IMP/001/911 - Code of Practice for the Economic Development of the LV System

1. Purpose

The purpose of this document is to state Northern Powergrid's policy for the economic development of the low voltage (LV) system. The document states the requirements to achieve a robust, economical and efficient LV system, taking into account the initial capital investment, system losses and the maintenance and operational 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.

This Code of Practice (CoP) also helps to ensure the company achieves its requirements with respect to the Electricity Act 1989 (as amended by the Utilities Act 2000 and the Energy Act 2004), the Health and Safety at Work Act 1974, The Electricity Safety, Quality and Continuity (ESQC) Regulations 2002 (as amended),[1] the Electricity Distribution Licences and the Distribution Code.

This document supersedes the following documents; all copies of which should be withdrawn from circulation.

Reference	Version	Date	Document
IMP/001/911	6.0	Nov 2018	Code of Practice for the Economic Development of the LV System

2. Scope

2.1 General

This document applies to:

- The LV distribution systems of Northern Powergrid Northeast and Northern Powergrid Yorkshire;
- All LV distribution system developments including new connections, system reinforcement and asset replacement; and
- All assets with a nominal operating voltage of 230/400V ac three phase, 230/460V ac split-phase and 230V ac single-phase, including those at a HV to LV substation including the HV to LV transformer.

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

Where distributed generation is embedded within the LV system or embedded into a higher voltage system and may have an impact on the LV distribution systems, 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.

Connection arrangements, including those for multi-occupancy premises and embedded 'independent' networks, are covered in the Code of Practice for Standard Arrangements for Customer Connections, IMP/001/010.

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

ICPs and IDNOs

Since this Code of Practice specifies the way in which the Northern Powergrid LV distribution system develops, it applies to all the providers of adopted extensions to the system including those provided by Independent Connections Providers (ICPs). Extensions provided by ICPs shall be compliant with this Code of Practice before being adopted by Northern Powergrid.[2]

Requirements for connections to Independent Distribution Network Operators (IDNOs) are provided in the Code of Practice for Standard Arrangements for Customer Connections, IMP/001/010.

[2] Approval shall be provided by Northern Powergrid or a National Electricity Registration Scheme (NERS) accredited ICP in line with IMP/001/010/001 - ICP Self-Select Point of Connection limits, Design Considerations and ICP Design Approval Requirements.

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3. Code of Practice

Assessment of Relevant Drivers

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

- Employee commitment - achieved by developing a safe LV 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.

The external business drivers relating to the development of the LV systems are detailed in the following sections.

3.1.1 Requirements of the Electricity Act 1989 (as amended)[3]

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 this document in providing guidelines on the efficient development of the LV 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;
- Requiring consideration to be given to the level of risk to which employees and the public are exposed by a proposed overhead line route;
- Requiring that circuits and plant have appropriate cyclic, continuous and short circuit ratings; and
- Providing permissible values for fuses.

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

3.1.3 Requirements of The Electricity Safety, Quality and Continuity (ESQC) Regulations 2002[4]

The ESQC Regulations 2002 (as amended) impose a number of obligations on the business, mainly relating to quality of supply and safety. All the requirements of the ESQC Regulations that are applicable to the design of LV systems shall be complied with, specifically:

Reg. No	Text	Application to this Policy
3(1)(a)	…distributors…shall ensure that their equipment is sufficient for the purposes for and the circumstances in which it is used; and	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. This requirement is absolute, and not subject to a 'reasonably practicable' test.
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) the prevention of danger achieved through fusing (reg. 6) and defining where the use of overhead lines and pole mounted substations is permissible and b) the prevention of interruption of supply, so far as is reasonably practicable, by defining LV system topology (reg. 23(1)).
6	A…distributor shall be responsible for the application of such protective devices to his network as will, so far as is reasonably practicable, prevent any current, including any leakage to earth, from flowing in any part of his network for such a period that that part of his network can no longer carry that current without danger.	This CoP requires that appropriate protection is fitted to LV circuits in accordance with Northern Powergrid policy.
23(1)	…[the] network shall be: (a) so arranged; and (b) so provided, where necessary, with fuses or automatic switching devices, appropriately located and set, as to restrict, so far as is reasonably practicable, the number of consumers affected by any fault in [the] network.	This 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 a LV circuit between isolation points.
24(4)	Unless he can reasonably conclude that it is inappropriate for reasons of safety, a distributor shall, when providing a new connection at low voltage, make available his supply neutral conductor or, if appropriate, the protective conductor of his network for connection to the protective conductor of the consumer's installation.	This CoP requires that a new LV systems to be developed in accordance with Engineering Recommendation G12.

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

Reg. No	Text	Application to this Policy
25(2)	A distributor shall not give his consent to the making or altering of [a connection from [that] distributor's network to…another distributor's network], where he has reasonable grounds for believing that - (a) the…other distributor's network fails to comply with British Standard Requirements or these Regulations; or (b) the connection itself will not be so constructed, installed, protected and used or arranged for use, so as to prevent as far as is reasonably practicable, danger or interruption of supply.	This CoP requires that all LV system developments, including those made by another distributor, shall be developed in accordance with this CoP. Note that this does not oblige Northern Powergrid to check each installation, but instead to take reasonable steps where there are reasonable grounds for concern.
27(2)	Unless otherwise agreed in writing…the voltage declared in respect of a low voltage supply shall be 230 volts between the phase and neutral conductors at the supply terminals.	This CoP states the nominal supply voltage for customer connected to the LV system.
27(3)	For the purposes of this regulation, unless otherwise agreed in writing by those persons specified in paragraph (2), the permitted variations are— (a) a variation not exceeding 1 per cent above or below the declared frequency; (b) in the case of a low voltage supply, a variation not exceeding 10 per cent above or 6 per cent below the declared voltage at the declared frequency.	This CoP states the acceptable limits of voltage variation experienced by customers connected to a LV system and describes the means of controlling the LV system voltage within these limits.

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.

3.1.5 The Environmental Protection Act 1990

Section 79 of the Environmental Protection Act 1990 defines 'statutory nuisance'[5] and Section 80 sets out the steps a Local Authority can take to address the cause of a statutory nuisance. Northern Powergrid assets should be designed and operated such that the risk of statutory nuisance being caused is minimised by giving due consideration to the siting of HV to LV substations and other distribution assets.

3.1.6 Requirements of Northern Powergrid's Distribution Licences

Additional external business drivers relating to the development of the LV system are the distribution licences applicable to Northern Powergrid Northeast and Northern Powergrid Yorkshire.

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:

[5] Statutory nuisance includes noise and vibration.

- 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 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 the distribution system to be developed to a standard not less than that set out in Engineering Recommendation P2/7, Security of Supply, or any subsequent approved version of Engineering Recommendation P2. Engineering Recommendation P2 does not apply to the supply connection to single Customer premises, and these supply connections shall be considered on their own merits by discussion with the Customer. Generally, LV systems fall within Class of Supply A (less than 1 MW), and therefore do not require alternate infeeds.

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.[6] In particular:

- Standard Licence Condition 49.2 requires the licensee to design, build, and operate its distribution system in a manner that can 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:
    a) the distribution losses characteristics of new assets to be introduced to its distribution system;
    b) whether and when assets that form part of its distribution system should be replaced or repaired;
    c) the way that its distribution system is operated under normal operating conditions; and
    d) 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 Incentives Scheme (IIS). This scheme is a driver to reduce Customer Minutes Lost (CML) and Customer Interruptions (CI), which may incentivise investment beyond that needed to meet the requirements of Engineering Recommendation P2. This requirement is addressed in this Code of Practice by requiring a level of interconnection above that required by Engineering Recommendation P2 where this can be provided economically.

This is addressed in this Code of Practice through minimising the numbers of customers per circuit on new LV systems and providing for cost-effective interconnection on existing systems.

[6] This is stated in Northern Powergrid's Strategy for Losses, May 2020.

3.1.7 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 economical system for the distribution of electricity;
- facilitate competition in the generation and supply of electricity; and
- 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 is particularly relevant given the introduction of a suite of European Network Codes which place additional obligations on Generators and DNOs.

The Distribution Planning and Connection Code 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 the Northern Powergrid systems.

It also sets out principles relating to the design of equipment and its operating regime. Equipment on the Northern Powergrid system and on User's systems[7] connected to them shall comply with relevant statutory obligations, international and national specifications and Energy Networks Association technical specifications and standards.

The Distribution Code also gives force to a number of Engineering Recommendations. Those particularly relevant to this policy, in terms of defining Northern Powergrid's obligations, are: [8]

- 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;
- Engineering Recommendation - P2 - Security of Supply;
- Engineering Recommendation G12 – Requirements for the Application of Protective Multiple Earthing to Low Voltage Networks;
- Engineering Recommendation P25 - The short-circuit characteristics of single-phase and three-phase Low Voltage distribution networks;
- Engineering Recommendation P28 - Voltage fluctuations and the connection of disturbing equipment to transmission systems and distribution networks in the United Kingdom; and
- Engineering Recommendation P29 - Planning Limits for Voltage Unbalance in the United Kingdom.

3.2 Key Requirements

The general objective in developing the LV system is to obtain a simple and robust system having minimum overall cost, taking into account the initial capital investment, system losses, maintenance and operational costs

[7] DPC 4.4 refers specifically to the requirements of Users Systems.

[8] Engineering Recommendation G81, Part1 Low voltage underground networks for new housing estates, applies to ICPs when providing connections to the Northern Powergrid system, is a relevant document cited in the Distribution Code, although it does not set out any additional obligations on Northern Powergrid.

over the life of the asset. Any development of the LV system should seek to improve the reliability and availability of the supply provided to customers.

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

- prevent danger to the public and Northern Powergrid staff and its contractors;
- optimise network reliability, availability and losses;
- maintain power quality experienced by all connected customers;
- discharge the obligation under section 9 of the Electricity Act 1989 , and specifically to have due regard to future requirements and network performance;
- facilitate the use of standardised plant and equipment to reduce capital and operating costs;
- to minimise environmental pollution and statutory nuisance; and
- satisfy all other relevant obligations.

3.3 LV System Development

3.3.1 Background

The purpose of the LV system is to distribute electricity in localised urban and rural areas in an economic, efficient, safe and secure manner, meeting the needs of customers currently and likely to be connected to it in the future. The LV system is the lowest distribution voltage between the Northern Powergrid HV system and the end customer.

The LV system supplies predominantly domestic (demand and generation customers) and, increasingly, LV systems owned and operated by IDNOs. Historically, only demand has been connected to the LV system, however increasing amounts of generation, including electricity storage devices, are being connected. The type of demand is also changing with increasing amounts of Low Carbon Technology (LCT) devices, such as Heat Pumps (HPs) and Electric Vehicle Charging Points (EVCPs), being connected.

The LV system shall be developed and operate as a network of radial circuits supplied from a HV to LV substation placed near to the load centre, however LV interconnection should be provided as a means to manage the risks associated with increased demand on the LV system associated with an increase in the volume of LCTs being connected. Further guidance is provided in section 3.5.6.

Urban LV systems normally comprise underground cables supplied from ground mounted HV to LV substations. Rural LV systems comprise either underground cables or overhead lines supplied from ground mounted or pole mounted HV to LV substations.

3.3.2 Application

This Code of Practice shall be applied in full when designing new LV circuits, whether from new or existing HV to LV substations. It is not a requirement to apply this Code of Practice retrospectively, but when design schemes are produced for the LV system, the opportunity shall be taken to improve existing sections of the LV system to comply with this Code of Practice when it is practicable and economic to do so.

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

The requirements outlined in this document are expected to apply to the majority of situations where the LV system is developed. However, there will be a small number of cases where special arrangements, which are not strictly in accordance with the documented principles, may be more appropriate and these can be considered where there are benefits to both Northern Powergrid and its customers. Any such deviations relating to local implementation at an individual site shall be agreed with the relevant Design Team Manager[9] at an early stage of the design process. Any deviations relating to strategic system development shall be agreed with the Smart Grid Development Manager[10] at an early stage of the design process.

This Code of Practice shall be read in conjunction with relevant Engineering Recommendations[11] 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;
- Code of Practice for 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; and
- Code of Practice for the Economic Development of the High Voltage System, IMP/001/912.

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

- voltage;
- voltage and waveform quality;
- neutral and earth loop impedance; and
- short circuit levels.

comply with the requirements of the following sub-sections.

3.3.3 Voltage

The LV system shall be designed to operate at the nominal voltages set out in the Code of Practice for Distribution System Parameters, IMP/001/909. The voltage at the LV busbars at HV to LV transformers is not generally controlled and the voltage is dependent on the HV voltage supplying, and the load on, the HV to LV transformer (both of which are variable), the selected transformer tap position (which can be considered to be fixed in the case of a HV to LV transformer equipped with a de-energised tap-changer (DETC)) and the transformer nominal ratio (which is fixed). Where a HV to LV transformer equipped with an on-load tap-changer (OLTC) is installed, the operating voltage of the HV system is less important, as the OLTC will control the LV voltage within the limits of its tapping range.[12]

The Electricity Safety, Quality and Continuity Regulations 2002 (including amendments) require that the voltage at LV customers supply terminals is 230/400V[13] +10%/-6%. As the voltage on the LV system is managed by design, rather than being explicitly controlled, there are coordinated design principles which allocate the permitted voltage regulation on the HV and LV system.

LV system design principles:

- The voltage at the LV terminals of the HV to LV transformer should be a minimum of 230V;

[9] The Design Team Manager is a defined term - see section 5.
[10] The Smart Grid Development Manager is a defined term – see section 5.
[11] See section 3.1.7.
[12] Further guidance can be found in IMP/001/912 - Code of Practice for the Economic Development of the HV System, and IMP/001/915 – Code of Practice for Managing Voltages on the Distribution System.
[13] Care needs to be taken where design tools use 240V as the base voltage rather than 230V.

- The lowest permitted voltage is 216.2V i.e. max voltage drop of 13.8V (6% of 230V);
- The maximum calculated voltage drop on the LV system (i.e. on the main as well as the service) should not exceed 6%. Typically, the voltage drop on a service would be no more than 0.3% (based on a typical 20m service and 4.60kW demand); and
- Longer services (ideally no longer than 40m are acceptable) provided that the overall voltage drop on the LV system remains less than 6% and the earth loop impedance is acceptable. Typically these services would be to:
    - unmetered supplies, for example street lighting and telecoms supplies;
    - metered/unmetered low capacity EVCPs;[14]
    - supplies from pole mounted equipment; or
    - supplies to premises remote from a LV main where a mains extension would not be an economic and efficient development of the LV system.

HV system design principles:

- The voltage at the LV terminals of the HV to LV transformer under HV first circuit outage conditions should be a minimum of 230.0V. This is equivalent to a 4.5% voltage drop on a HV feeder under first circuit outage conditions.[15]
- Where the HV voltage drop under first circuit outage conditions is more than 6%, this may be acceptable provided that the LV systems supplied from the HV system has a suitably small voltage drop.

Applying these design principles:

- Under normal operation conditions, customers' terminal voltage should be between 245V (no load)[16] and 222V (high load)[17] based on a 2% typical HV voltage drop under HV system intact conditions, 6% voltage drop on the LV circuit and assuming that the EHV to HV transformer AVC is sitting at the midpoint of its deadband.
- Under normal operation conditions and where a LV system predominantly supplies load, between 11V and 4V headroom is available for generation depending on where the AVC relay operates with its bandwidth. Where the EHV to HV transformer AVC operates at:
    - the upper end of it deadband (equivalent to 249V) there is 4V headroom;
    - the mid-point of it deadband (equivalent to 245V) there is 8V headroom; and
    - the lower end of it deadband (equivalent to 242V) there is 11V headroom.

With increasing levels of LV connected distributed generation, designers should consider the potential for voltage rise arising from generation in addition to voltage drop arising from demand.

3.3.4 Voltage and Waveform Quality

New connections provided at LV shall meet the requirements of:

[14] Although they are referred to as unmetered connections, public unmetered EVCPs utilise portable meters as opposed to a fixed meter installed adjacent to the Point of Supply. Elexon publishes a list of approved Measured Central Management Systems (mCMS) on their website, including portable meters to be used for unmetered connections.

[15] Based on an 11.1kV target voltage, 2.5% HV to LV transformer tap, 2% regulation on the transformer, 6% voltage drop on the LV circuit & 11kV base voltage.

[16] Increasing to 250V with the HV busbars operating at the upper end of the 2% dead band.

[17] Reducing to 218V with the HV busbars operating at the lower end of the 2% dead band.

- 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 United Kingdom; and
- 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.

LV design studies shall assess flicker, voltage unbalance and harmonic voltage distortion by abnormal loads such as motors, welders, non-linear loads and inverter connected generation plant to assess the impact on customers. Such studies should assess existing abnormal loads and those of any new connections, particularly where there is a cluster of new connection applications or a cluster of existing connections with abnormal loads.[18] Whilst there is no requirement for the LV system itself to operate within the parameters set out in these Engineering Recommendations it should generally be designed to do so. The Engineering Recommendations listed above also provide guidance as to the types and sizes of customer load that may be connected without detailed assessment.

HP and EVCP data is published in database format on the Energy Networks Association (ENA) website for HP and EVCP devices that have been technically assessed by the ENA.[19] This database contains records of the manufacturer, make, model and reference number of HP and EVCP devices along with technical data including power quality compliance with British Standards. If a device is not included in the ENA database or is marked as ‘apply to connect’ the designer shall carry out an assessment in line with the engineering recommendations above to ensure there will be no power quality issues following the connection of the device.

Single-phase loads shall be equally distributed (balanced) across all three phases of the LV main as far as reasonably practicable. Consideration should be given to the existing demand on each phase[20] including existing LCTs and distributed generation where data is available. This is particularly important where some premises supplied from the LV mains might have a higher demand than others where, for example HPs, EVCPs and other LCTs are, or could in the future be, installed. This will minimise voltage unbalance and reduce losses.

When replacing a single phase transformer with a three phase transformer on a split phase system (for example in areas of Northumberland and Leeds) special attention should be paid to the unbalanced loading of three phase transformer to ensure the unbalance is managed as far as reasonably practicable. When replacing these systems guidance should be sought from the relevant Design Team Manager to coordinate with any planned asset reinforcement works.

3.3.5 Neutral and Earth Loop Impedance

There are two loop impedance paths that must be considered:

- phase to neutral, which affects voltage regulation and fluctuation (flicker); and
- phase to earth, which affects both fusing of the LV system and the quality of the earth provided to customers.

On CNE systems, these paths are the same, so the two issues can be considered together.

[18] For example multiple applications to connect HPs or EVCPs to a small part of the LV system.
[19] Low Carbon Technologies HP Database - https://www.energynetworks.org/industry-hub/resource-library/low-carbon-technologies-heat-pump-database.xls, Low Carbon Technologies EVCP Database - https://www.energynetworks.org/industry-hub/resource-library/low-carbon-technologies-electric-vehicle-charge-point-database.xls.
[20] For example, using substation load monitoring data when available.

This section specifies the absolute maximum values for loop impedance. It is essential that fusing and phase to earth loop impedance are co-ordinated, and it may be necessary to limit the impedance of the system in order to secure adequate fault clearance times.

