electricity north west

Bringing energy to your door

The future

Low Voltage Network Solutions
Summary Report

LCN Fund
Low Carbon Networks

MANCHESTER 1824
The University of Manchester

GRIDKEY
UNLOCKING THE SMART GRID

nortech

LV Network Solutions was a three-year project completed in summer 2014 and was Electricity North West's largest project under the First Tier of the Low Carbon Networks fund.

The project developed our approach to how to monitor our low voltage (LV) networks at substations and along feeders, without customer interruptions. We applied this across 200 distribution substations to increase our understanding of how our LV networks perform. Across the network, the project has validated and improved our existing estimates of network loading, and provided us with a tool to assess future capacity headroom in different scenarios.

The University of Manchester built LV network models from our GIS records, with the network configurations validated by the monitoring data. For a sample of underground networks, they assessed voltage and thermal constraints to identify the capacity of the LV feeders to accept low carbon technologies (LCTs) such as solar PV, electric vehicles and heat pumps, and made recommendations about what to monitor in future. This project has validated our approach to connect and monitor/manage PV; this avoids delaying customers wishing to connect clusters of PV systems to our electricity network. The project also developed a 'Smart Joint' used in a programme of LV cable midpoint/endpoint monitoring.

LV Network Solutions has contributed to a variety of Electricity North West innovation projects, such as our Second Tier Low Carbon Networks Fund projects Smart Street and CLASS, and other smaller projects such as Customer Voltage and Power Quality, Voltage Management on LV Busbars and Low Voltage Integrated Automation.

Further details on LV Network Solutions and all of these projects are available at **electricitynorthwest.co.uk/thefuture**

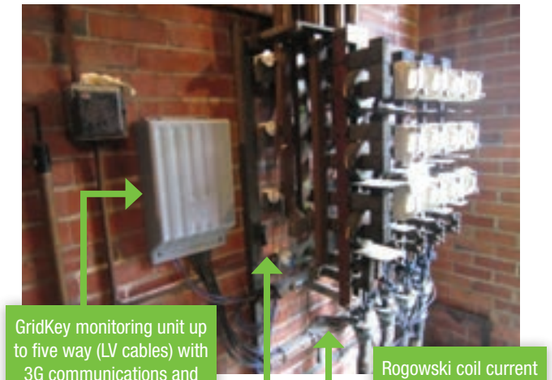
Background

Low voltage distribution networks in Great Britain were created on a fit-and-forget basis, assuming that customer demands and diversity would not significantly change. There is no routine real-time monitoring of the low voltage networks. However, as we look forward to future scenarios where customers increasingly adopt LCTs, those assumptions about customer behaviour may not hold true. So distribution network operators (DNOs) like Electricity North West now need to better understand the performance of their low voltage networks, how that could change in the future as customer behaviour changes and to explore potential responses.

Monitoring the network

Following a tender process, we worked with GridKey and Nortech as suppliers of monitoring equipment, developing both their products and our installation procedures.

GridKey substation monitoring on an open LV fuse board



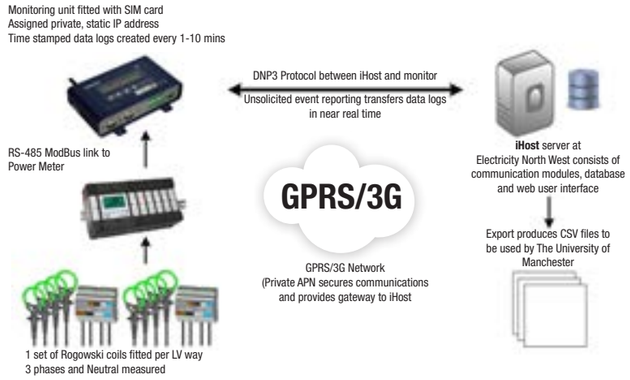
Cable midpoint monitoring 'Smart Joint'

Nortech substation monitoring on a pole (left) and indoors (right)

200 distribution substations were selected for monitoring. They represented a range of network situations but with a focus on ground-mounted transformers and areas with photovoltaics (PV). The final site selection was informed by substation surveys. Monitoring was installed during 2012 and 2013 to measure a variety of parameters at the transformers and at the head of each low voltage feeder. A live installation approach - using Rogowski current coils and novel voltage connections - enabled deployment of monitors without causing customer interruptions. Outputs of this project included how to monitor eg equipment procurement specifications, a Code of Practice and associated procedures for safe installation and commissioning, plus recommendations from the University of Manchester on what, where and when to monitor in future.

Monitoring data was sent by GPRS back to Electricity North West's iHost server and then exported to the University of Manchester. The monitoring collected nearly 10,000 days of valid data up to January 2014, despite great challenges in data collection and archiving. Particularly given that this data includes information by phase and by feeder, rather than just transformer totals, this represents a truly significant step forward in terms of data collection characterising LV distribution networks in Great Britain.

Data Collection Approach from Monitors



The University used the available monitoring data to make the first ever detailed assessment of the performance of the Electricity North West LV network. This evaluation covered issues such as transformer utilisation, substation busbar voltages, voltage unbalance factor across phases, power factor, neutral currents and indicative values of total harmonic distortion. Although issues in some specific locations are being investigated further, the overall conclusion was that our LV substations are performing within expectations.

