WESTERN POWER DISTRIBUTION

NETWORK TEMPLATES

LV NETWORK TEMPLATES FOR A LOW-CARBON FUTURE

Use of Project Findings to Implement Voltage Reduction at Primary Substations in South Wales

LCN Fund Low Carbon Networks

Llywodraeth Cymru Welsh Government

npower

University of Bath

imagination at work

passivenergy

1. INTRODUCTION

Western Power Distribution (WPD) submitted a Tier 2 project to Ofgem in 2010 entitled " LV Network Templates for a Low-carbon Future " [ref 1] It proposed widespread monitoring of HV/LV substations and LV feeder end voltages across wide areas of urban, suburban and rural areas of South Wales. The primary aims of the project were to establish a set of "templates" characterising different cluster types of load and associated voltage profiles to aid in future UK LV network planning and to identify headroom constraints and opportunities available against each template for the absorption of future low carbon stresses.

Present day electricity networks are gradual evolutions of those originally installed in cities over 100 years or more and throughout the countryside through rural electrification into the 1950s. As further demand or generation is attached, networks have been extended or strengthened, with network *design* being checked at that time using the design tools available. Whilst there are many years of data showing half hourly demands and voltages that occur at the EHV/HV substations (typically 33/11kV or 66/11kV), there has been no equivalent level of monitoring on the 11kV and low voltage networks due to unavailability of suitable and economic monitoring and related communication systems. Information on patterns of demand of individual customers has essentially been restricted to knowing their annual electricity energy consumption in kWh

The WPD LV Templates Project has taken the opportunity to addressed this information gap through monitoring 10 minute average voltages (a measure set out in EN 50160 [ref 2] at over 4,400 points on the LV network. These points, at the HV/LV substation and at the ends of low voltage feeders were deliberately selected to identify the highest and lowest LV network voltages experienced by customers. The measurements extended over a period of April 2012 to the end of February 2013 and captured over 177 million readings. It is understood to be the widest and most extensive LV monitoring project ever undertaken in UK. The findings of this work are reported in detail in WPDs report "Stresses on the LV Network caused by Low Carbon Technologies" [ref 3] . Tables 11 and 12 of that report, , show that over 99.4% of these 177 million voltage measurements were within limits, and of the small number outside, the majority were overvoltage and just 0.015% were below the lower limit

Given this Project finding, and recognising that a reduction in the target voltage settings of the automatic voltage control relays at primary substations would bring worthwhile benefits to Customers and the community at large, WPD are implementing a setting change from 11.4kV to 11.3kV on some 147 primary substations. The benefits of this action are described below, and key reference documents forming the source of benefit analysis are listed.

2. WHAT ARE THE BENEFITS OF THE REDUCTION IN 11Kv TARGET VOLTAGE AND HOW HAVE THEY BEEN CALCULATED?

a) Reduction in demand on the network

If all electricity demand were purely resistive, Ohms law would mean that instantaneous power demand (ie kW) would drop in proportion to the square of the voltage, so, using a simple figure to illustrate the point a 10% drop in voltage would reduce demand by 19% (0.9 x 0.9) . In practice the demand on the UK electricity networks comprises a mix of demand types, including motors, which do not respond in such fashion.

In times of severe system stress, National Grid can call on network operators to reduce demand through widespread application of voltage reduction in two steps; -3% and -6%.
(The Grid Code - OC6)] [ref 4)] These are applied by sending signals to the automatic voltage control equipment at grid or primary substations which control the on load tap changers fitted to 33/11 kV and higher voltage distribution network transformers. It had traditionally been the case that demand reduction of 10% would be achieved from a 6% voltage reduction. However, during actual events since 2006/7 and subsequent trial involving domestic, commercial and large industrial demand groups, a 3% voltage reduction gave an average of 3.4% demand reduction against the 5% historically expected.(source - National Grid - Grid Code OC6 Demand Control Working Group) [refs 5 & 6] Consequently the estimation has been reduced to a 3% voltage reduction producing a 3% demand reduction. Further voltage reduction system tests are planned to be undertaken in September and October 2013 [ref 7]

The above studies relate to the drop in instantaneous *demand* (kW), but not to the reduction in *energy* demand (kWh). For example, if the voltage supplied to a nominally 3kW electric kettle were reduced, it would produce less than 3kW, but it would still boil the water, albeit over a longer period, so the kWh usage would be the same. A light bulb however would produce less output but the time it was on would not be influenced. Motors may take higher current to compensate for reduced voltage. Thus as above, the mix of demand types means that there is not a straightforward relationship between *demand* reduction and *energy* reduction. Arguably the best data to date has come from the above National Grid / GCRP tests, which have quoted a 1 for 1 relationship; 1% voltage reduction producing both a 1% demand reduction and a 1% energy reduction. This is a higher level of reduction than that used in the above WPD LV Templates project "Stresses" paper [ref 3] to provide an estimate of benefit.

