

**ASSESSING SOLAR
PANEL IMPLICATIONS
FOR NETWORKS**

LCN FUND TIER 1
CLOSE DOWN REPORT

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1. Introduction

This project was initially proposed by Central Networks, with project ownership and responsibility transferring to Western Power Distribution (WPD) as a result of the business acquisition in April 2011.

The introduction of Feed in Tariffs (FiT) within the UK showed a dramatic increase in the connection of micro generation especially that connected to the low voltage distribution network. Government policy has greatly increased the investment proposition of installing micro-generation. The range of companies offering free PV installations in exchange for the revenue from the tariffs meant that high numbers of micro generation were being installed in compact suburban environments.

The LV distribution networks have not traditionally been designed to accommodate significant levels of micro generation and two way power flows. Single micro-generation installations up to 16A per phase can be made under G83 Stage 1, with the DNO being informed up to 30 days after the installation. If the connection of generation causes the network to operate outside of its design limits network reinforcement is planned.

Multiple installations require a developer to make an application under G83 Stage 2. The proposed installations are modelled to ensure that the cumulative micro generation effect will not have a substantial impact on the distribution network causing it to operate outside of its design limits. If the system studies identify issues, a developer can request network reinforcement to be carried out or reduce the scale of their development to avoid network reinforcement.

PV impact on suburban networks intended to install suitable monitoring equipment into a number of substations in the Meadows, Aspley and Broxtowe areas, where a significant number of PV panels were being installed in one location and assess the impact micro generation has on the distribution network operation and any required updates to WPD's policies.

2. Executive Summary

This report details the work undertaken and the findings from the Tier 1 project, PV impact on suburban networks. The project had three project phases which were achieved throughout the project:

- Selection of substation monitoring equipment,
- Installation in distribution substations,
- Recovery and Analysis of data to determine the impact of dense PV panels on suburban networks.

The project selected three split core current transformers, rogowski coils with transconductance amplifiers to measure current, modified fuse carrier handles and Nylon G clamps to measure voltage and EDMI and Subnet units as monitoring equipment. Devices were configured together to provide the most appropriate solutions for the networks requiring monitoring.

Substation monitoring was installed on seven LV feeders and one substation transformer measuring and recording a range of characteristics including minimum/average/maximum voltage and current, current Total Harmonic Distortion, voltage Total Harmonic Distortion, individual voltage harmonics up to 50th, power factor, real and reactive power flows.

Key Conclusions

- The magnitude of power flows from the HV network, through the distribution transformer into the LV network is significantly reduced during periods of high solar irradiance due to the export from the installed micro generation.
- The data shows that even during the longest summer days the installed solar PV had a relatively modest effect at reducing the traditional network peak demands at breakfast (7:00am – 8:30 am) and during the evening (6pm – 8pm)
- The project did not record any reverse power flows across the eight monitored locations due to a level of diversity and a lower than expected output from the multiple small scale installed solar
- The absence of reverse power flows for the duration of the trial means the voltage profile is still largely dominated by the tap changers on primary transformers and not by voltage rise from the embedded solar PV.
- The installed PV generation operates at unity power factor, the connected domestic loads operating at a lagging power factor. At periods where the PV generation supports the majority of the network demand, the power factor was shown to be as low as 0.185.
- The analysis of current and voltage waveforms shows the voltage remains relatively sinusoidal at all times. The sinusoidal current waveform is highly distorted due to harmonics.
- WPD's existing design policies and software tools have been amended to allow the connection of a further 20% solar PV on multiple LV properties, this is due to the measured diversity and lower than expected kW outputs. Exceeding a further 20% PV would lead to reverse power flows and could lead to unacceptable voltage rise.

The original project budget was £100k, the costs at the project was £76k.

3. Project Suppliers

EDMI are one of the leading smart energy solutions providers in the world. Their portfolio includes metering products, infrastructure and energy management systems.

Other component suppliers include EMS, Haysys Ltd, Invirotech Ltd, Schneider, Fluke, Northern Design (Electronics Ltd).

- EDM I supplied the Mk6E meter, this is an advanced I&C meter that was tested as a substation monitor.
- EMS supplies the sub.net, a portable network monitoring set that can be configured with either current transformers or Rogowski coils.
- Haysys Ltd developed and supplied an interface box and Rogowski coils for current monitoring
- Invirotech Ltd manufactured and supplied fused nylon G clamps to be used as a voltage connector.
- Schneider supplied modified fuse carrier handles used as a voltage connector.
- Fluke supplied two different specifications of current transformers used for current monitoring.
- Northern Design Ltd supplied a current transformer used for current monitoring.

Suppliers for this project were selected through our normal business as usual low value process.

4. Project Background

Project Background as submitted 02/2011

The introduction of feed in tariffs within the UK has shown an increase of micro generation connected to the low voltage distribution network. This is becoming increasingly evident from the range of companies offering free PV installations in exchange for the revenue from the tariffs. If a high penetration of micro generation is installed in a compact suburban environment, the cumulative effect is expected to have a substantial impact on the existing distribution network.

Nottingham is one location where a significant number of PV panels have already been installed in dense locations; further dense areas are also due to be developed.

106 kW of PV Panels have been installed and up to 1235kW are scheduled to be installed in Aspley and the Meadows by the Meadows Partnership Trust, Nottingham City Council and Blueprint.

As the UK transitions to a lower carbon economy, it will see an evolution in our customers' behaviour. The installation of micro generation has seen the greatest uptake, especially solar PV due to government led measures. Micro generation can have a substantial impact on the distribution network, especially at the end of the low voltage network. WPD have planning guidelines to facilitate our customer's low carbon aspirations, allowing the multiple connections of micro generation whilst ensuring the networks operate safely within their design limits. Network monitoring projects, engagement with manufacturers and trade bodies, can lead to a better understanding in customers' use of new technologies and their cumulative effects on the network. Through LCNF projects, WPD are able to update the planning guidelines to maximise the capacity of the network before network reinforcement is triggered.

This project sought to comprehensively monitor sections of suburban network identified as having a dense PV penetration. The project aimed to better understand how multiple Solar PV installations impacts all aspects of the LV network operation, improving the future planning assumptions.

4.1. Nottingham as a trial location

Nottingham was one of the first areas within the Midlands to propose and install solar PV in focussed urban areas. These connections were carried out by the Meadows Partnership and Nottingham City Council in two phases across three locations within Nottingham.

The Meadows Partnership

Installed over 100kW of PV panels onto terraced properties constructed between 1900 and 1970's and PV installed on 38 new build eco homes constructed 2010-2012. In December 2009 the Meadows won £500,000 in a competition as part of the Low Carbon Communities Challenge to pay for the installation of solar panels on 55 houses 3 primary schools and a community garden. The properties include social housing, low income owner occupier houses and 10 privately owned homes. Construction was completed by March 2010.

Nottingham City Council

Installed 1200kW in conjunction with Nottingham City Homes & E.ON. Aspley and Broxtowe were selected in 2011 to install PV panels on 1450 suitable properties. These were all social housing, terraced and semi-detached properties constructed in 1970's. Figure 1 shows the network trial locations and part of Broxtowe after PV was installed.

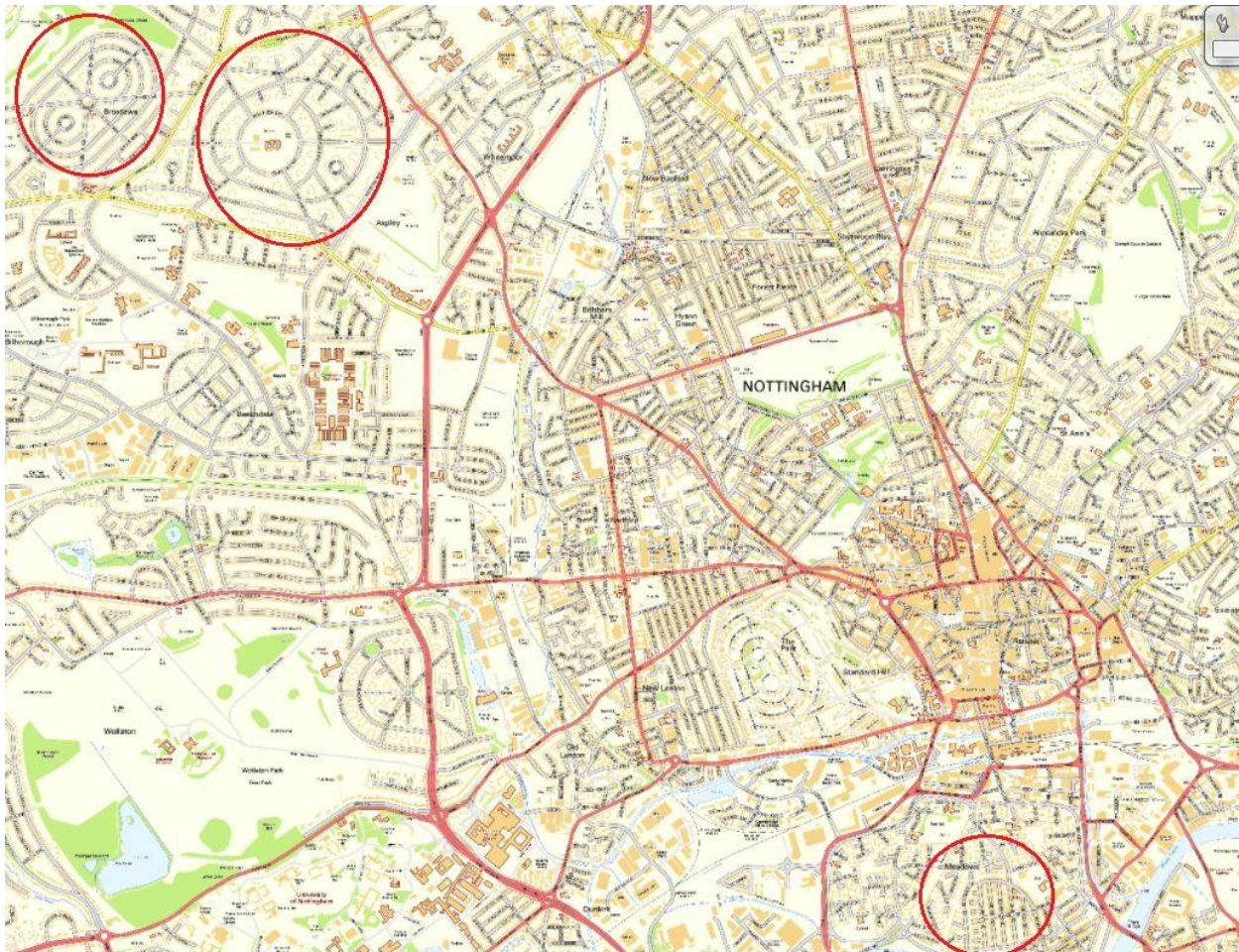




Figure1- Monitoring areas and aerial photography of Broxtowe, Nottingham

The distribution networks in the trial locations were all modelled and selected as they were deemed to be generic and representative sub-urban networks in many different areas.

