Customer-Led Network Revolution

Voltage Control Policy

Proposals for a voltage control policy from CLNR learning

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1 Introduction

This document describes the proposed approach to voltage control on Northern Powergrid's HV and LV distribution network. The document will be appropriate for adoption in part or full by other Distribution Network Operators (DNO).

In order to implement this policy further analysis and guidance will be required and this is captured in section 5. This document has been written following the network trials and trial analysis undertaken as part of the Customer-Led Network Revolution (CLNR) project.

2 Purpose

The purpose of this document is to propose an approach to voltage control on HV and LV networks.. For clarity, voltages at EHV and 132kV are not covered within this document as they were out of the scope of the CLNR project.

This document ensures that the requirements with respect to the Electricity Act 1989 (as amended) (the Act), the Electricity Safety, Quality, and Continuity (ESQC) Regulations 2002 (as amended), the Electricity at Work (EAW) Regulations 1989, the Distribution License conditions and the Distribution Code, are adhered to, by laying out the way in which Northern Powergrid will develop efficient, co-ordinated and economical HV and LV networks.

3 Scope

This document covers the control of voltages on HV and LV networks (i.e. below 22kV) of Northern Powergrid (Northeast) Ltd and Northern Powergrid (Yorkshire) plc, the licensed distributors of Northern Powergrid.

The document combines conventional voltage control procedures as well as enhanced automatic voltage control approaches that can be implemented on the Northern Powergrid network.

This document establishes guidance on the elements needed to create a policy on voltage control; separate commercial policies will apply. This document does not detail site specific requirements for the enhanced automatic voltage control approaches but sets out the generic requirements and provides guidance on establishing the site specific settings and configurations.

4 Policy

4.1 Assessment of Relevant Drivers

The key internal business drivers relating to voltage control are:

- Safety;
- Quality of supply, and in particular, accommodating new distributed generation and other low carbon technologies; and
- Financial.

The external business drivers relating to the economic development of voltage control and applications of this policy are detailed in the following sections.

4.1.1 Requirements of the Electricity Act 1989 (as amended)

The Electricity Act 1989 (as amended by the Utilities Act 2000) ('the Act') lays down the core legislative framework for Northern Powergrid operations as a distributor. Specifically, it gives force to the ESQC Regulations 2002, and in section 9 creates the key obligation to develop and maintain an efficient, co-ordinated and economical system of electricity distribution. Discharge of this obligation shall be supported in this document by providing guidelines on efficient development of the wider network.

4.1.2 Requirements of The Electricity Safety, Quality and Continuity (ESQC) Regulations 2002[1]

The ESQC Regulations 2002 (as amended) impose a number of obligations on the business, mainly relating to:

- Ensuring the safety of the public;
- Ensuring quality of supply; and
- Ensuring continuity and reliability of supply.

All the requirements of the ESQC Regulations that are applicable to the control of voltage on HV and LV networks shall be complied with, specifically in Table 1 below:

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

Table 1 – Related ESQCR sections

Reg. No	Text	Application to this policy
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 will be achieved by providing guidelines for permissible voltage swing on networks
27(2)	Unless otherwise agreed in writing…the voltage declared in respect of a high voltage supply shall be the specific declared voltage at the supply terminals	This will be achieved by providing guidelines for permissible voltage swing on networks

The ESQC Regulations (2002) place obligations on distributors to provide supply voltages within the following limits:

Supply	Tolerance
Low Voltage	+10% or -6%
High Voltage	+6% or -6%

4.1.3 The Health and Safety at Work Act 1974

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

4.1.4 Requirements of the Distribution Code

Each Distributor License holder is required to hold, maintain and comply with the GB Distribution Code.

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 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; and
- Facilitate competition in the generation and supply of electricity.

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

- Engineering Recommendation P2/6: Security of supply;
- Engineering Recommendation P28 Planning limits for voltage fluctuation caused by industrial, commercial and domestic equipment in the United Kingdom.

The DNO's Distribution System shall be designed to enable the normal operating frequency and voltages supplied to customers to comply with the ESQC Regulations.

Any extension or connection to the DNO's Distribution System shall be designed in such a way that it does not adversely affect the voltage control employed on the DNO's Distribution System. Information on the voltage regulation and control arrangements shall be made available by the DNO if requested by the user.

