THE PERFORMANCE OF AN LV NETWORK SUPPLYING A CLUSTER OF 500 HOUSES EACH WITH AN INSTALLED 1kWe DOMESTIC COMBINED HEAT AND POWER UNIT

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ABSTRACT

Lovell Partnerships is currently building a new development of approximately 500 houses in East Manchester. Each house will have a WhisperGen™ dCHP (Domestic Combined Heat and Power) unit supplied by Powergen. This will be the first cluster of dCHP units in the UK, and represents an ideal opportunity to monitor the effects of such a cluster in the local network. Each WhisperGen has an induction generator of roughly 1kWe rating.

There are currently three projects monitoring different aspects of the site such as the performance and energy efficiency of the dCHP units, demand and generation profiles and the network impacts

Module 5 of EA Technology's Strategic Technology Programme (STP) has agreed to undertake, in collaboration with the local Network Operator (United Utilities) and Lovell Partnerships, a programme of detailed electrical network monitoring. It is this project on which this paper is concentrates.

INTRODUCTION

The Lovell homes partnerships development in East Manchester of some 500 modern domestic dwellings, each with a 1kWe WhisperGen dCHP unit, is the first of its type in the UK.

The WhisperGen is a co-generation (heat and power) system based on a small four cylinder Stirling engine (www.whispergen.com). It is designed to replace a central heating boiler and simultaneously generates 1kWe of electricity and provides up to 12kW of heat. It is similar in size to a domestic dishwasher. The 1kWe output from the unit is similar to the ADMD (After Diversity Maximum Demand) for the properties.

The work presented in this paper outlines the early results from a 12 month programme of electrical monitoring carried out on one the LV feeders (LV - 230V single phase, 400V three phase).

Figure 1. Typical dwelling

Feeder being monitored

The monitoring for this project is on the first phase of the housing development. The LV feeder being monitored supplies 69 properties, which to date all but 2 are occupied.

The monitored LV feeder points are the substation (point A), approximate mid feeder location (point B) and end feeder location (point C). This is illustrated in Figure 2.

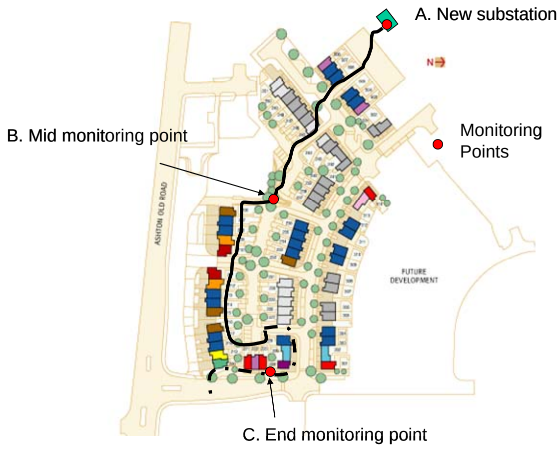

Figure 2. LV Feeder Monitoring points

In figure 2 there are 38 houses connected between the substation and mid feeder location. There are then 31 houses from the mid feeder location to the feeder end point. A 300mm^2 AL LV cable is used throughout the circuit length.

At the substation both the three phase voltage and feeder current is monitored. At location B (mid point) the three phase voltage and feeder current is again monitored. At location C (end point) the three phase voltage only is monitored since it is the end of the LV feeder for these 69 dwellings.

Equipment being used

The equipment used to monitor the feeder voltage and current at the three locations is a LEM Memobox 300A 3 phase power quality analyzer. An illustration of the logger is shown below in Figure 3.

Figure 3. LEM Memobox 300A

This equipment has the capability to measure and record the following standard power quality parameters:

- Voltage, mean, min & max
- Current, mean, max
- Flicker (Pst, Plt) [1]
- Total Harmonic Distortion (THD) of Voltage and Current) [2]

The substation logger is located within the LV panel of the brick built 1000kVA urban substation. For the mid point and end point feeder locations, an LV Feeder Pillar was installed to house the logger and necessary cut-outs, switched fuses and ducting to ensure a safe and secure enclosure for the positioning of the monitoring equipment.