4.2 Project Overview

This LCNF Tier 1 Project was split into several distinct phases, each with its own aims:

Phase 1 – Project Design

- Selection of substation monitoring technology,
- Selection of transducers,
- Selection of trial locations.

At the project inception, no suitable, cost effective off the shelf, semi-permanent distribution substation monitoring solution with appropriate transducers was available. A monitor capable of analysing all the network characteristics was sourced from a smart metering company, EDMI. The meter was configurable and designed for Transmission, Distribution and Industrial customers. A range of suitable transducers had to be combined together to provide a safe, easy way of monitoring distribution substations.

The trial locations were selected across the Meadows, Aspley and Broxtowe networks to monitor the feeders with the greatest modelled impact from the embedded generation. Appendix D and Appendix E identifies the LV networks monitored.

Phase 2 – Installation in distribution substations

The project required installation of the most suitable monitoring equipment, transducers and remote communications in selected substations on either the substation or individual feeders.

Phase 3 – Recovery and Analysis of data

The data generated from the eight substation feeders required analysing to better understand the impact of Solar PV as observed at the distribution substation. The learning from this project has been used in conjunction with the WPD Projects, LV Network Templates and Early Learning, to update to WPD's policies concerning the connection of LV connected solar PV generation.

The learning from these projects is complementary to other projects which have been monitoring PV under different circumstances.

- PV impact on suburban networks – Installation of PV on existing homes in large suburban estates with an existing electricity distribution network.
- LV Network Templates – Identifying the distribution network headroom for Low Carbon Technologies (LCTs) across a whole region.
- Early Learning – Installation of PV on a small estate of new properties, clustering of LCTs on every property, installed with a switchable distribution network configuration.

5. Scope and Objectives

Scope and Objective as submitted 02/2011

The project will monitor the profile of eight selected substations or individual feeders in areas where PV panels have already been installed or are expected to be installed.

Through this project, CN will explore the following aspects:

- How to measure and capture voltage, current, harmonic, real and reactive power data on a range of distribution assets in suburban areas.
- How to install equipment safely with minimal or no interruption of supply
- How often the network characteristics need to be monitored (for example 1min, 5min, 15min)
- How we can interrogate the large amounts of data generated to highlight significant network issues created by the installation of PV panels
- What the effect is of installing large numbers of PV panels on the LV network

We aim to share our learning with other DNOs in November 2012.

The project encountered a number of delays; these resulted in a change request of the project being submitted to increase the project duration by 12 months. The WPD internal change mandates associated with this amendment are included in Appendix C.

Ofgem were notified on 10/2012 in line with the LCNF governance document how the project would still achieved its original scope and objectives.

6. Success Criteria

Success criteria as submitted 02/2011

- Select a range of sensors to be developed and tested by April 2011
- Install the substation monitoring equipment by May 2011
- Determine the frequency of monitoring each characteristic by July 2011
- Analysis 12 months data, highlighting the measured impact of PV on the distribution network by September 2012
- Write a close out report around the key objectives and the lessons learnt by November 2012.

The success criteria detailed above were identified at the point of project registration. These success criteria will be used to determine the positive and negative learning throughout this report. All success criteria have been met through the project, however delays identified in the change request lead to the delay in the installation of substation monitoring and all further milestones.

7. Details of the work carried out

7.1 Phase 1

7.1.1 Selection of substation monitors

WPD's existing network monitoring solutions have traditionally been used for two very different purposes.

1. **LV feeder, Voltage and Current measurements - Temporary (typically 2 weeks).** These devices record current and voltage parameters, they do not have a full range of power quality analysis capability. Data from these devices is by a manual downloaded, i.e. it has no wireless backhaul of information.

2. **HV and EHV, Power Quality, Voltage and Current measurements – Temporary (typically 1 month).** The devices and transducers are designed for HV networks and are not ideally set up for LV network monitoring and as such isn't a cost effective for roll out on the LV network. Often the data can only be downloaded manually from the device, i.e. it has no wireless backhaul of information.

This project required a monitoring solution suitable of recording and storing phase - neutral Voltage, single phase Current flows, voltage and current Harmonics, 2 – 50th, real and reactive power flows. It was deemed essential that the data could be recovered remotely as the monitors were required to record data for over 12 months.

The project selected two monitoring solutions after a review of the market, seven EDM1 Mk6E and one EMS subnet as seen in figure 2.

EDMI Mk6E

Advanced Three Phase Electronic Revenue Meter the Mk6E is a high precision meter created for generation and transmission applications. GPRS Capability, Power Quality Indication, Advanced Tamper Detection & AMI ready.

EMS Subnet

This substation monitor carries out full analysis within each unit and can send auto prioritised graphical and numerical reports. The Monitor can be upgraded without removal or recalibration. Sub.net will report on voltage, current, power quality, voltage dips, frequency, harmonics and flicker.



Photo EDM1 Mk6e



Photo EMS subnet

Figure 2- Monitoring Solutions

7.1.2 Selection of Voltage Connections

Most of the historic distribution substations do not have voltage monitoring points suitable for connecting a network monitor for over a 12 month period. The project required at least two different fused voltage connections which could be installed on a semi-permanent basis for typical LV distribution boards installed in Nottingham.

Two voltage connectors were selected to provide an effective fused measuring point between the LV busbars and neutral bar, as seen in figure 3.

Schneider voltage handle EE:200

The Schneider EE:200 has been developed to provide a fused voltage connection for an insulated connector and lead providing a voltage reference point on either the busbar or feeder.

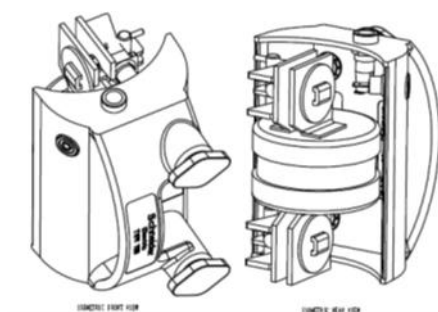
- ✓ A minor modification to an existing WPD approved device
- ✓ Can be installed without any customer interruptions
- ✓ Maintains the IP rating of the LV distribution board
- ✗ Requires a separate neutral connection
- ✗ Requires a circuit to be paralleled “back feed” from a neighbouring substation to install without an outage.

Nylon G Clamp

The Nylon G Clamp is an approved method of gaining a fused, doubly insulated connection for an open LV Distribution board. New nylon G clamps were manufactured to the existing specification providing a semi-permanent method of getting a voltage reference point on the LV busbar.

- ✓ Existing approval for use on the distribution network
- ✓ Transducers are safely installed without any customer interruptions
- ✗ Only suitable on open LV distribution boards.

The use of both voltage connectors allowed for the network voltage to be effectively monitored without the requirement for a network outage.



Voltage Handle



Nylon G Clamp

Figure 3- Voltage connectors

7.1.3. Selection of Current Transducers

Most distribution substations have Current Transformers installed for Maximum Demand Indicators (MDI's) to provide a guide to the substation demand. Their function requires them to have a relatively low accuracy for 50Hz signals. This project required higher accuracy transducers for power quality analysis.

Four different current transducers were selected for use with the EDMI Mk6E meter.

Split core current transformers

This split core current transformer is a method of retrofitting accurate current transducers around LV feeders without requiring any outages.

- ✓ High accuracy
- ✓ They are robust solution for longer time monitoring.
- ✓ Don't require any calibration post manufacturing.
- ✗ The design and construction must be matched to the application.
- ✗ The design and construction must be match to the monitor
- ✗ Most have a limited secondary wiring length.

The different network design characteristics required three different split core current transformers to be selected. CT's were selected to fit within the physical available space, operate safely with the maximum LV feeder current, connect to the monitor with the original or an extended lead and fit around the existing cable.

US1000A:1A

- ✓ The largest jaw aperture of the three split core CT's selected
- ✓ Designed for sustained monitoring up to 1000A
- ✓ 4mm safety plugs for users to supply and fit custom leads
- ✗ Large CT not suitable for some distribution substations where LV feeders have a modest separation between cores.

