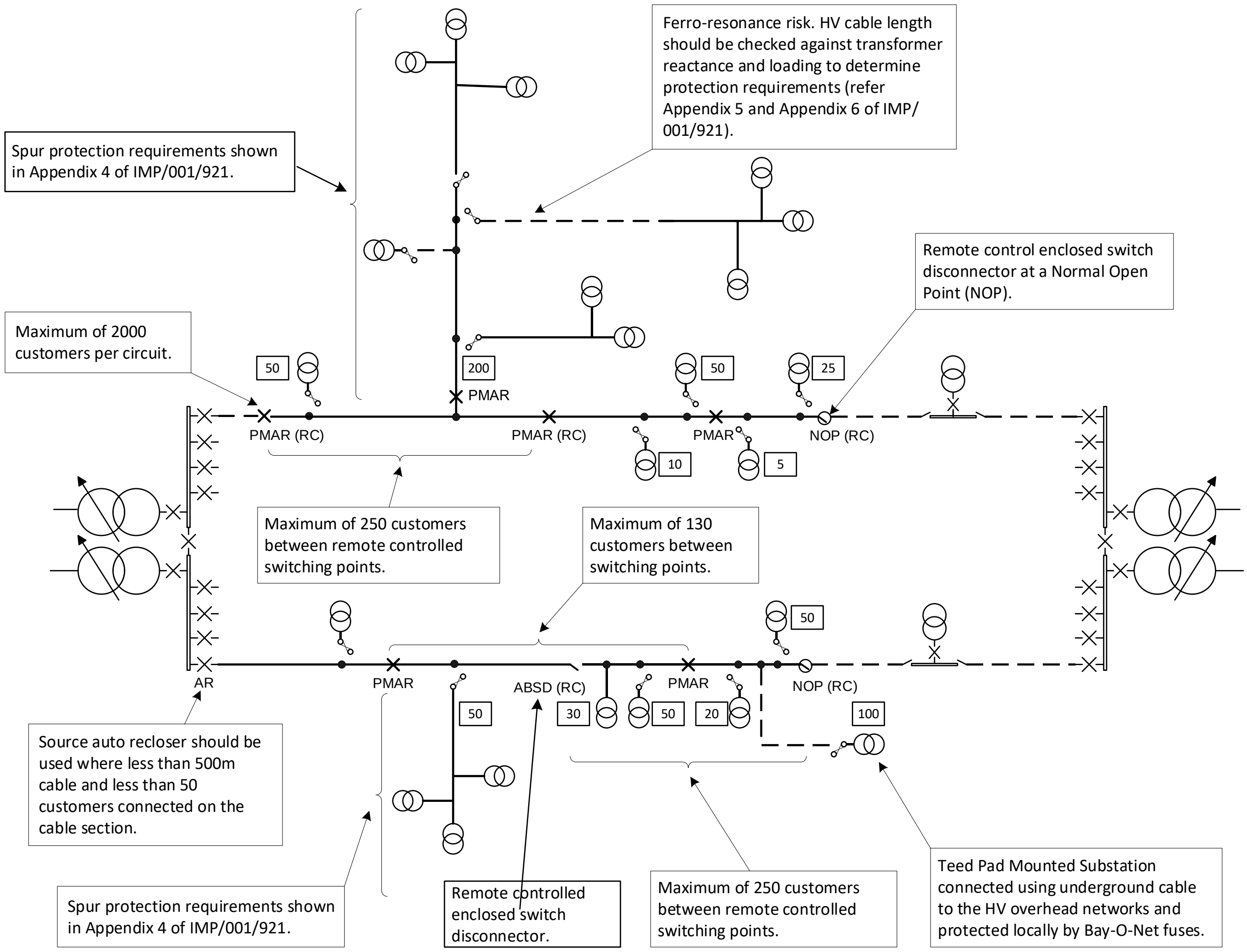

Figure 2 – HV overhead line configuration

Appendix 3 – Summary of Overhead Line Protection Design Process

This appendix summarises the stages in the design process to implement the overhead line protection requirements set out in section 3.5.3.