3.3.5.1 Neutral Loop Impedance

Phase to neutral loop impedance on new systems shall not exceed 250mΩ including the transformer, main and service. To provide for the loop resistance of a typical 20m service, which is between 30mΩ and 50mΩ, LV mains cables laid in advance of providing services should be designed to a maximum of 200mΩ through the transformer and main.

For many years LV systems were designed to a phase to neutral loop impedance limit of 400mΩ. There is no intention of investing significant capital on these existing systems to reduce loop impedance, however when extending existing systems, the opportunity should be taken to limit the loop impedance of the new system to 250mΩ unless it is uneconomic to do so.[21]

Although Northern Powergrid has an obligation under ESQC regulation 24(4) to provide an earth terminal when providing a new connection (i.e. the first electric line, or the replacement of an existing electric line, to one or more customers' installations) at LV, the impedance of that earth is not specified. The ESQC regulations, and their guidance notes, do not state a value however the LV system should be designed in line with the values in this document.

3.3.5.2 Earth Loop Impedance

Engineering Recommendation P23 gives nominal phase to earth loop impedance values to be provided to customers for indicative purposes (800mΩ for SNE and 350mΩ for PME/PNB networks), however, it does not specify a maximum value. Engineering Recommendation P23 is not a planning standard; it explicitly provides only 'typical maximum values' that can be quoted to customers in the absence of a specific assessment. There is a difference between 'typical' and 'maximum design' values. This CoP provides the maximum value that should be used for any modifications (including connections) to the LV system. Table 1 shows the maximum earth loop impedance at the end of new single phase services.

There is no clear need to set a design value for the end of SNE services other than the 800mΩ typical value quoted in Engineering Recommendation P23. Northern Powergrid already has a large proportion of CNE-capable systems designed to 400mΩ (rather than the 350mΩ typical value quoted in Engineering Recommendation P23).[22]

Table 1 : Maximum earth loop impedance values at the end of new single-phase services:

Service type	Connection to new circuits[23]	Connections to existing circuits[24]
CNE service: Phase-neutral and phase-earth loop impedance	250mΩ	400mΩ
SNE service: Phase-neutral loop impedance	-	400mΩ
SNE service: Phase-earth loop impedance	-	800mΩ

[21] For example, a connection to street furniture distant from the HV system and LV source substation.

[22] 350mΩ is often quoted by customer's as being the maximum impedance, however provided the loop impedance at a service cut-out is less than the relevant value in Table, the loop impedance is considered to be acceptable to Northern Powergrid and no remedial action will be taken to reduce the impedance. It will be the responsibility of the customer to ensure their protective equipment operates correctly.

[23] Including extensions of existing systems designed to the current 250mΩ standard.

[24] These values are intended to be applied primarily to modifications of existing systems designed to the former 400mΩ phase-neutral loop impedance. They should not be applied to significant modifications to systems designed to the current 250mΩ phase-neutral loop impedance; i.e. they should not be seen as a relaxation permitting the impedance on main and services to be extended beyond the 250mΩ limit.

As noted earlier, these impedance values may need to be reduced to meet the fusing requirements for a specific part of the LV system.

The figures in Table 1 may be quoted to ICPs as 'maximum design values'. Customer enquiries will generally involve the 'typical maximum values' discussed in Engineering Recommendation P23, which shall be quoted in such circumstances.

3.3.6 Short circuit levels

Equipment shall be specified to the following short circuit levels to accommodate infeed from the higher network and LV-connected generation:

- 18kA for single-phase connections up to 100A, consistent with BS 7657;
- 30kA for other connections; and
- 35.5kA for equipment at general network substations, i.e. the LV distribution board at a HV to LV substation.

These figures may be quoted to ICPs and customers as 'maximum design values', i.e. the performance standards to which they should specify their equipment.

Typically, maximum values of fault infeeds are:

- 18kA for single-phase connections up to 100A, consistent with BS 7657;
- 22kA for other connections; and
- 26kA at substation LV busbars.

In the absence of site-specific assessment, and particularly in the absence of distributed generation, these figures may be quoted to customers as 'typical maximum values', i.e. the likely infeed against which they should perform their protection calculations.

Further detail is provided in Appendix 1 – Short Circuit Levels.

3.3.7 Losses

It is envisaged that for most routine design work on the LV system, the use of minimum circuit conductor sizes and the selection of transformers based on the economic loading set out in Appendix 3 will be sufficient to demonstrate compliance with the Northern Powergrid losses strategy.[25]

3.4 Design Approach and Design Demand

3.4.1 Design Approach

There are two established approaches to determine the demand that the LV system needs to cater for from thermal and voltage regulation perspectives:

- a probabilistic method, laid out in the ACE 49 Report which forms the basis of the 'P-Q' approach; and
- a deterministic method, derived from probability studies, which forms the basis of the 'After Diversity Maximum Demand (ADMD)' approach.

Both approaches are valid and recognise that customers' electricity consumption is sufficiently different such that the average of their aggregate maximum demand reduces with increasing numbers of

[25] https://www.northernpowergrid.com/losses and IMP/001/103 – Code of Practice for the Methodology of Assessing Losses.

customers. Northern Powergrid Northeast currently uses the DEBUT LV Design software package based on the P-Q approach and Northern Powergrid Yorkshire currently uses a MS Excel based calculator based on the ADMD approach.[26] As both approaches are valid and, provided that appropriate parameters are used, equivalent, it is acceptable to continue to use both approaches. Further detail for each approach is given below:

- The ADMD approach: This approach historically[27] used a simple linear model with a fixed part representing the demand of a single customer and a variable part representing the mean demand across a large number of customers, hence:

  a) The ADMD approach better reflects the observed demands for groups of fewer than twelve customers, because of its significant fixed element; and

  b) It doesn't represent the co-incidence of the demand effectively.

- The P-Q approach: This approach is based on the observed relationship between demand caused by a group of customers and their annual consumption. The mean power demand is derived from the annual electricity consumption and translated into design demand by adding a level of demand equivalent to 1.28 standard deviations[28] from the mean power demand as detailed in ACE 49 and applied in DEBUT.[29] This approach assumes that the customer demands follow a normal distribution, and uses the mean and standard deviation of a large sample of customers. The impact of standard deviation declines with greater number of customers, hence:

  a) The P-Q approach better helps understand the coincidence between the electricity demands of different customers as it contains co-efficients[29] for each half hour of the worst case day. This allows for an assessment to be made for each half hour rather than simply adding the highest demand at any point in the day.

  b) It underestimates the observed customer demand significantly with lower customer numbers.

3.4.2 Design Demand

The design demand to be used when designing LV systems supplying industrial and commercial customers is set out in section 3.4.2.1. The design demand to be used when designing LV systems supplying domestic customers is set out in sections 3.4.2.2 to 3.4.2.6. Where a LV system supplies a combination of industrial, commercial and domestic customers the requirements of sections 3.4.2.1 to 3.4.2.6 apply as appropriate.

The existing and future demand on a LV feeder or distribution substation will vary depending on the type of existing premises connected and premises to be connected. Appendix 2.2 provides an overview of the ADMD assessment method that should be followed and an example of a typical assessment. The demand of existing customers supplied from a LV system can be established from LV substation monitoring data where it is available.[30] If available, this data shall be used to refine or validate the design demand for the part of the LV system which is being assessed.[31]

Northern Powergrid has historically used the principles in reports ACE 49 and ACE 105.[32] These broadly defined domestic customer demand according to their electricity tariff (e.g. unrestricted), type of heating

[26] Northern Powergrid document reference - NI30 – 'NPg LV Volt Reg_FL Calculator V1.1'.
[27] The approach was refined as part of the CLNR project.
[28] As detailed in ACE 49, adding 1.28 standard deviations to the mean demand means that the probability of the actual design demand exceeding the expected demand reduces to 10%; which is an acceptable probability for a robust system.
[29] For further details of the methodology employed by ACE 49 to establish the design demand using the P-Q approach and the relevant co-efficient, see Appendix 2 - Design Demands.
[30] LV monitoring is installed at a number of ground mounted HV to LV substations. Alternatively, measurements can be made by temporarily installing Rogowski coil measurement devices. Where available aggregated consumption data from the smart metering system can also be used.
[31] For example, the demand per premises can be reduced or increased in line with the measured total demand on the relevant part of the LV system.
[32] Report ACE 49: Statistical Method for Calculating Demands and Voltage Regulations on LV Radial Distribution Systems, introduced a design method using annual kWh consumption data and daily load characteristics for establishing the design demand that should be used to design the network.

(e.g. electric water heating or electric space heating) and electricity consumption (i.e. low, medium and high). This approach has been applied in the past and still remains valid, but the parameters have been updated to reflect changing demand on the system as a result of changing customer lifestyles and increasing penetrations of different types of LCT devices connected to the LV system.

This Code of Practice presents a set of ADMD and DEBUT[33] parameters for general domestic demand and the demand of LCT devices including HPs, EVCPs and photo-voltaic devices (PV) that shall be used when designing the LV system. The ADMDs and DEBUT parameters are derived from data collected from the field trials[34, 35] carried out in the Northern Powergrid Customer-led Network Revolution (CLNR) project.

Appendix 2 - Design Demands, show a worked example for assessing the design demand of an asset supplying 200 domestic customers. The demand is based on previous ADMD parameters together with new ADMD parameters for general domestic load and that of two LCT devices. This demonstrates the application of the new ADMD parameters compared to previous ADMD values. The P and Q values to be used in the DEBUT calculations are also detailed in Appendix 2.

An ADMD based design demand calculator has been developed in Excel to assess the design demand associated with multiple types of customer demand. An overview of the methodology used in the demand calculator can be found in Appendix 2.

3.4.2.1 Industrial and Commercial Demand

The design demand of a LV system supplying industrial and commercial (I&C) customers shall be based on a combination of the existing customer demand[36] and any proposed new customer demand as follows:

- New I&C demand shall be based on the customer's requested import capacity. As part of the connection design process, the existing demand shall be reviewed and where appropriate validated.

- Existing I&C demand should be based on the observed maximum demand where available. The maximum demand for half-hourly metered customers can be obtained from the Durabill system. Where half-hourly metered data is unavailable the demand may be estimated based on the type of premises shown in Table 2 or from the observed maximum demand of similar premises.

Table 2 : Typical I&C demands

Customer type	Typical after diversity demand (kW)
Small Retail	8
Place of Worship	20
Garage/Workshop	30
Take Away	20
Small Supermarket	20
Small Hotel	20
Small Office	20

Report ACE 105: The Design of Low Voltage Underground Networks for New Housing, details the key parameters to be considered for the economic design of the low voltage underground system for new housing developments.

[33] Based on the P–Q method.

[34] CLNR-G026 provides further details of the trial which was based on monitoring of 10,006 domestic customer's (9,096 general, 344 HPs, 160 PVs, 14 CHPs, 159 EVCPs and 233 with electric hot water / storage heating); 1,880 small commercial customers; and 160 merchant generators.

[35] CLNR-L217 details the ADMD calculations for the different scenarios based on the measurements from the various trials.

[36] Including LCT demand.

Public House/Bar	25
Café	15
Beauty Salon	10
Care Home	55

Where the existing observed or assumed maximum demand is near to the plant rating[37] consideration shall be given to basing the design demand on the aggregate of the import capacity of each existing customer as defined in their Connection Agreement or installing LV monitoring at the distribution substation.

Where an LV system supplies a mixture of industrial and commercial customers the diversity factors shown in Table 3 may be applied.[38]

Table 3 : Diversity factors for non-domestic LV connections

Customer type	Diversity factor
Industrial/Commercial	0.8
Large commercial (office parks, retail parks)	0.5
Hospitals	0.7

3.4.2.2 General Domestic (GD) Demand

The CLNR trials demonstrated that general domestic annual consumption has reduced over time and that the associated load curve has flattened, probably reflecting two changes in the customer's practices:

- a reduction in energy use overall, due in part to using more energy efficient appliances; and
- the use of energy more evenly through the day and year.

The revised ADMD and DEBUT parameters, based on the CLNR trials, for general domestic demand, including conventional space and water heating that should be used for development the LV system are set out in Table 4. The general domestic ADMD component of the nth customer be represented by equation 1:

$$ADMD\ (GD) = 4.60n^{-0.22} \quad (kW) \quad \textbf{(1)}$$

For the avoidance of doubt, ADMD associated with LCTs are covered separately from the GD component of demand, as detailed in subsequent pages of this CoP.

Table 4 : General Domestic load ADMD & DEBUT parameters per premises[39]

Customer load	ADMD (kW)	DEBUT (URMC)
General Domestic (GD)	$ADMD\ (GD) = 4.60n^{-0.22} \quad (kW)$	3,565kWh URMC
Storage heaters	ADMD (GD) + 10% of installed heating (day) ADMD (GD) + 60% of installed heating (night)	900kWh per kW of installed restricted heating load

[37] for example greater than 80%.

[38] For example, where there is a commercial customer and a hospital on a LV feeder the maximum demand of the commercial customer can be multiplied by 0.8 and the demand of the hospital multiplied by 0.7 to calculate the demand on the LV feeder.

[39] Appendix 2 - Design Demands, sets out the P & Q values to be inputted in DEBUT to represent the new half hourly values based on an annual consumption of 3,565kWh. The CLNR project concluded that the actual consumption was 3,523kWh but didn't provide P & Q values for that consumption value; hence the closest matching profile, the medium consumption profile with an annual consumption of 3,565kWh has been selected.

Direct-acting Space Heating (DASH)	1kW + 50% of installed DASH load	no direct equivalent
Other electric heating	1kW + 100% of installed load	no direct equivalent

.

Table 5 details the ADMD of the specific nth customer based on the general domestic ADMD formula in Table 4. In Table 5, the 1.67kW figure is the ADMD of the 100th customer alone, the ADMD of the 99th customer will be slightly higher and the ADMD of the 98th customer will again be slightly higher. Hence, to establish the demand on assets supplying all 100 customers, the ADMD of the 100th, 99th, 98th….2nd and 1st customer need to be calculated and summated. It is this summated value that should be used as the design demand for the asset being considered.

Table 5 : Design Demand for the nth GD Customer

nth Customer	ADMD	DEBUT (URMC)
1	4.60kW	3,565kWh
25	2.27kW	
50	1.95kW	
75	1.78kW	
100	1.67kW	
500	1.17kW	

Appendix A2.2 – ADMD design demand, provides an example assessment of the design demand that should be used for an asset supplying up to 200 customers.

The design demand for an asset supplying fewer than 10 and more than 90 customers[40] using the new parameters will be lower than that calculated via the historical parameters, suggesting that assets with a lower capacity are required. This is the case when assessing the sufficiency of existing assets, however, where new assets are being designed, the economically efficient sizing of assets required to comply with the Standard Licence Condition 49 losses obligation, in most cases, will result in assets with a great capacity being installed compared to the previous design approach. Compliance with this losses obligation requires the use of transformers as set out in the transformer maximum economic initial loading guide (section 3.4.4, Table 10) which are typically larger than those that would have been previously deployed and the use of larger capacity LV cables e.g. a LV main should comprise a LV 300mm^2 Al waveform cable.

3.4.2.3 Heat Pumps

The majority of the heat pumps currently connected to domestic premises are single phase units with a rated input electrical demand of between 3kW and 4kW. Heat pump rated power can be defined in different ways including the total heat pump system maximum demand, in kW, and output rated heat also in kW. The rated electrical input total system maximum demand in kW[41,42] should be considered when designing LV systems. For example, a heat pump installation may comprise the main heat pump and an additional heating element referred to as back-up, inline or boost elements which can be operated at the same time as the main heat pump to provide additional heating. It is the combined

[40] As detailed in Appendix 2 - Design Demands, the graph also shows that i) the design demand for assets calculated using the new ADMD parameters for between circa 10 to 90 customers is higher than the design demand calculated based on the historical ADMD parameters and ii) the design demand for assets calculated using the new ADMD values for fewer than 10 and more than 90 customers is lower than the design demand calculated based on the historical ADMD parameters.

[41] A HP with 10kW rated heat output (which is typically how HPs are referred to in manufacturer's datasheets) equates to circa 3.6kW electrical input with a coefficient of performance (COP) of 2.8; i.e. 10/2.8=3.6kW.

[42] This value is normally provided in the ENA low carbon technologies heat pump database as the 'Total Heat Pump System Maximum Demand'. The database can be found at https://www.energynetworks.org/industry-hub/resource-library/low-carbon-technologies-heat-pump-database.xls

rating of these components that should be considered when establishing the heat pump system maximum demand.

Trials carried out as part of the Northern Powergrid CNLR project showed that:

- Heat pumps typically run steadily through the day at a 1:2 duty cycle, e.g. a heat pump with an electrical input rated at 3kW will normally operate such that the average demand over several hours is 1.5kW;
- The morning spike in heat pump demand (when the duty cycle may be higher than 1:2) is less than the diversified evening general domestic and heat pump demand, i.e. the design demand relates to the evening peak period; and
- In the absence of evidence to the contrary, it is reasonable to design the LV system assuming that the duty cycle, on average, remains at 1:2 during periods where the winter temperatures are below average.[43]

Following planned and unplanned outages in winter, demand on the system will increase due to Cold Load Pickup (CLPU). This occurs when all the heat pumps may be initially running at full power for a period of time. To cater for this, in absence of detailed research, when more than 50%[44] of customers on part of a LV system have a heat pump installed, guidance should be sought from the Smart Grid Implementation Unit.[45,46]

Where homes in a new housing development are not fitted with a heat pump at the construction stage it is reasonable to assume that the installed heating system will remain in place for 20 years and hence no allowance for future load growth due to heat pump demand shall be made when designing the LV system.

The heat pump ADMD component (kW) of the nth customer with a heat pump of system maximum demand h[47] can be represented by equation 2:[48]

$$ADMD\ (HP) = h(2.03n^{-0.25} - 1.53n^{-0.22})\ \ (kW) \qquad \textbf{(2)}$$

The ADMD (kW) of the nth customer who has general domestic and heat pump demand, where the heat pump has a system maximum demand of h, can be represented by equation 3:

$$ADMD\ (GD + HP) = 4.60n^{-0.22} + h(2.03n^{-0.25} - 1.53n^{-0.22})\ \ (kW) \qquad \textbf{(3)}$$

Table 6 details the ADMD of the nth customer-based equation 3 for a GD customer with a 3kW HP. In Table 6, the 1.93kW figure is the ADMD of the 100th customer alone, the ADMD of the 99th customer will be slightly higher and the ADMD of the 98th customer will again be slightly higher. Hence, to establish the demand on assets supplying all 100 customers, the ADMD of the 100th, 99th, 98th….2nd and 1st customer need to be calculated and summated. It is this summated value that should be used as the design demand for the asset being considered.

Appendix A2.2 – ADMD design demand, provides an example assessment of the design demand that should be used for an asset supplying up to 200 customers.

