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Bringing energy to your door

SMART STREET

Management of LCT Clusters

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VERSION HISTORY

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First draft	3 April 2018	Geraldine Paterson	0.1	
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CONTENTS

1 INTRODUCTION

1.1 Purpose of document

The purpose of this document is to disseminate the deliverable associated with Smart Street successful delivery reward criteria 9.6.2**:** *Publish Electricity North West's approach to managing LCT clustering***.**

This document describes how Electricity North West will use the learning gained from the Smart Street trials to manage clusters of low carbon technologies (LCTs) such as photovoltaic (PV) generation, heat pumps (HP) or electric vehicles (EV).

1.2 What is Smart Street?

Smart Street used advanced real time optimisation software to simultaneously manage high voltage (HV) and low voltage (LV) network assets to respond to customers' changing demands. Voltage management on HV networks reduced network losses while conservation voltage reduction (CVR) on the LV networks reduced energy demand. Capacitor banks on the HV network were used to help manage network losses by adjusting the network's power factor. On the LV network, a mix of capacitor banks and controlled meshing of networks were integrated to flatten the voltage profile and improve energy efficiency. The meshing of LV networks also released additional network capacity.

1.3 Conservation voltage reduction (CVR)

Electrical equipment made for the European market, including household appliances and lighting, is designed to operate most efficiently in the region of 220 to 230V. This equipment can, however, operate adequately at voltages in the region of 200V. If power is delivered at voltages higher than these optimum levels, then energy will be wasted. Excess voltage can shorten the useful life of electrical equipment, since the excess energy is dissipated as heat. Therefore optimising network voltages reduces overall energy consumption, improves power quality and extends the life of customer's equipment. Smart Street optimised network voltages by using CVR on the LV trial networks.

CVR on a distribution network is defined as a reduction of energy consumption resulting from a decrease in feeder voltage. Smart Street optimised the voltage by using on-load tap changing (OLTC) transformers. These transformers regulated the voltage along the feeder while maintaining statutory limits. This allowed for the peak load to be reduced, hence reducing the annual energy consumption.

Additionally Smart Street used shunt capacitors on the LV feeders to allow for a voltage boost at the end of the circuit to reduce voltage drop. This allowed for a flatter voltage profile, allowing for the OLTC to tap closer to the lower limit.

1.4 Low voltage network meshing

In addition to the proposed CVR techniques, Smart Street assessed the benefits of meshing LV networks to balance load while releasing network capacity at times of high demand.

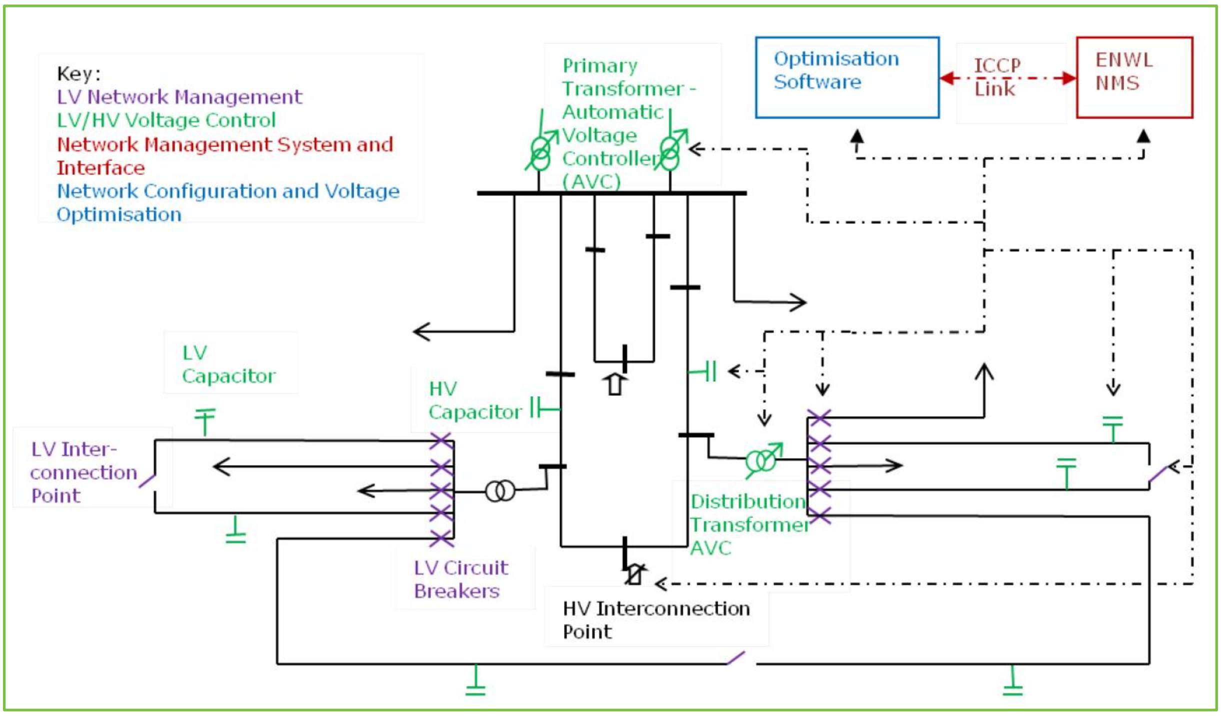
Our project partner, Kelvatek, developed new controllable retrofit vacuum switching devices especially for this project. These devices were used at the existing distribution boards and in link boxes across the LV trial circuits. The devices were remotely controlled allowing sensing of feeder flows and reconfiguration of the LV network.