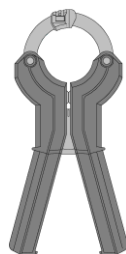


Figure 4 – US1000 Current transducer

Fluke i800 Current Clamp

- ✓ Designed for sustained monitoring upto 800A
- ✓ Highest accuracy CT including at low Currents
- ✗ Large CT not suitable for some distribution substations where LV feeders have a modest separation between cores
- ✗ Fixed length leads with safety plugs fitted



Figure 5 – Fluke i800 Current transducer

Fluke i400 Current Clamp

- ✓ Designed for sustained monitoring upto 400A
- ✓ The smallest overall size of the three split core CT's selected
- ✗ Fixed length leads with safety plugs fitted
- ✗ Not suitable for some high current feeders.



Figure 6 – Fluke i400 Current transducer

Rogowski Coils

- ✓ Designed to fit around any LV feeder
- ✓ No maximum current limitation
- ✗ Requires a transconductance amplifier when used with some monitors
- ✗ Requires calibration between the rogowski coil and transconductance amplifier.
- ✗ The transconductance amplifier requires additional space
- ✗ Rogowski Coils with an interface box is a higher cost solution compared to split core current transformers.

Requirements for a Transconductance amplifier

The EDM1 Mk6E energy monitors procured for this project, like most energy monitors, is designed to measure an alternating current between 0A and 1A from Current Transducers. The US1000, Fluke i800 and i400 Current transformers all have a 0-1A secondary output and could be easily integrated with the EDM1 Mk6E meter.

Rogowski coils measure current like a current transformer, however the output is in mV rather than 0 – 1A current. To use a Rogowski coil with a traditional energy monitor requires a transconductance amplifier. The input voltage (mV) is converted into a variable current output. Haysys Ltd built a transconductance amplifier to allow rogowski coils to be integrated with an EDM1 Mk6E meter. This uses an off the shelf op amp and follows standard engineering designs, not generating any new IPR.



Figure 7 – Rogowski coil and transconductance amplifier Current transducer

7.1.4 Selection of trial locations

The project selected substations likely to have the greatest impact from the connected solar PV, though either the number of connections, the location of panels along the network or the network design. By selecting the substations likely to see the greatest impact, we selected the substations likely to produce the greatest amount of learning.

Meadows

Three substations were selected within the Meadows, South Nottingham.

1 - Wilford Crescent East - Transformer. Selected due to combination of new energy efficient housing with solar PV and the retrofitting of solar PV to existing 1920's housing stock.

2 - Ayton Close Meadows A – Feeder 1. Selected due to the dense connection of solar PV to existing 1940's housing stock.

3 - Ayton Close Meadows B – Feeder 4. Selected due to the dense connection of solar PV to existing 1940's housing stock.

Aspley

4 - Tunstall Crescent – Feeder 4. Selected due to the dense connection of solar PV to existing 1940's housing stock.

5 - Hilcot Drive Aspley – Feeder 4. Selected due to the dense connection of solar PV to existing 1940's housing stock.

Broxtowe

6 - Lindbridge Road – Feeder 5. Selected due to the dense connection of solar PV to existing 1940's housing stock.

7 - Frinton Road – Feeder 3. Selected due to the dense connection of solar PV to existing 1940's housing stock.

8 - Broxtowe Lane – Feeder 4. Selected due to the dense connection of solar PV to existing 1940's housing stock.

7.2 Phase 2 Installation

The site surveys and installation of all equipment was carried out by a team from the WPD Nottingham depot over a two week period with guidance from the Future Networks team. The installation of equipment took approximately half a day per substation and was completed without any interruption of supplies.

Each installation followed the same process:

1. Installation of the Monitoring equipment in a suitable location
2. Installation of cable ducting, maintaining the IP rating of the WPD package substations
3. Installation of transducer cabling between the LV feeder pillar and monitoring equipment
4. Installation of current transducers
5. Installation of voltage transducers
6. Commissioning monitors
7. Commissioning the GPRS communications
8. Affixing a notice in the substation, providing guidance for staff unfamiliar with the project.



Figure 8 - Example equipment installed in Meadows Crescent East and Lindbridge road distribution substations

7.3 Phase 3

The intention of the project was to maximise the learning, monitoring different characteristics at each site, changing the monitoring equipment characteristics. Each meter was configured to record a combination of Voltage, Current, Power Factor, Voltage Total Harmonic Distortion, Current Total Harmonic Distortion, and Individual Voltage Harmonics.

In addition to monitoring the individual characteristics, the waveform was analysed regularly to highlight any particular issues.

Over the duration of the project the monitoring equipment at each site has been configured for a period of time to recover data as detailed in the Figure 9.

	211377894	211377895	211377896	EMS	211377897	211377898	211377899	211377900
	Frinton Road	Meadows Crescent	Ayton Close A	Ayton Close B	Tunstall Crescent	Hilcot Drive	Broxtowe Lane	Lindbridge Road
Average Voltage	○	○	○	○	○	○	○	○
Max & Min Voltage				○				
Average Current	○	○	○	○	○	○	○	○
Max & Min Current				○				
Average Power Factor		○			○		○	○
Power (kW, kVA, kVAr)				○				
Average Voltage THD	○		○		○	○		
Average Current THD						○		
Individual Odd Voltage Harmonics	○	○	○		○	○	○	○

Figure 9 – Configuration of network monitoring

8. The outcome of the Project

8.1 Measure and capture LV Performance on a range of distribution assets in suburban areas

The project developed and installed monitoring solutions to measure and capture the performance of the LV network on a range of distribution network assets in suburban areas. At the project inception a cost efficient LV monitoring solution did not exist. Off the shelf meters, current transducers and voltage connectors were selected where available. Nylon G clamps were manufactured as an additional voltage connector and a transconductance amplifier was designed and manufactured to facilitate the use of Rogowski coils as an additional current transducer.

The project measured and captured the LV performance including network Voltages, Current magnitudes, Power Factor, Voltage THD, Current THD and individual Voltage harmonics. Over the duration of the project, 2,192,750 data points was measured and recorded.

The EDM1 Mk6E has a modest sized internal memory size meaning data had to be recovered manually for several months due to issues EDM1 had configuring the monitors to recover data remotely.

Current Transducers, Voltage connectors and monitoring solutions.

- Both types of voltage connectors have proven to be very suitable for semi-permanent monitoring of LV busbar voltages and could be used for future rollouts. WPD's other projects are using these voltage connectors.
- The monitoring solutions and current transducers have shown to be adequate for the projects purpose, however it would not be appropriate to use both the monitors and current transducers as other better solutions now exist as detailed in section 12.

8.2 How to install equipment safely with minimal or no interruption of supply

The project designed and installed all monitoring solutions safely with no interruptions of supplies to customers. This was feasible as the substations in suburban areas have suitable alternative points of supplies allowing new fuse carrier handles as a voltage connector as some substations.

The lessons learnt from this project when installing monitoring equipment into distribution substations has been included in WPD's current LV monitoring policy.

8.3 How often the network characteristics need to be monitored (for example 1min, 5min, 15min)

The project analysed 2,192,750 data points monitoring key parameters as part of the PV impact on suburban network project. These included Average Voltage, Maximum Voltage, Average Current, Maximum current, Power Factor, % Voltage THD, % Current THD and Individual Harmonics. Data was recovered at a range of sampling rates between the Shortest, Recommended and Maximum timescales as detailed in Figure 10. All recovered data was plotted graphically and analysed in detail to determine the impact on the LV network operation when integrating PV in suburban networks. Particular

attention was paid around the factors that would limit the further implementation of solar PV to the LV network.

When configured to the most granular data sampling, analysis of the data showed the impact of the network operation due to high density PV as observed at the distribution substation. This data was compared to the statutory, engineering recommendations and design limits of key items of plant to determine if any limitations were being reached.

The shortest sampling duration for all parameters produces the most granular view of the impact of PV on each parameter being monitored. However, analysing the shortest duration datasets was disproportionately challenging. Each parameter sampling rates across multiple sites were ever systematically extended or the data averaged, with the data being reviewed for a loss in learning. At the recommended duration, no significant loss of learning was recorded. If installing further monitoring to record the impact of solar PV on suburban networks, it is suggested that the recommended sampling duration would generate all the key learning in most locations for long term monitoring installations, whilst producing a manageable amount of data. If the data being recovered from a location showed it was particularly close to statutory or design limits, there may be a requirement to increase the sampling frequency.

The analysed data from PV impact on suburban networks showed that when extending out to the longest duration periods, some learning would be lost due to longer averaging periods.

Parameter	Duration (minutes)		
	Recommended	Shortest	Longest
Voltage (Average)	10	1	30
Voltage (Maximum)	15	1	1440
Current (Average)	10	1	30
Current (Maximum)	15	1	1440
Power Factor	30	10	60
Voltage THD %	60	10	1440
Current THD %	60	10	1440
Individual Harmonics	60	10	1440

Figure 10 – Proposed network monitoring characteristics

8.4 Effect of installing a high density of PV panels on the LV Network

The installation of a high density of PV panels on a LV network can substantially change the characteristics of the distribution network. Figure 11 shows solar irradiance data provided by the met office plotted against monitored data. During high solar irradiance periods such as the 22nd May 2012 Figure 12 shows the feeder current as the distribution substation was only 20A due to the export from the installed micro generation. (a) During the 19th May the solar irradiance was considerably lower and the minimum feeder current was 79A. (b)