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[43] Further research is required to examine whether the increase in duty cycle (and hence average demand) with lower than average winter ambient temperatures is material when designing a LV system.
[44] 50% is a conservative estimate of the level of LCT connection penetration when issues on the LV system may need to be investigated in detail.
[45] NPG_NIA_033 – 'Impact of LCTs on the Design of LV Networks' concluded CLPU has limited impact on the LV system following an outage. The report found that any load related issues are introduced by the demand associated with the normal operation of the HPs and would be identified at the connection design stage. In effect the system will be designed to cater for the peak HP demand.
[46] It may be that the capacity of the asset supplying the high concentration of HPs and the associated voltage drop may not be an issue given the use of higher capacity assets to comply with the SLC49 losses obligation.
[47] h is measured in kW.
[48] The equation is based on CLNR trials for a domestic premises fitted with a 3kW HP (i.e. General domestic + HP).

Table 6 : Design Demand for the nth General Domestic Customer with a 3kW Heat Pump

n^{th} Customer	ADMD	DEBUT (URMC + 3kW HP)
1	6.09kW	6,306kWh
25	2.72kW	
50	2.29kW	
75	2.07kW	
100	1.93kW	

The current trend is for heat pump installations to be designed such that inline heaters are not expected to operate in normal operating conditions; they are operated only once a week for relatively short periods of time (circa five minutes) to preventing legionnaires disease in the water system. In these cases the effect of inline heaters can be ignored as diversity should be sufficient to cater for this additional demand.

Where an inline heater with a rating of i kW is expected to be used under normal operational conditions within a heat pump with a system maximum demand of h kW, the ADMD (kW) component for the n^{th} customer should be calculated can be represented by equation 4:

$$ADMD\ (HP) = h(2.03n^{-0.25} - 1.53n^{-0.22}) + i\ \ (kW) \qquad \textbf{(4)}$$

Communal heat pump systems may be installed in new multiple dwelling unit developments as well as retrofitted to replace existing heating systems in multiple dwelling units. Such installations typically comprise a central heat source and an individual heat pump located in each premises. In these scenarios ADMD values for a general domestic premises plus heat pump demand should be used to calculate the design demand of the development which can then be used assess the impact on the LV system.

3.4.2.4 Electric Vehicle Charging Points (EVCPs)

The design demand for a premises or facility with one or more EVCPs depends on the:

- Number and rating of the EVCPs installed; and
- Location and intended use of the EVCPs e.g. domestic, commercial or public.

These factors will also influence the overall demand profile and utilisation of the EVCP.

Section 3.4.2.4.1 provides guidance on the design demand for a single EVCP up to and including 32A installed in a domestic premises. Section 3.4.2.4.2 provides guidance on the design demand for the following types of EVCP facilities:

- Single EVCPs rated at greater than 32A or multiple EVCPs in domestic premises;
- EVCPs of any rating in non-domestic premises e.g. commercial; and
- Public EVCPs.

3.4.2.4.1 Domestic Premises with an EVCP up to and including 32A

The guidance below applies to domestic premises with one single phase EVCP that has a maximum charging current of up to and including 32A.

The combined results of the CLNR project and My Electric Avenue (MEA) project[49] show that for a domestic premises fitted with a 16A (3.68kW) rated EVCP, the EVCP ADMD component (kW) for the n^{th} customer can be represented by equation 5:

$$ADMD\ (16A\ EVCP) = 2.59n^{-0.15}\ \ (kW) \quad \textbf{(5)}$$

Both the CLNR and MEA analysis were based on domestic premises fitted with a 16A EVCP. It is expected that use of an EVCP of up to and including 32A rating in domestic premises will result in an increase in the design demand in the premises, but the shorter charge period is likely to result in increased diversity with other customers supplied by the same circuit. However, the effect of diversity is unlikely to completely negate the higher load (double) associated with a 32A EVCP particularly where there are only a small number of customers supplied from the circuit. The 'General domestic and 16A EVCP' ADMD has therefore increased to calculate a 'General domestic plus 32A EVCP ADMD'.

Hence, for a 32A rated EVCP, the EVCP ADMD component (kW) for the n^{th} customer can be represented by equation 6:

$$ADMD\ (32A\ EVCP) = 5.15n^{-0.15}\ \ (kW) \quad \textbf{(6)}$$

The ADMD (kW) of the n^{th} customer who has general domestic and EVCP demand, where the EVCP has a rating of 16A, can be represented by equation 7:

$$ADMD\ (GD + 16A\ EVCP) = 4.60n^{-0.22} + 2.59n^{-0.15}\ \ (kW) \ \textbf{(7)}$$

The ADMD (kW) of the n^{th} customer who has general domestic and EVCP demand, where the EVCP has a rating of 32A, can be represented by equation 8:

$$ADMD\ (GD + 32A\ EVCP) = 4.60n^{-0.22} + 5.18n^{-0.15}\ \ (kW) \ \textbf{(8)}$$

Table 7 : Design Demand for the nth General Domestic Customer with i) a 16A EVCP or ii) a 32A EVCP

n^{th} Customer	ADMD (GD & 16A EVCP)	ADMD (GD & 32A EVCP)	DEBUT (URMC+ 16A EVCP)	DEBUT (URMC+ 32A EVCP)
1	7.19kW	9.78kW	10,546kWh	10,546kWh [50]
25	3.86kW	5.46kW		
50	3.39kW	4.83kW		
75	3.13kW	4.49kW		
100	2.97kW	4.27kW		

Table 7 details the ADMD of the specific n^{th} customer, based on the above 'General domestic plus EVCP' ADMD formula for a 16A EVCP, and the modified formulae for a 32A EVCP. For example, in Table 7, the 2.97kW figure is the ADMD of the 100^{th} customer alone, the ADMD of the 99th customer will be slightly higher and the ADMD of the 98^{th} customer will again be slightly higher. Hence, to establish the demand on an asset supplying all 100 customers, the ADMD of the 100^{th}, 99^{th}, 98^{th}….2^{nd} and 1^{st} customer need to be calculated and summated. It is this summated value that should be used as the design value for the asset being considered.

Table 7 also details the DEBUT parameters for a General Domestic customer with 16A EVCP or a 32A EVCP.

Appendix A2.2 – ADMD design demand, provides an example assessment of the design demand that should be used for an asset supplying up to 200 customers.

These values should be used when:

[49] My Electric Avenue SDRC 9.8 – Volume 1 (Nov 2015).

[50] Although the annual energy consumption will typically be unaffected by the rating of the EVCP, the load profile is expected to have greater peak values. Further analysis is needed to establish the appropriate p and q figures to use in DEBUT for 32A EVCPs. In the interim period where DEBUT is used to assess 32A EVCPs, the load should be treated as any other comparable load and therefore assessed without applying any diversity.

- The developer of a new housing development has advised Northern Powergrid that EVCPs up to and including 16A (3.68kW) or 32A (7.36kW) will be provided as standard in new homes. The assumption here is that vast majority of the homes with EVCPs installed will be occupied by customers who own an electric vehicle (EV) within the lifecycle of the LV system; and

- When Northern Powergrid is aware that an EVCP rated at up to and including 7.36kW is installed in an existing customer's premises.

3.4.2.4.2 Other EV Charging Facilities

Due to their differing expected operating cycles, it is anticipated that all other electric vehicle charging facilities including EVCPs greater than 32A installed in domestic premises, EVCPs of all ratings in non-domestic premises and public EVCPs, will have a different impact on the distribution system. Until there is more evidence on the impact of such charging facilities on distribution systems, the load of an EVCP should be treated as any other comparable load and therefore it should be assessed without applying any allowance for diversity.

For installations comprising several EVCPs, the design demand shall be the sum of all EVCP equipment ratings unless there is a load management scheme that will limit the load to a particular value. A load management scheme compliant with Engineering Recommendation G100, may be used at a single EVCP (e.g. EVCP installed at a domestic premises) to ensure that the load does not exceed the supply capacity.

Note:

The connections to a public EVCP can be either metered or unmetered. Section 3.4.7.2 provides additional information on public EVCPs. Where an unmetered EVCP is derived from an existing unmetered connection such as a street lighting column, the design demand should be that of the street light (typically 260W for a single street lamp and 520W for a double street lamp) plus that of the rating of the EVCP (without applying any diversity).[51] [52]

3.4.2.5 Multiple Demand Related LCTs

The guidance in sections 3.4.2.2 to 3.4.2.4 can be used to establish the individual ADMD components of a customer's premises.[53] Where multiple LCT devices are installed in a domestic customer's premises the DEBUT parameters can be established by a summation of DEBUT energy component for each individual LCT device.

Where a LV system supplies a mixture of customers premises some of which have heat pumps and some of which have EVCPs installed, the design demand for a particular asset used should be based on appropriate combination of the ADMD or DEBUT parameters based on the number of customers with each type of LCT as described above.

For example, the ADMD of the nth customer with a HP of system maximum demand h (kw) and a 32A EVCP, the GD demand component must be added to the HP and EVCP components.[54] This can be represented by equation 9:

$$ADMD\ (GD + HP + 32A\ EVCP) = 4.60n^{-0.22} + h(2.03n^{-0.25} - 1.53n^{-0.22}) + 5.18n^{-0.15}\ \ (kW)$$
(9)

[51] Typically, the installer will de-rate the EVCP to allow for the street lamp load, e.g. for a 25A cut-out, 23.87A will be allocated to the EVCP and 1.13A for the street lamp.
[52] NIA_SSEN_0055 - is an ongoing ENA Net Zero termination project that will assess the capability of service terminations when submitted to LCT demand profiles. The results of this project will determine the maximum rating of an unmetered EVCP within a street lighting column.
[53] This is combined in the design demand calculator.
[54] Diversity is included between LCT devices of the same type but is not considered between different types of LCT devices.

3.4.2.6 Photo-voltaic (PVs)

In addition to designing a LV system to accommodate the load as described above there is a need to assess system constraints arising at times of low load demand (e.g. summer minimum demand) and high export from PV generation. Output from PV generation is affected by various atmospheric parameters which can vary geographically. The CLNR project concluded that it is difficult to derive a single combined net load profile (e.g. for a domestic premises equipped with a HP and PV) to cater for network diversities across a group of customers under all different operating scenarios. This means that the effect of load on the system and export from PV generation need to be considered separately.

When assessing the effect of PV installations on the LV system, a diversity[55] factor shall be applied to the nominal rated capacity of each PV installation. The diversity to be applied depends on the number of PVs connected to the part of the LV system being assessed and whether the PV arrays are randomly oriented (as might be the case in a new housing development) or aligned (as might be the case where PV arrays are installed on south facing roofs of a row of refurbished terraced housing).

Based on the CLNR analysis[56] of the output from 100 PV distributed generation installations, the diversified per unit maximum output which varies between 0.9 and 1.1 of the nominal rated capacity as detailed in Table 8 and Table 9. These values shall be used for the economic development of the LV system. This analysis considered the diversity across PV arrays from a variety of manufacturers, installation orientation and geographic location.

When assessing the impact of PV generation on a LV system a minimum demand per domestic premises on that LV system of 0.3kW should be assumed.

Table 8 : PV installations where the arrays are randomly orientated

Number of premises equipped with a PV array (per phase)	Diversity factor
Greater than 30	0.9
Between 5 and 30	0.95
Fewer than 5	1.0

Table 9: PV installations where the arrays are aligned

Number of premises equipped with a PV array (per phase)	Diversity factor
Greater than 30	0.95
Between 5 and 30	1.0
Fewer than 5	1.1

3.4.2.7 Electricity Storage Devices

An electricity storage device is any device which can consume and produce electrical energy. A Battery Electrical Storage System (BESS) is the most common form of an electricity storage device connected to the LV system and is typically installed in a premises with other forms of generation e.g. PV. The volume of BESS devices connected to the LV system is increasing as technology costs reduce and customers seek ways to self-consume as much of the electricity they generate as possible.

A BESS is considered to be a demand when importing power (charging) and generation when exporting power (discharging). An assessment to determine system constraints shall consider the peak import

[55] The diversity comprises two components, a physical component (arising due to the number and orientation of PV installations) and a network component (arising due to differences in way the electricity generation from PVs is consumed within a customer premises – i.e. there will be a diversity in the net export to the distribution system). For the purpose of establishing the design demand, due to lack of conclusive analysis, the network diversity component has been assumed to be zero or insignificant.

[56] CLNR-L095 – Technical Note: PV installations which addressed the two areas 1) difference in the declared peak values against the measured peak values 2) examination of the diversity of the PV panels.

and peak export from the device along with existing demand and generation at the connection point. The import and export of the device shall be considered separately. Diversity should not be applied when considering a BESS device.[57]

3.4.2.8 Customer Limitation Schemes

A customer limitation scheme which meets the requirements of Engineering recommendation G100 may be used to restrict the import to, or export from, a customer's installation to the LV. These devices are typically installed where a customer wants to increase the capacity of demand and/or generation devices within their premises without the cost or time pressures associated with any system reinforcement works that may otherwise be required. Further details on the application of customer imitation schemes can be found in ENA Engineering Recommendation G100, Technical Requirements for Customer Export and Import Limiting Schemes.

Selection and Configuration of Plant

3.4.3 Standard Plant

Section 9(1) of the Electricity Act 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 LV 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 transformers, switchgear and circuit ratings.

3.4.4 Transformers

To ensure compliance with Engineering Recommendation P2, supplies to multiple customers with an aggregate demand of 1MW or more shall not be supplied from a single transformer.[58, 59] Transformers up to and including 1600kVA may be used to supply individual customers from dedicated substations.

The maximum transformer size may also be limited by the need to constrain short circuit levels on systems with significant amounts of embedded generation.

When assessing the rating of a new transformer the following factors shall be taken into account:

- the developer's estimate of demand (where appropriate);
- the existing network demand (where appropriate);
- diversity between customers and feeders;
- credible future development, i.e. DFES scenarios;[60]

[57] Additional guidance on BESS systems is included in IMP/001/007/001 – Battery Energy Storage System Guidance Document.
[58] There is provision in Engineering Recommendation P2 to supply more than 1MW of demand from a single transformer if it can be accommodated within the cyclic capability of a 1MVA transformer. Before applying this relaxation, guidance should be sought from the Smart Grid Development Manager.
[59] In some situations, it may be reasonable to supply more than 1MW of demand from a suitably rated single transformer provided that there is sufficient LV system interconnection to meet the requirements of Engineering Recommendation P2 Class of Supply B. Where this is being considered, guidance should be sought from the Smart Grid Development Manager.
[60] Distribution Future Energy Scenarios - https://datamillnorth.org/dataset/northern-powergrid-dfes-2021

- additional load from adjoining substations interconnected at LV, that might be picked up under outage conditions;
- the cost of losses, in particular compliance with the Northern Powergrid Distribution SLC49 Losses Obligation;[61] and
- its cyclic capability and the impact of enclosure in accordance with Power Transformers: Loading guide for oil immersed power transformers, BS IEC 60076-7: 2005.

To comply with these requirements, where a new HV to LV transformer is to be installed its rating should be selected based on the maximum economic initial loading guidance in Table 10.[62] This guidance should only be applied when establishing the rating of a new transformer to be installed as part of new connections or asset replacement works rather than when assessing the capability of an existing transformer.

Three generic load profiles have been used to establish three maximum initial loading levels for each of the standard transformer sizes currently purchased. The transformer rating selected should be based on the most appropriate generic load profile. The wind profile relates to LV systems supplying wind generation installations only and not to a 'general domestic + wind' profile. If the transformer will supply load reflecting a combination of profiles, then the general domestic load profile shall be used to select the transformer rating, as the generation could be offline for a considerable amount of time or be decommissioned in the future, leaving only the domestic load.

For new transformers with a general domestic load duty, the initial transformer loading shall not exceed 85% of the transformer nameplate rating. This is based on the load duty of transformer supplying domestic load being capped at 115% of nameplate rating in year 45. This includes a 0.5% annual load growth allowance[63] and assumes a low ambient temperature coinciding with domestic peak in accordance with BS IEC 60076-7: 2005.

For new transformers with only generation load duty, the initial transformer loading can be up to 110% of the transformer nameplate rating. This assessment does not include any annual growth allowance. Whilst the transformer may experience load in excess of the nameplate rating, analysis[64] has shown that this is likely to occur for a relatively short period of time and that the overall loss of life will be less than one day per overloaded day.

The economic load duty has been calculated in accordance with the Code of Practice for the Methodology of Assessing Losses; IMP/001/103, taking into account the transformer cost,[65] transformer load and no load losses. Further explanation of the maximum economic transformer load guidance and the loss of life calculations is detailed in Appendix 3 – Transformer selection – maximum economic initial loading. This analysis also shows that 16kVA single-phase pole mounted transformers are uneconomic and shall therefore not be used. To reduce the need for future reinforcement, where a single-phase pole mounted transformer supplies one single domestic customer or provides an unmetered supply a 25kVA transformer shall be used. For all other scenarios, a 50kVA transformer shall be the minimum capacity transformer used.

[61] See section 3.1.6.

[62] This table is provided for guidance. There may be situations when a higher level of initial loading is economic, e.g. when selecting the rating of a transformer replacing an existing transformer only supplying a block of domestic flats.

[63] This allowance predominantly facilitates an increase in the number of customer's being supplied from the asset, and to a lesser extent additional consumption from existing customer's (e.g. for EVCPs).

[64] In accordance with BS IEC 60076-7: 2005.

[65] Based on Eco design Tier 1 transformers.

Table 10 : Transformer selection - maximum economic initial loading

Rating (kVA)	Maximum economic initial loading (kVA)			Type of transformer
	Typical general[66] domestic load profile	Wind generation profile	PV generation profile	
25	21	25	25	single phase pole mounted
50	35	40	50	single/split phase pole mounted
100	85	110	110	
200	170	220	220	
100	85	110	110	three phase pole mounted
200	135	185	220	
315	265	315	315	
315	220	300	345	three phase ground mounted
500	315	440	540	
800	555	750	880	
1000	625	845	1035	
1250[67]	1000	1270	1375	
1600[67]	1000	1600	1600	

The analysis used to create Table 10 did not assess the economics of specifying:

- a single/split phase pole mounted transformer compared with a three phase pole mounted transformer of the same rating;
- a 315kVA three phase pole mounted transformer compared with a 315kVA three phase ground mounted transformer.

In such cases a bespoke assessment should be carried out. For example, it may be economic to operate a 315kVA pole mounted transformer at a higher initial loading level than that in Table 10 as the extra costs of installing a 500kVA ground mounted transformer (including the associated switchgear and building and civil costs) could be significant; however it would not be economic to operate a 315kVA ground mounted transformer at the same higher initial loading level as the additional costs of using 500kVA ground mounted transformer is relativity small since the switchgear and building and civil costs would be unchanged.

When assessing the need to reinforce an existing substation to accommodate new demand, the design demand for the existing and new demand should be assessed in accordance with section 3.4.2 and the capability of the existing transformer[68], particularly those serving industrial and commercial customers, shall be considered on their merits. According to BS IEC 60076-7: 2005:

- the nameplate rating is based on a continuous load at 20°C ambient;
- cyclic loading can allow uprating by up to 15% for typical domestic load curves;
- each 1°C increase (decrease) in ambient temperature requires a 1% de(up) rating; and

[66] These design demand values should be used only for general domestic load i.e. gas heated premises.
[67] 1250kVA and 1600kVA transformers shall not be used to the supply demand of multiple customers >1MW to ensure P27 compliance. See clause 3.5.2.
[68] Consideration should be given to the retrofit of thermal monitoring to assess the ambient temperature of the transformer. Consideration should also be given to the retrofit of cooling technologies that can directly control the temperature of the asset and increase the rating of the transformer.