The analysis software used by the logger is CODAM Plus (version 4.1.2.6) with Microsoft Excel also used in the data handing.

INITIAL RESULTS

A 12 month monitoring period has been established for this project. The information presented in this section is for a period during November and December 2006. The operation of the WhisperGen dCHP unit during this cold period is therefore likely.

To assist with the comparison of the results, a single mid week day (Wednesday) is selected and the trends during the period compared for the different locations.

Substation logger observations

Due to a limitation at the substation, phase L1 was only available for the voltage measurement (three available for current measurement). It is assumed that the other two voltage phases are similar in magnitude at the substation location for the purposes of comparison.

Voltage

The plot below illustrates the observed mean 10 minute voltages for the mid week day monitored.

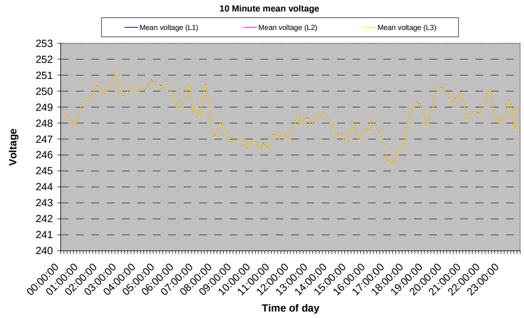

Figure 4. 10 minute average voltage

The applicable standard [3] for public networks states that the 95% of 10 minute averages should be within 230 +10% (253V) and 230 -10% (207V). (In the UK the statutory limits are 230+10% and 230 -6%.) It is shown in figure 4 that the voltage observed at the substation for this period is within the permissible limits. The standard target voltage for the substation is 250V (433/√3) which is further supported by Figure 4.

Current

The plot below illustrates the mean 10 minute currents for the mid week day monitored. A conventional domestic profile (scaled to maximum current) is also illustrated.

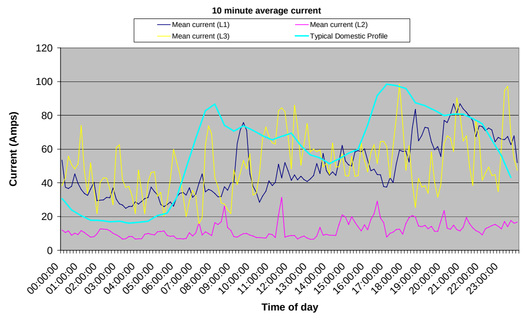

Figure 5. 10 minute average current

Figure 5 shows that L2 phase is more lightly loaded than L1 and L3. The main demand peak is observed to be midday and late evening. The morning peak when compared to a conventional domestic load profile appears to be displaced towards midday. The overall load factor also appears to be higher than that of a more typical domestic load profile.

Voltage Flicker (Pst)

The plot below illustrates the observed short term flicker severity (Pst) for the mid week day monitored.

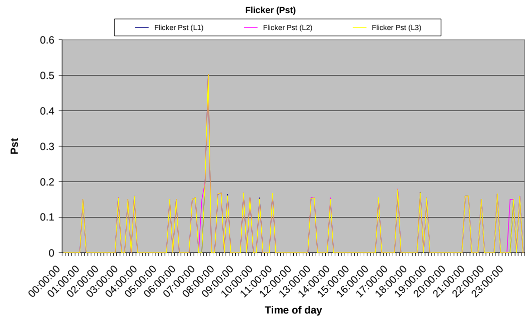

Figure 6. Voltage flicker Pst

The acceptable limit [4] for public networks of Pst is 1.0. Figure 6 shows that the short term flicker is significantly below these limits for the period. There is however a abnormal spike at approximately 7:30hrs which is likely to be when the dCHP units start. Over a larger sample this could be an issue.