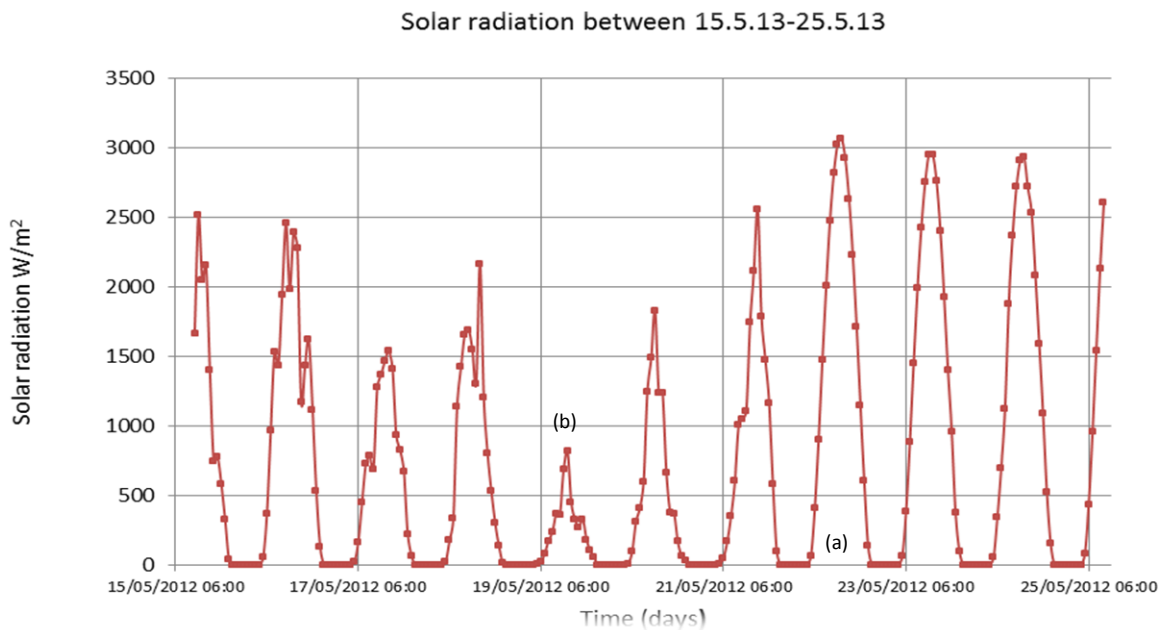


Figure – 11 Solar Radiation Measured

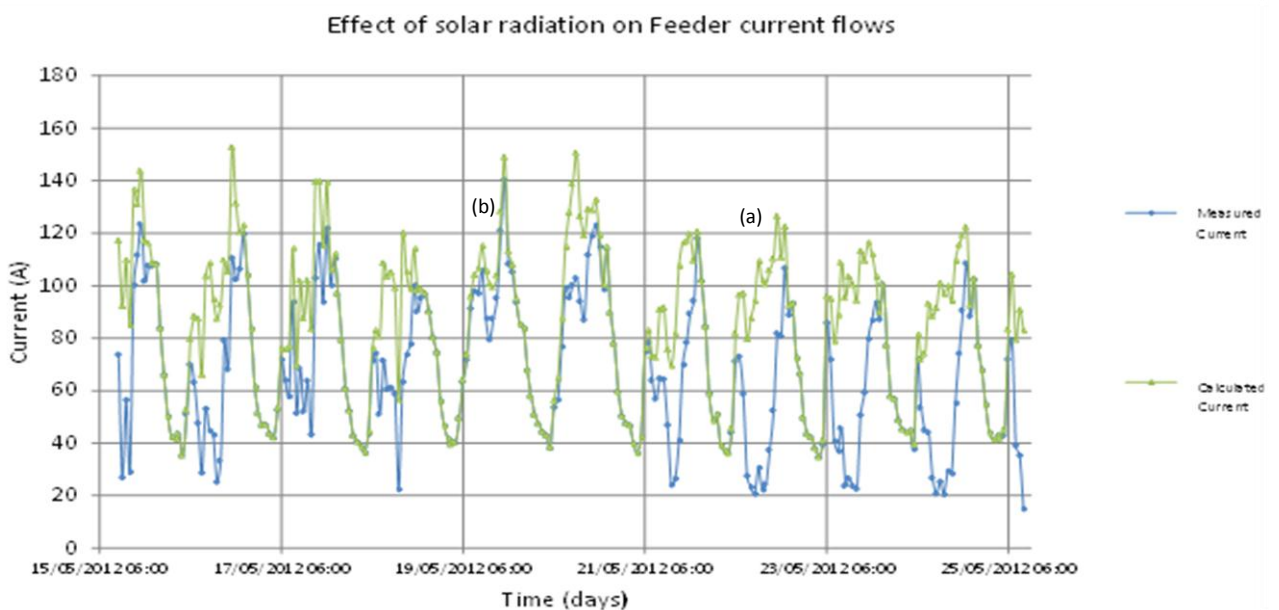


Figure – 12 Impact of solar PV on network current

The key constraint identified from the network monitoring was any voltage rise that would occur during periods of reverse power flows. The project did not record any reverse power flows across the eight monitored locations due to a level of diversity from the multiple small scale installed solar PV. The analysis shows the network would still operate within its design and statutory limits if customers installed a further 20% PV across all network locations.

The numbers of properties with PV across the monitored trial network totals 368, the majority of these schemes are 2kW and 1.5kW systems retrofitted to domestic properties. In total 715.4kW of PV generation was installed, a combined 1,300kW of PV was installed across all substations in Meadows, Aspley and Broxtowe. The modelling assumed each PV panel would export the full panel capacity and each property would have a minimum demand of 200W during this period. This in a small number of cases the further connection of PV was limited as the modelling assessment predicted a greater than 1% voltage rise due to reverse power flow. The measured data from the same network feeders shows the assumptions (each PV panel would export the full panel capacity and each property would have a minimum demand of 200W) was slightly too conservative as we have failed to record reverse power flow over the duration of the network.

The project selected the feeders and substations shown to have the greatest impact from the installed PV generation to model due to number of PV installations and network construction.

The LV Network Templates project Report on the use of proxy PV FiT meters to reflect local area Generation, Page 21 – 22, detailed the learning from the LV Network templates report regarding the overstatement in PV maximum export capacity in more northerly parts of the UK from South Wales, and the South. This recorded the output from individual domestic PV systems and showed that maximum power output did not reach the installed capacity.

The data measured at the substation supports this finding. When the LV networks are re modelled to take into account the recorded data, an additional 20% generation at each site could have been added at all location (i.e. 1.5kW modelled as a 1.8kW and 2kW as 2.4kW installations) before the modelling estimated the voltage rise approached 1% on any of the feeders. This is due to the fact the maximum installed capacity is approximately 20% greater than the measured Maximum output capacity.

The measured effects at the distribution substation of the specific network operating characteristics have been detailed below.

8.4.1 Power Flow Analysis

Current flows

The analysis of network data showed the effect of installing high density PV has a significant effect on the network power flows. The magnitude of power from the HV network, through the distribution transformer into the LV network is significantly reduced during periods of high solar irradiance. However, all sites showed throughout the trial period the flow of power was always from the HV network into the LV network. The installed solar PV never created conditions of reverse power flow

with power flowing from the LV feeder through the LV bars or from the LV network into the HV network. The absence of reverse power flows is due to the higher than assumed daytime loads across the trial locations and diversity between the installed PV Panels.

The data shows that even during the longest summer days the installed solar PV had a relatively modest effect at reducing the traditional network peak demands at breakfast (7:00am – 8:30 am) and during the evening (6pm – 8pm), Figure 11 and 12 shows the impact of solar PV on the measured current flows.

The LV network is designed to operate as a balanced network across all three phases to reduce the current flow through the neutral conductor. The data analysis shows the network can operate with substantial levels of imbalance. Due to the random distribution of solar PV, during high irradiance periods this reduces the system imbalance on some feeders and increases the system imbalance at other feeders. Although the level of imbalance measured at the LV network currents is higher than the expected, it is not a network factor limiting the connection of dense PV. Figure 13 shows the level of current imbalance for a week in May 2012. The level of imbalance on the network will cause current to flow through the neutral conductor. This could have a greater impact on the networks thermal limit when incorporating other LCTs such as single phase heat pumps and electric vehicles. This analysis was outside of the scope of this project.

The impact of Solar PV changing power flows, impacting on network losses will complement other on-going research being conducted by Imperial University. The work being carried out by Imperial University is a separate project being funded through IFI; the scope is to examine the opportunities of moving further towards a loss-inclusive network design rather than the more traditional approach of peak-driven network design. The outputs from this project when it is complete will be shared using the normal mechanisms.

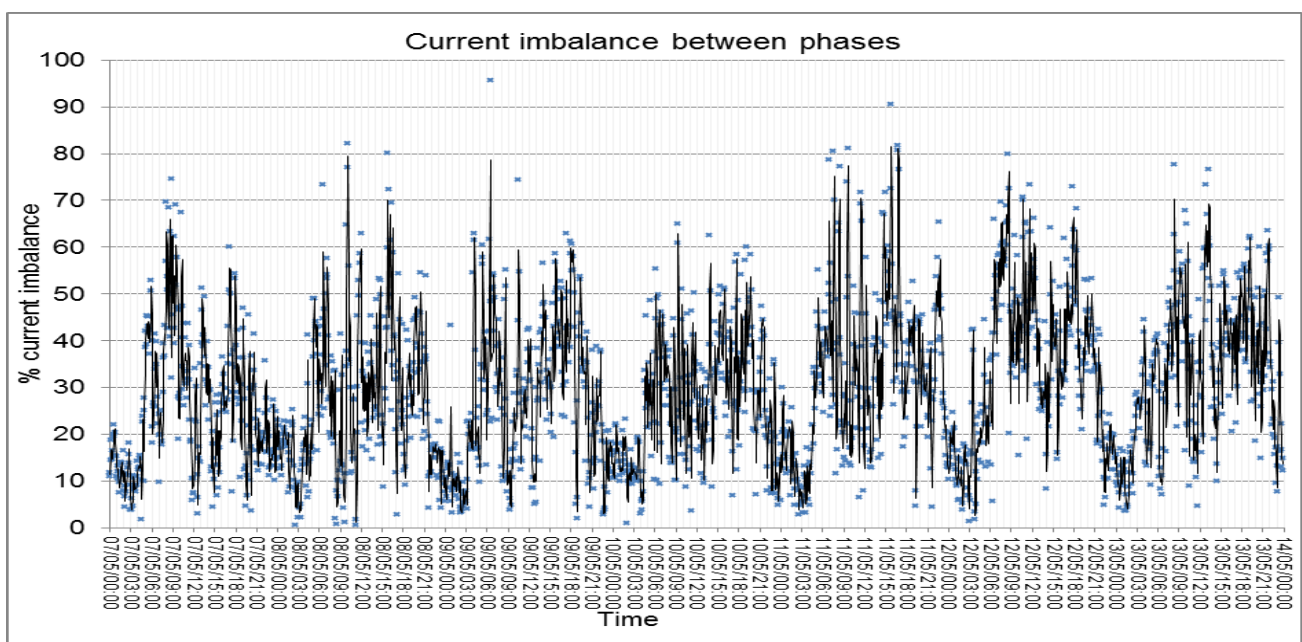


Figure 13 – LV current imbalance

The percentage of current imbalance between phases has been plotted; a trend line has been included to show how the level of imbalance varies over a week.