- enclosure adds about 5ºC to the effective ambient temperature, and poor ventilation adds another 5ºC.

These factors can have a material impact on the capacity of a transformer, and consideration shall be given to these issues when assessing the capability of an existing transformer. The following examples illustrate the potential impact:

- domestic cyclic load with a winter peak (assumed 5°C external temperature, plus 5°C for the effects of enclosure) allows up-rating to 125% of nameplate; and
- continuous load with summer peak and poor ventilation (assumed 25°C external temperature, plus 10°C for the effects of an unventilated enclosure) requires derating to 85% of nameplate.

3.4.5 Switchgear

Substations used on the LV system shall normally be ground mounted. Ground mounted substations equipped with transformers of 315kVA and above shall be fitted with two fault-making load-breaking line switches on the HV side.[69]

Pole mounted substations, whether part of an overhead line or fed from an underground cable (typically referred to as an Inverted Pole Equipment (IPE)) shall be used only where an overhead line would be acceptable on safety and amenity grounds. This includes open countryside up to the edge of settlements, but excludes sites bounded by development. Pole mounted substations shall be limited to a maximum rating of 200kVA.[70]

Where the use of a pole mounted substation is unacceptable and where there is a need for LV system capacity of 315kVA or less; the use of pad mounted transformer should be considered. For further details on the application of pad mounted transformers refer to the Code of Practice for the Economic Development of the HV system, IMP/001/912.

To facilitate further development of the LV system supplied from a ground mounted substation, a pole mounted transformer or pad mount transformer, at least one outgoing LV way per 100kVA of nameplate transformer capacity shall be provided up to a maximum of 9 LV ways.[71] Table 11 shows the number of LV ways which should be provided for each rating of transformer.

1250kVA and 1600kVA transformers are typically installed to supply a single customer; in this case only one LV way, typically a LV Air Circuit Breaker (ACB), will be required.[72]

Provisions for the connection of a mobile generator to the LV distribution board shall be provided. When establishing a new distribution substation consideration should be given to the practicalities of safely siting a mobile generator in outage scenarios.[73]

Table 11: Transformer selection – minimum number of LV outgoing ways

Rating (kVA)	Type of Transformer	Minimum LV ways
25	single phase pole mounted	1
50	single/split phase pole mounted	1
100		1
200		2

[69] i.e. a UDE / RMU.
[70] Where a 315kVA transformer is to be installed a pad mounted substation shall be installed.
[71] A smaller number of LV ways is permissible for a restricted site subject to an assessment of the LV system.
[72] The opportunity to use such a distribution substation to provide interconnection to other LV system substations should be considered, giving consideration to the rating of the transformer and capacity of the customer's connection.
[73] Consideration should be given to physical space for the generation, noise and exhaust fumes.

100	three phase pole mounted	1
200		2
315		2
315	three phase ground mounted	3
500		5
800		8
1000		9
1250		N/A[74]
1600		

3.4.6 Underground and Overhead Mains

LV underground and overhead mains shall be designed and selected to meet the design demand, load growth and credible future connections. Asset ratings are defined in the Code of Practice for Guidance on the Selection of Overhead Line Ratings, IMP/001/011 and the Code of Practice for Guidance on the Selection of Underground Cable Ratings, IMP/001/013.

The system shall be laid out so as not to exceed the maximum permissible value:

- for voltage drop as specified in section 3.3.3;
- for customer as specified in 3.5.6;[75]
- for phase-neutral loop impedance as specified in section 3.3.5; and
- for fusing, such that a fault at the end of any service cable will be cleared within 60s.

In some cases, it may be necessary to reduce LV system impedance to stay within the statutory supply voltage levels of 230/400V +10%/-6%.

In some cases, the fuse rating necessary for 60s clearance is below the anticipated load current, although real LV systems would generally be constrained by voltage limits before fusing limits are reached. In such cases, either loop impedance shall be reduced (e.g. by installing larger transformers) or load shall be reduced by splitting feeders in the vicinity of the source substation.

3.4.6.1 Underground Mains

Underground cables used for the LV system shall comply with the Technical Specifications for LV Distribution and Service Cables, NPS/002/019.

Analysis in accordance with the Northern Powergrid Losses Strategy and Code of Practice for the Methodology of Assessing Losses; IMP/001/103 shows that 185mm^2 Al waveform cables are economically viable for only a limited range of system loadings. Therefore, the LV system shall be laid out using 300mm^2 Al waveform cables other than for short tail-end spurs (e.g. cul-de-sacs), where 95 mm^2 Al waveform cable is acceptable. This facilitates extension in the future and supports the objective of developing and an economical efficient and co-ordinated LV system.

New underground circuits and overlays/extensions of existing LV underground circuits shall normally be constructed using either 300mm^2 or 95mm^2 Al waveform 3c CNE cables. A PME system shall be established in accordance with Engineering Recommendation G12, Requirements for the application of protective multiple earthing to Low Voltage networks.

[74] 1250kVA and 1600kVA typically installed to supply a single customer and would be equipped with an ACB.
[75] For new networks the average number of connections across all LV feeders from a single distribution substation shall not exceed 80.

However, it is permissible to use 4c SNE cables for LV circuits where this is beneficial for safety or economic reasons in accordance with the requirements detailed in Code of Practice for Earthing LV Networks and HV Distribution Substations, IMP/010/011.

Cables should be installed in accordance with Policy for the Installation of Power Cables, NSP/002.

The phase conductors of three phase LV mains and services shall be jointed phase to phase, using core number or colour as appropriate. The neutral or earth conductors of a three phase cable shall not be bonded to any phase conductors. The practice of bonding a phase conductor to a neutral conductor in a three phase cable to provide a large capacity or lower impedance single phase service is not permitted even for sections laid within the customer's boundary.

When extending single phase or split single phase systems with three phase mains cable, spare phase conductors should be bonded to another phase at the source to ensure that all conductors continue to be energised and monitored. The bonded spare phase conductor of a three phase service cable should be terminated at the customers' Point of Supply. This 'spare' phase termination shall be equipped with a sealed empty fuse carrier i.e. with no fuse installed to avoid loading the spare phase conductor. Records shall accurately reflect the nature and location of all such phase conductor bonding and empty fuse carriers.

No load shall be connected to a bonded spare phase conductor of a three phase cable until the main is supplied from a three phase source.

Where an existing small section mains [76] is to be extended to serve more than three domestic customers all the main shall be overlaid with a suitably sized conductor.[77]

3.4.6.2 Overhead Mains

Overhead conductors used for the LV system shall comply with the Technical Specification for Overhead Line Conductors, NPS/001/007.

New overhead mains should only be installed where underground mains are not economic or would not comply with the criteria set out in section 3.6.2.2.

New LV overhead systems shall be constructed using either 4 core 120mm^2 Aerial Bundled Conductor (ABC) or 4 core 185mm^2 ABC dependent upon the load to be connected. 70mm^2 ABC shall be considered for short tail end spurs (i.e. cul-de-sacs).[78] The overhead mains shall be constructed in accordance with Code of Practice for the Construction of LV ABC Overhead Lines, NSP/004/041 and the clearance requirements in accordance with Code of Practice for Guidance on Overhead line Clearances, NSP/004/011.

Where existing overhead lines are renovated, this shall be carried out in accordance with Specification for the Renovation of Existing LV Overhead Lines, NSP/004/041/001.

New surface wiring or under-eaves mains are not permitted. Where under-eaves mains are to be replaced, it is not permitted that the cable remains in a 'position where it is likely to be damaged or where persons going about normal everyday activities could come into contact with it.'[79] This can be satisfied by placing the new cable above the highest windows (i.e. directly under the eaves), mounted on the wall rather than barge boards or soffits. Under-eaves mains shall not be retained mounted on a wall which has a high likelihood of being clad with external thermal cladding in the future. For further guidance refer to the Specification for Overhead Services, Surface Wiring and Eaves Wall Mains, NSP/004/043.

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[76] Small section mains is defined as a cable with a rating equivalent to a 3 core 35 mm^2 Al waveform cable or less.

[77] For example, a section of 35mm² Al waveform cable would be replaced with a section of 95mm² Al waveform cable, subject to a system assessment.

[78] The loading and voltage drop shall be confirmed to be within limits on the tail end spurs where the 70mm^2 ABC is proposed to be installed.

[79] Extract from ENATS 43-8.

If a suitable position on the wall cannot be achieved, then either:

- where it is practicable to provide underground services, an underground main and services shall be provided; or
- where it is not practicable to provide underground services, an overhead main and services may be provided.

Where under-eaves mains are retained, any infeed:

- from underground mains shall be via a wall box fitted with 200A cartridge fuses; or where
- from overhead mains shall be via a 200A fused tee-off.

Where an existing small section overhead conductor[80] is to be extended to serve more than three domestic customers the whole main shall be overlaid with a suitably sized conductor.

3.4.6.3 Street Lighting 5th Core

Legacy systems, both overhead and underground, may include switched 'fifth' or even 'sixth' core conductors to which public lighting is connected. There are many different examples of how the conductors are currently controlled, including:

- control gear in a substation;
- control gear in an outside cabinet in a substation wall;
- separate street lighting pillar at a substation;
- separate street lighting pillar at a link box; and
- designated street lamps acting as control columns.

To minimise operational inconvenience to Northern Powergrid and Public Lighting Authority's (PLA), arrangements that embed PLA control gear in Northern Powergrid assets shall be removed at the earliest opportunity, in agreement with the PLA. Either the existing service connections shall be transferred to a phase conductor, or a PLA column shall be converted to control the fifth core conductor.

In co-operation with the PLA, existing "switched" street lighting 5th core systems should be converted to a permanently energised street lighting supply at the earliest opportunity and the records clearly marked accordingly. Where this is not cost effective or agreement from the PLA cannot be obtained, any new CNE mains shall be laid with a separate single phase CNE service cable to provide the 5th core street lighting supply.

The 5th core of LV main supplying street lighting shall be energised from the same LV source as the phase conductors within the main and this should normally be on grey (previously blue) phase. At link boxes and pillars the normal open point of the 5th core shall coincide with the open points of the phase conductors of the main and shall be "in phase" with any other energised 5th core across a linking point.

Where an existing street lighting column supplied via a 5th core is to be converted to an unmetered EVCP, it must be transferred to a phase conductor of a mains cable and meet the requirements set out in sections 3.3.5 and 3.4.7.

[80] Small section overhead conductor is defined as a conductor with a rating equivalent to a 35mm^2 ABC conductor or less.

3.4.7 Services and Termination Equipment

LV service cables used for the LV system shall comply with the Technical Specifications for LV Distribution and Service Cables, NPS/002/019. New single phase services shall comprise 35mm^2 Al concentric service cable. New three phase services shall comprise a minimum of 35mm^2 Al waveform cable.

Where a single phase service would have typically been provided to a domestic premises, where specifically requested by a customer and where considered reasonable by Northern Powergrid, a three phase service cable and cut-out may be installed to provide a single phase or a three phase point of supply.

LV customer connections shall be provided using a service termination unit on their premises, which is connected to a nearby LV main using a dedicated service cable. For further details refer Code of Practice of Standard Arrangements for Customer Connections, IMP/001/010, which includes connections to multi-occupancy buildings.

Distribution service termination equipment shall be designed and selected to meet the peak load requested by the customer; any potential for future load growth shall be discussed with the customer before design work starts.

The incoming side and busbars of three phase multi-way distribution units supplying multiple domestic customers in one building shall be sized using an appropriate ADMD. Diversity should not be applied when these units supply multiple commercial premises.

LV mains and services should be designed so that the voltage at the customer's Point of Supply remains within statutory voltage limits at all times and to allow substation fuse operation within 60s. These requirements can typically be satisfied by limiting the length of a new service cable supplying a domestic premises to 20m. In exceptional scenarios including:

- supplies to street furniture e.g. lighting columns or traffic signals;
- supplies to unmetered customers;[81] or
- where the customer is located next to the source HV to LV substation;

a service cable up to 40m in length is acceptable provided that all system parameters are within the required limits.[82]

3.4.7.1 Street Furniture

Wherever commercially viable, street furniture shall be connected by a single direct service as for any other customer.

In the case of street lighting furniture, where this is not viable or agreement from the PLA cannot be reasonably obtained, it is permitted to loop street lighting columns via the authority's own cable network up to a total power consumption of 1.38kW from one service connection onto a LV main. A sub-fuse rated at 25A shall be installed in the first (Control) column[83] and co-ordinated with the impedance to the last lighting column such that a fault shall be cleared in 5s. A 25A PLA fuse will provide such a fault clearance time for loop impedance up to 1Ω.

For larger capacity connections, two-and three-phase connections are permissible, although any connection anticipated to be above 1.38kW shall be metered in accordance with the Electricity

[81] In accordance with the Code of Practice for Standard Arrangements for Customer Connections, IMP/001/010.

[82] See Appendix 4 for further details.

[83] One method of integrating 5th core wiring with a street lighting control column is detailed in drawing C1010662, which shows the internal column wiring arrangement and drawing C1010669 which shows a breeches joint with 5th core termination (drawings referenced in section 4.2).

(Unmetered Supply) Regulations 2001,[84] with the exception of public unmetered EVCP. Section 3.4.7.2 provides further information on public (metered and unmetered) EVCP.

As for other connections, it is the developer's responsibility to provide a suitable enclosure for Northern Powergrid apparatus. Enclosures adjacent to high-speed roads including roundabouts, and central reservations are not permissible unless there is safe vehicular access and egress. The design and location of enclosures shall take into account public safety by providing secure accommodation. Suitable keys etc. shall be provided free of charge by the developer.

3.4.7.2 Public Electric Vehicle Charge Point (EVCP) Facilities

Public EVCPs can be either metered or unmetered and can be provided via dedicated charging facilities or street lighting columns with an EVCP outlet. Although unmetered EVCPs are referred to as being unmetered, public unmetered EVCPs utilise portable meters as opposed to a fixed meter forming part of the facility. Unmetered EVCPs should only be allowed if they are equipped with a Measured Central Management System (mCMS)[85] approved by Elexon. Both metered and unmetered public EVCPs must be directly connected to the mains via a dedicated service cable; looped connections are not permitted.

Where an existing street lighting column is to be converted to an unmetered public EVCP:

- the Smart Grid Implementation Unit should be consulted to discuss whether the street light cut-out can safely accommodate the new load under this operating cycle; and
- the capacity of all assets in the circuit (i.e. fuse, cut-out, mains and service cable or overhead line and transformer) must be checked to ensure they are capable of carrying the additional load. If any of these assets are insufficient (e.g. cut-out or fuse rating) they must be replaced to comply with the requirements of this CoP.

Existing street furniture fed via a looped service and/or via a 5th core must be transferred onto the phase conductor of a mains cable via a single direct service (see section 3.4.6.3 for street lighting on 5th core).

In accordance with the requirement of IMP/010/011, Code of Practice for Earthing LV Networks and HV Distribution Substations (section 3.15.15), public EVCPs shall always have a TT earthing system[86] and shall be equipped with a separate earth electrode and appropriate protection in accordance with BS 7671 (e.g. an RCD).

3.4.8 System Security and Interconnection

LV 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.

To meet the IIS and GS objectives,[87] new networks shall be arranged such that the average number of customers per LV circuit on a distribution substation shall not exceed 80 and the maximum number of customers on any one feeder shall not exceed 100. Where modifications are made to existing LV networks, and where reasonably practicable, these limits should be applied though it is recognised this

[84] The arrangements for unmetered supplies are set out in Code of Practice for the maximum load of unmetered supplies, CNN/006/001.
[85] Elexon publishes a list of approved Central Management System (CMS) on their website, including portable meters to be used for unmetered connections referred to as Measured CMS (mCMS) - https://www.elexon.co.uk/operations-settlement/unmetered-supplies/central-management-systems
[86] EREC G12 allows for an Approved O-PEN device to be installed as an alternative to TT earthing, but currently there is no recognised standard for these devices and hence no approved devices. Before any such devices are installed, they need to be tested by an independent test house.
[87] And to assist compliance with ESQC regulation 23(1)

may not be possible in all situations.[88] This limit is considered prudent with the likelihood of increased future demand on the LV system due to the installation of LCTs such as HPs and EVCPs.[89]

LV interconnection should be provided where it is economic so to do as a means to manage the risks associated with outages and increased demand on the LV system[90], particularly where the existing LV system is likely to see future increase in demand or generation, for example, arising from the number of LCT devices connected to the system.

Interconnection should be provided between HV to LV substations:

- where the HV to LV substation is fed from a teed HV source, if it can be achieved from a LV system with an independent HV source; and
- where the LV system is supplied from an existing HV to LV substations where the HV plant requires dead-tank maintenance; or
- where:
    - no more than circa 500[91] metres of additional main is required; or
    - an existing LV circuit has more than 100 customers or high demand, so that the interconnection facilitates splitting[92] the circuit; or
    - an existing LV circuit has a history of repeated failures, where interconnection is a more economical alternative to replacing the cable; and
    - the new LV cable can be laid in a common trench with a new HV cable.

Interconnection should be considered between HV to LV substations:

- where the maximum demand on either HV to LV substation(s) is high e.g. >80% of the transformer nameplate rating;
- where interconnection can be provided economically by the installation of relatively short lengths, e.g. 100m of LV cable; or
- where opportunities arise as part of a scheme to reconfigure the LV system.

Interconnection should be considered between LV circuits:

- where demand on the LV circuit(s) is high e.g. >80% of the circuit rating;
- where interconnection can be provided economically by the installation of relatively short lengths of LV cable e.g. 100m; or
- where opportunities arise as part of a scheme to reconfigure the LV system.

Where interconnection is provided between HV to LV substations or between LV circuits, a 300 mm^2 Al waveform cable or equivalent shall be installed.

Approved underground CNE feeder pillars[93] (this does not include 'Haldo' street lighting pillars) shall generally be used to interconnect underground LV systems. A 300mm^2 Al waveform cable with an

[88] Consideration may be given to splitting the circuit.
[89] NPG_NIA_033 – 'Impact of LCTs on the Design of LV Networks' concluded a maximum customer number between 45 and 90 for a number of decarbonisation scenarios. An average of 80 customers has been chosen as a reasonable number considering existing and future demand.
[90] For example, by facilitating demand to be permanently transferred to different sections of the LV feeder by moving open points.
[91] Any additional length of LV cable for interconnection shall only be installed if the voltage drop and loop impedance post interconnection is within the acceptable limits while operating under the main and alternative configuration loadings.
[92] The splitting of existing LV circuits shall also be considered where the maximum demand on a circuit is more than 80% of thermal rating, 40% of connections on the circuit supply a LCT device and the condition of the existing circuit is acceptable.

[93] Modern galvanised steel feeder pillars should be installed. These can accommodate multiple LV feeder ways and offer a more ergonomic working position than link boxes.

insulated end, with the end no less than 3m from the feeder pillar, shall be installed on each spare way of the feeder pillar to avoid supply interruptions when making future connections.

An underground link box may be used under certain scenarios such as when a feeder pillar may be vulnerable to vehicle collision or locations in which the feeder pillar may be vulnerable to the risk of flooding which cannot be reasonably mitigated by elevating the feeder pillar.