The effect of voltage step changes caused by the connection and disconnection of user's equipment to or from the DNO's Distribution System or changes to the user's demand drawn from the DNO's distribution System must be considered and be subject to limits to avoid unacceptable voltage changes being experienced by other customers connected to the DNO's Distribution System.

4.1.5 Requirements of the Grid Code

Grid Code OC6.5.3 requires DNOs to make arrangements to reduce demand on their network by implementing Demand Control by either:

- Two voltage reduction stages each of between 2 and 4 percent (nominal 3 per cent each), each of which can be expected to deliver around 1.5 percent demand reduction, and up to three Demand Disconnection stages, each of which can reasonably be expected to deliver between four and six percent demand reduction; or
- Four Demand Disconnection stages each of which can reasonably be expected to deliver between four and six per cent demand reduction.

Where the DNO elects to implement Demand Control via voltage reduction, the communication facilities and voltage control facilities at substations to implement both voltage reduction stages must be provided. In addition the voltage control system should be configured and operated such that under normal operational conditions both voltage reduction stages can be delivered in practice; under normal operational conditions there would need to be sufficient transformer taps available to deliver voltage reduction.

If the design and operation of the voltage control system is such that two voltage reduction stages are not available, the DNO should consider implementing Demand Control via Demand Disconnection only. The advantage of delivering Demand Control via voltage reduction is that limited demand reduction can be delivered without interrupting customer supplies.

4.2 Key Policy Requirements

Distribution networks should be developed in an efficient and cost effective manner to deliver electricity to the supply terminals of Northern Powergrid customers whilst meeting the requirements of the Act and the Licence.

The general objective in controlling voltage on distribution networks is to ensure that the voltage at customers supply terminals remains within statutory limits in all credible scenarios. Voltages shall be held within statutory limits for First Circuit Outage and Second Circuit Outage[2] where customer supplies are required to be maintained. Other network events, provided that they are considered to be 'exceptional' might result in voltage falling outside statutory limits The implementation of any changes to existing means of achieving this requirement shall take into account the changes imposed by the increasing distributed generation and low carbon technologies penetration.

Recognising the relationship between voltage levels and network losses, where it is believed that reducing network voltages would reduce losses, voltage levels may be reduced provided statutory limits are maintained. In this regard, consideration of losses is a secondary objective.

This policy is written to ensure that the control of voltages of HV and LV networks are performed in such a way as to:

- Ensure the general safety of the public;
- Prevent Northern Powergrid from having a major breach of legal compliance though incorrect control of network voltages;
- Comply with Distribution and Grid Code requirements;
- Minimise network losses where practicable;
- Optimise power quality experienced by all connected customers; and
- Satisfy all other relevant obligations.

[2] As defined in P2

4.3 Voltage Control Application

4.3.1 HV and LV Statutory Voltage Levels

The HV and LV statutory voltage limits, defined in the ESQCR, are set as per below:

- The voltage declared in respect of a supply to a LV customer shall be 230V/400V +10% /-6% at the supply terminals.
- Unless otherwise agreed with the customer, the voltage declared in respect of a supply to a HV customer shall be the specific declared voltage +6%/-6% at the supply terminals.

Note that there is no restriction on the operating voltage of the network itself, which may be tailored to local network conditions.

4.3.2 Plant Ratings

The voltage at any part of the distribution system shall not exceed the voltage rating of the plant forming part of the distribution system. These are stated in Table 2.

Table 2 – Distribution system plant voltage rating

System Voltage	Plant Rating
230/400V	600V / 1000V
11kV	12kV
20kV	24kV

4.3.3 Customer Connections

It is Northern Powergrid policy to allow any customer (either with load or generation) who wishes to connect to our system to do so at a minimum cost, most technically feasible solution to that customer whilst maintaining security of supply and ensuring statutory voltage limits for all existing customers.

Northern Powergrid will provide the most cost effective solution that allows a customer to connect to the HV and LV system, be it, by utilising assets better or installing additional assets.

4.3.4 Choice of Connection Voltage

The connection voltage will depend upon the type and size of the customer's demand, and shall be determined by Northern Powergrid and agreed with the customer as part of the connection application process.

The connection voltage shall be the lowest voltage such that an arrangement can be used without exceeding the rating of any equipment. This ensures that:

a) There is an enduring opportunity to supply existing and future other customers from Northern Powergrid assets either now or in the future thus developing an economical efficient and co-ordinated system;

b) The total assets (i.e. Northern Powergrid and customer assets) forming the overall electricity infrastructure are generally minimised; and

c) It generally results in a fairer allocation of the DUoS charges across the whole customer base.