Voltage profile

The absence of reverse power flows for the duration of the trial means the voltage profile is still largely dominated by the tap changers on primary transformers as shown in figure 14 and not by voltage rise from the embedded solar PV.

The LV feeder voltage profile can be modelled from the measured substation data to show the voltage drop across the network is reduced during high irradiance periods however the peak voltage drops across the LV network still occur during periods of maximum demand with little or no contribution from solar PV.

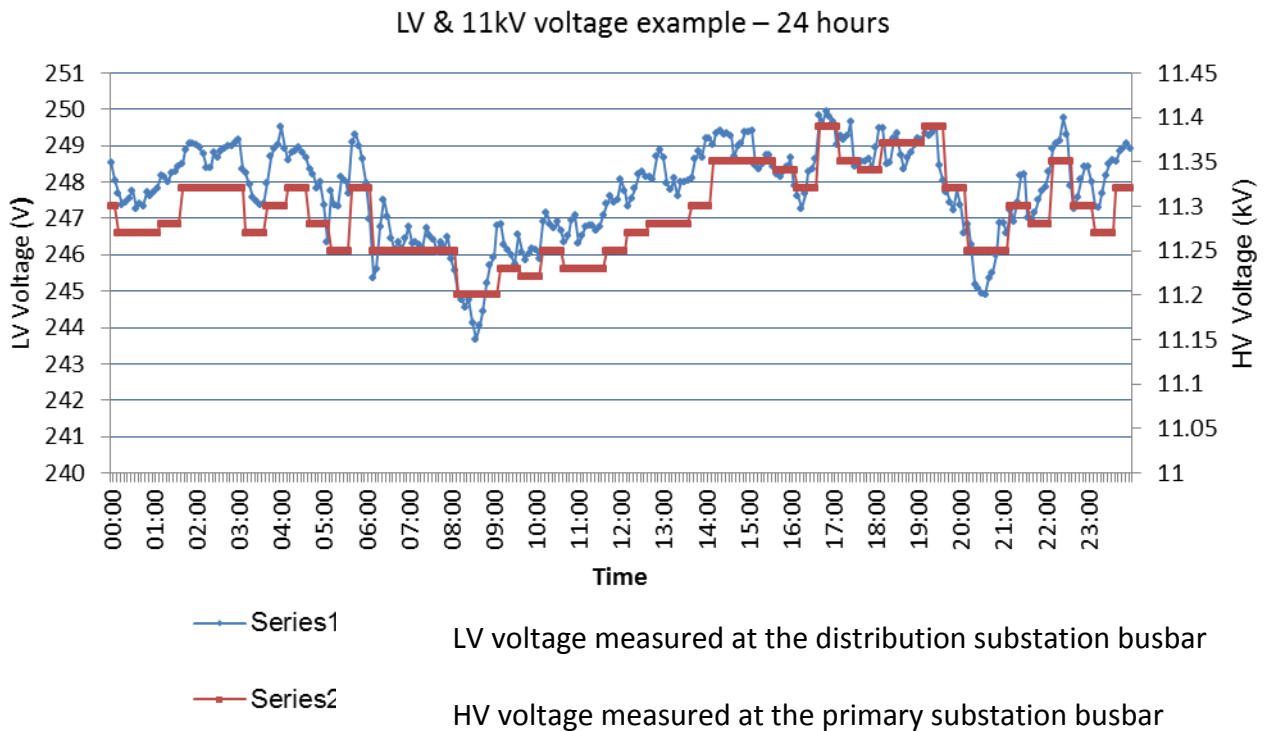


Figure 14 – LV and 11kV feeder voltage profile

Power Factor

One effect of installing significant amounts of PV generation operating at unity power factor onto a network where connected domestic loads operating at a lagging power factor is a worsening power factor at the substation during periods where the PV generation supports the majority of the network demand. The required reactive power demands are imported through the distribution network resulting in a poor power factor. Data analysed from other sites shows the issue is greatest when the measured demand is low.

The measured data shows the three phase power factor reducing to 0.2 during periods of high solar irradiance as shown in figure 15. The same substation had an average power factor of 0.98 for Q1 2013.

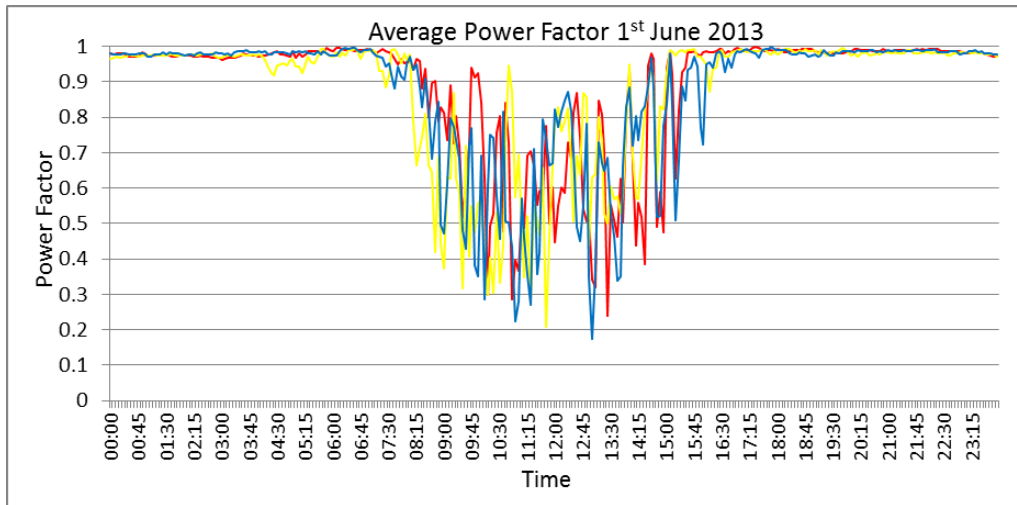


Figure 15 – LV power factor

8.4.2 Power Quality

Waveform Analysis

The analysis of current and voltage waveforms shows the voltage remains relatively sinusoidal at all times. The sinusoidal current waveform is distorted due to harmonics. The lower order odd harmonics are a significant % of the fundamental current at times of minimum demand. The effects of significant lower order odd harmonics are significant distortion to the current waveform resulting in a triangle waveform at the distribution substation. The results shown below were verified by two separate monitors using both split core current transformers and Rogowski coils to rule out any measurement errors.

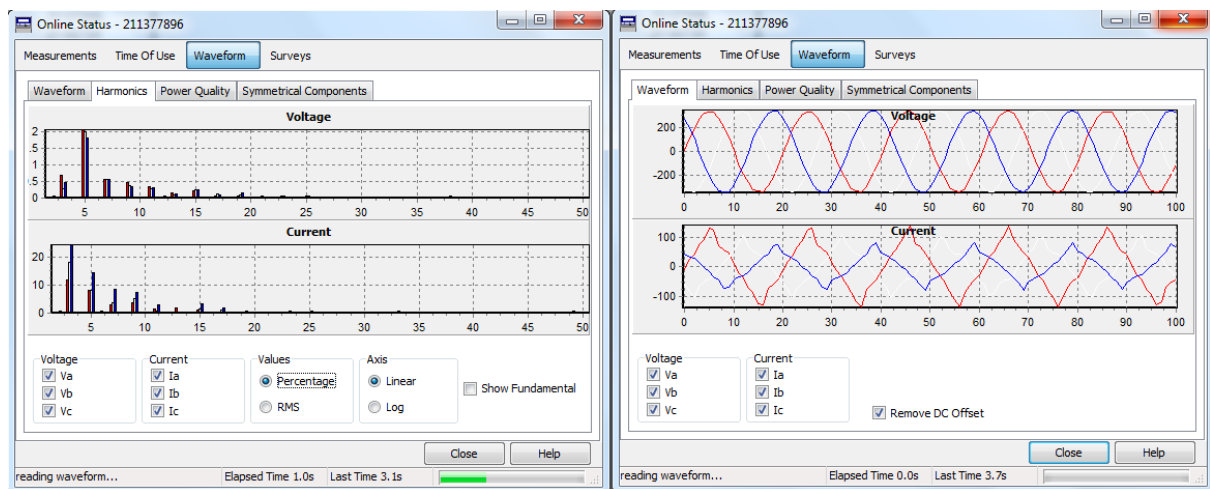


Figure -16 Effect of harmonics on the LV current and voltage wave forms

Current THD

The measured current THD was higher during periods where the fundamental current imported from the HV network is reduced, i.e. when the installed solar PV is reducing the fundamental current being imported from the HV network. The results in Figure 16 are due a reduction in the fundamental current rather than excessively high current harmonics. Existing guidelines do not require the distribution network operator to maintain levels of current harmonics at the distribution substation. Whilst PV has a substantial impact on the current waveform it is not a limiting factor to further PV installations. Distribution network operators do have an Engineering Recommendation G5/4-1 for planning and compatibility levels which is applied to Electricity Networks.