1.5 Control systems

Figure 1.1 shows an example of how the various Smart Street technologies were installed across the trial networks. The software included the ability to optimise for violations, losses and to minimise load as a single volt var compensation (VVC) function. The opportunity to mesh the trial networks was also included in this function, but radial configurations were the preferred running arrangement. This is specified to minimise customer outages during electrical faults. Therefore the switching equipment was closed (create loop or mesh networks) when the objective-function resulted in positive changes to the network above a set threshold.

The software application calculated the best solution to reach the optimisation objectives, which may be different for HV and LV depending on the chosen function. The user selected whether the switching equipment should be included or inhibited in the optimisation scheme.

Figure 1.1: Smart Street network management



2 NETWORK ISSUES

The UK's decarbonisation journey through to 2050 will see a reduction in the carbon footprint of heat, transport and electricity generation. Current forecasts suggest that there may be up to a 60% increase in total electricity demand. The substantial increase in new electricity loads from HPs and EVs coupled with PV will create thermal and voltage challenges for the management of networks.

DNOs have historically employed traditional reinforcement to address the problems created by new LCTs; this option is no longer appropriate due to the high cost and associated disruption.

For an estate of domestic premises with gas central heating, the network is designed to supply a peak demand after diversity of less than 2kW per property. Changing the gas heating system to an electric alternative could add 6kW per property; and when a household replaces a family car for an electric alternative, a further 3.5 or 7kW could be added.

In isolation these new LCT loads may not cause an issue, but LCT clusters will create thermal, harmonic and voltage issues, with the latter resulting in voltages below the statutory threshold, due to the effect of the increased loads.

Where a household installs PV panels on its roof, typically 3.6 kW of generation would be added to the property which creates a voltage rise at the point of connection. Again, in isolation, PV will not cause an issue but clusters will reverse the power flow causing thermal, harmonic and voltage rise issues.

The introduction of multiple LCTs with their differing operating regimes will result in complex network flow patterns making managing real time network voltage within statutory limits a considerable challenge. Using the learning from Smart Street, these challenges can now be addressed.

3 EXISTING POLICY

ACE Reports produced during the 1980s recommended using 1.5kW for the After Diversity Maximum Demand (ADMD) of a domestic property and 7% for the voltage drop along an LV cable and these values are still used today for LV network design calculations.

Based on the trials and learning from Smart Street and the predicted uptake of LCTs, it is obvious that the application of these global assumptions is no longer valid and design policies will need to be adapted.

Additionally, existing policy only allows for reinforcement through upgrading of transformers and cables which is time consuming and causes disruption to customers. Smart Street gives the opportunity to increase the capacity of the existing assets faster than traditional reinforcement with minimal disruption.

4 SMART STREET LEARNING

Trials carried out as part of the Smart Street project have generated significant learning which is expected to drive policy changes and inform new methods to cater for increases in demand and generation.

The deployment of Weezaps, Lynx and end point monitors provided greater visibility of voltages and currents on the LV network. Analysis of the data from these devices has shown that the volt drop is actually much less than the assumed 7% and, on some cables, there is virtually no voltage drop along the feeder.