Feeder mid point logger observations

Voltage

The plot below shows that the voltage observed is within the permissible limits for this period.

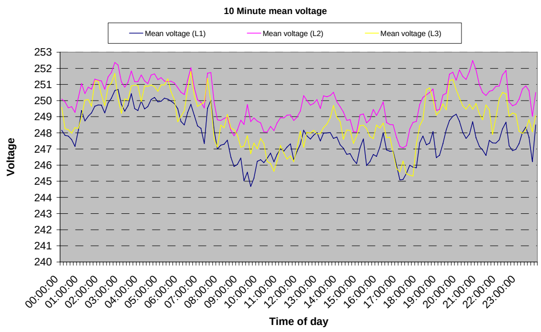

Figure 7. 10 minute average voltage

Current

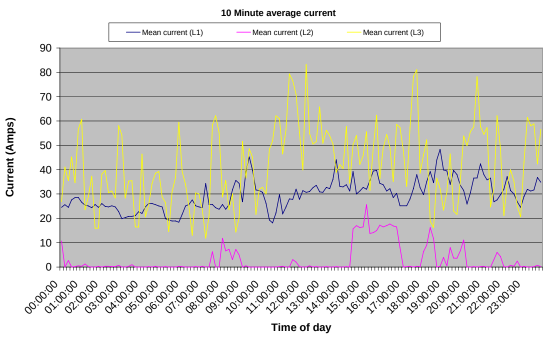

Figure 8. 10 minute average current

As observed at the substation, there is light loading on phase L2 although no reversal of current is evident. L3 is more dynamic over the period. Again, the overall trend for L1 and L3 is that there remains a lack of peak in the morning period when compared to that of a more conventional domestic load profile.

Voltage Flicker (Pst)

The plot below illustrates the observed short term flicker severity (Pst) and is below accepted limits for this period. Again there remains an abnormal spike at approximately 7:30hrs which is likely to be when the dCHP units start.

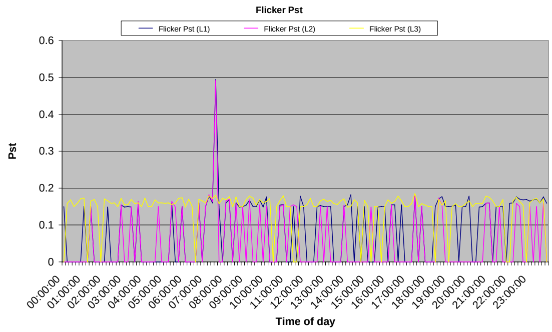

Figure 9. Voltage flicker Pst

Harmonic voltage distortion (THD)

The plot below illustrates the observed total harmonic voltage distortion (THD) for the mid week day monitored.

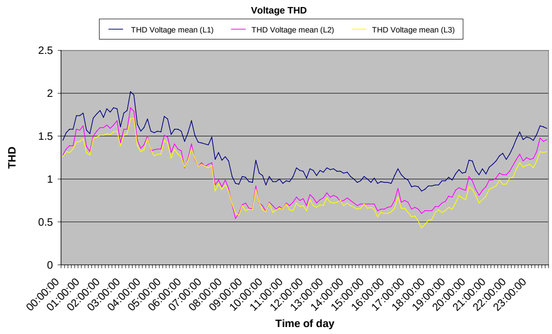

Figure 10. Harmonic voltage distortion

UK harmonic voltage distortion limits are outlined in G5/4 [2] and are limited to 5% at the 400V network level. The plot above shows that the observed levels of THD are significantly less than the permissible limits.

Feeder end point observations

Voltage

Figure 11 shows that the voltage observed remains just within acceptable limits.