Voltage THD & individual harmonics

The voltage THD remained within the prescribed limits at all sites with little evidence from the network monitoring that the solar PV was have a detrimental effect on the voltage harmonics in this sub urban network environment. This was believed to be due to the fault levels associated with urban networks. The effect of dense PV on power quality may differ in very rural networks where the fault level is much lower.

The analysis of the measured data showed a greater presence of lower order odd voltage harmonics (5th); however the embedded generation appears to have little impact on the power quality in these sub urban networks. Figure 17 shows a sample of measured voltage harmonics (plotted in Volts) during a high solar irradiance period.

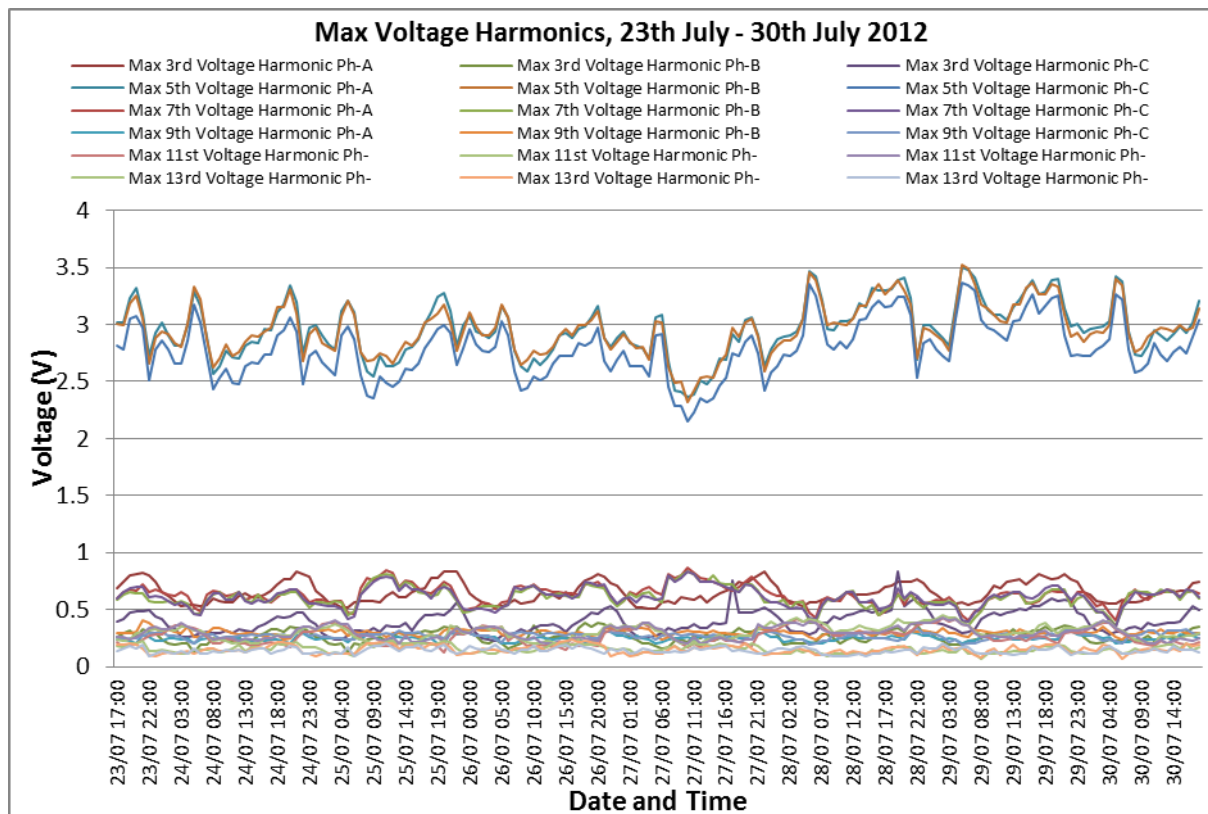


Figure 17 – 3rd- 13th maximum voltage harmonics

8.5 How we can interrogate the large amounts of data

The project recovered data as comma separated variables (.csv) files remotely from the installed meters, analysing and plotting the data within Microsoft excel. All data has been displayed graphically and analysed manually to identify the network limiting factors.

This has been an adequate solution for a finite duration project with less than 10 distribution substations. The approach taken has highlighted that for anything greater than a small short term project there is a requirement for either purpose build data repositories and graphical displays or monitors reporting by exception. Neither of these was available at the inception of the project.

This is currently under evaluation for a further project study.

9. Performance compared to the original Project aims, objectives and success criteria

Objective1 - The project will monitor the profile of eight selected substations or individual feeders in areas where PV panels have already been installed or are expected to be installed.

The project installed EDMI Mk6E and Subnet monitoring equipment in eight selected substations across the Meadows, Aspley and Broxtowe. Selected feeders and transformers were monitored in the areas where a high density of PV panels were installed. See Section 7 for more information.

Objective2 - Through this project, CN will explore the following aspects:

- How to measure and capture voltage, current, harmonic, real and reactive power data on a range of distribution assets in suburban areas.

The project measured and captured voltage, current, harmonic (Current THD, Voltage THD, Individual voltage harmonics), real and reactive power data on the LV network of the 8 selected substations in Aspley, Broxtowe and Meadows areas. GPRS communications, a standalone PC and 56k message modem allowed data to be remotely recovered and stored. See section 8.1 for more information.

- How to install equipment safely with minimal or no interruption of supply

The project safely installed the network monitoring equipment & transducers with no interruption of supplies to customers. See section 8.2 for more information.

- How often the network characteristics need to be monitored (for example 1min, 5min, 15min)

The project varied the duration of monitoring network characteristics and has recommended the typical and range of durations for network measurements. The project recorded all network characteristics with a range of sampling durations to recommend how often the network characteristics needed to be monitored. See section 7.3 and 8.3 for more information regarding the longest, shortest and the recommended duration.

- How we can interrogate the large amounts of data generated to highlight significant network issues created by the installation of PV panels

The project will interrogate large amounts of data generated as comma separated variables (.csv) files over the 16 month period to highlight significant network issues created by the installation of PV panels. The project also recommended possible alternatives for future investigation. See section 12.5 for more information.

- What the effect is of installing large numbers of PV panels on the LV network. We aim to share our learning with other DNOs in November 2012.

The effects of installing large number of solar PV on LV distributions networks have been recorded and summarised in this report, including the key network limiting factors for further PV integration to the distribution network.

Success Criteria

The following success criteria have been included below and the

	Activity	Target	Updated	Actual	Comments
Success Criteria 1	Select and test a range of sensors	April 2011	-	April 2011	Conducted in line with the project plan
Success Criteria 2	Install and configure substation monitoring equipment	May 2011	May 2012	Feb 2012	Completed in line with the amended project plan
Success Criteria 3	Determine the frequency of monitoring each characteristic	July 2011	July 2012	July 2012	Completed in line with the amended project plan
Success Criteria 4	Analysis 12 months data,	Sept 2012	Sept 2013	May 2013	16 months of data has been analysed
Success Criteria 5	Write a close out report	Nov 2012	Nov 2013	Jan 2014	Published Jan 2014 as per the governance document

The project change request was needed, allowing sufficient time to successfully complete all the original project aims, objectives and success criteria.

Learning

The learning from this project has been shared with other DNOs at different stages throughout the project, including:

- The project was presented on at both LCN Fund conferences 2012 and 2013,
- This and other complementary projects was presented on during a LV network monitoring event hosted at Leicester space station, attended by over 100 people including all UK DNOs
- The full close down report detailing the key knowledge generated.
- The data from this project is available to other UK DNOs for their own analysis and comparison.

10. Required modifications to the planned approach during the course of the project

There were three main areas where the approach taken differed from the original plan. Whilst the project has completed all the intended aims and objectives, these modifications to the planned approach introduced significant delays.

10.1 Delays in equipment delivery

CR001

The project selected and procured Mk6E meters from EDMI after a demonstration unit was tested within a laboratory environment. After ordering the meters, the delivery of the EDMI meters took significantly longer than forecasted.

- The quoted delivery time was 8 weeks & shipping,
- The meters took 23 weeks & shipping to be built, configured and tested.

The project intended to select a cost effective meter off the shelf as used in other applications to de risk the delivery. The meters selected for the PV impact on suburban networks project were selected due to their wide range of functionality making them suitable for a wide range of network monitoring applications capturing voltage, current, harmonic (Current THD, Voltage THD, Individual voltage harmonics), real and reactive power characteristics

10.2 Technical support & data recovery

CR001

The technical support including data recovery for the project was originally from E.ON Smart Metering. Following the WPD purchase of Central Networks, the E.ON Smart Metering business no longer wanted to support the project. Several companies were approached to recover data. The costs were significant due to the small number of meters and high start-up costs associated with calibration and testing. Western Power Distribution Smart Metering configured a system to recover data remotely from the meters, reducing the requirement for support from an external body.

10.3 Meter configuration

CR001

The meters selected have turned to be very complex, with a limited processor power and memory. This caused issues setting them up and further problems recovering data. Within EDMI, there is no significant expertise within the UK for detailed configuring of the meters. Even at the point of receiving and installing the monitoring equipment, significant further configuration changes were required over the next 12 months with support from EDMI's manufacturing base in Singapore.