This absence of volt drop can be advantageous in a number of ways:

- The voltage can be kept high at the sending end which will allow the connection of more demand before the lower statutory limit is reached
- The voltage can be kept low at the sending end which will allow the connection of more generation before the upper statutory limit is reached
- As the voltage profile along the cable is already flat there is no requirement to install capacitors at cable mid-points to boost the voltage. It should be borne in mind that as LCT uptake increases, the volt drop may increase and the installation of capacitors could provide an alternative to reinforcement.

Smart Street carried out extensive customer engagement to see if customers noticed a difference to their supply as a result of the trials. This research reinforced the findings from the Second Tier LCN Fund CLASS project, which demonstrated that customers did not notice any difference in the quality of their supply when voltages were reduced.

The academic research also studied the effect of the trials on power quality metrics such as harmonics, fault levels, voltage unbalance, etc. This identified that the meshing element of the trial could cause an increase in fault level but currently not above the design rating. As the penetration of LCTs increases and meshing is proposed as a solution, fault level will need to be reassessed to ensure it remains below the design rating.

4.1 Tap changers

Providing an optimised voltage supply offers significant benefits for customers and DNOs. Customers will have reduced energy consumption and therefore reduced bills, while the DNO may be able to avoid costly, time-consuming and carbon intensive reinforcement. This optimisation can be delivered in a number of ways:

- Alter the tap position on the off-load tap changer. This may be required on a seasonal basis to account for differing demand and generation conditions
- Install a distribution transformer with an on-load tap changer and set the voltage target. This is the same process as primary transformer tap changers
- Install a distribution transformer with an on-load tap changer and allow the central optimisation software to dynamically alter the set-point as required.

Using on-load tap changers to deliver the optimised voltage results in greater energy reduction and increased capacity than using off-load tap changers.

4.2 Meshing

Meshing networks increases available headroom by capacity sharing. The academic studies into meshing have demonstrated that permanent meshing is no more beneficial than meshing only when power flows require it. Furthermore, if permanent meshing is applied, it may subject more customers to interruptions during a fault.

Meshing can be applied by:

- Installing Lynx devices and communications to the network management system (NMS) and sending instructions to open or close the mesh on a timed basis, ie close at 09:00 and open at 15:00
- Installing Lynx devices and communications to the NMS and allowing the central optimisation to send instructions to open or close the mesh as required.

5 PROPOSALS FOR NEW POLICY

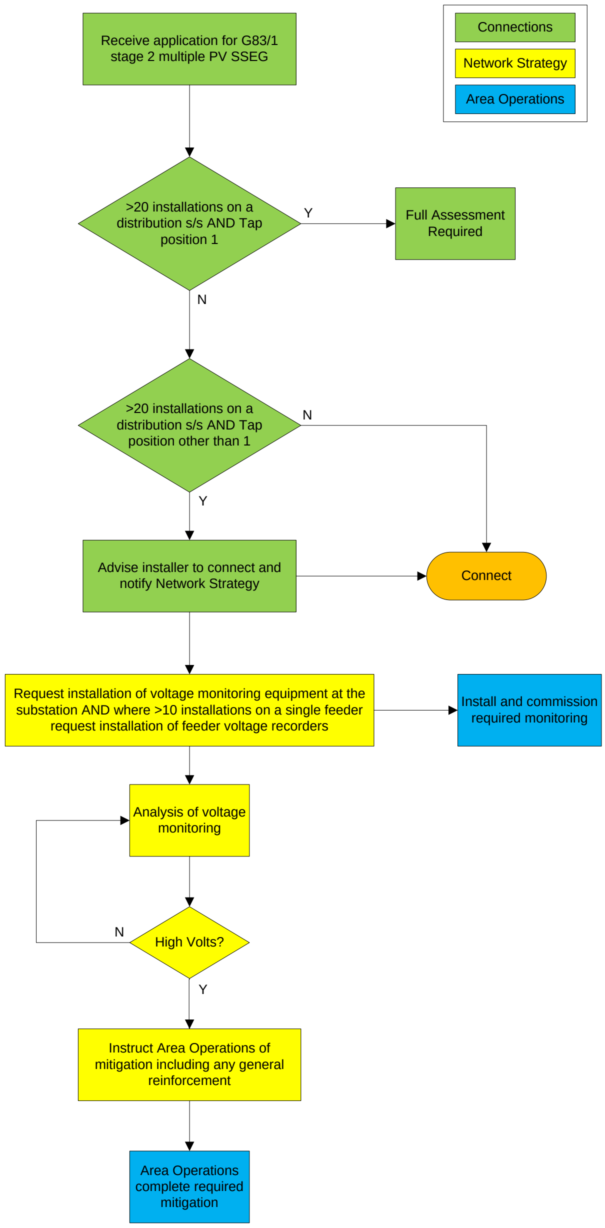
The Smart Street technologies can be deployed in stages to cater for the uncertainties associated with LCT uptake. There are differences in the solutions application depending on the root cause of the network issue ie demand or generation.