1. Collect circuit information and identify main and spur lines, customer numbers and distribution.
2. Design main line protection

    2.1. Source circuit breaker

    2.1.1. If protected circuit has less than 1 km of overhead; no auto-reclose and settings as per IMP/001/014 – Code of Practice for the Protection of Distribution Networks.

    2.1.2. Source CB does not have auto-reclose facilities. Fit PMAR as close as possible to the start of the first section of overhead line.

    2.1.3. Source CB should be set for auto-reclose unless there is a section of underground cable greater than 500m in length or supplying more than 50 customers prior to the first section of overhead line. If so, then consider placing the auto-recloser at the first section of overhead line rather than at the EHV to HV substation.

    2.2. Position additional PMARs on the circuit in line with the following guidelines using the approved software modelling tool (GROND) to assist in achieving the optimal solution:

    - No customer should experience on average more than four HV interruptions per year over a three-year period;
    - Aim for no more than 250 customers between remote control switching points;
    - Aim for a maximum of 130 customers between switching points; and
    - A maximum of three auto-reclose devices (i.e., source circuit breaker and two PMARs) should be used in series.

    2.3. Consider the impact of the changes on any arc suppression coil fitted at the primary substation.

3. Design spur protection

    3.1. Define the type of spur (major, medium or minor).

    3.2. If spur is longer than 0.5 km and the minimum load current is >300mA then protect using an auto sectionalising link as long as the fault level at the point of installation is below the rating of the conductor. Small conductor within the first protection zone may need to be protected by an expulsion fuse where fault levels are exceeded. See Appendix 5 of Code of Practice on Fusing IMP/001/921 for the detailed rules on auto sectionalising link locations and calculation of the required rating.

    3.3. If spur contains any triggered spark gaps, then avoid using expulsion fuses unless fault level and conductor size considerations force the use of fuses.

    3.4. If spur is located in the final protection zone, then check the benefits of fitting an auto sectionalising link. Where there are a low number of customers in the final protection zone then it will be unlikely that spur line protection can be justified.

    3.5. Otherwise protect with an expulsion fuse.

4. Consider protection of transformers.
5. Ensure spur is protected against ferro-resonance (with significant HV underground cable).
6. Design lightning protection in line with IMP/007/011 and re-check position against 3.3 above.
7. Position fault passage indicators as required.