LV feeder pillars shall be used in areas with high water tables and these should be located to minimise the risk of vehicular damage and vandalism.

LV feeder pillars should also be used to provide a supply to an embedded network in accordance with the Code of Practice for Standard Arrangements for Customer Connections, IMP/001/010 - for connections up to 55kVA or where it is necessary to use a 300A or 400A fuse.[94]

Points of interconnection on overhead mains shall be provided using approved pole mounted LV fuses. Further details are provided in the Code of Practice on fusing, IMP/001/921.

When planning to joint out the LV mains of a distribution substation which is to be permanently recovered, a feeder pillar shall be provided near the existing site, maximising the opportunity to minimise the number of joints that might otherwise be required (i.e. using terminations to the feeder pillar where straight joints or pot ends might otherwise be used).

When planning to rebuild or install a new HV to LV substation, the costs of installing interconnection to adjacent systems shall be compared to the cost of deploying mobile generation to cater for outages (if practicable) and the impact of the IIS incentive scheme. Most value from interconnection comes through sectioning ideally at mid-point of the LV circuit in regard to customer numbers, as a suspected faulty cable cannot be back-fed.

3.4.9 System Earthing

To discharge the obligation under ESQCR regulation 24, the LV system shall be developed in accordance with Engineering Recommendation G12, to enable Northern Powergrid to offer a PME Earthing terminal at all new and existing customers' supply points unless it is unsafe to do so. The Code of Practice for Earthing LV Networks and HV Distribution Substations, IMP/010/011 provides further guidance.

3.4.10 System Development

Where reinforcement of the LV system is required and where possible, consideration should be given to sharing demand across new and existing LV feeders. This is on the basis that the relevant existing LV assets are in good condition and do not require replacement. This will reduce losses and provide additional capacity for the connection of additional demand such as HPs and EVCPs.

3.5 System Protection

LV mains shall be fused at the source to clear faults at the end of services within 60s or, if systems are laid out in the absence of detailed knowledge of services, to clear faults at the end of the main within 30s. This requirement will be satisfied if the loop impedance doesn't exceed the values stated in Table 12:

[94] The intention is to provide a supply to an embedded network via a LV feeder pillar (with one incoming and one outgoing connection) which can accommodate up to a 500A fuse.

Table 12 : Maximum loop impedance values

Fuse rating (A)	Loop impedance to end of service (mΩ)	Loop impedance to end of main (mΩ)	Circuit capacity (kVA)[95]
315 or less	280	242	218
400	212	191	276
500	164	146	345

As set out in section 3.3.5 new LV systems shall be laid out with loop impedance to the end of the service not exceeding 250mΩ.

It may be necessary for the loop impedance to be lower than the maximum value stated in 3.3.5 Table 1 to ensure that the fuse will operate within the permitted time.

LV fuses shall be selected in accordance with Code of Practice on Fusing, IMP/001/921 as they need to discriminate with the HV protection.

Where connections to individual customers with a capacity above 138kVA (where 200A cut-out fuses are provided), are being designed, designers shall have regard to discrimination with substation fuses.

Where material modifications are being made to existing feeders, the fusing on those feeders should be reviewed to meet the requirements of this code of practice.

Underground systems shall not normally be fitted with section fuses. Section fuse can be used in feeder pillars to protect a small section cable against short circuits currents in excess of their short circuit capability. Only 200A or 160A fuses, selected in accordance with the Code of Practice on Fusing, IMP/001/921, should be used. On overhead systems, one set of 200A or 160A section fuses, selected in accordance with the Code of Practice on Fusing, IMP/001/921 shall be provided in series with the substation fuse. This shall be located at the customer-weighted centre point (subject to loading). Under-eaves mains (surface wiring) shall be protected by 200A fuses; any upstream section fuses shall be deemed to satisfy this requirement.

More detail is provided in section 3.2 and Appendix 3 of the Code of Practice on Fusing, IMP/001/921.

3.6 Substation Location and Routing of Circuits

3.6.1 Substation Location

When establishing new or renewing existing substation sites a risk assessment in accordance with the Code of Practice for the Risk Assessment of Ground Mounted substations, MNT/006/001 should be carried out.

Despite the use of modern equipment in small enclosures a HV to LV substation is a relatively expensive item. Many kilometres of LV cable can be installed for the price of a single substation. Because of this, it is essential that maximum utilisation is obtained for each substation.

Substation optimum utilisation is however a function of the load density of the area to be supplied. For general gas heated housing estates, it may be possible to obtain a LV system supply radius of up to 700 metres whereas for estates with off-peak electric heating the radius may be limited to as low as 200 metres with a 1000 kVA transformer installed and highly utilised. Town centre load densities should enable good utilisation of substations equipped with the larger transformers. Industrial estate load densities vary considerably from place to place and with time.

To maximise substation utilisation and minimise system losses, substations shall be located as near as possible to the load centre, taking account of credible scenarios for future development. At the very

[95] Taken as 3 x 230 V x fuse rating (or, in the case of 500 A fuses, the capability of a 300 mm² waveform).

least, unless fully utilised by the first phases of development, the substation shall be placed towards the extremity of the development towards the areas to be developed.

Securing an appropriate location for the substation to reflect credible future development will require dialogue between Northern Powergrid, the Independent Connections Provider[96] and the developer as appropriate.

Future load growth on the LV system due to the connection of LCTs should be considered when establishing the size of a substation site.[97] [98]

To facilitate ongoing maintenance, the connection of mobile generation, and eventual replacement or reinforcement, free access shall be provided to the substation site, with sufficient space for vehicles to be parked without unduly obstructing traffic. Where mobile generation is most likely to be needed, i.e. on sites with a single HV infeed where the provision of interconnection is uneconomic, suitable safe access for mobile generators (vehicle- or skid-mounted) shall be secured.

All substations shall be situated such that Northern Powergrid staff or their contractors can gain direct access at any time using only operational keys.

To satisfy planning constraints, the substation should be sited on or behind the building line. This will generally secure the minimum required distance of 1m from the back of the footpath required to allow doors to be opened without causing an obstruction.

Ground mounted substations shall be enclosed in accordance with the Policy for the Enclosure of Ground Mounted Distribution Substations, IMP/009, and precautions taken against the risk of flood, fire and explosion in accordance with the Policy for Flood Risk Mitigation at Substation Sites, IMP/001/012 and the Policy for Fire Mitigation at Operational Premises, IMP/011 (which includes criteria for the use of fixed CO_2 installations).

All substations shall be designed and located to avoid creating a statutory nuisance, which would otherwise arise primarily due to noise, vibration or electro-magnetic interference. This requires a minimum distance of 3m from new indoor substations, or 6m from new pole mounted substations, to adjacent dwellings.

Due to the potential for statutory nuisance, the increased risk of fire, and generally poor ventilation (leading to lower effective transformer capability), substations integral to other buildings should be avoided. It is permissible for substations to share a party wall (so long as constructed of brick or similar material with no breach that might permit the spread of fire) with industrial or commercial buildings. The use of common trenches between the substation and customers' switch rooms is no longer permitted; any ducts shall be sealed with an approved fire-resistant material.

If an integral substation cannot be avoided, the following precautions must be undertaken at the developer's expense:

- for the safety of staff:
    - substations should be at ground level with unrestricted 24-hour access from the public highway. If this cannot be achieved the agreement of the System Design Manager should be sought. When deciding if alternative access arrangements are acceptable, facilities for bringing Northern Powergrid's heavy lifting equipment (e.g. a HIAB wagon) should be considered; and
    - the creation of a confined space is not permitted, and there must be free natural ventilation of the site. This will generally preclude basement substations.

[96] Where the substation building is to be adopted by an IDNO.
[97] Forecasts of LCT connection should be obtained from the Northern Powergrid Distribution Future Energy Scenario (DFES) to establish future demand on the local LV network.
[98] For example, a substation site should be sufficiently large to accommodate a transformer adequate to supply forecasted future demand.

- to minimise statutory nuisance:
  - the substation chamber shall be of dimensions that attenuate, rather than amplify, transformer hum. At 100Hz, and assuming 330ms^{-1} as the velocity of sound, this means that dimensions approaching multiples of 3.5m should be avoided;
  - low-loss, and hence low noise, transformers, shall be used;
  - the transformer shall be mounted so as to damp vibration (e.g. via the use of anti-vibration pads);
  - ventilation shall be arranged so as to conduct noise away from the site;
  - a minimum of 3m clearance shall be provided between all conductors and any chamber likely to be used by the customer for electronic equipment; and
  - the chambers immediately adjoining the substation chamber shall not be such that they will, or might credibly at some time in the future, be used as dwellings. For example, in blocks of flats, only communal areas are permitted adjacent to the substation chamber.[99]

Stand-alone substation buildings shall, wherever practicable, have an internal volume less than 29m^3 to avoid the need to obtain planning permission.

Where future development is likely (e.g. in town centres or commercial/industrial estates), substation sites should, where possible, be large enough to accommodate a second transformer and associated HV and LV switchgear.

3.6.2 Routing of Circuits

When routing new mains cables, to discharge the obligation under section 9 of the Electricity Act, consideration shall be given to the potential for future network extension to cater for load development.

This means that cable size and route shall have due regard to credible future developments as well as to immediate need. For example, it may be appropriate to run a 300mm^2 rather than a 95mm^2 cable in a cul-de-sac to support a second phase of development, even though immediate connections might only require a lower capability. This will require dialogue between the licensee and, where appropriate, the connections provider.

LV mains shall be installed in the public highway. Care should be taken when accepting cable routes in ‘service strips’ and ‘mews courts’ as these may not become part of the public highway. Where adoption is assured, it is preferable to install mains in ‘service-strips’ rather than footpaths.

LV mains shall not be routed within the boundary of private properties and shall not be installed in footpaths at the rear of properties with only pedestrian access. Services (whether overhead or underground) shall be run only within the boundary of the premises each cable supplies, (i.e. a service to any one premises shall not cross land associated with another) and shall avoid running at angles across gardens of the premises.

Consideration should be given to locations where ducting is essential i.e. road/rail crossings, across bridges and town centre locations, and the associated cable de-rating. The Code of Practice for Guidance on the Selection of Underground Cable Ratings, IMP/001/013 shall be used to establish the laid direct and ducted ratings of cables.

In Areas of Outstanding Natural Beauty (AONB) and National Parks consideration should be given to installing underground cable instead of overhead lines when rebuilding an existing overhead line or constructing a new circuit. Approved Northern Powergrid asset reinforcement/replacement work

[99] SAGE report Second Interim Assessment 2009 – 2010, Electricity Distribution (including low-voltage and intermediate-voltage circuits and substations) and Report on Discussions on Science, Date of issue: 8 June 2020, provides further information.

programmes[100] should be checked to confirm ongoing/approved schemes for undergrounding LV assets in an AONB.

3.6.2.1 Underground Mains

In the interests of public safety and network resilience, mains and services should be installed underground.

When routing new mains cables, to discharge the obligations under section 9 of the Electricity Act and ESQCR regulations 3(1)(b) and 23(1), consideration shall be given to:

- the potential for future network extension to cater for load development;
- the possibility of an incident of inadvertent contact damaging more than one cable at the same time;
- the need for free access to cables; and
- the adverse impact on circuit capability if cables are in undue proximity.

This means that HV and LV cables from substations should be separated as far as it is economic so to do. For example, it may be appropriate to run one HV cable and two LV cables in each of two common trenches, one either side of the road, to balance economies in construction with effective ongoing operation.

3.6.2.2 Overhead Mains

In all cases an underground cable option is preferred unless uneconomic or impractical. New LV overhead lines shall only be erected in rural areas and where routes can be selected to minimise the impact on the environment and local amenity and where:

- the main would not create a high-risk site, as defined in the Guidance on the Risk Assessment of Overhead Lines, NSP/004/012;
- the route would not create other public hazard, e.g. crossing of railways or high-speed roads; and
- the cost of underground mains would be disproportionate, because either:
    - the length of mains per customer would be abnormally high; or
    - significant excavation and reinstatement costs might otherwise be incurred.[101]

Where LV overhead mains are to be installed, fully-insulated conductor shall be used. Unless disproportionate costs would otherwise be incurred, services from overhead mains and pole mounted transformers shall be run underground, to help ensure safety and reliability, and also to support discharge of the obligation under section 9 of the Electricity Act by facilitating future undergrounding of the network.

New LV overhead lines shall not be installed under any overhead lines operating at a higher voltage.

3.6.2.3 Services

All customer connections, including those provided from overhead lines, shall be made via dedicated underground services. Looped services for new connections are not permitted.

[100] Currently Northern Powergrid work programme; WP 14/05 holds the allocation for undergrounding LV assets.
[101] For example, if road crossings or significant lengths of cable within an existing footpath were required. For infill developments, the establishment by the developer of civil infrastructure will generally reduce these costs to a level where underground distributors remain economic.

Where existing looped connections are to be replaced new dedicated services shall be installed to each premises where reasonably practicable. This facilitates the future connection of LCT devices.

For new developments, the developer shall, in accordance with NJUG Volume 2, install a service tube with a draw-wire covered by tile tape in accordance with the Policy for the Installation of Power Cables, NSP/002 from each service position in a straight line[102] either:

- normal to an underground main; or
- to a point as close as practicable to the nearest pole supporting an overhead main.

The service tube shall be laid in the land of the final owner of the premises serviced. For outdoor meter positions a 'hockey stick' or equivalent shall be installed between the service tube and the meter cabinet to provide mechanical protection for the service cable. Designers shall have regard to the de-rating required when ducts are installed in cavity walls.

When replacing or re-locating existing assets, dedicated underground services as described above shall be provided.

[102] Provided that the service remains within the curtilage of the premises being supplied.

4. References

4.1 External Documentation

Reference	Title
BS 7657	Specification for Cut-Out Assemblies up to 100 A rating, for Power Supply to Buildings
BS 7671	British Standard Requirements for Electrical Installations (The IET Wiring Regulations)
BS IEC 60076-7 (IEC 354)	Guide to Loading of Oil-Immersed Power Transformers
CLNR-L186	Review of the Distribution Network Planning and Design Standards for the Future Low Carbon Electricity System
CLNR-L217	After Diversity Maximum Demand (ADMD) Report
EAW regulations	The Electricity at Work Regulations 1989
ENATS 09-8	Impregnated Paper Insulated 600/1000V Cable with Three Solid Aluminium Phase Conductors and Aluminium Sheath/Neutral Conductor (Consac)
ENATS 12-6	Time Fuse Links for Use with Current Transformer Releases on Circuit Breakers
ENATS 12-8	The Application of Fuse-links to 11kV/415V and 6.6kV/415V Underground Distribution Networks
ENATS 37-1	415V AC Switchgear, Control gear and Fusegear
ENATS 37-2	Low Voltage Distribution Fuse Boards
ENATS 43-8	Overhead Line Clearances
ENATS 43-13	Aerial Bundled Conductor Insulated with Cross-linked Polyethylene for Low Voltage Overhead Distribution
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
Engineering Recommendation G12	Requirements for The Application of Protective Multiple Earthing to Low Voltage Networks
Engineering Recommendation G100	Technical Requirements for Customers' Export and Import Limitation Schemes
Engineering Recommendation P2	Security of Supply
Engineering Recommendation P5	Design of LV Underground Networks for Housing Estates
Engineering Recommendation P23	Consumers' Earth Fault Protection for Compliance with the IET Wiring Regulations
Engineering Recommendation P25	The short-circuit characteristics of single phase and 3 phase Low Voltage distribution networks
Engineering Recommendation P27	Current Rating Guide for High Voltage Overhead Lines Operating in the UK Distribution System
Engineering Recommendation 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
ESQCR	The Electricity Supply, Quality and Continuity Regulations 2002
Guaranteed standards of performance	The Electricity (Standards of Performance) Regulations 2001
HASAWA 74	The Health and Safety at Work etc. Act 1974
IEC 853	Calculation of Cyclic and Emergency Current Ratings of Cables
IEEE 1584	Guide for Performing Arc-Flash Hazard Calculations
NJUG Volume 2	National Joint Utilities Group (NJUG) Guidelines on the Positioning of Underground Utilities Apparatus for New Development Sites

Reference	Title
Standard Licence Condition	Standard conditions of the Electricity Distribution Licence
SAGE report	SAGE report Second Interim Assessment 2009 – 2010, Electricity Distribution (including low-voltage and intermediate-voltage circuits and substations) and Report on Discussions on Science, Date of issue: 8 June 2020, provides further information.
The Act	The Electricity Act 1989 (as amended by the Utilities Act 2000, Energy Act 2004)
The Distribution Code	The Distribution Code of Great Britain
The Electricity (Unmetered Supply) regulations	Regulations 2001

4.2 Internal Documentation

Reference	Title
C1010662	Public lighting termination for 5th core control network, 16mm^2 CNE copper service cable
C1010669	Mains service breeches joint with 5th core connection, PILC main 5 cores with CNE single service
CNN/006/001	Code of practice for the maximum load of unmetered supplies
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/001/012	Code of Practice for Flood Mitigation at Operational Premises
IMP/001/013	Code of Practice for Underground Cable Ratings and Parameters
IMP/001/103	Code of Practice for the Methodology of Assessing Losses
IMP/001/206	Guidance for assessing Security of Supply in accordance with Engineering Recommendation P2/8
IMP/001/909	Code of Practice for Distribution System Parameters
IMP/001/912	Code of Practice for the Economic Development of the HV System
IMP/001/921	Code of Practice on Fusing
IMP/009	Policy for the Enclosure of Ground Mounted Distribution Substations
IMP/010/011	Code of Practice for Earthing LV Networks and HV Distribution Substations
IMP/011	Policy for Fire Mitigation at Operational Premises
MNT/006/001	Code of Practice for the Risk Assessment of Ground Mounted Sub Stations
NPS/001/007	Technical Specifications for Overhead line Conductors
NPS/002/019	Technical Specification for LV Distribution and Service Cables
NSP/002	Policy for 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/004/041	Code of Practice for the Construction of LV ABC Overhead Lines
NSP/004/041/001	Specification for the Renovation of Existing LV Overhead Lines
NSP/004/043	Specification for Overhead Services, Surface Wiring and Eaves Wall Mains

4.3 Amendments from Previous Version

Clause	Subject	Amendments
Whole document	Editorial	Minor editorial changes across the document.
3.3.2	Referral process	Design manager and planning manager references added.
3.3.3	Voltage & waveform quality	Guidance around clustered connections updated, HP & EVCP database details updated.
3.3.4	Voltage and waveform quality	Reference to HPs and electric vehicle charge points added.
3.3.5	Neutral and loop impedance	350mΩ clarification added.
3.4	Design approach and demand	Notes around smart metering and LV monitoring added. Methodology for assessing ADMD modified to component form for HPs and EVCPs.
3.4.2.1	Industrial and Commercial Demand	New section, with guidance tables for typical demands and diversity factors.
3.4.2.3	Heat Pumps (HP)	Cold load pickup guidance modified; communal HP guidance updated. ADMD equations combined and modified. Inline heater calculation modified.
3.4.2.4	Electric vehicles (EV)	ADMD equations modified.
3.4.2.7	Electricity storage systems	Section on electricity storage systems added.
3.4.2.8	Customer limitation schemes	Section on customer limitation schemes added.
3.5.2	Transformers	DFES guidance added, no. customers on small transformers modified, monitoring and cooling added.
3.5.3	Switchgear	Pad mount transformer enforced for 315kVA; 9 Way LV board added. Number of LV ways required at HV/LV substations increased, table added.
3.5.4.1	Underground Mains	No. customers per feeder and distribution substation modified. Small section mains guidance added.
3.5.4.2	Overhead Mains	Option for 185 ABC added, replacement mains and small section conductor clarifications added.
3.5.6	System security and interconnection	Interconnection guidance updated, interconnection scenarios revised, feeder pillars to replace link boxes. Customer numbers reduced.
3.7.1	Substation location	Load growth guidance added when considering a substation site.
3.7.2.3	Services	Looped service guidance updated.
Appendix 2	Table 13	ADMD table revised – GD + 16A EVCP removed. GD + HP + 32A EVCP added. Table added to provide an overview of ADMD assessment. Example added.
Appendix 6	System Configuration	Modified to reflect reduced customer numbers per feeder.
Appendix 7.2	Triple concentric systems	Modified to include reference to an increase in LCT installations.