Manual downloads of data from May 2012 as a workaround to avoid the loss of data and further delays as remote recovery of data was not responding. The issue was due to a missing section of code, not included in the original factory set up. Due to the complexity of the meters, this took 4 months of debugging and a site visit from a technical specialist from Malaysia before remote recovery of data could be initiated.

11. Significant variance in expected costs and benefits

11.1 Project Costs

Description	Forecast	Actual	Variation (%)
WPD Project Management	£20,000	£ 20,588.65	+2.94%
WPD Labour	£46,000	£ 26,356.30	-42.7%
Equipment	£34,000	£ 30,253.55	-11.02%
TOTAL	£100,000	£ 77,198.50	

11.1.1 WPD Project Management

This element of work is associated with the running and managing of the project. Due to a slightly greater level of the work being completed internally the actual cost is 3% greater than the planned cost.

11.1.2 WPD Labour

This element of the work included pre installation site visits, installation of network monitoring, recovery and analysis of the data. The cost associated with the installation was substantially lower than forecasted due to the internal delivery by WPD Nottingham depot. The project was also completed without any network outages, reducing the amount of resource required at the installation phase. The project did not require any of the contingency funds.

11.1.3 Equipment

This element of the project included the purchasing of meters, Current Transducers, Voltage connections and all connectors. The contingency associated with the network monitoring equipment was not required, leading to a 10% variation in the final costs.

11.2 Expected Benefits

Benefits of PV impact on Suburban networks

Monitoring eight different sites across two different areas should be sufficient to detect any anomalous results. This low voltage network will allow ample opportunities for further projects to install new technology or carry out operational network changes to reduce the apparent effects of micro generation.

The expected learning from this project include:

- 1) An assessment of the impact of PV panels on the LV network and which network factors could limit the further installation of more PV panels.
- 2) An assessment of the effectiveness of the range of sensors selected
- 3) The feasibility of installing monitoring equipment
- 4) An assessment of any incurred CML's or CI's and any safety concerns
- 5) An outline of the key constraints of installing high levels of PV panels in Suburban areas (Voltage, Current, Harmonics, 2 – 50th, real and reactive power flows)
- 6) A definition of an optimal interval of data capture and recovery
- 7) An assessment of how many panels can be installed before network reinforcement is required.

Figure - 18 Benefits from the PV's in Suburbia project

The project met all of the expected benefits as detailed throughout the report.

1	Completed	The project has assessed that a further 20% PV connections can be made in multiple small scale installations due to diversity	✓
2	Completed	An assessment has been conducted, those deemed suitable have been used in further network monitoring projects.	✓
3	Completed	The project has concluded that better kit for LV network monitoring is now available, LV Sensors project	✓
4	Completed	No Customer Interruptions or Customer Minutes Lost were required. All network monitoring was installed with no safety concerns.	✓
5	Completed	The future network constraints were identified though this project, no major issues were recorded. – See section 8.	✓
6	Completed	See Figure 10, section 8.	✓
7	Completed	A further 20% PV installations could now be made from the assessment of the diversity and the modifications to WPDs planning tools.	✓

12. Lessons learnt for future Projects

The project has produced significant learning, influencing many of our current innovation portfolio projects.

12.1. Developing network monitoring solutions using off the shelf components

At the time of project inception, an appropriate LV distribution substation monitoring solution for mass roll out didn't exist. The project aimed to use off the shelf components to demonstrate how LV networks could be monitored with more cost effective solutions. Whilst the project successfully installed and monitored network feeders, the solution was not user friendly and would not be ideally suited for a mass roll out. In the time since the problem was highlighted, the market has responded creating solutions which are easier, quicker to install and are more user friendly. Please see the LV Network sensors project for further information.

Product Engineering

- When the original project was scoped, the LV monitoring supplier market was very immature and off-the-shelf solutions were not suitable for this application.
- A cost effective monitoring solution didn't exist within the market leading us to innovate and create one.
- The solution created was functional, however not ideal.
- When the market place caught up, they quickly overtook the solution installed.

Despite this learning, we recorded the data needed and were able to meet all of the expected project benefits.

12.2. Where to install monitoring in a LV substation

Different substation designs and equipment have varied over the last 60 years; however most substations don't have an ideal location for easily installing substation monitoring equipment. The most appropriate option is to select substation monitoring equipment that is suitably sized so it can be installed inside the LV feeder pillar of distribution substation. This allows for a quick and safe installation within most substations, especially the most modern LV feeder pillars. The latest WPD specification for substation designs includes accessible voltage monitoring points and high accuracy current transducers for monitoring purpose.

12.3. Relying on GPRS

GPRS is a low capital cost communications solution; it was selected due to the high signal strength and low Bit Error Rate across a number of communication network operators in the project areas. Recovering information over GPRS using a B2B solution proven to be unreliable and unpredictable causing regular issues when trying to recover data or reconfigure settings remotely.

The specific communications issues encountered through the PV impact on Suburban Networks project were:

1. The EDMI monitors were ordered with GPRS modems, one of several compatible communications methods. However, the meters could not be contacted over GPRS, due to a configuration error when leaving the factory. This was corrected manually at each site.
2. The B2B (Business to Business) SIM cards were installed in the monitors, several of the sites failed to communicate during the remotely commissioning process. The solution was an additional site visit to carry out a hard reset of the problem SIM cards. This involved installing in a suitable mobile phone, turning on and off before re installing into the monitors. This solved the issues and allowed all contact to all sites.
3. The monitors were configured to be interrogated during the night, recovering data regularly. Throughout the project, some monitors would exceed 7 days before any data could be recovered. This required continual monitoring of recovered data to ensure data was being received from each site regularly. There appear to be no reason or pattern for any unresponsive communications.
4. Throughout the project there was a requirement to regularly change the configuration of the monitors, allowing different parameters and sampling frequencies to be tested. A number of monitors proved unresponsive for long periods of time or would lose communications before the parameter changes could be completed. The communications issues were particularly problematic during working hours. In some locations amendments or parameters could only be made out of office hours.

12.4. Ensure companies have sufficient technical expertise within the UK

The EDMI monitoring solution provided was a particularly comprehensive meter suitable for a range of applications. However the meter was very complicated, and was not supplied with a detailed user guides step by step details to solve issues with the meter.

As the meter was specialist there was very little expertise when configuring and debugging this product, increasing delays when recording and recovering information. In the future further emphasis should be placed on vendors being able to demonstrate they can provide UK support on site if needed.

12.5. Data analysis

The data analysis solution selected for this project allowed us to manipulate large amounts of data generated by the eight monitors for more than an 18 month period to determine impact of PV panels on suburban networks. However, the solution selected was labour intensive.

For permanent monitoring locations with a larger numbers of meters would benefit from custom software or meters capable of reporting by exception. Further research is to be carried out "Big Data", this is beyond the scope of this project.

13. Planned implementation

13.1. Policies updated for the installation of multiple LV PV systems

This project has led to a better understanding in the operation of LV distribution networks after dense connection of PV panels into LV suburban distribution networks. The early learning from this project and the learning from LV Network templates and Early learning projects have been used to update WPD's policies and design tools. WPD's design tools have profiles for solar PV when modelling future PV connections. The LV design tool also applies a 20% diversity to the output of multiple PV installations, taking learning from lessons learnt from innovation projects.

This key learning can be included within future Transform modelling. Transform requires users to set their own limits before applying the model, manual manipulation will allow users of Transform to model for the increased capacity, taking the learning from this and other LCNF projects.

13.2. Installations

LV monitoring will continue to be rolled out to substations which are deemed to be of strategic importance or have the potential to operate load patterns which fall outside of a template approach. LV monitoring technologies will be deployed using best practise from the LV Sensors report.

Voltage and current sensors avoiding Customer Interruptions and Customer Minutes Lost are not part of our Business As Usual for all new projects.

13.3. Further Research and Development work

If the installation of long term, large scale LV substation monitoring is required, then further development work will be required to find a software system that can handle large amounts of complex data with less manual intervention. A future "Big Data" project is being developed.

14. Facilitate Replication

14.1 Knowledge Required

The knowledge required to install monitoring equipment, measuring the distribution system operation and analyse the results to determine the impact of densely connected PV is outlined below:

- Electrical network topology,
- Electrical network impedance data,
- Customer demand and generation connectivity,
- Geographic asset locations,
- Installation of working on and around live LV distribution equipment,
- Communications methods and data requirements,
- Programming and reprogramming network monitoring equipment
- Understanding of Voltage profiles, current flows and power quality analysis.

Other DNOs are welcome to request copies of papers and policies, these will be sent to them from the WPD staff responsible for engaging with the buddy DNO.

14.2 Products/Services Required

As well as general project management and installation resources at the disposal of a distribution network operator, there are a number of other products and services that have been identified in this project as being prerequisites requirements before the network operation can be monitored.

- Substation monitoring equipment
- Voltage and current transducers
- Communications (GPRS used for this project)
- Data recovery system (PC with 56k message modem)

14.3 Project IPR

This project integrated a number of existing products and services as outlined in section 7 to enable successful delivery against the project criteria. Whilst there was no foreground IPR generated, there have been a number of learning outcomes developed and disseminated across the wider business and other projects, as described in sections 12 and 13.

The transconductance amplifier built for this project by Haysys Ltd has been designed using off the shelf components using good engineering knowledge, this has not generated any new IPR.

The nylon G clamps manufactured by Invirotech Ltd have been based on an existing WPD standard for nylon G Clamps; this has not generated any new IPR.