However, in exceptional circumstances a connection at a higher voltage may be provided where:

a) The customer specifically requests a higher voltage connection and it is technically and commercially reasonable for us to do so;

b) The location of the Point of Supply substation is such that there are very limited opportunities for supplying other customers from it; or

c) The nature of the customer demand is such that there would be technical difficulties in supplying other customers from common assets e.g. if the connection would create a 'dirty busbar'.

4.3.5 Voltage Control Principles

The preferred approach to efficiently ensure customer supply point voltages are within statutory limits on HV and LV networks is to actively control voltage at the HV busbar of a EHV/HV substation and limit the voltage excursion of downstream networks through sets of design practices to:

a) Restrict the amount of voltage swing; and

b) Allocate the voltage swing appropriately across the HV and LV systems.

Downstream of the HV busbar, a 16% and 12% voltage swing is permitted under ESQCR for customers connected at LV and HV respectively. This document sets out the policy for allocating this permitted swing across the HV and LV network, accounting for Automatic Voltage Control (AVC) relay settings and conductor voltage drops.

This policy defines the thresholds for the design of new circuits and provides a staged approach to releasing voltage headroom on existing and circuits by the use of:

- AVC relays with fixed a voltage set point, allowing for voltage rise due to generation;
- The Line Drop Compensation function within existing and new AVC relay;
- Enhanced automatic voltage control approaches including:
    - an area controller to optimise voltage levels; and /or
    - voltage control devices installed downstream of the HV busbar.

The application of advanced voltage control solutions will be dependent on the network topology, the existing voltage profile and future uptake of low carbon technologies.

When analysing a network containing generation, network designers should consider the potential for voltage rise due to export from generation. To ensure that voltages remain within statutory limits, it may be necessary to optimise existing assets, reduce network impedance or use traditional or enhanced automatic voltage control approaches.

The default permitted design voltage swing on HV feeders is 8% for First Circuit Outage (FCO) as defined under P2. Where voltage control solutions exist on HV feeders or at LV, the voltage drop limit for HV feeders can be bespoke.

4.3.6 EHV/HV Transformer AVC Fixed Set Point

The default arrangement for the management of voltages at the HV busbar of an EHV/HV substation is to set the AVC with a fixed set point, calculated as described in this section. The preferred arrangement is to use a standard fixed set point. Where this is inadequate, a bespoke set point can be applied.

4.3.6.1 Standard AVC Fixed Set Point

The standard set point shall be set according to the following principles:

- Zero load (no voltage drop on circuits or transformers);
- 1.5% AVC relay dead-band;
- The target HV voltage at the EHV/HV substation HV busbar to deliver a voltage on the LV busbar of a HV/LV substation to be 1% below statutory maximum to create some headroom for generation.

This gives the values in Table 3 below:

Table 3 - Standard AVC fixed set point voltages

Tap Position of the Majority of HV/LV Transformers	20kV[3]	11kV[4]
105%	20,700	11,900
102.5%	20,200	11,600
100%	19,700	11,300
97.5%	19,200	11,100

Where the tap position of the majority distribution of HV/LV transformers is not known, a tap position of 102.5% (tap position 2) shall be assumed[5].

The 16% voltage swing (+10%/-6%) allowable under the ESQC Regulations in practice reduces to a design allowance of 12% on the combined HV and LV feeders after allowing for:

- A 1.5% dead-band on Automatic Voltage Control (AVC) relay at the EHV/HV substation;
- [x]% regulation across a loaded HV/LV transformer;
- A maximum of [x]% service cable voltage drop;
- An allowance for VT error.

For this voltage control regime (AVC fixed set point), LV networks shall be designed not to exceed a voltage drop on the main under normal running conditions, from a 240V nominal base, of:

- 6% for LV networks with a source within 15 km of a EHV/11kV substation, or within 30 km at 20kV (i.e. up to 6% drop on the HV); or
- 4% for LV networks with a source more than 15 km of an EHV/11kV substation, or beyond 30 km at 20kV (i.e. up to 8% drop on the HV).

Where the application of these voltage limits to existing circuits would lead to a requirement for network reinforcement, the designer shall assess the HV and LV network based on expected voltage swing at both HV and LV.