5. Definitions

Term	Definition
ADMD	After Diversity Maximum Demand is the maximum demand to be catered for at a point in the system after taking into consideration the diversified (coincident peaks) demand which is aggregated to account for a large number of customers.
AONB	Area of Outstanding Natural Beauty is an outstanding landscape designated the status in recognition of its national importance and to ensure that its character and qualities are protected.
CNE	Combined Neutral/Earth (TN-C) is a system in which neutral and protective functions of earthing are combined in a single conductor throughout the system.
Design Team Manager	The manager responsible for tactical and strategic decisions associated with implementing this Code of Practice.
DETC	De-Energised Tap Changer. The correct IEC terminology for a tap changer that is only rated to operate when de-energised. The commonly used off-load tap changer implies tap changer can be operated when energised, but this is not the case.
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.
ENA	Energy Networks Association.
ENATS	ENA Technical Standard.
ER or EREC	(ENA) Engineering Recommendation.
EVCP	An electric vehicle charging point is a facility for charging an electric vehicle.
EV charging facility	One or more electric vehicle charging points located either in domestic, industrial, commercial premises or in a public location.
Fast Charger	An electric vehicle charger typically rated between 7kW and 22kW. Typically, AC with the DC converter being installed in the vehicle.
HP	A heat pump is a device that transfers heat from a colder area to a hotter area to heat premises.
HSE	Health and Safety Executive.
ICP	Independent Connections Provider is an accredited company that can build electricity networks to agreed standards and quality required for them to be owned by either a Distribution Network Operator such as Northern Powergrid or an Independent Distribution Network Operator.
IDNO	Independent Distribution Network Operators (IDNO) develop, operate and maintain electricity distribution networks. IDNO networks are directly connected to the Distribution Network Operator (DNO) networks or indirectly to the DNO via another IDNO.
IEC	International Electrotechnical Commission.
IET	The Institute of Engineering and Technology.
IEEE	The Institute of Electrical and Electronic Engineers.
IIS	Interruption Incentive Scheme has symmetric annual rewards and penalties depending on the DNO's performance against their targets for the number of customers interrupted per 100 customers (CI) and the number of customer minutes lost (CML).
Northern Powergrid	Northern Powergrid (Northeast) plc and Northern Powergrid (Yorkshire) plc.
PLA	Public Lighting Authority.
PME	Protective Multiple Earthing is an earthing arrangement found in TN-C-S systems in which the supply neutral conductor is used to connect the earthing conductor of an installation with earth in accordance with ESQCR 2002.
PSCC	Prospective Short Circuit Current.
Rapid charger	Chargers typically rated greater than 40kW typically DC (where the DC converter being in the charger).
Smart Grid Development Manager	The manager appropriate to the part of the network where the policy is being applied, who is accountable for the implementation of this policy. Will ensure responsible persons are appointed to implement this policy.

SNE	Separated Neutral/Earth (TN-S) arrangement has the neutral of the source of energy connected with earth at one point only, at or as near as is reasonably practicable to the source and the consumers earthing terminal is typically connected to the metallic sheath or amour of the DNO's service cable into the premises.
System Design Manager	The manager appropriate to the part of the network where the policy is being applied, who is accountable for the implementation of this policy. Will ensure responsible persons are appointed to implement this policy.
URMC	Unrestricted Tariff Medium Consumption is a profile of annual electrical energy consumption (kWh) based on a tariff.

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 authorisation.

		Date
Liz Beat	Governance Administrator	04/12/2023

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 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			
Should this document be displayed on the Northern Powergrid external website?			Yes
			Date
Chris Artist		Smart Grid Development Engineer	04/12/2023

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 authorisation.

		Date
Alan Creighton	Senior Smart Grid Development Engineer	15/05/2024
Phil Jagger	System Design Manager	12/12/2023
Mark Callum	Smart Grid Development Manager	11/12/2023

6.4 Authorisation

Authorisation is granted for publication of this document.

		Date
Mark Nicholson	Director of Engineering	21/05/2024

Appendix 1 – Short Circuit Levels

ESQC regulation 3 requires Northern Powergrid to ensure that equipment is sufficient for the purposes for and the circumstances in which it is used. Amongst other issues, this requires Northern Powergrid to assess system short circuit levels and define maximum prospective short circuit current (PSCC), to ensure that equipment is specified to withstand reasonably anticipated duty.

ENATS 37-1 requires LV switchgear and fusegear to withstand 43.3kA for 0.2s; 36kA for 1.0s; or 21.6kA for 3.0s, dependant on protection characteristics. ENATS 37-2 requires LV fuse boards to withstand only 18kA for 0.5s for single transformers up to 500kVA[103] and 35.5kA for 0.5s for larger units.[104] BS 7657 has superseded ENATS 12-10 and requires that single phase cut-outs up to 100A be rated at 16kA short-circuit current. Engineering Recommendations P25 and P26 give guidance as to estimating PSCC for LV connections as for Engineering Recommendation P23 and earth loop impedance, they do not mandate maximum short circuit levels. However, Engineering Recommendation P5 does create a requirement to control loop impedance to manage short circuit levels, specifically that, at the point of connection of any service cable to the LV distributor, the phase to neutral loop impedance should not be less than (0.00825 + j 0.0125) ohms to give a phase maximum design prospective short circuit current of 16kA at that point, assuming a nominal 240V.

These standard values may be compared to likely system conditions, using typical impedance values from Engineering Recommendation P28:

- a 1600 kVA transformer close to a high fault level primary gives a PSCC at 433V of around 36kA;
- a 1000 kVA transformer close to a high fault level primary gives a PSCC at 433V of around 26kA;
    - 20m of 300 mm^2 cable after such a transformer reduces PSCC at 433V to around 22kA; and
    - a further 10m of 25 mm^2 cable reduces PSCC at 433V to around 12kA.

It is appropriate to use these values for all sites, as HV system configuration will change during the life of the substation and the fault level infeed from the higher network may therefore approach the maximum values used here. Similarly, while a 500kVA transformer close to a high fault level primary reduces the PSCC at 433V to around 13kA, the potential for transformers to be replaced means that the higher values should be used.

These figures can be compared to the assumed maximum values quoted in Engineering Recommendation P25 of:

- 16kA at the junction of a single-phase service with the main;
- 18kA at the junction of a three-phase service and the main; and
- 25kA at the LV fuse board.

It can be seen that, in practice, slightly higher values can be found on the network than assumed in those engineering recommendations.

In accordance with the section 9 obligation, the contribution of customers connected at LV to these short circuit levels must also be addressed, and specifically the potential spread of generation. If we assume that 500kVA of generation with 10% impedance were connected to a typical network, then we might reasonably expect an additional fault level infeed of 5MVA. This equates to an additional short-circuit current of about 7kA at 433V, giving a potential PSCC of around 33 kA for a 1000kVA transformer, or 20kA for a 500kVA unit.

Similarly, the PSCC at connections close to a large transformer on a generation-rich system might be expected to rise. If the PSCC at the LV fuse board rose to 33 kA, the fault level for a three-phase connection would be expected to rise to around 30 kA, but still be 16kA for a single-phase 100A connection.

These figures require application of the higher ENATS 37-2 standard (35.5kA) to all LV fuse boards, and also confirm that most credible systems will remain within those limits.

Where more than 500 kVA of LV-connected generation is expected on a system, it may be necessary to reduce the size of transformer to constrain the contribution to fault level from the HV system. Individual studies will be required for each such scheme but as noted earlier, standard values should still be used for the fault level infeed from the higher system.

In summary, short circuit levels to accommodate infeed from the higher system and LV-connected generation are:

[103] The paper actually quotes 800A, or about 600kVA.

[104] Up to 1600A, or about 1000kVA: 50kA rating is required for the largest units, but these are approved only for individual customer connections and not for use on the general network.

- 16kA for single-phase connections up to 100 A, consistent with BS 7657;
- 30kA for other connections; and
- 35.5kA for equipment at general network substations.

These figures may be quoted to customers as ‘maximum design values’.

Similarly, fault infeed from the higher-voltage system can be taken as:

- 16kA for single-phase connections up to 100 A, consistent with BS 7657;
- 22kA for other connections; and
- 26kA at substation LV busbars.

In the absence of site-specific assessment, these figures may be quoted to customers as ‘typical maximum values’.

Appendix 2 - Design Demands

This appendix provides:

- further details on the P-Q approach for estimation of design demands derived in the ACE 49 Report including the explanations of the parameters. It also details the set of new P and Q values calculated by the CLNR project for the LCTs considered in this Code of Practice based on the P-Q approach; and
- a worked example calculating the design demand for an asset supplying 200 customers based on the previous domestic load ADMD and new domestic load ADMD plus new ADMDs for the different demand LCTs considered in this Code of Practice.

A2.1 P-Q Approach

The statistical method for the estimation of demand is based on studies performed over a number of years in the 1970s which concluded that:

- The mean demand caused by a group of customers in any half hour during the central winter period, November to March, is approximately proportional to the annual unit consumption of those customers; and
- The demands for any half-hour of weekdays during the central winter period have a statistical distribution that can be regarded as normal.

The statistical method uses these two observations to define the design demand as the mean demand plus a number of standard deviations from that mean value. These are derived for different times of the day and thus the basic expression used for the design demand over any half-hour during the central winter period for a group of customers is given by Equation 9.

$$\boldsymbol{D = G + Z \cdot \sigma} \qquad \textit{(9)}$$

'*D*' is the design demand, '*G*' is the mean demand over the half-hour being considered, '*σ*' is the standard deviation of the distribution of demands over the half-hour being considered and '*Z*' is the chosen number of standard deviations added to the mean for design purposes.

The mean demand and the standard deviation components of equation 1 can be represented by equation 10 and Equation 11 respectively.

$$\boldsymbol{G = N \cdot C \cdot \Psi} \qquad \textit{(10)}$$

'*N*' is the number of customers, '*C*' is average annual unit consumption and '*Ψ*' is the demand estimation coefficient (i.e. constant of proportionality) for that half-hour.

$$\boldsymbol{\sigma = N \cdot C \cdot \Psi \cdot \sqrt{\sigma_1^2 + \sigma_2^2 + \frac{\sigma_3^2}{N}}} \qquad \textit{(11)}$$

'σ_3^2' is the relative variance due to the differences between individual customers within a group, 'σ_2^2' is the relative variance due to the temperature sensitivity of demand and 'σ_1^2' is the relative variance due to residual causes.

Approximating the central winter demand for any half-hour to a normal distribution and considering the mean demand '*G*' as the design demand, it would be concluded that there is a 50% probability that the demand could exceed the design demand. Moreover, selecting a number of standard deviations '*Z*' equal to 1 leads to a 15.9% probability of exceeding the design demand. Under two standard deviations, the probability of exceeding the design demand falls to 2.3%. Hence, it is possible to design a more, or less, robust network circuit (i.e. LV cable or overhead line) depending on the number of standard deviations of the mean demand included to produce the design demand.

The ACE 49 Report considers that the acceptable level of risk probability of meeting demand within the design voltage regulation is 90% (i.e. the 90^{th} percentile of the standard normal distribution). This probability is obtained by adding to the mean demand 1.28 standard deviations. Thus, the design demand for a group of customers can be expressed by Equation 12.

$$D = G + 1.28 \cdot \sigma \qquad (12)$$

Since the values of '*C*', '*Ψ*', 'σ_1', 'σ_2' and 'σ_3' can be determined for a given type of customer then Equation 4 can be simplified. In this respect, the design demand per customer, for a group of size '*N*' customers can be written as in Equation 13.

$$\overline{D} = P + \frac{Q}{\sqrt{N}} \qquad (13)$$

'$\overline{D}$' is the design demand per customer over the half-hour being considered, '*P*' is the mean demand per customer over the half-hour being considered and '*Q*' is the chosen number of standard deviations (based on the 90th percentile of the standard normal distribution) times the standard deviation of the customer demand distribution over the half-hour being considered. The values of '*P*' and '*Q*' have been calculated for various types of customer and are tabulated in the Appendix of the ACE 49 Report.

The design demand per customer in Equation can be expanded to define the design demand for group of '*N*' customers in the half-hour being considered over the central winter period as in Equation 14.

$$D = \overline{D} \cdot N = N \cdot P + Q \cdot \sqrt{N} \qquad (14)$$

The values of '*P*' and '*Q*' are dependent upon the annual unit consumption '*C*' of the customers. In order to have values that are independent of a particular customers' unit consumption, the values of '*P*' and '*Q*' can be rewritten as in Equation 15 and Equation 16 respectively.

$$P = p \cdot C \qquad (15)$$

$$Q = q \cdot C \qquad (16)$$

The factor 'p' is called the mean demand factor whilst the factor 'q' is termed as the enhancement demand factor. These factors are provided in the Appendix of the ACE 49 Report for various types of customers together with the associated '*P*' and '*Q*' values.

The mean demand factor '*p*' is defined in Equation 17 as follows:

$$p(\textit{Mean demand factor}) = \frac{P(\textit{Average demand per half-hour})}{C(\textit{Annual unit consumption in kWh})} \cdot 10^3 \qquad (17)$$

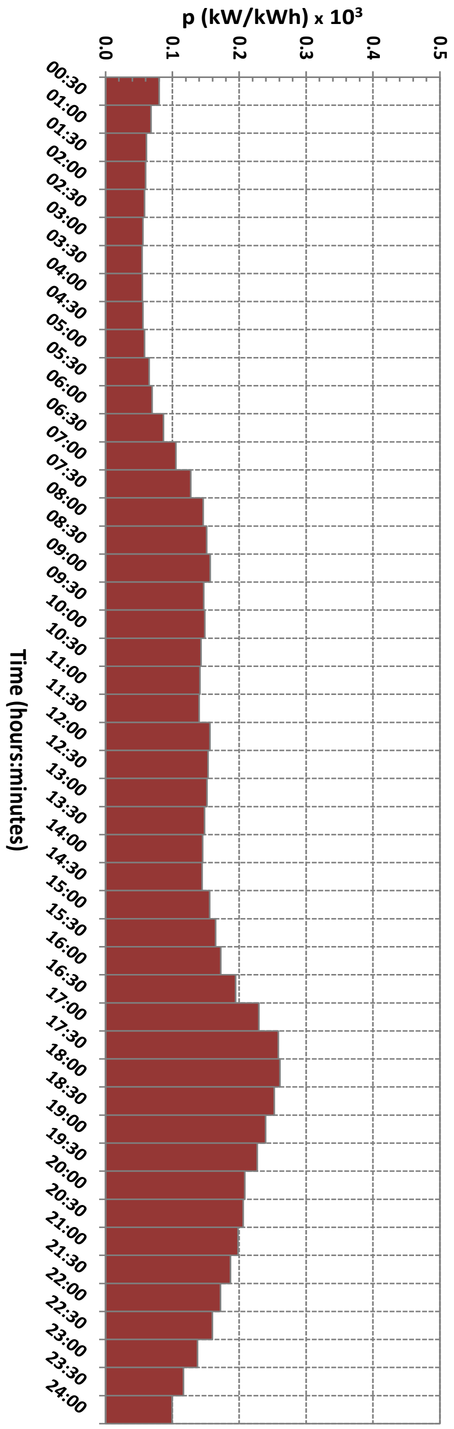
The enhancement demand factor '*q*' is defined in Equation 18 as follows:

$$q(\textit{Enhancement demand factor}) = \frac{Q(\textit{Enhancement demand per half-hour})}{C(\textit{Annual unit consumption in kWh})} \cdot 10^3 \qquad (18)$$

The following tables detail the P & Q values for the individual profiles to be used for the DEBUT calculations employed by the LV Design software package in Northern Powergrid Northeast.

Domestic Load Profile: P & Q values[105]

Time	p	q	P	Q
00:30	0.080	0.109	0.29	0.39
01:00	0.068	0.081	0.24	0.29
01:30	0.061	0.073	0.22	0.26
02:00	0.060	0.093	0.21	0.33
02:30	0.058	0.102	0.21	0.36
03:00	0.056	0.074	0.20	0.27
03:30	0.055	0.071	0.20	0.25
04:00	0.055	0.078	0.20	0.28
04:30	0.056	0.071	0.20	0.25
05:00	0.059	0.078	0.21	0.28
05:30	0.065	0.103	0.23	0.37
06:00	0.070	0.107	0.25	0.38
06:30	0.087	0.142	0.31	0.51
07:00	0.105	0.161	0.38	0.57
07:30	0.127	0.174	0.45	0.62
08:00	0.146	0.193	0.52	0.69
08:30	0.151	0.199	0.54	0.71
09:00	0.157	0.217	0.56	0.77
09:30	0.147	0.182	0.52	0.65
10:00	0.148	0.200	0.53	0.71
10:30	0.143	0.185	0.51	0.66
11:00	0.141	0.183	0.50	0.65
11:30	0.140	0.180	0.50	0.64
12:00	0.156	0.277	0.56	0.99
12:30	0.153	0.221	0.55	0.79
13:00	0.152	0.216	0.54	0.77
13:30	0.148	0.187	0.53	0.67
14:00	0.145	0.186	0.52	0.66
14:30	0.144	0.184	0.51	0.66
15:00	0.156	0.213	0.55	0.76
15:30	0.165	0.204	0.59	0.73
16:00	0.172	0.208	0.61	0.74
16:30	0.195	0.225	0.69	0.80
17:00	0.229	0.263	0.82	0.94
17:30	0.258	0.295	0.92	1.05
18:00	0.261	0.272	0.93	0.97
18:30	0.252	0.259	0.90	0.92
19:00	0.239	0.239	0.85	0.85
19:30	0.227	0.222	0.81	0.79
20:00	0.208	0.195	0.74	0.70
20:30	0.206	0.207	0.73	0.74
21:00	0.198	0.187	0.71	0.67
21:30	0.187	0.212	0.67	0.76
22:00	0.172	0.153	0.61	0.55
22:30	0.160	0.156	0.57	0.56
23:00	0.138	0.136	0.49	0.49
23:30	0.116	0.125	0.41	0.45
24:00	0.099	0.123	0.35	0.44

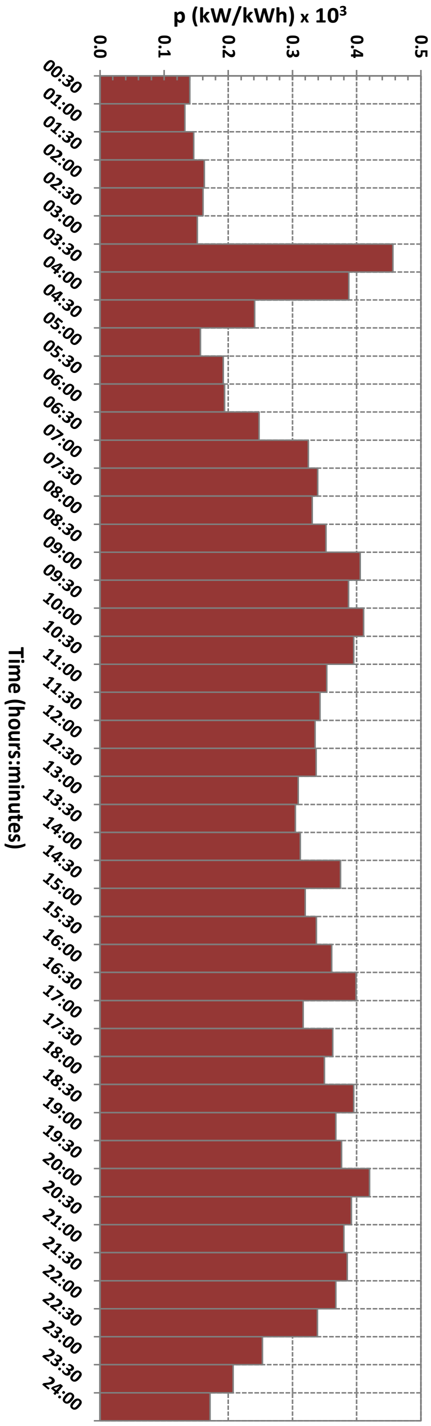


'*P*' and '*Q*' values were obtained from '*p*' and '*q*' respectively using a sample average annual consumption of 3,565kWh.