Appendix 4 – Overview of Overhead Line Protection arrangements

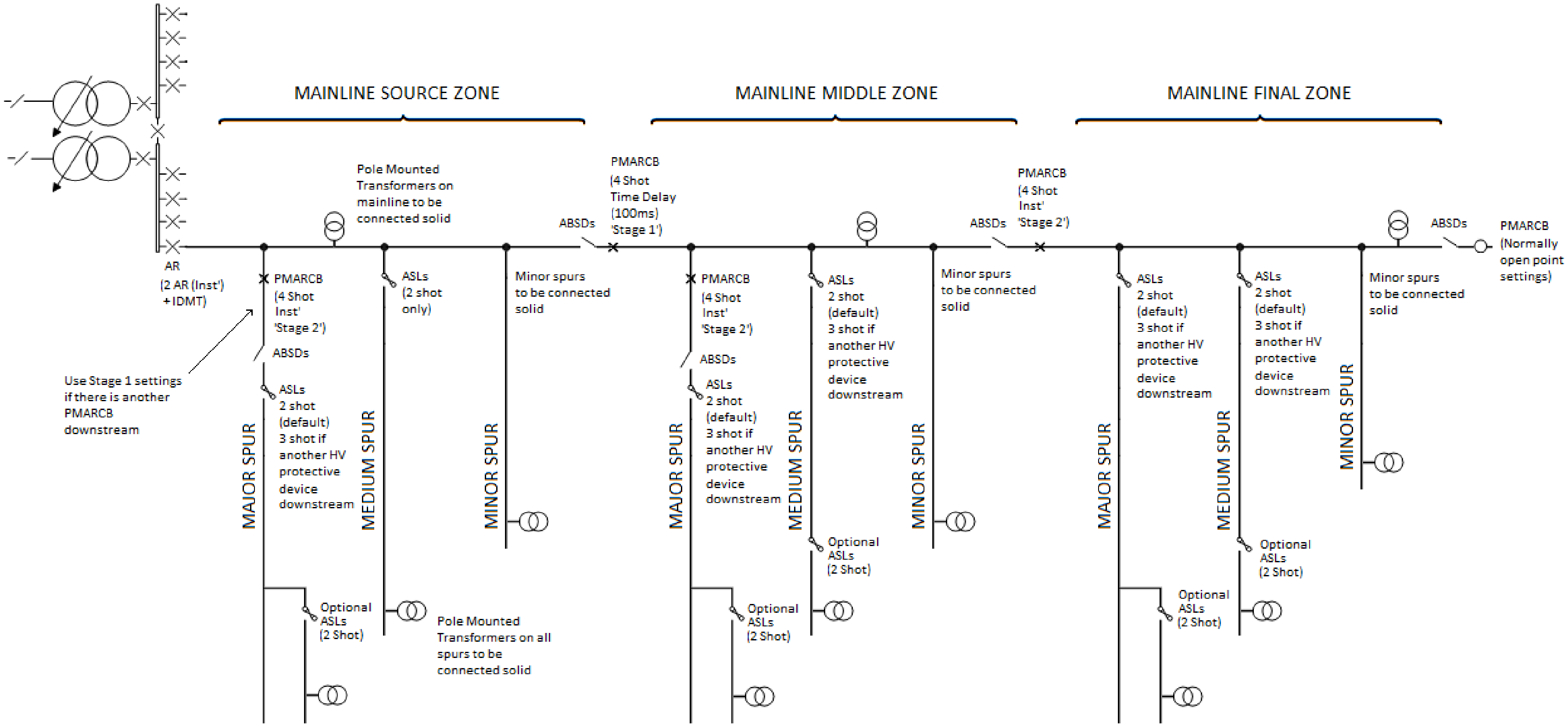

Figure 3: Yorkshire 11kV

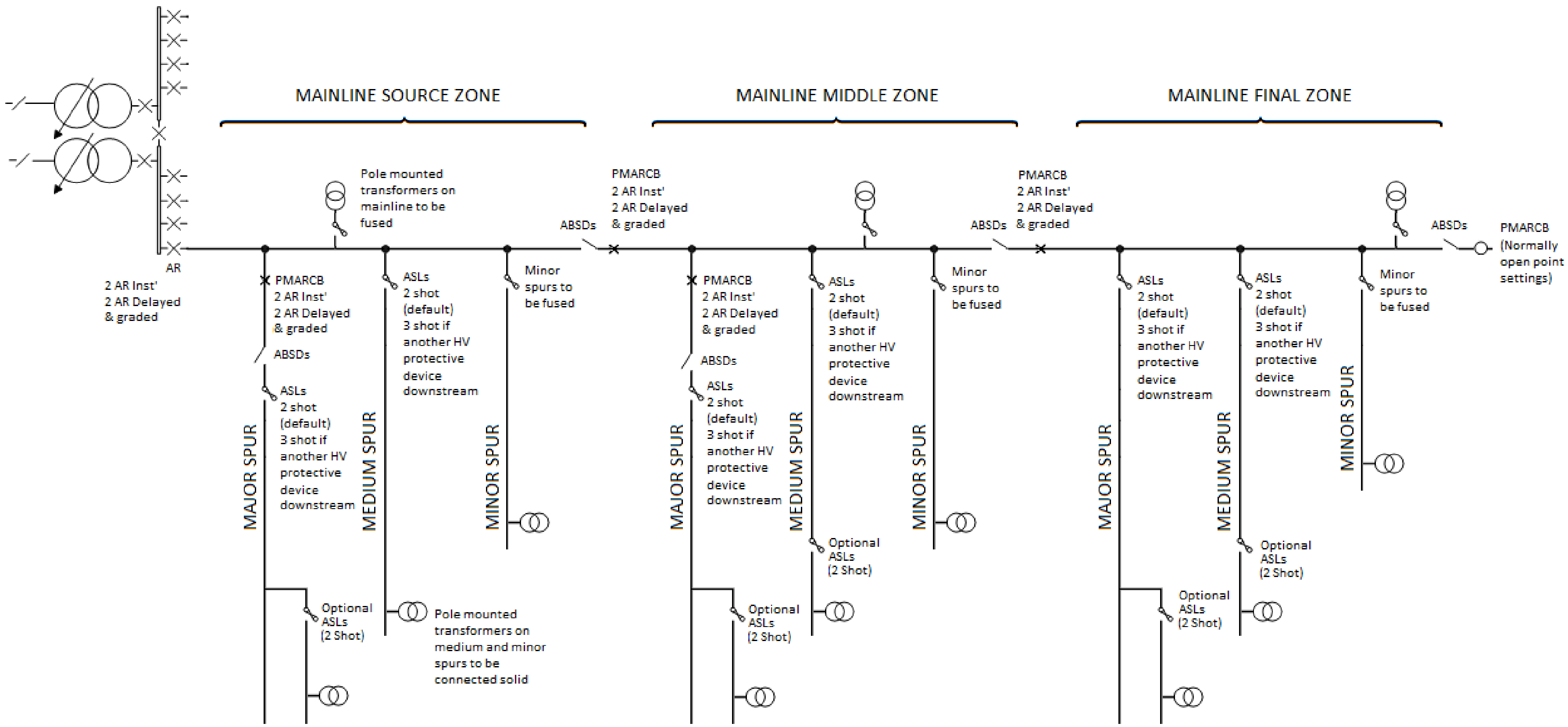

Figure 4: Northeast 11kV and 20kV

AR delay times typically 160ms.

Appendix 5 – Cable Lengths to avoid Ferro-resonance

This appendix sets out the aggregate cable length in HV circuit sections comprising underground cable and overhead line circuit below which ferro-resonance is unlikely to occur.

Table 16: Table showing maximum 11kV three core cable lengths to avoid ferro-resonance

Aggregate Transformer Capacity (kVA)	Cable Lengths in Metres					
	0.04in^2	0.06in^2	0.1in^2	95mm^2	185mm^2	300mm^2
5	1.2	1.1	0.83	0.9	0.7	0.5
10	2.4	2.1	1.6	1.7	1.4	1.1
15	3.6	3.3	2.5	2.5	2.0	1.7
25	6.0	5.5	4.2	4.0	3.4	2.7
50	12.0	11	8.3	8.0	6.6	5.4
100	23.8	22.2	16.7	16.0	12.0	11.0
200	47.7	44.4	33.4	32.0	23.0	22.0
315	75.0	69.9	52.6	50.0	35.0	34.0