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[3] Northern Powergrid transformers are mainly 20,000V/433V as opposed to 20,000V/398.4V

[4] Northern Powergrid transformers are mainly 11,000V/433V as opposed to 11,000V/398.4V

[5] Existing HV/LV transformers may have different tap positions and the actual tap position may need to be verified on site

4.3.6.2 Bespoke AVC Fixed Set Point

Where a standard fixed set point proves to be inadequate, a bespoke set point can be applied based on the following principles:

- Zero load (no voltage drop on circuits or transformers);
- 1.5% AVC relay dead-band;
- Consideration of existing and future forecast for load and/or generation connections.

The set point shall be set to equally balance the risk of over and under voltage considering ten years forecast of load growth and LV generation connections where available. Design for HV connected generation will be conducted as part of specific connection requests; forecasts for HV connected generation will not be used, however, where likely future connections are expected, these shall be taken into account.

4.3.7 Primary Transformer AVC Line-Drop Compensation

Where modelling suggests that fixed AVC voltage set points cannot provide the required capacity, the existing Line Drop Compensation (LDC) function on AVC relays, if available, shall be set to provide “generation-rise” compensation, set according to these principles:

- Assume 1.5% relay dead-band;
- Set primary target voltage at maximum demand to deliver a secondary output voltage at statutory maximum, assuming no voltage drop on circuits or transformers;
- Set primary target voltage at minimum demand to deliver a secondary output voltage 4% below statutory maximum (assuming no voltage drop on circuits or transformers) to create some headroom for generation.

This gives the values on Table 4 below:

Table 4 - Maximum and minimum standard default values for primary target voltages

Tap Position of the Majority of HV/LV Transformers	Target at Max Demand (20kV)	Target at Min Demand (20kV)	Target at Max Demand (11kV)	Target at Min Demand (11kV)
105%	20,900	20,300	12,000	11,700
102.5%	20,400	19,800	11,800	11,400
100%	19,900	19,300	11,500	11,100
97.5%	19,400	18,900	11,200	10,800

Where the majority tap position of distribution transformers is not known, a position of 102.5% (tap position 2) shall be assumed[6].

For the extra voltage rise permitted by this compensation, LV networks shall be designed for voltage swings of +2/-4% rural and +3%/-6% urban.

4.3.8 Active Management

This section details how active management of voltage, whether it be on a local or area basis, may be considered on networks with generation. Area control is not yet proven to be an effective solution for managing existing OLTCs for networks without significant generation.

Where generators are contributing to voltage rise on the network, control of their reactive and real power output can reduce those issues. Further guidance is provided in the connection policy for Distributed Generation.

There are different types of voltage management options available, for example generators may be instructed to operate in PV mode, so that they import reactive power to reduce voltage at their point of connection; where this is insufficient, local controllers (smart RTUs) may be installed to issue set-points for that generator's reactive and real power output. At times where generator(s) output would not lead to a voltage constraint, the local controller shall minimise losses by allowing

[6] Legacy networks have different standard tap positions

the generator to export with a power factor as close as possible to the network to which it is connected.

Where there are multiple generators contributing to voltage rise on a given feeder then, in addition to the fall-back local controls described above, an area voltage control scheme may be deployed to manage voltage rise caused by generators in near real-time. The broad functional specification is:

- Look across an area of network and identify emerging voltage constraints;
- Identify the generation to be constrained, either by increasing reactive power import or reducing real power export, having regard to:
    - Sensitivity factors, i.e. how effective a control action would be in offsetting voltage rise at the pinch point;
    - Merit orders, i.e. the commercial basis for which generators should be constrained first.
- Issue commands to the relevant generators, either as a soft inter-trip (i.e. a binary signal to move to a pre-defined output level), or as a variable MW/MVAr set-point.
- A mechanism is required at the generator site to limit the potential for excessive voltages where the local controller is unable to communicate with the generator.

Where network studies identify a material benefit, these area control schemes may be extended to controlling OLTCs. Again, the instruction may be a binary signal to enact a pre-defined voltage reduction (likely mirroring OC6 provision) or a variable kV set-point.

4.3.9 Voltage Control Downstream of Primary Bar

This section provides a list of the available voltage control solutions permitted for use on Northern Powergrid's HV and LV networks. The sections contain brief guidance on the application of each technology; this supplements but does not replace existing design guidance.

4.3.9.1 HV Voltage Control Solutions

The preferred option to mitigate voltage issues is to consider the design of the network prior to management schemes or regulators. For example re-configuring the network should be investigated first, especially where this provides additional security.