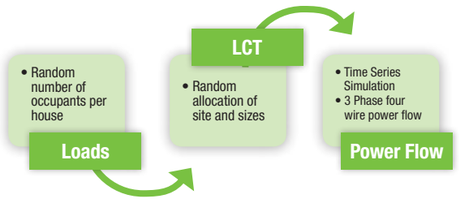
Improving load estimates

The LV Network Solutions project also recognised that our detailed analysis only considered a small fraction of the LV network (200 out of around 33,000 distribution substations). In a separate IFI project Load Allocation, Electricity North West has developed a method for load estimation for the whole secondary network, based on existing connectivity data. LV Network Solutions used monitoring data to review, validate and improve the baseline load estimates produced by Load Allocation. The project also used the Load Allocation as a baseline to create a Future Capacity Headroom model, to estimate thermal and voltage overloads in future scenarios of LCT uptake. This was used in the early stages of Electricity North West's preparation for the RIIO-ED1 Well Justified Business Plan.

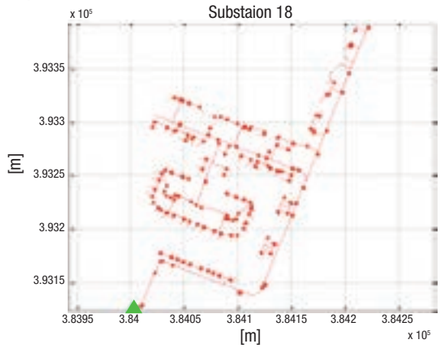
Modelling the network

In parallel to the monitoring, the University of Manchester developed a method to build models of the monitored networks. This used Electricity North West's detailed GIS network and policy data (lengths, connectivity and impedances) and GIS customer data (types and locations), loading this into the OpenDSS modelling platform. This allowed a three-phase four-wire analysis of the monitored low voltage networks. The University ensured the network models were accurate by using the monitoring data to validate the network topology, working with Electricity North West to review open-point positions/ status if the initial validation failed. The challenge in this stage of the work reflects the issue which all DNOs face with translating their LV data – which has been fit for purpose up to now - into systems for further analysis. For use with the network models, the University identified suitable profile data to represent the diversity of existing customer demands, and suitable trial data to represent electric vehicles, heat pumps, solar PV and micro combined heat and power units.

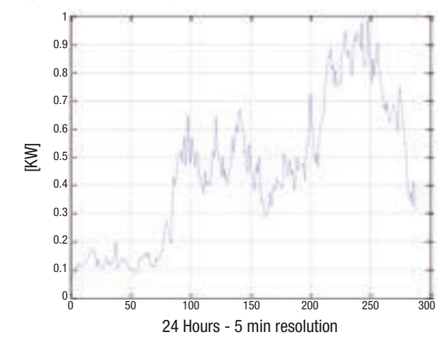
Impact Assessment Methodology Flow Chart



Example Feeder



Average for 100 domestic profiles



Using its models of the monitored networks, the University of Manchester then developed a method to assess the hosting capacity of networks, in terms of the percentage of customers who could adopt a particular low carbon technology before any voltage or thermal issue arises.

Understanding customer behaviour and low carbon technologies

The analysis method developed by The University of Manchester included three-phase four-wire models in open DSS, and time-series analysis with a minimum of 10 minute resolution. In a Monte Carlo approach, many simulations were carried out to cater for the diversity and uncertainties of customer behaviour, as well as the location, size and behaviour of low carbon technologies. A simpler analysis approach would underestimate the impacts of new low carbon technologies. Their method represents a major step forward compared to what has been done previously, both by DNOs and in other analysis by industry and academics. Although more time-consuming than could be employed business-as-usual by DNOs, it has a valuable role to inform policy decisions.

Example – findings from analysis of a sample of LV suburban underground networks

- As uptake of PV increases, the first problem is always a voltage issue, not thermal. For heat pumps and electric vehicles respectively, the first problem is voltage in 55% and 65% of cases. This is one reason why Electricity North West is working on voltage management techniques at LV eg in the Smart Street project.
- Many feeders can accept very high levels of PV uptake before there is a voltage problem. For example, all of the feeders studied with less than 25 customers and 1/3 of feeders with more than 25 customers would have no voltage problems even if every customer had PV. Many other feeders have no voltage problems until around 40 customers have PV. So we should not assume that current PV uptake will necessarily cause a problem, and it's appropriate to let our customers quickly connect PV.
- However, the PV hosting capacity of our LV feeders is actually quite variable. Factors such as customer numbers, feeder length and utilisation give some indication of hosting capacity, but it is difficult to quickly and accurately predict. So if there is a PV cluster, we should monitor to identify if there is a voltage problem, and be ready to manage voltage if there is. This is the 'connect and monitor/ manage' approach now being adopted by Electricity North West.

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Analysis of solutions

The University modelled the increases in LCT hosting capacity for specific examples of interventions on the LV networks eg on-load tap changers and network meshing. Alongside capacitors and automation, these methods are being investigated further practically in the projects Voltage Management on LV busbars, Low Voltage Integrated Automation and Smart Street. The 'Smart Joint' approach to monitor current and voltage on LV feeders, developed under LV Network Solutions is also being used in these projects and in CLASS. The University also identified representative types of underground LV feeder for further analysis.

Find out more

The project closedown report and appendices are available at **electricitynorthwest.co.uk/lvns**. These include further detailed information on the project, including comparisons with Western Power Distribution's LV Network Templates project and with the Transform model produced by EA Technology for Work Stream 3 of the Smart Grid Forum.

Find out more about our other low carbon projects at **electricitynorthwest.co.uk/thefuture**

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