[105] CLNR-186 p. 56.

Heat Pumps: P & Q values[106]

Time	p	q	P	Q
00:30	0.140	0.251	0.38	0.69
01:00	0.132	0.220	0.36	0.60
01:30	0.146	0.247	0.40	0.68
02:00	0.162	0.267	0.45	0.73
02:30	0.161	0.261	0.44	0.72
03:00	0.152	0.233	0.42	0.64
03:30	0.457	0.482	1.25	1.32
04:00	0.388	0.623	1.06	1.71
04:30	0.241	0.357	0.66	0.98
05:00	0.157	0.321	0.43	0.88
05:30	0.192	0.549	0.53	1.51
06:00	0.194	0.321	0.53	0.88
06:30	0.248	0.311	0.68	0.85
07:00	0.325	0.368	0.89	1.01
07:30	0.339	0.377	0.93	1.03
08:00	0.331	0.309	0.91	0.85
08:30	0.352	0.311	0.97	0.85
09:00	0.406	0.543	1.11	1.49
09:30	0.387	0.303	1.06	0.83
10:00	0.411	0.376	1.13	1.03
10:30	0.395	0.337	1.08	0.92
11:00	0.353	0.346	0.97	0.95
11:30	0.343	0.301	0.94	0.83
12:00	0.335	0.294	0.92	0.81
12:30	0.337	0.269	0.92	0.74
13:00	0.309	0.295	0.85	0.81
13:30	0.305	0.281	0.83	0.77
14:00	0.312	0.298	0.86	0.82
14:30	0.375	0.429	1.03	1.18
15:00	0.320	0.292	0.88	0.80
15:30	0.337	0.279	0.92	0.76
16:00	0.361	0.327	0.99	0.90
16:30	0.399	0.676	1.09	1.85
17:00	0.317	0.306	0.87	0.84
17:30	0.363	0.326	0.99	0.89
18:00	0.350	0.292	0.96	0.80
18:30	0.395	0.372	1.08	1.02
19:00	0.368	0.454	1.01	1.24
19:30	0.376	0.325	1.03	0.89
20:00	0.420	0.392	1.15	1.07
20:30	0.392	0.397	1.07	1.09
21:00	0.380	0.417	1.04	1.14
21:30	0.385	0.444	1.06	1.22
22:00	0.368	0.415	1.01	1.14
22:30	0.339	0.385	0.93	1.06
23:00	0.253	0.388	0.69	1.06
23:30	0.208	0.365	0.57	1.00
24:00	0.172	0.317	0.47	0.87

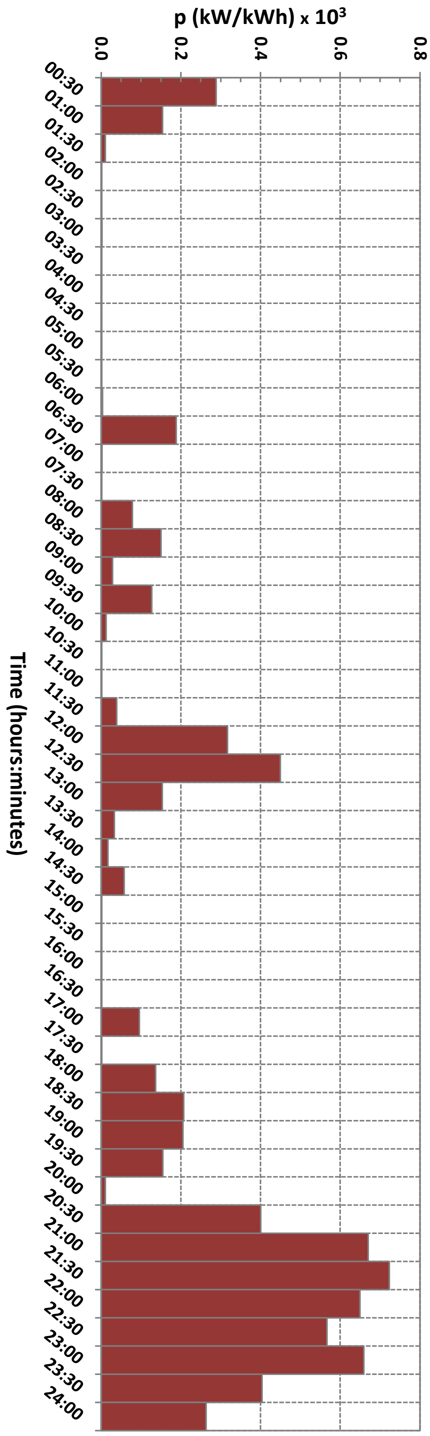


'P' and 'Q' values were obtained from 'p' and 'q' respectively using a sample average annual consumption of 2,741kWh.

[106] CLNR-186 p. 75.

EVCP (16A charger): P & Q values[107]

Time	p	q	P	Q
00:30	0.289	0.610	2.01	4.26
01:00	0.154	0.338	1.08	2.36
01:30	0.011	0.020	0.07	0.14
02:00	0.002	0.001	0.01	0.00
02:30	0.002	0.000	0.01	0.00
03:00	0.002	0.000	0.01	0.00
03:30	0.002	0.001	0.01	0.00
04:00	0.002	0.000	0.01	0.00
04:30	0.002	0.000	0.01	0.00
05:00	0.002	0.000	0.01	0.00
05:30	0.002	0.000	0.01	0.00
06:00	0.003	0.003	0.02	0.02
06:30	0.189	0.414	1.32	2.89
07:00	0.002	0.000	0.01	0.00
07:30	0.001	0.001	0.01	0.00
08:00	0.079	0.123	0.55	0.86
08:30	0.150	0.287	1.05	2.00
09:00	0.029	0.069	0.20	0.48
09:30	0.127	0.304	0.89	2.13
10:00	0.012	0.024	0.09	0.17
10:30	0.002	0.000	0.01	0.00
11:00	0.002	0.000	0.01	0.00
11:30	0.039	0.083	0.27	0.58
12:00	0.317	0.554	2.22	3.87
12:30	0.450	0.589	3.14	4.12
13:00	0.153	0.272	1.07	1.90
13:30	0.033	0.070	0.23	0.49
14:00	0.017	0.034	0.12	0.24
14:30	0.058	0.124	0.40	0.87
15:00	0.002	0.000	0.01	0.00
15:30	0.001	0.000	0.01	0.00
16:00	0.002	0.000	0.01	0.00
16:30	0.002	0.000	0.01	0.00
17:00	0.096	0.210	0.67	1.46
17:30	0.002	0.000	0.01	0.00
18:00	0.137	0.299	0.95	2.09
18:30	0.207	0.455	1.45	3.18
19:00	0.205	0.451	1.43	3.15
19:30	0.155	0.339	1.08	2.37
20:00	0.011	0.021	0.08	0.14
20:30	0.401	0.512	2.80	3.58
21:00	0.670	0.527	4.68	3.68
21:30	0.723	0.350	5.05	2.44
22:00	0.650	0.578	4.54	4.04
22:30	0.566	0.582	3.96	4.07
23:00	0.659	0.446	4.60	3.12
23:30	0.404	0.537	2.82	3.75
24:00	0.263	0.580	1.84	4.05



'*P*' and '*Q*' values were obtained from '*p*' and '*q*' respectively using a sample average annual consumption of 6,983kWh.

[107] CLNR-186 p. 76.

A2.2 ADMD Design Demand

Figure 1 gives an example of the cumulative design demand for an asset supplying up to 200 customers calculated based on the previous and new ADMD values for domestic load and new ADMD for the LCT device demand detailed in the section 3.3.4.

It can be seen that the cumulative design demand for general domestic load based on the ADMD figures is higher between 10 and 90 customers compared to previous ADMD of 2kW; post 90 customers it diversifies significantly to being 365kW for 200 customers. It can also be observed that the cumulative design demand for 200 domestic customers with a HP equates to circa 420kW and similarly 200 domestic customers each with 32A EVCP equates to 915kW. Finally, the cumulative design demand for 200 domestic customers with a 32A EVCP and 3kW HP increases significantly to 979kW.

In Northern Powergrid Yorkshire, which uses the ADMD MS Excel calculator, the cumulative design demand stated above can be divided by number of customers to come up with an equivalent ADMD to be used in the calculator for voltage regulation purposes and to ensure that the thermal capacity of assets is not exceeded.

The Design Demand Calculator uses the formulas provided in sections 3.4.2.2 to 3.4.2.5 to assess the total demand for up to 1000 connections. The calculator summates General Domestic (GD), heating, commercial and EVCP demand components separately. The resultant values can then be summated to obtain the design demand. This method allows the diversity built into General Domestic, HP and domestic single phase 16A and 32A EVCP assessments to remain. Table 13 shows a breakdown of the components of the ADMD equations provided in sections 3.4.2.2 to 3.4.2.5.

Table 13: Assessment of ADMD components[108]

<table>
<tr><th>Premises Demand Type</th><th>General Domestic/I&C Component (kW)</th><th>Heating Component (kW)</th><th>EVCP Component (kW)</th></tr>
<tr><td>GD Only</td><td>ADMD = $4.60n^{-0.22}$</td><td>N/A</td><td rowspan="7">1ph 16A EVCP = $2.59n^{-0.15}$
1ph 32A EVCP = $5.18n^{-0.15}$

Any other EVCP = 100% requested load</td></tr>
<tr><td>GD & HP</td><td>ADMD = $4.60n^{-0.22}$</td><td>$h(2.03n^{-0.25}-1.53n^{-0.22})$</td></tr>
<tr><td>GD & HP + inline heater</td><td>ADMD = $4.60n^{-0.22}$</td><td>$h(2.03n^{-0.25}-1.53n^{-0.22}) + i$</td></tr>
<tr><td>GD & D.A.S.H</td><td colspan="2">ADMD = 1 + (0.5 x D.A.S.H load)</td></tr>
<tr><td>GD & Storage Heating Day</td><td>ADMD = $4.60n^{-0.22}$</td><td>0.1 x installed heating load</td></tr>
<tr><td>GD & Storage Heating Night</td><td>ADMD = $4.60n^{-0.22}$</td><td>0.6 x installed heating load</td></tr>
<tr><td>GD & Other Electric Heating</td><td colspan="2">ADMD = 1 + installed load</td></tr>
<tr><td>EVCP Only</td><td>n/a</td><td>n/a</td><td>100% requested load</td></tr>
<tr><td>Industrial & Commercial</td><td colspan="2">100% requested demand</td><td>n/a</td></tr>
</table>

[108] Where n represents the nth customer supplied from the system assets being designed, h represents the HP system maximum demand (kW) and i represents the rating of inline heater (kW).

Table 14 shows an example assessment for ten domestic premises each with 3kW HPs and 32A EVCP. These values are calculated in line with sections 3.4.2.2 to 3.4.2.5 and the assessment components in Table 13.

Table 14: Example ADMD assessment for 10 domestic premises each with a 3kW HP and 32A EVCP

Premises (n)	GD Component (kW)	Heat Component (kW)	EVCP Component (kW)	Total (kW)
1	4.6	1.5	5.2	11.3
2	3.9	1.2	4.7	9.8
3	3.6	1.0	4.4	9.0
4	3.4	0.9	4.2	8.5
5	3.2	0.9	4.1	8.2
6	3.1	0.8	4.0	7.9
7	3.0	0.8	3.9	7.6
8	2.9	0.7	3.8	7.4
9	2.8	0.7	3.7	7.3
10	2.8	0.7	3.7	7.1
Total	**33.4**	**9.1**	**41.6**	**84.1**

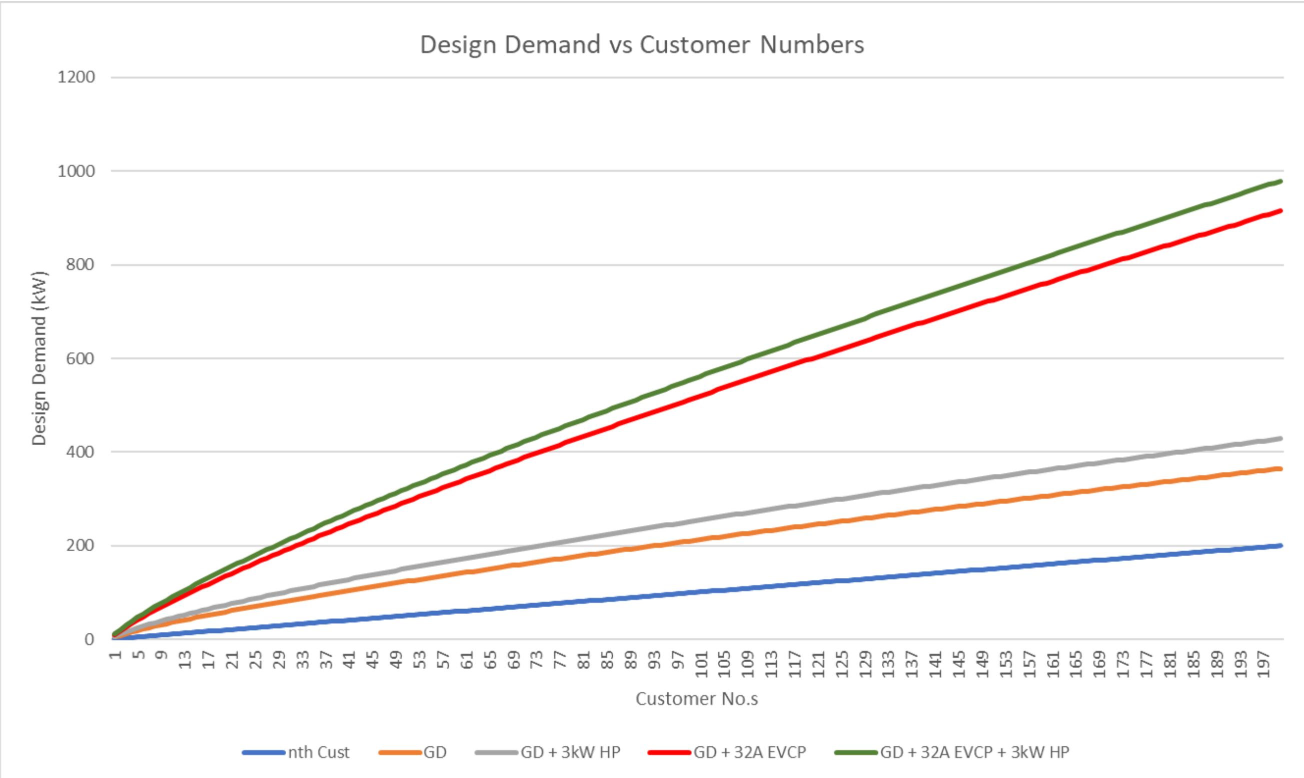


Figure 1: Design demand (based on n^{th} customer ADMD) for GD + associated LCTs

Table 15 – nth customer ADMD (kW) and cumulative design demand (kW)

Customer No.	GD		GD + 3kW HP		GD + 32A EVCP		GD + 3kW HP+ 32A EVCP	
	Design demand of the nth customer	Cumulative design demand	Design demand of the nth customer	Cumulative design demand	Design demand of the nth customer	Cumulative design demand	Design demand of the nth customer	Cumulative design demand
1	4.6	4.6	6.1	6.1	9.8	9.8	11.3	11.3
2	3.9	8.5	5.1	11.2	8.6	18.4	9.8	21.1
3	3.6	12.2	4.6	15.9	8.0	26.4	9.0	30.1
4	3.4	15.6	4.3	20.2	7.6	34.0	8.5	38.6
5	3.2	18.8	4.1	24.3	7.3	41.3	8.1	46.7
6	3.1	21.9	3.9	28.2	7.1	48.4	7.9	54.6
7	3.0	24.9	3.8	31.9	6.9	55.2	7.6	62.2
8	2.9	27.8	3.6	35.5	6.7	61.9	7.4	69.6
9	2.8	30.6	3.5	39.1	6.6	68.5	7.2	76.9
10	2.8	33.4	3.4	42.5	6.4	74.9	7.1	84.0
11	2.7	36.1	3.3	45.8	6.3	81.3	7.0	90.9
12	2.7	38.8	3.3	49.1	6.2	87.5	6.8	97.8
13	2.6	41.4	3.2	52.3	6.1	93.6	6.7	104.5
14	2.6	44.0	3.2	55.5	6.1	99.7	6.6	111.1
15	2.5	46.5	3.1	58.6	6.0	105.7	6.5	117.7
16	2.5	49.0	3.1	61.6	5.9	111.6	6.5	124.1
17	2.5	51.5	3.0	64.6	5.9	117.4	6.4	130.5
18	2.4	53.9	3.0	67.6	5.8	123.2	6.3	136.8
19	2.4	56.3	2.9	70.5	5.7	129.0	6.2	143.1
20	2.4	58.7	2.9	73.4	5.7	134.7	6.2	149.3
21	2.4	61.0	2.8	76.3	5.6	140.3	6.1	155.4
22	2.3	63.4	2.8	79.1	5.6	145.9	6.1	161.5
23	2.3	65.7	2.8	81.9	5.5	151.4	6.0	167.5
24	2.3	68.0	2.8	84.6	5.5	156.9	6.0	173.4
25	2.3	70.2	2.7	87.3	5.5	162.4	5.9	179.4
26	2.2	72.5	2.7	90.0	5.4	167.8	5.9	185.2
27	2.2	74.7	2.7	92.7	5.4	173.2	5.8	191.1
28	2.2	76.9	2.7	95.4	5.4	178.6	5.8	196.9
29	2.2	79.1	2.6	98.0	5.3	183.9	5.8	202.6
30	2.2	81.3	2.6	100.6	5.3	189.2	5.7	208.3