The default permitted design voltage drop on HV feeders is 8% in First Circuit Outage (FCO).

Primary Transformer AVC

All new primary transformers shall be fitted with an On-Load Tap Changer (OLTC) which is to be controlled by an AVC relay with a Line Drop Compensation (LDC) feature as standard and 3%/6%

voltage reduction facilities (OC6 Grid Code). Existing sites highlighted for replacement of the voltage control equipment shall be fitted with an AVC relay to the same specification.

Existing AVCs with dormant LDC capability shall have the feature activated where there is concern over generation headroom on downstream circuits. For legacy equipment, it should be noted that the setup of LDC may be limited by reverse power flow capability and the ability to operate at low power factors.

HV Connected In-Line Regulator

Where network design options have released all the available voltage headroom, consideration shall be given to the design and installation of In-line Regulators on HV feeders. These are attractive where localised control of voltage is needed for multiple LV network areas, particularly to be fitted on HV spurs.

All new regulators shall have both buck and boost capability and include a controller that has LDC functionality. LDC shall be set to compensate for generation voltage rise, and reverse reactive power sensing to cater for both abnormal running conditions and also generation causing reverse power flow in normal running.

HV Shunt Connected Capacitors

Where network design options have released all the available voltage headroom, consideration shall be given to the design and installation of shunt connected capacitor banks on HV feeders.

These solutions may be cost effective, compared to In-Line Regulators where:

- There is a significant reactive element to the network or customer load, leading to high losses;
- Additional benefits in terms of reliability can be achieved by the inclusion of a firm bar at the proposed capacitor site.

Shunt connected capacitors are effective at limiting voltage swings due to long spans of overhead lines and have the added benefit of reducing losses.

4.3.9.2 LV Feeder Solutions

LV Connected In-Line Regulator

Individual feeder voltage control shall be considered in the rare cases where several LV feeders are connected to a single substation and one or two of the feeders have significantly higher voltage swing at the end of the feeder. In-line voltage regulators either located at the substation or midway along the LV feeder shall be considered to combat voltage swings on such overloaded or variable loaded feeders. This can include connection of pole mounted devices for overhead networks and cabinet based solutions for underground networks.

In-line LV regulators are usually more cost effective than distribution transformers with OLTCs where voltage issues are related to only one feeder of a multiple feeder LV network. Dependent on the network and the amount and variability of connected load and generation, it may be acceptable to install regulators with fixed boost or buck with no control.

Where fixed settings are not suitable, regulators with variable tapping shall be installed with an appropriate AVC relay to maintain the voltage to a fixed output. Regulators with buck and boost shall be fitted where future generation is reasonably likely (most domestic networks).

Installing the units closer to the voltage constraints (i.e. midway down the feeder, or towards the end) may reduce costs as lower rated units can be installed.

Distribution Transformer with OLTC

For new distribution transformers, in cases where customer practices differ so significantly from those on surrounding networks that control from the primary is unlikely to be sufficient, OLTCs shall be considered versus traditional transformers. Ten year forecasts of voltage swings using low carbon technology uptake predictions shall be used to assess the need for OLTC on new secondary transformers.

The automatic voltage control relay parameters shall be optimally adjusted to the line voltage behaviour to achieve a balanced control response with less required tap-change operations. The number of tap positions and tap steps will limit the voltage regulation rate.

Where OLTC are available on secondary transformers the AVC setpoint shall be informed by design taking account of future forecasts for load and/or generation connections. The setpoint shall equally balance the risk of over and under voltage considering the ten years forecast.

For existing distribution transformers serving voltage constrained networks, consideration shall be given to the age and potential for load expiry within the ten year period. The designer shall assess if the overall least cost solution is to replace the transformer with a higher rated unit with OLTC capability to address both voltage and power flow issues.

4.3.10 Real Power Services

Electrical Energy Storage (EES) and Demand Side Response (DSR), as real power services, are currently not cost effective for voltage constraints alone. This will be regularly reviewed. Where these interventions already exist or are being considered to alleviate distribution level power flow constraints they should also be considered as solutions for voltage constraints.

Additional capital and utilisation costs in order to add to the operational remit of EES and DSR installed for power flow benefits may prove cost effective over other voltage-led reinforcement options.

4.3.11 Generation Impacts on Voltage Control

Reverse Power Flow

The systems employed by the company for maintaining the voltage provided to connected customers' within statutory limits were developed in an environment when there was very little distributed generation connected to the network. Consequently, when generation may exceed the local load requirements, careful consideration must be given to the effect of 'reverse' power flow through the system as this will influence the voltage control systems.