The following sections detail the deployment of the Smart Street solutions and form the basis of proposed policy changes.

5.1 Connect and manage

The learning from the First Tier LCN Fund project, Low Voltage Network Solutions allowed Electricity North West to implement a ‘connect and manage’ policy for generation as in Figure 5.1. The learning from Smart Street reinforces the use of this policy and suggests it could be extended to include demand clusters. The learning also demonstrates a staged approach to managing the mitigation with traditional reinforcement being the option of last resort.

Figure 5.1: Process diagram for managing applications for connection of generation



5.2 Deployment of monitoring

- The first stage in the 'connect and manage' process is to install monitoring so the effects of the cluster can be assessed.
- At the feeding substation Weezaps or an equivalent shall be installed.
- If a link box is installed at the end of the feeder Lynx or an equivalent shall be installed.
- If there is no link box available end point monitors shall be installed at the end of the feeder.
- To allow the data to be readily accessed and cater for future functionality these devices shall be installed with full communications to the NMS.

5.3 Mitigation

Using the monitoring data gathered the mitigation can be deployed in stages.

Optimisation of off-load tap changers

- Ensuring the off-load tap changers are set to the optimum tap to cater for the demand and/or generation on the network can offer benefits for capacity and energy reduction.
- The monitoring data gathered shall be used to assess the maximum and minimum voltages on the feeder.

- The tap position shall be set to ensure the transformer delivers the lowest voltage to customers without exceeding statutory limits. A low voltage will allow increased headroom for demand while a high voltage will allow headroom for increased demands.
- Checks shall be made to ensure the voltage remains within statutory limits at all times of day taking into account the demand and generation operating cycles.
- This optimised tap setting may need to be changed on a seasonal basis, ie a summer tap setting and a winter tap setting to allow for winter demand peaks and summer generation peaks.
- Where the demand and generation cause voltage swings on a daily basis this technique cannot be used and consideration shall be given to installing an on-load tap changer.

Meshing

- Before deploying meshing techniques, network studies shall be carried out to ensure that there is no detriment to customers' quality of supply in particular that the fault level is not exceeded.
- If the Lynx devices were already installed as part of the monitoring, switching instructions shall be sent from the NMS to open and close the mesh.
- If there is no link box available network studies shall be carried out to assess where a link box with Lynx devices can be installed.
- Based on the academic work the instructions could be sent on a timed basis, ie close the mesh at 09:00 and open the mesh at 15:00. If the optimisation software is available in the NMS these meshing points can be enabled to allow the software to mesh dynamically as the demand and generation changes.

On-load tap changers

- Install a distribution transformer with an on-load tap changer with full communications to the NMS system.
- The monitoring data gathered shall be used to assess the maximum and minimum voltages on the feeder.
- The voltage target shall be set to ensure the transformer delivers the lowest voltage to customers without exceeding statutory limits taking into account possible changes to voltages on the HV network. A low voltage will allow increased headroom for demand while a high voltage will allow headroom for increased demands.
- If the optimisation software is available in the NMS these can be enabled to allow the software to dynamically alter the voltage target as the demand and generation changes.

Capacitors

- If the monitoring data gathered shows an increased voltage drop along the feeder due to high demands, a capacitor shall be installed.
- Network studies shall be carried out to determine the size and optimal location of the capacitor. As these devices are installed in street cabinets, consideration shall be give to the customer impact when determining the exact location.
- The capacitor shall be set to operate based on a voltage setting.
- If the optimisation software is available in the NMS, these can be enabled to allow the software to dynamically alter the voltage setting as the demand and generation changes.