500	119.0	111	83.5	75.0	55.0	52.0
750	178.7	166.6	125.3	115.0	90.0	82.0
1000	238.0	222.1	167.0	155.0	125.0	110.0
1250	298.0	276.6	208.0	194.0	156.0	137.0
1600	381.2	355	267.0	248.0	200.0	175.0

Table 3 Table showing maximum 20kV three core cable lengths to avoid ferro-resonance

Aggregate Transformer Capacity (kVA)	Cable Lengths in Metres					
	0.04in^2	0.06in^2	0.1in^2	95mm^2	185mm^2	300mm^2
5	0.36	0.33	0.25	0.27	0.21	0.15
10	0.72	0.63	0.48	0.51	0.42	0.33
15	1.08	0.97	0.75	0.75	0.6	0.51
25	1.8	1.64	1.26	1.2	1.04	0.81
50	3.6	3.23	2.49	2.4	1.98	1.62
100	7.14	6.5	5.01	4.8	3.6	3.3
200	14.31	13.0	10.04	9.6	6.9	6.6
315	22.5	20.5	15.78	15.0	10.5	10.2
500	35.7	32.5	25.05	22.5	16.5	15.6
750	53.61	48.7	37.5	34.5	27.0	24.6
1000	71.4	65	50.1	46.5	37.5	33.0
1250	89.4	81.1	62.4	58.2	46.8	41.1
1600	114.36	104.1	80.1	74.4	60.0	52.5

Table 18: Table showing maximum 11kV & 20kV single core (triplex) cable lengths to avoid ferro-resonance