Connections may be provided that lead to reverse power flow, on the understanding that assets, including main and auxiliary plant, are assessed as being capable. All new assets on the HV and LV systems must be capable of operating with forecast levels of reverse power flow.

Low Power Factors

When local demand and generation are similar, the power factor, as seen by the transformer, may reduce significantly due to the generators often having near unity power factor. Such a situation could occur where the real power output from a generator matches the real power requirements of the network and the reactive power requirement of the network is provided by the transformer. Where a transformer is equipped with an on-load tap changer there may be limits to its suitability to manage voltage effectively as the voltage control scheme may not function correctly if the power factor as seen by the transformer is lower than approximately 0.7. The capability of the specific AVC relay installed at the site shall be considered for generation connections.

Generator Effect on Voltage Control

Voltage control and power factor control systems used by distribution generators are linked. Controllers are usually set to fix the power factor, and let the terminal voltage fluctuate, or fix the voltage and let the power factor fluctuate. These two control options are generally referred to as PQ and PV respectively. Generators should normally be set to operate in PQ mode where the generator would not lead to voltage constraints. For new generation connections the user can be given the option of an alternative connection arrangement, usually for lower cost, where the generator operates in PV mode to limit the potential for excessive voltage rise on feeders.

4.3.12 Voltage Fluctuations

Voltages at the point of connection to customers' premises shall remain within statutory limits at all times. Voltage fluctuations should be assessed under full and minimum system loading conditions. The minimum load used when undertaking analysis should be based on a realistic minimum demand rather than an absolute minimum, this would normally be assessed from historical monitoring data.

Under all generator operation any voltage fluctuations shall be within the limits stated in Engineering Recommendation P28. Operations include synchronising, increasing output to the maximum and taking the generators off line. Limits on the generator ramp up and ramp down rates may need to be imposed to ensure that network tap changers have time to operate if required. Under sudden loss of generation, the step voltage change at the point of common coupling shall not exceed 10%. Where a distributed generation installation comprises a number of generation units, the step voltage change considered shall be that under the most onerous condition. This is likely to be loss of the metering circuit breaker.

5 Further Work

In order to implement this document, further analysis and guidance will be required. This section lists potential further work:

- When changing fixed primary set points a design study is required to fully understand the effect of lowering the set points compared with the existing set point setting on the voltage levels witnessed by customers on feeder ends;
- The impact of any voltage reductions upon the OC6 compliance should be considered;
- For new distribution transformers, there is potential benefit in changing the default nominal voltages. It is recommended that further work is undertaken to assess the feasibility of changing procurement specifications for new distribution transformers to specify a nominal output voltage of 400V as opposed to 433V;
- Further guidance on specific LDC settings is required based on analysis of the various types of LDC for each of the main relay types operational on the network;
- Wider verification of the comparison of HV and LV networks with and without LDC applied at the primary is needed to fully understand the effect on the voltage levels witnessed by customers. Sample calculations should also be undertaken to promote the change and gain buy in across the business;
- A procurement specification is required for an AVC relay with the appropriate LDC functionality;
- Forecasts of LCT uptake are required for new and existing substation sites. Default assumptions of uptake can be used, however, these need defining for various types of network;
- Guidance and training is required for design engineers to be able to derive set points for primary LDC and LV OLTC AVC relays;
- Reference is needed to OLTC device specification parameters to guide the designer on appropriate settings;
- The application of local and area active voltage control will require additional guidance derived from the CLNR trials and lessons learnt from other DNO projects.

6 Definitions

Term	Definition
AVC	Automatic Voltage Control
CLNR	Customer-Led Network Revolution
EAW	Electricity at Work
FCO	First Circuit Outage
DG	Distributed Generation
DNO	Distributor Network Operator
DSR	Demand Side Response
DUoS	Distribution Use of System
EES	Electrical Energy Storage
EHV	Extra High Voltage (greater than 22kV, less than 131kV)
ESQC	Electricity Safety, Quality and Continuity (Regulations)
HV	High Voltage (less than 22kV, greater than 1kV)
LDC	Line Drop Compensation
LV	Low Voltage (less than 1kV)
OLTC	On-Load Tap Changers
P2	Engineering Recommendation P2 Security of Supply
RTU	Remote Terminal Unit

Customer-Led Network Revolution

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