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Changing Standards (Statutory Voltage Limits)

Changing Standards is the first large scale piece of customer research carried out to expressly establish the measured power quality values at which customers express dissatisfaction about their electricity supply.

This project was funded by Ofgem's Innovation Funding Incentive (IFI) scheme, which was replaced in April 2015 with the Network Innovation Allowance (NIA). The schemes encourage distribution network operators (DNOs) to invest in smaller technical, commercial or operational projects, which have the potential to improve network operation, maintenance and deliver financial benefits to the DNO and its customers.

The Changing Standards project explored customers' perception of power quality. The aim of the research was to determine if customers are sensitive to the provision of an electricity supply at, or near to, the extremes of statutory limits.

The research examines perceived changes in power quality and satisfaction with service amongst customers occasionally exposed to minor exceedances of mandated limits; and a control group of customers supplied consistently within the standards.

Background

Distribution network operators are required to supply electricity to customers within two statutory operating standards relating to voltage and total harmonic distortion (THD). These standards have existed for many years and their origins are based on the requirements of appliance technologies from the 1960s. Modern appliances are designed to operate in many countries and therefore across a much wider voltage and THD range than the 230V + 10%/-6% limits set out in UK legislation and planning/compatibility limits for THD as defined in G5/4 BSEN5010.

Low voltage (LV) networks that are presently compliant with existing standards may breech these limits as the numbers of low carbon technologies (LCTs), such as electric heat pumps (EHP), electric vehicles (EV) and micro generation increase. If these standards could be relaxed, even by a relatively small amount, significant savings could be made in network reinforcement expenditure required to maintain compliance.

Electricity North West estimates that less than 2% of households in its region might occasionally receive voltages that are slightly lower than 216V or higher than 253V for very short durations. This is substantiated by findings from our Tier One LV Network Solutions project, which examined networks likely to be operating at the limits of voltage. Of 200 observed networks, four distribution substations were occasionally found to record voltages under 216V representing less than 2% of the circuits monitored.

There is little evidence that minor exceedances by either magnitude or duration cause any noticeable effects for customers in terms of adverse impact on appliances or customer satisfaction and empirical evidence shows no correlation to complaints. While protracted extreme voltages or THD levels are noticeable, these are very rare.

Objectives

DNOs face significant challenges in making the transition to a low carbon future, ensuring their networks can meet the anticipated increase in demand for electricity, while ensuring they are sufficiently robust to support the adoption of low carbon technologies.

Given these unprecedented challenges and their specific impact on the voltage profile of our LV networks, there is a pressing need to examine whether existing parameters can be extended by voltage limits and duration of exceedance.

Traditionally, voltage control on LV networks is not actively managed. Therefore it has not been technically possible to definitively determine whether any given potential revised value is 'correct'.

The Changing Standards research sought to determine evidence that either:

- Customers do notice and are sensitive to minor changes outside existing power quality standards, implying the current limits are correct and should remain unaltered, or
- The analysis supports the argument that customers exhibit little sensitivity to minor exceedance of power quality limits beyond the current standards.

If established:

- Empirically determine revised power quality limits that are likely to be acceptable to customers and define the new voltage and THD limits that should be adopted by the UK.

What did we do?

Changing Standards was tasked with collating the largest possible sample of LV power quality measurements and comparing these with corresponding customer data. Customer feedback was obtained from a detailed survey, designed to gauge sensitivity to changes in voltage and THD, exceeding current statutory limits. The survey was aligned to that used in our Second Tier Low Carbon Networks (LCN) Fund project CLASS, which examined satisfaction among a group of customers supplied consistently within mandated limits. This alignment allowed direct comparison of results from customers experiencing voltage at the extremes of the limits.

An independent peer review verified that the research methodology was robust in assessing customer perception against comparative technical voltage data.

The research was undertaken in two phases, over summer 2014 and winter 2014/15, during which time almost 1,800 customers were consulted and around 7,000 LV networks data sets interrogated. This research provides the first comprehensive assessment of the voltage profile across a representative range of LV feeders on Electricity North West's distribution network.

The LV network data collated during this project came from a number of sources.

- Over 250 networks of interest, thought to be at potential risk of minor exceedances, were identified and monitored in two phases. This focussed on LV networks with a high penetration of photovoltaic (PV) panels over summer; and highly loaded networks in winter. The monitoring regime took place during the hottest and coldest months, when embedded generation and demand on local networks was expected to present the greatest risk of voltage and THD exceeding present limits.
- Other data was collected as a consequence of normal operational activities ie planning studies, LV fault detection and investigations in response to voltage enquiries.
- Power quality measurements from devices installed on LV networks as part of other LCN funded projects including Capacity to Customers, CLASS and LV Network Solutions were also examined.

Voltage and THD measurements were plotted on a power quality matrix, with the highest and lowest measurements segmented into specific data points. This matrix highlighted the duration of time that each voltage value was recorded over the monitoring period.

This data influenced selection of the survey population and ensured the satisfaction measures accurately represented the view of customers exposed to voltage at a specific value for a statistically significant period of time. The majority of surveys were completed by customers exposed to exceedance of the standards for over 5% of the monitoring period.

What did we find?