Customer No.	GD		GD + 3kW HP		GD + 32A EVCP		GD + 3kW HP+ 32A EVCP	
	Design demand of the n^{th} customer	Cumulative design demand	Design demand of the n^{th} customer	Cumulative design demand	Design demand of the n^{th} customer	Cumulative design demand	Design demand of the n^{th} customer	Cumulative design demand
31	2.2	83.4	2.6	103.2	5.3	194.4	5.7	214.0
32	2.1	85.6	2.6	105.8	5.2	199.6	5.6	219.6
33	2.1	87.7	2.5	108.3	5.2	204.8	5.6	225.3
34	2.1	89.8	2.5	110.8	5.2	210.0	5.6	230.8
35	2.1	91.9	2.5	113.3	5.1	215.2	5.5	236.4
36	2.1	94.0	2.5	115.8	5.1	220.3	5.5	241.9
37	2.1	96.1	2.5	118.3	5.1	225.4	5.5	247.4
38	2.1	98.2	2.5	120.8	5.1	230.4	5.5	252.8
39	2.1	100.2	2.4	123.2	5.0	235.5	5.4	258.2
40	2.0	102.3	2.4	125.6	5.0	240.5	5.4	263.6
41	2.0	104.3	2.4	128.0	5.0	245.5	5.4	269.0
42	2.0	106.3	2.4	130.4	5.0	250.5	5.3	274.4
43	2.0	108.3	2.4	132.8	5.0	255.4	5.3	279.7
44	2.0	110.3	2.4	135.2	4.9	260.4	5.3	285.0
45	2.0	112.3	2.4	137.5	4.9	265.3	5.3	290.3
46	2.0	114.3	2.3	139.9	4.9	270.2	5.3	295.5
47	2.0	116.3	2.3	142.2	4.9	275.1	5.2	300.8
48	2.0	118.3	2.3	144.5	4.9	279.9	5.2	306.0
49	2.0	120.2	2.3	146.8	4.8	284.8	5.2	311.2
50	1.9	122.2	2.3	149.1	4.8	289.6	5.2	316.3
51	1.9	124.1	2.3	151.4	4.8	294.4	5.2	321.5
52	1.9	126.0	2.3	153.7	4.8	299.2	5.1	326.6
53	1.9	127.9	2.3	156.0	4.8	304.0	5.1	331.7
54	1.9	129.9	2.3	158.2	4.8	308.7	5.1	336.8
55	1.9	131.8	2.2	160.4	4.7	313.5	5.1	341.9
56	1.9	133.7	2.2	162.7	4.7	318.2	5.1	347.0
57	1.9	135.5	2.2	164.9	4.7	322.9	5.0	352.0
58	1.9	137.4	2.2	167.1	4.7	327.6	5.0	357.0
59	1.9	139.3	2.2	169.3	4.7	332.3	5.0	362.0
60	1.9	141.2	2.2	171.5	4.7	337.0	5.0	367.0
61	1.9	143.0	2.2	173.7	4.7	341.6	5.0	372.0

Customer No.	GD		GD + 3kW HP		GD + 32A EVCP		GD + 3kW HP+ 32A EVCP	
	Design demand of the nth customer	Cumulative design demand	Design demand of the nth customer	Cumulative design demand	Design demand of the nth customer	Cumulative design demand	Design demand of the nth customer	Cumulative design demand
62	1.9	144.9	2.2	175.9	4.6	346.3	5.0	377.0
63	1.8	146.7	2.2	178.0	4.6	350.9	4.9	381.9
64	1.8	148.6	2.2	180.2	4.6	355.5	4.9	386.8
65	1.8	150.4	2.1	182.3	4.6	360.1	4.9	391.8
66	1.8	152.2	2.1	184.5	4.6	364.7	4.9	396.7
67	1.8	154.1	2.1	186.6	4.6	369.3	4.9	401.5
68	1.8	155.9	2.1	188.7	4.6	373.9	4.9	406.4
69	1.8	157.7	2.1	190.8	4.6	378.4	4.9	411.3
70	1.8	159.5	2.1	193.0	4.5	383.0	4.8	416.1
71	1.8	161.3	2.1	195.1	4.5	387.5	4.8	421.0
72	1.8	163.1	2.1	197.2	4.5	392.0	4.8	425.8
73	1.8	164.9	2.1	199.2	4.5	396.6	4.8	430.6
74	1.8	166.7	2.1	201.3	4.5	401.1	4.8	435.4
75	1.8	168.5	2.1	203.4	4.5	405.5	4.8	440.1
76	1.8	170.2	2.1	205.5	4.5	410.0	4.8	444.9
77	1.8	172.0	2.1	207.5	4.5	414.5	4.8	449.7
78	1.8	173.8	2.1	209.6	4.5	419.0	4.7	454.4
79	1.8	175.5	2.0	211.6	4.4	423.4	4.7	459.1
80	1.8	177.3	2.0	213.7	4.4	427.8	4.7	463.9
81	1.7	179.0	2.0	215.7	4.4	432.3	4.7	468.6
82	1.7	180.8	2.0	217.7	4.4	436.7	4.7	473.3
83	1.7	182.5	2.0	219.7	4.4	441.1	4.7	478.0
84	1.7	184.2	2.0	221.8	4.4	445.5	4.7	482.6
85	1.7	186.0	2.0	223.8	4.4	449.9	4.7	487.3
86	1.7	187.7	2.0	225.8	4.4	454.3	4.7	492.0
87	1.7	189.4	2.0	227.8	4.4	458.6	4.6	496.6
88	1.7	191.1	2.0	229.8	4.4	463.0	4.6	501.2
89	1.7	192.9	2.0	231.7	4.4	467.4	4.6	505.9
90	1.7	194.6	2.0	233.7	4.3	471.7	4.6	510.5
91	1.7	196.3	2.0	235.7	4.3	476.0	4.6	515.1
92	1.7	198.0	2.0	237.7	4.3	480.4	4.6	519.7

Customer No.	GD		GD + 3kW HP		GD + 32A EVCP		GD + 3kW HP+ 32A EVCP	
	Design demand of the nth customer	Cumulative design demand	Design demand of the nth customer	Cumulative design demand	Design demand of the nth customer	Cumulative design demand	Design demand of the nth customer	Cumulative design demand
93	1.7	199.7	2.0	239.6	4.3	484.7	4.6	524.3
94	1.7	201.4	2.0	241.6	4.3	489.0	4.6	528.9
95	1.7	203.1	2.0	243.5	4.3	493.3	4.6	533.4
96	1.7	204.7	1.9	245.5	4.3	497.6	4.6	538.0
97	1.7	206.4	1.9	247.4	4.3	501.9	4.5	542.5
98	1.7	208.1	1.9	249.4	4.3	506.2	4.5	547.1
99	1.7	209.8	1.9	251.3	4.3	510.5	4.5	551.6
100	1.7	211.4	1.9	253.2	4.3	514.7	4.5	556.1
101	1.7	213.1	1.9	255.2	4.3	519.0	4.5	560.6
102	1.7	214.8	1.9	257.1	4.3	523.2	4.5	565.1
103	1.7	216.4	1.9	259.0	4.2	527.5	4.5	569.6
104	1.7	218.1	1.9	260.9	4.2	531.7	4.5	574.1
105	1.7	219.7	1.9	262.8	4.2	535.9	4.5	578.6
106	1.6	221.4	1.9	264.7	4.2	540.2	4.5	583.1
107	1.6	223.0	1.9	266.6	4.2	544.4	4.5	587.5
108	1.6	224.7	1.9	268.5	4.2	548.6	4.5	592.0
109	1.6	226.3	1.9	270.4	4.2	552.8	4.4	596.4
110	1.6	227.9	1.9	272.3	4.2	557.0	4.4	600.9
111	1.6	229.6	1.9	274.2	4.2	561.2	4.4	605.3
112	1.6	231.2	1.9	276.0	4.2	565.4	4.4	609.7
113	1.6	232.8	1.9	277.9	4.2	569.5	4.4	614.2
114	1.6	234.5	1.9	279.8	4.2	573.7	4.4	618.6
115	1.6	236.1	1.9	281.6	4.2	577.9	4.4	623.0
116	1.6	237.7	1.9	283.5	4.2	582.0	4.4	627.4
117	1.6	239.3	1.9	285.4	4.1	586.2	4.4	631.8
118	1.6	240.9	1.9	287.2	4.1	590.3	4.4	636.1
119	1.6	242.5	1.8	289.1	4.1	594.4	4.4	640.5
120	1.6	244.1	1.8	290.9	4.1	598.6	4.4	644.9

Appendix 3 - Transformer Selection - Maximum Economic Initial Loading

The initial economic loading of a transformer has been assessed in accordance with the Code of Practice for the Methodology of Assessing Losses, IMP/001/103 taking into account the difference in costs of transformers, typical Load Loss Factors for demand, wind farm output, PV output and the cost of losses. The LLF for solar, wind and domestic profiles was 0.1, 0.15 and between 0.08 and 0.245 respectively depending on typical customer numbers on transformer size; as observed from the CLNR trials.

A 0.5% annual growth for the domestic load profile, zero growth on solar and wind were used in the modelling. The results of the analysis were rounded up to the nearest 5kVA and are presented in Table 16.

The analysis indicated that in the case of a transformer supplying a PV installation, the economic loading was in excess of the nameplate rating. Further assessment was therefore undertaken to assess if this would have any adverse implications on the transformer loss of life.

The Guide to Loading of Oil-Immersed Power Transformers, BS IEC 60076-7:2005, details a mathematical approach for modelling the thermal ageing and loss of life (LOL) of transformers. The modelling approach applying the differential equations from section 8.2.3 of BS IEC 60076-7:2005 was applied to a typical 315kVA distribution transformer from Schneider to calculate the loss of life for different loadings.

The differential equations have multiple inputs including thermal characteristics constant which were obtained from Table 5 of BS IEC 60076-7 for ONAN Transformers. The hot spot temperature rise for the rated current input was obtained from the Schneider Test Sheet. The output of the solar farm connected to Stow 33/11kV substation was used as the load curve input and the corresponding daily temperature was used.

The results of the analysis i.e. the percentage loss of life for a distribution transformer is presented in the following Table 16.

Table 16 – Loss of life results on distribution transformers

Loading %	LOL/DAY in hours	LOL/YEAR in days	% LOL over lifetime
100	0.22	9.24	3%
105	0.41	17.22	5%
110	0.75	31.5	9%
115	1.37	57.54	16%
120	2.5	105	29%

The exact lifetime of the transformer is unknown but as long it is maintained in good condition (good ventilation, oil checks, protection from weathering) a small amount of accelerated ageing is considered to be acceptable. Hence, a 10 % initial overloading equating to a 9% loss of life for a transformer supplying PV installation is deemed to be acceptable.

Appendix 4 - Service Lengths

40m is considered to be a pragmatic limit on the length of a new service cable installed in the public highway taking into account:

- Experience designing LV systems and services shows that capping the service cable length to 40m is usually achievable without installing an excessive length of LV main. When designing a new service connection to the end of a LV main whilst it may initially be more expensive to extend the main along the public highway this does facilitate the provision of further service connections as it is not permitted to breach a new service cable on to an existing service cable.
- Assuming a 200mΩ earth loop impedance at the end of a main, the earth loop impedance at the end of a 30m $35mm^2$ Al service cable will be 250mΩ, suggesting that 30m would be an appropriate limit. Experience shows that the earth loop impedance at the end of a main may be less than 200mΩ, and the use of a 40m service cable produces acceptable earth loop impedance at the service termination.
- The voltage drop on a service cable is dependent on the customer load and length. A 40m service cable supplying a 12.2kW demand (the maximum half hour demand of a customer measured in CLNR) would result in a 1.6% voltage drop on the service cable, leaving 4.4% voltage drop available on the main. A longer permitted service cable length would restrict the capability of the LV main to supply additional load.

Appendix 5 - System Security and Interconnection

The key factor here is the obligation under ESQC regulation 3(1)(b) to ensure that equipment is so constructed as to prevent danger or interruption of supply, so far as is reasonably practicable. LV interconnection allows Northern Powergrid to minimise the impact of both faults and planned outages on all or part of a LV network.

To assess the value of interconnection, we must assess the likely causes of outages. These include:

- HV faults;
- LV faults;
- HV planned outages; and
- LV planned outages

For substations looped into HV rings, the only fault that would lead to a sustained interruption that might be mitigated by LV interconnection is disruptive failure at the HV/LV substation, which is rare.

Conversely, substations fed by HV tees do create a need for LV interconnection to support the LV network under HV fault conditions. Such interconnection is of value only if provided from an independent HV source.

Given the restrictions on the number of customers per LV feeder laid out in section 3.4.8, the impact of LV interconnection on overall restoration times for LV faults will be limited for new systems. For existing networks, this may not be the case and, as will be explored later, the case can be made to providing interconnection.

Planned HV circuit outages have a similar impact to faults, so the need for interconnection arises primarily for substations fed from teed circuits. Improvements in asset specification (e.g. the use of SF_6 insulation) and maintenance techniques (e.g. live-tank oil sampling) reduce the number of planned HV plant outages, but do not eliminate them. Therefore, the need for interconnection arises primarily where dead-tank maintenance is still required. The requirement for LV planned outages is rare, particularly on underground systems where most work is carried out live.

Therefore, interconnection should be provided only where opportune so to do, specifically to support:

- the LV network of a substation fed from a tee, if interconnection can be found from a LV network with an independent HV source;
- the LV systems of existing substations where plant requires dead-tank maintenance; and
- existing LV distributors with poor fault performance.

As broad guidelines:

- no more than 500 metres of additional cable should be laid to provide interconnection from any LV network;
- to support substations under a wide range of conditions, as large a cable size as practicable should be applied. This may be higher than would otherwise be required; and
- interconnection will not normally be provided between substations with interdependent HV circuits, unless it becomes as easy to install a feeder pillar as two pot-ends (or, on existing LV OHL systems, where a section point is as easy as two terminal poles one span apart).

The 500m limit has been calculated using the OFGEM CBA to decide the economic viability with the potential IIS savings over the 45 years. For the CBA LV mains with a typical length of 1km 300WF; potentially interrupting 120 customers with a mean fault rate of 18.4/100km from the ENA NAFIRS report was used. Assumed typical costs for additional link box maintenance cost and avoided generation costs incurred for substation maintenance due to providing interconnection have been included in the CBA as well.

Approved underground CNE feeder pillars should normally be used to interconnect underground LV systems. LV pillars shall be used only in areas with high water tables and these should be located to minimise the risk of vehicular damage and vandalism. Points of interconnection on overhead mains shall be provided using approved pole mounted LV fuses.

When planning to joint out the LV mains of a distribution substation which is to be permanently recovered, consideration shall be given to installing a feeder pillar rather than jointing the mains through or terminating them with insulated ends.

A spreadsheet is available from Asset Management to calculate the amount of cable that can be justified to provide interconnection, so long as the existing feeder is sectioned at or about the mid-point.

Additional costs may be justified for circuits with poor fault histories by substituting the site-specific fault rate Table 17 below gives an indication only of the additional length of LV cable which can be potentially viable to install for creating interconnection based on the number of customers on the LV feeder and the number of faults experienced against the potential penalties faced in absence of interconnection. Adding interconnection on faulty feeders shall not be used as a way to avoid designing a permanent fix which could be a replacement or reinforcement of the faulting LV main to avoid future faults rather than using just adding interconnection for easier network restoration.

Table 17: Indicative length of LV cable required to achieve interconnection on faulty feeders

Metres of cable that may be laid		Faults in last five years		
		1	2	3
Customers on feeder	80	0	0	0
	100	0	56	113
	120	11	79	147
	150	28	113	198

Appendix 6 - Legacy LV Systems

A number of legacy LV underground systems exist in the Northern Powergrid. These are remnants of historical system and should not be extended or developed further unless there are no alternatives that it would be reasonably practicable to implement.

A6.1 Split-phase Systems

Split phase LV systems are typically found on overhead systems. Split-phase underground systems enable the best utilisation of ex direct current three-core cables, but as load is only connected to two phases of the three phase HV network they present an imbalanced load to the HV network.

Where split-phase 250/500V or 230/460V systems are to be replaced, upgraded or extended, the opportunity to convert to a three-phase system shall be taken if economically viable.

Where a split phase system is being replaced with a three phase system, connected customers should be asked to check whether they have any split-phase equipment.

New split phase connections should not be provided unless the provision of a single phase connection or a three phase connection from a three phase system is not economically viable.

Where a three-phase replacement network cannot be achieved, split-phase transformers are available for use where only a single-phase HV network exists.

In remote parts of the existing Northern Powergrid Northeast system some three phase HV to LV transformers are supplied from single-phase HV systems[109]. In these situations, the transformer is de-rated to 75% of the nameplate rating. Before offering a new three phase connection from three phase transformers in these areas, the design engineer should check that the transformer is supplied from a three phase HV source.

A6.2 Triple Concentric Systems

Triple concentric cables were commonly used historically. There are practical difficulties jointing onto such cables; it is not possible to breech on to these cables hence a piece of three core CNE cable has to be let in to the section of triple concentric so that a breech can be made onto the modern cable.

New connections to this kind of cable shall be avoided but if this is not possible the System Improvement Design Team should be contacted to check whether there is any planned upgrade work or to check possibility of sharing the costs of overlaying the triple concentric cable with a modern three phase cable. As demand increases due to connection of LCT devices there is an increased risk of the system becoming unbalanced due to the presence of triple concentric conductor in a circuit. A system assessment should be completed[110] to determine the extent of the system unbalance and if necessary, the triple concentric cable should be replaced with 300 mm^2 Al waveform cable

A6.3 Parallel Feeders/Ring Systems

LV systems in the Northern Powergrid Northeast especially in the Sunderland area have two parallel incoming LV feeds to the feeder pillar/link boxes to cater for load and historical practices with sub fusing; which provide a safety and security concern under fault scenarios. Hence new connections to the incoming[111] parallel feeders only (connection to the outgoing feeders could be possible) shall not be carried out without mitigation and Northern Powergrid shall be consulted. Discussions with System Improvement Design shall be undertaken to align new connections with reinforcement work to develop the network further in the most economical and efficient manner.s

[109] e.g. where a transformer has been replaced in advance of a programme to upgrade a single phase HV system to three phase.
[110] Consideration should be given to using existing LV monitoring data or installing LV monitoring on the circuit.
[111] Incoming parallel feeders are classified as any parallel feeds throughout the LV feeder and not just the first leg i.e. if on the second leg there are parallel feeds from one feeder pillar/link box to second feeder pillar/link box; this would be classed as incoming parallel feeds as well.