WPD identified a list of 147 primary substations where the target voltage will be reduced from 11.4kV to 11.3kV. The maximum demands on those substations have

been taken from the 2011/12 Maximum demands listed for each substation in WPD's Long Term Development Statement (LTDS) s published (on-line) as a Licence requirement. The sum of those MVA figures has then been converted to MW by applying the power factors listed in the LTDS; giving an MD of 1747MW . From the above referenced work, the calculated demand reduction will be in proportion to the voltage reduction, i.e 11.3/11.4; a reduction of of 0.88%., or 15.7 MW.

The reduction in HV in target voltage, will reduce maximum demand by 15.7 MW

b) Reduction in customers energy bills

The related energy saving over a year has then been calculated by applying the South Wales Load Factor, derived from half hourly monthly settlements data returns for total Grid import + embedded generation over a full year, vs system maximum demand. The annual energy consumption of the 147 primary substations is thus calculated to be 10,618 GWh and so the above saving would amount to 93,143 MWh (please note change of units).

On the basis that cost of marginal units of electricity to Customers remains at DECCs most recently published levels, the cost saving to Customers can be calculated.

DECC 2013 Digest of UK Energy Statistics ("DUKES") published July 2013, [ref 8] provides data on the split of Domestic and Industrial / Commercial energy use in Wales; taking the same proportion, provides for a saving of 33,286 MWh to domestic customers and 59857 MWh to I&C customers. Further DECC data provides average unit costs for domestic customers [ref 9] and unit costs for small medium and large I&C customers. (The latter data is now in Govt. Archive and the most recent data is for Q2 2012). The give Standard domestic rate at 12.66p / kWh and for small I&C 9.12p / kWh and medium I&C at 8.27 p/kWh. The benefit has employed the mean of these two I&C rates.

The annual savings to domestic customers then amount to some £4.2M p.a and to I&C Customers of some £5.2M p.a; a combined saving to customers of some £9.4M p.a

The reduction in HV and LV system voltage will reduce Customer bills by a calculated £9.4M each year, based on current unit charges

c) Reduction in CO2 emissions

The reduction of 93,143 MWh energy use reduces CO2 emissions from generating plant.

DECC 2013 DUKES data (Table 5C) [ref 8] for 2012 shows a provisional figure of 483 Tonnes of CO2 / GWh of electricity supplied (457 Tonnes in 2010 and 440 Tonnes in 2011. The saving in emissions from the above voltage reduction action would thus be calculated to save some 41,000 Tonnes of CO2

The reduction in HV and LV system voltage will reduce CO2 emissions by some 41,000 Tonnes each year, based on DECC 2011 data. DECC provisional 2012 data would give a figure 10% higher than this.

d) Provision of additional headroom to accommodate further LV distributed generation

Although not quantified, reduction in operating voltage, will allow further LV DG to be connected without breaching the upper 230V +10% statutory voltage limit

(A spreadsheet setting out the above benefit calculations is available on request)

3 HOW WILL SUPPLY VOLTAGES OF CUSTOMERS BE VERIFIED?

The end of the mass roll out of smart meters across UK is scheduled to be completed by 2020 [ref 10] DECC Smart Meters Programme Delivery Plan, 10th May 2013 The latest (1st July 2013) specification of those smart meters [ref 11] includes a for a number of voltage quality measurements -

- Average RMS voltage
- RMS extreme over voltage detection
- RMS extreme under voltage detection
- RMS voltage sag detection
- RMS voltage swell detection

There are thus already established detailed plans for national roll out of devices which will provide widespread continual monitoring of voltages supplied, providing confirmation that supplies are within limits, and on the basis of the LCNF LV Templates project findings, exceptionally those instances where they are not.

4 REFERENCES

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2 EN 50160 – 2007 "Voltage characteristics of electricity supplied by public distribution networks"..

3 Stresses on the LV Network caused by Low Carbon Technologies" - Western Power Distribution - http://lowcarbonuk.com/downloads/StressReport.pdf

4 Grid Code OC6 - http://www.nationalgrid.com/NR/rdonlyres/33623B15-D351-4489-9BF9-11AF8E921BA5/55761/13_OPERATING_CODE_6_I5R0.pdf

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7 National Grid - Grid Code Working Group - Demand Control - OC6 - verbal update from WG Member 14 Aug 2013 - system tests are planned to be undertaken in September and October 2013

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