Technical data collated during this project provided little evidence to suggest that LV networks in Electricity North West's distribution region are currently at risk of breaching the permissible 5% planning limit for background harmonics. From over 4,000 network measurements, voltage THD over 5%, (based on 95th percentile values), was recorded at the busbar of only 12 distribution substations, with the highest measurement being only fractionally over 5%.

The analysis of customer survey data indicates that in both seasons, only 7% of respondents initially reported any perceived change in power quality or in the operation of appliances. This increased significantly when customers were prompted to think specifically about lighting. This resulted in approximately 22% of participants claiming to have noticed an effect. While this may appear to be a high response, there was no significant difference from the observations of the control group of customer surveys conducted during CLASS. Customers on CLASS trial circuits were supplied consistently within statutory limits, yet 21% reported perceived changes in appliances or lighting.

Notably, customer satisfaction was extremely high among the targeted sample of Changing Standards survey respondents, despite this population being skewed to customers at the extremes of voltage limits. Overall, approximately 90% of Changing Standards respondents gave high satisfaction ratings of between eight and ten (ten representing complete satisfaction and one completely dissatisfied).

There was no statistically significant difference in the average level of satisfaction among customers at the extremes, or exceeding limits, compared to those supplied consistently within the standard. 91% of customers exposed to minor exceedances were satisfied, compared to 87% satisfaction for those supplied consistently well within the limits. Again, these results are statistically no different from the CLASS measure of satisfaction at 89%.

There was also no difference when respondents were segmented by subgroup, ie domestic and priority service customers.

Voltage enquiry networks

On average Electricity North West receives 360 voltage-related enquires per year, roughly one per day.

Examination of voltage enquiries was key to understanding the network conditions and voltage range which drive perception of service. Customers who had contacted Electricity North West about voltage, and were therefore sensitised to actual or perceived power quality problems, were not surveyed to avoid distorting results.

To benchmark sensitivity at recorded values more accurately, we engaged with customers residing or operating businesses in the immediate vicinity of the property from where the enquiry was generated. These customers were carefully selected to ensure they were fed from the same LV main and phase, and therefore subject to the same or a very similar voltage profile. Customer satisfaction in this group was very high at 91%, (above the baseline measure of 89%).

PV cluster networks

Monitoring of PV cluster networks over summer 2014 revealed that 29% were subject to voltage values over 253V for short periods of time over the three-week monitoring period.

Customers on these feeders reported the highest level of satisfaction, giving a score of 10/10. These results and analysis of voltage enquiries suggest that dissatisfaction among customers with solar panels is largely driven by invertors cutting out, affecting export income from the feed in tariff (FIT), rather than a voltage effect observed in other appliances or lighting.

These findings underpin those from our LV Network Solutions project, which identified that networks in areas of very high PV penetration may see voltages occasionally above 253V for short periods.

The effect of supply interruptions

Notably, experience of a supply interruption seems to be a much stronger indicator of dissatisfaction than voltage in both the confirmed exceedance sample and those supplied within prescribed limits. A decline in satisfaction was significant among customers who had contacted Electricity North West as a direct result of a power cut.

Conclusions

The Changing Standards research has identified that customers who perceived changes in power quality or in the operation of appliances and lighting are no more likely to have experienced a recent or significant exceedance in power quality standards, than those who had not. This indicates a very weak relationship between detection and actual voltage.

However, the high level of satisfaction within the target population, supplied occasionally at the extremes of limits, implies a weak correlation between voltage and customer satisfaction.

While Changing Standards has proven that customers exhibit little sensitivity to minor exceedance of mandated operating limits, it was unable to definitively determine the values at which sensitivity is universally observed. The primary reason for this was that the data set beyond current limits was not sufficiently large to be statistically robust.

The research was therefore unable to identify the most appropriate revised upper and lower limits. However, the findings suggest that opportunities exist for an extension of the limits and Electricity North West believes this could be achieved without customers noticing or experiencing any detriment to service.

Changing Standards challenges the statutory requirement for absolute compliance to the permitted variations in voltage characteristics declared in the Electricity Safety, Quality and Continuity Regulations (ESQCR). Based on the findings, this research supports the debate for the UK's adoption of the wider EU voltage parameters of 230V +/- 10% (EN60038-2011), and potentially a further expansion beyond these limits.

This recommendation is based on the perception of a statistically robust sample of domestic and industrial and commercial customers served by typical LV distribution networks, assets and configuration. However, the research was deliberately skewed towards customers supplied at, or beyond, the extremes of operating standards and is therefore not strictly representative of most of Electricity North West's customers fed from networks with normal voltage characteristics.

To support this recommendation other wider factors may need to be addressed, including technical considerations around the voltage tolerance of electrical and electronic apparatus designed for the UK market and more specifically, the operating limits of older equipment still connected to UK networks.

In the short term there are no operational benefits arising from this research; and further work is required to understand the full implications of widening the statutory voltage limits.

Benefits of extending operating limits

- Widening the present limits will better utilise LV networks, creating headroom which will allow DNOs to support environmental improvement by hosting increased penetration of PV and installations of EHP or EV. Extending the parameters will also enable customers to easily adopt these LCTs at an affordable cost and without delay.
- Avoidance of unnecessary maintenance and traditional reinforcement costs, arising from compliance with existing, restrictive parameters, allowing:
    - DNOs to manage the transition to a low carbon economy more effectively
    - Reduced distribution use of system (DUoS) charges
    - Reduced carbon cost of replacing infrastructure.

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