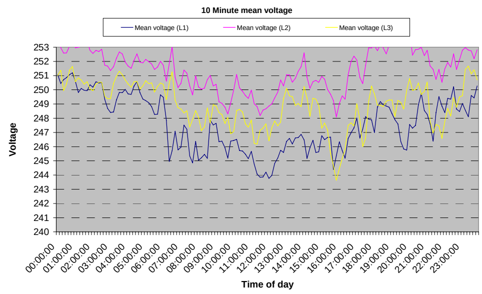

Figure 11. 10 minute average voltage

Voltage Flicker (Pst)

The plot below illustrates the observed short term flicker severity (Pst) for the mid week day monitored. The level observed is significantly below these limits for the period.

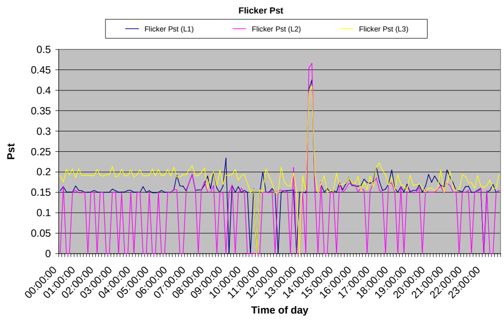

Figure 12. Voltage flicker Pst

Harmonic voltage distortion (THD)

The plot below illustrates the observed harmonic voltage distortion for the mid week day monitored. The observed levels of THD are again significantly less than the permissible limits.

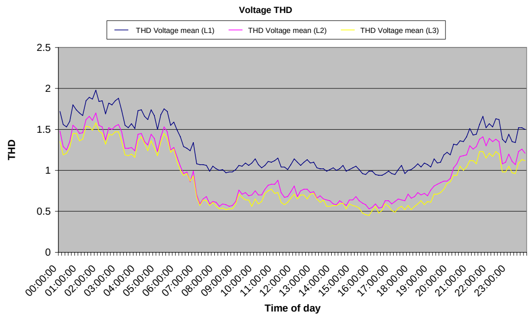

Figure 13. Harmonic voltage distortion

RESULTS DISCUSSION

From the results presented, it can be seen that:

- The observed load profiles differ from that of a more conventional domestic dwelling that have no power export from the site.
- The morning demand peak is a flatter profile, with the demand at the substation not increasing until around 9 or 10am when the micro-chp units are likely to be shutting down.
- The early hours of the morning and later in the evenings are when the network voltages are at their highest values
- The morning voltage peak does appear to be on a more downward trend when approaching 8 and 9am as load is seen to increase during this period
- 6 to 7am appears to show the peak voltage point. This would agree with the view that the dCHP units will be on and generating at this time
- Flicker and voltage harmonic distortion from the values observed are below the acceptable limits, but an abnormal spike at approximately 7:30hrs suggests operation of the dCHP units. Over a larger sample this could be an issue..
- Similar trends in the data presented are also observed for other days which data has been collected for.

CONCLUSION

The load profile observed in the results presented shows that there is a difference from that of a more 'typical' domestic property, with a generally higher observed load factor. The impact of this load profile is such that the network must be able to cope with a more peaky voltage profile in the mornings and later evenings. There remains therefore an opportunity to optimise the tap setting of the distribution transformer for this particular arrangement, or deploy an on load tap changer as highlighted in [5].

As this project is in its early phases of data acquisition and interpretation, recent data will be available at the time of conference presentation.

Acknowledgments

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REFERENCES

[1] Engineering Recommendation P28, Planning Limits for Voltage Fluctuations Caused by Industrial, Commercial and Domestic equipment in the United Kingdom,1989.

[2] Engineering Recommendation G5/4-1, Planning levels for harmonic voltage distortion and the connection of non linear load equipment to transmission systems and distribution networks in the UK , Feb 2001

[3] BS EN 50160 : 2000 – Voltage characteristics of electricity supplied by public distribution systems

[4] Engineering Recommendation G83/1, Sept 2003, Recommendations for the connection of small scale embedded generators (up to 16V per phase) in parallel with public low-voltage Distribution Networks

[5] V. Levi, M. Kay, M. Attree & I. Povey. 2005, Design of low voltage networks for premises with small scale embedded generators, CIRED 05, paper 147, Session 4.