Aggregate Transformer Capacity (kVA)	11kV cable lengths in Metres			20kV cable lengths in Metres	
	95mm^2	185mm^2	300mm^2	95mm^2	185mm^2
5	2.8	2.2	1.8	1.2	1
10	5.7	4.4	3.7	2.5	2
15	8.5	6.7	5.5	3.7	3
25	14.2	11.1	9.1	6.2	5
50	28.3	22.2	18.3	12.4	9.9
100	56.7	44.4	36.5	24.9	19.9
200	113	89	73	50	40
315	179	140	115	78	63
500	283	222	183	124	100
750	425	333	274	186	149
1000	567	444	365	249	199
1250	709	555	457	311	249
1600	907	710	585	398	318

Appendix 6 – HV Circuits affected by Ferro-resonance

This appendix illustrates the combinations of underground cable and distribution substation transformers in a circuit where ferro-resonance could be an issue, and the application of additional switching or isolating devices to manage the ferro-resonance risk operationally where it is impractical to manage the risk by the design of the network.

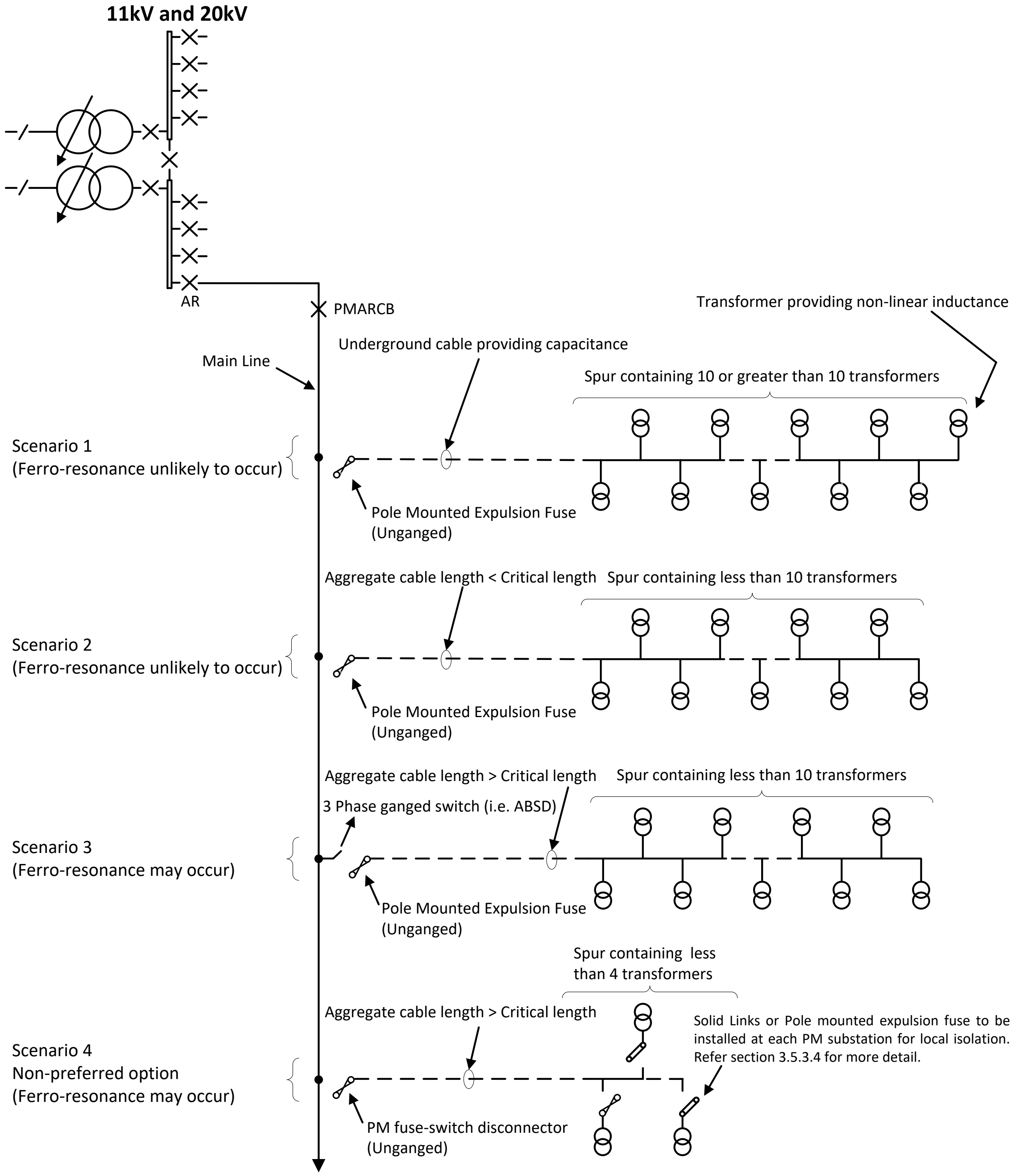

Figure 5: Schematic arrangement for HV circuits to avoid ferro-resonance.

Appendix 7 – Pad mounted distribution substations

A7.1 Introduction

Pad mounted substations are a relatively new piece of distribution equipment.[88] This appendix provides a brief description of design and functionality of pad mounted substations.

Pad mounted substations are a single piece of distribution equipment comprising a transformer, disconnectable HV terminations and a LV cabinet, containing between one and three fused LV ways, which comply with the Technical Specification for 11 & 20kV Pad-mounted Transformers, NPS/003/041.

Pad mounted substations can be used on the 11kV and 20kV distribution networks and provide standard transformer capabilities in a compact space. They are available in single-phase, split phase and three-phase HV configuration with a rating between 50kVA to 315kVA (see section 3.6.2).

Pad mounted substations are more expensive than an equivalent pole mounted transformer installation but are inherently safer.

A7.2 Application

Consideration should be given to the installation of a pad mounted substation:

- In rural or semi-rural areas where a risk assessment identifies that the installation of a pole mounted HV-LV substation would be unsuitable, where there are safety or clearance concerns. See section 3.5.3; or
- In urban areas where there are specific reasons why a ground mounted substation would be uneconomic. See section 3.5.2.

A7.3 Construction and operation

Pad mounted substations have a limited HV operational functionality compared to a ground mounted substation, RMU, ground mounted transformer and LV fuse cabinet) as there is no HV switchgear.

Access to the HV and LV compartment is available and there is a steel divider between the two compartments with the HV compartment on the left and LV compartment on the right.

The HV compartment contains the HV bushing where HV fuses are fitted and allows access to the HV fuses. HV fuses provide overload protection and overcurrent protection for both the HV and LV transformer windings, the tap changer and the LV PENDA components. HV overcurrent protection includes a Bay-O-Net [89]fuse and backup current-limiting fuse.

The Northern Powergrid specification is for a dead-front[90] arrangement where separable connectors used to form the connection between the HV cable and the HV busing can be removed from ground level under live conditions using live line techniques with the aid of suitable insulated tools such as live line rod or hot stick.

A Bay-O-Net fuse link, which is connected in series with a current limiting fuse, operates for HV overcurrent including a fault on the LV network that is not cleared by the LV fuse. If necessary, Bay-O-Net fuses can be replaced using a hot stick without removing the transformer lid. The additional current limiting fuse (HV fuse) only operates for a failure within the transformer tank and cannot be replaced. The Bay-O-Net fuse-link ratings for various 11kV and 20KV pad mounted transformers are provided in the Code of Practice on Fusing, IMP/001/921.

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88 There are few distribution substations, predominantly on the Northern Powergrid Northeast system, where legacy HV to LV pad mounted substations are installed.

89 A Bay-O-Net fuse is a current sensing fuse link manufactured by Cooper Power. In a pad mounted substation they are used in conjunction with a current-limiting fuse. In this arrangement, secondary faults and overload currents are cleared by the Bay-O-Net fuse, and high level faults are cleared by the current-limiting fuse.

90 The HV compartment can be specified as either 'live-front' or 'dead-front'. A 'live-front' compartment would have typical HV terminations as can be found within a conventional dry type HV cable box, the cable termination onto the bushings may be insulated to some degree but would still have to be treated as being live. A 'dead-front' arrangement uses separable connectors to make the connection between the cable and the bushing. The connections are fully insulated.

A pad mounted substation has a LV fuse board and depending upon the kVA rating, there will be either one or two LV feeder ways. For any operational work on a pad mounted transformer, it shall be made dead by removing the HV separable connectors.