14.4 Points of Contact

Further details on replicating the project can be made available from the following points of contact:

- Philip Bale, Western Power Distribution, Pegasus Business Park, East Midlands Airport, Castle Donington, Derbyshire, DE74 2TU. pbale@westernpower.co.uk
- Future Networks Team, Western Power Distribution, Pegasus Business Park, East Midlands Airport, Castle Donington, Derbyshire, DE74 2TU. wpdinnovation@westernpower.co.uk

Appendices

- A) Project Proforma
- B) Project change
- C) Internal Change request
- D) Broxtowe and Aspley - LV feeders
- E) Meadows – LV feeders

First Tier LCN Project Registration

Project description	
Project title	PV impact on Suburban networks
Project background	<p>The introduction of feed in tariffs within the UK has shown an increase of micro generation connected to the low voltage distribution network. This is becoming increasingly evident from the range of companies offering free PV installations in exchange for the revenue from the tariffs. If a high penetration of micro generation is installed in a compact suburban environment, the cumulative effect is expected to have a substantial impact on the existing distribution network.</p> <p>Nottingham is one location where a significant number of PV panels have already been installed in dense locations; further dense areas are also due to be developed.</p> <p>106 kW of PV Panels have been installed and up to 1235kW are scheduled to be installed in Aspley and the Meadows by the Meadows Partnership Trust, Nottingham City Council and Blueprint.</p>
Scope and objectives	<p>The project will monitor the profile of eight selected substations or individual feeders in areas where PV panels have already been installed or are expected to be installed. Through this project, CN will explore the following aspects:</p> <ul style="list-style-type: none"> • How to measure and capture voltage, current, harmonic, real and reactive power data on a range of distribution assets in suburban areas. • How to install equipment safely with minimal or no interruption of supply • How often the network characteristics need to be monitored (for example 1min, 5min, 15min) • How we can interrogate the large amounts of data generated to highlight significant network issues created by the installation of PV panels • What the effect is of installing large numbers of PV panels on the LV network <p>We aim to share our learning with other DNOs in November 2012.</p>
Success criteria	<ul style="list-style-type: none"> • Select a range of sensors to be developed and tested by April 2011 • Install the substation monitoring equipment by May 2011 • Determine the frequency of monitoring each characteristic by July 2011 • Analysis 12 months data, highlighting the measured impact of PV on the distribution network by September 2012 • Write a close out report around the key objectives and the lessons learnt by November 2012.
TRL(s)	TRL 7-8

Predicted end date	Nov-2012
External Collaborators and external funding	<p>Central Networks will be working with the MOZES group, Haysys Ltd and Nottingham City Council.</p> <p>Central Networks will not be funding the installation of any PV panels.</p>
Solutions	The solution consists of using industrial meters with GSM/GPRS capability, a number of voltage and current sensors.
Potential for new learning	<p>The expected learning from this project include:</p> <ul style="list-style-type: none"> • An assessment of the impact of PV panels on the LV network and which network factors could limit the further installation of more PV panels. • An assessment of the effectiveness of the range of sensors selected • The feasibility of installing monitoring equipment • An assessment of any incurred CML's or CI's and any safety concerns • An outline of the key constraints of installing high levels of PV panels in Suburban areas (Voltage, Current, Harmonics, 2 – 50th, real and reactive power flows) • A definition of an optimal interval of data capture and recovery • An assessment of how many panels can be installed before network reinforcement is required.
Risks	<p>To comply with CN's safety rules, there is a risk that during installation of the sensing equipment, we may have to enforce an outage, which would have an impact on CML's or CI's</p> <p>There is a risk that PV panels may not be visible at the substation, which means other LV locations need to be monitored to gather the required data, therefore incurring additional cost and increased timescales.</p> <p>There is a risk that installations of further PV panels may be delayed; this may impact on the timescale of the project.</p>
Scale of Project	<p>The project incorporates monitoring eight distribution substations in the Meadows and Aspley area.</p> <p>These substations have been selected because they have the greatest theoretical effect from PV panels or can be used as a direct comparison to the other sites.</p> <p>Monitoring eight different sites across two different areas should be sufficient to detect any anomalous results. This low voltage network will allow ample opportunities for further projects to install new technology or carry out operational network changes to reduce the apparent effects of micro generation.</p>
Geographic area	The Meadows and Aspley, Nottingham
Does the Project involve customer engagement?	Yes

Funding	
Revenue allowed for within the DPCR5 settlement (£)	£0
Indication of the total Allowable First Tier Project Expenditure (£)	£100,000
Publication	
Does the DNO provide Ofgem with consent to publish its First Tier LCN Project Registration Pro-forma in full?	Yes
If not, please justify which parts the DNO considers to be confidential	N/A
Related Undertakings	
Payments to Related Undertakings (£)	0
If a payment is to be made to any Related Undertaking that is a Distribution System User, have the same terms been offered to similar Distribution System Users of the part of the network that is within the project boundary?	
Has the DNO used reasonable endeavours to make the opportunity available to similar Distribution System Users of the part of the network that is within the project boundary?	
IPR arrangements	
If IPRs are generated, will they conform to the default IPR arrangements set out in the LCN Fund Governance Document?	Yes
If no, then please provide a compelling justification for the project being approved	N/A

Predicted end date	01/11/2012	01/11/2013	<p>The Project has suffered a number of delays:</p> <ol style="list-style-type: none"> 1. The delivery of the EDMI meters took significantly longer than forecasted. <ul style="list-style-type: none"> • The quoted delivery time was 8 weeks & shipping, • The meters took 23 weeks & shipping to be built, configured and tested. <p>The meters selected for the PV impact on Suburban networks were selected due to their wide range of functionality making them suitable for a wide range of network monitoring applications. The meters selected have shown to be very complex with a limited processor power causing problems setting them up and further problems recovering data. Within EDMI, there is no significant expertise within the UK for detailed configuring of the meters.</p> <ol style="list-style-type: none"> 2. The Central Networks New Connections team were due to install the meters during the summer 2011. Due to the delayed delivery of the meters and the acquisition of of Central Networks to PPL the allocated New Connections delivery team were transferred to new delivery teams and unable to commit to the install the substation monitoring in their new teams. 3. An alternative delivery team started installing the monitoring in January 2012, the installations was finalised in February 2012 due to modifications of the installation kit being required at some sites. 4. Manual downloads of data at all sites was available from May 2012, remote recovery of data was not responding. 5. The original recovery of data was planned through E.ON smart metering due to the sale and separation of IT systems they were unable to support this function. Several companies were approached to recover data. The costs were significant due to the small number of meters and high start-up costs associated with calibration and testing. 6. The meters although ordered with GPRS capability and modems were unable to support this method of communications. After 4 months of debugging it was confirmed the set up was missing a section of code from the initial factory installation. 7. The meters are now installed and remotely recovering data, WPD would like to extend the trial by 12 months to recover data.
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WPD Future Networks Programme Change Mandate

Project Number CNT1001 Change Number 01

Originator: Philip Bale		Tel: 01332 827448	Date: 28/09/12
Project Manager: Philip Bale		Project: PV impact on Suburban Networks	
Change Title: Extension of the PV's impact on Suburban Networks by 12 months.			
Change Type:			
Resource	<input type="checkbox"/>	New Requirement	<input type="checkbox"/>
Change in Scope	<input type="checkbox"/>	Budget Change	<input type="checkbox"/>
Milestone Change	<input checked="" type="checkbox"/>		
Other dependent projects affected: None			
Proposed change: WPD would like to extend the length of this project by twelve month to account for delays in the project, this period would be used for further analysis of data being received.			
Reason for change: WPD have only been able to record sporadic data up to September 2012, these problems have now been solved and regular data is being recorded. WPD would like to analysis a further twelve months of data before closing the project.			
Effect of NOT making change: There will only be a limited amount of data to be analysed, reducing the amount of learning that can be shared with the industry.			
Impacts of Change:			
Milestones	<input type="checkbox"/>	Deliverables	<input type="checkbox"/>
Resources	<input type="checkbox"/>	Project End Date	<input checked="" type="checkbox"/>
Costs	<input type="checkbox"/>	Benefits	<input type="checkbox"/>
Project Scope	<input type="checkbox"/>	Learning Outcomes	<input checked="" type="checkbox"/>
Describe the impacts on the project for the categories above : Project end date: This will be increased by 12 months to allow for further monitoring. Learning Outcomes: The further 12 months extension will allow all of the learning outcomes to be completed.			

Cost of making the change (and justification):

£None

There will be no further increase in the costs.

Supporting Information:

The Project has suffered a number of delays:

1. The delivery of the EDMI meters took significantly longer than forecasted.
 - The quoted delivery time was 8 weeks & shipping,
 - The meters took 23 weeks & shipping to be built, configured and tested.

The meters selected for the PV impact on Suburban networks were selected due to their wide range of functionality making them suitable for a wide range of network monitoring applications. The meters selected have shown to be very complex with a limited processor power causing problems setting them up and further problems recovering data. Within EDMI, there is no significant expertise within the UK for detailed configuring of the meters.

2. The Central Networks New Connections team were due to install the meters during the summer 2011. Due to the delayed delivery of the meters and the acquisition of Central Networks to PPL the allocated New Connections delivery team were transferred to new delivery teams and unable to commit to the install the substation monitoring in their new teams.
3. An alternative delivery team started installing the monitoring in January 2012, the installations was finalised in February 2012 due to modifications of the installation kit being required at some sites.
4. Manual downloads of data at all sites was available from May 2012, remote recovery of data was not responding.
5. The original recovery of data was planned through E.ON smart metering due to the sale and separation of IT systems they were unable to support this function. Several companies were approached to recover data. The costs were significant due to the small number of meters and high start-up costs associated with calibration and testing.
6. The meters although ordered with GPRS capability and modems were unable to support this method of communications. After 4 months of debugging it was confirmed the set up was missing a section of code from the initial factory installation.
7. The meters are now installed and remotely recovering data, WPD would like to extend the trial by 12 months to recover data.

Signed:

Project Manager

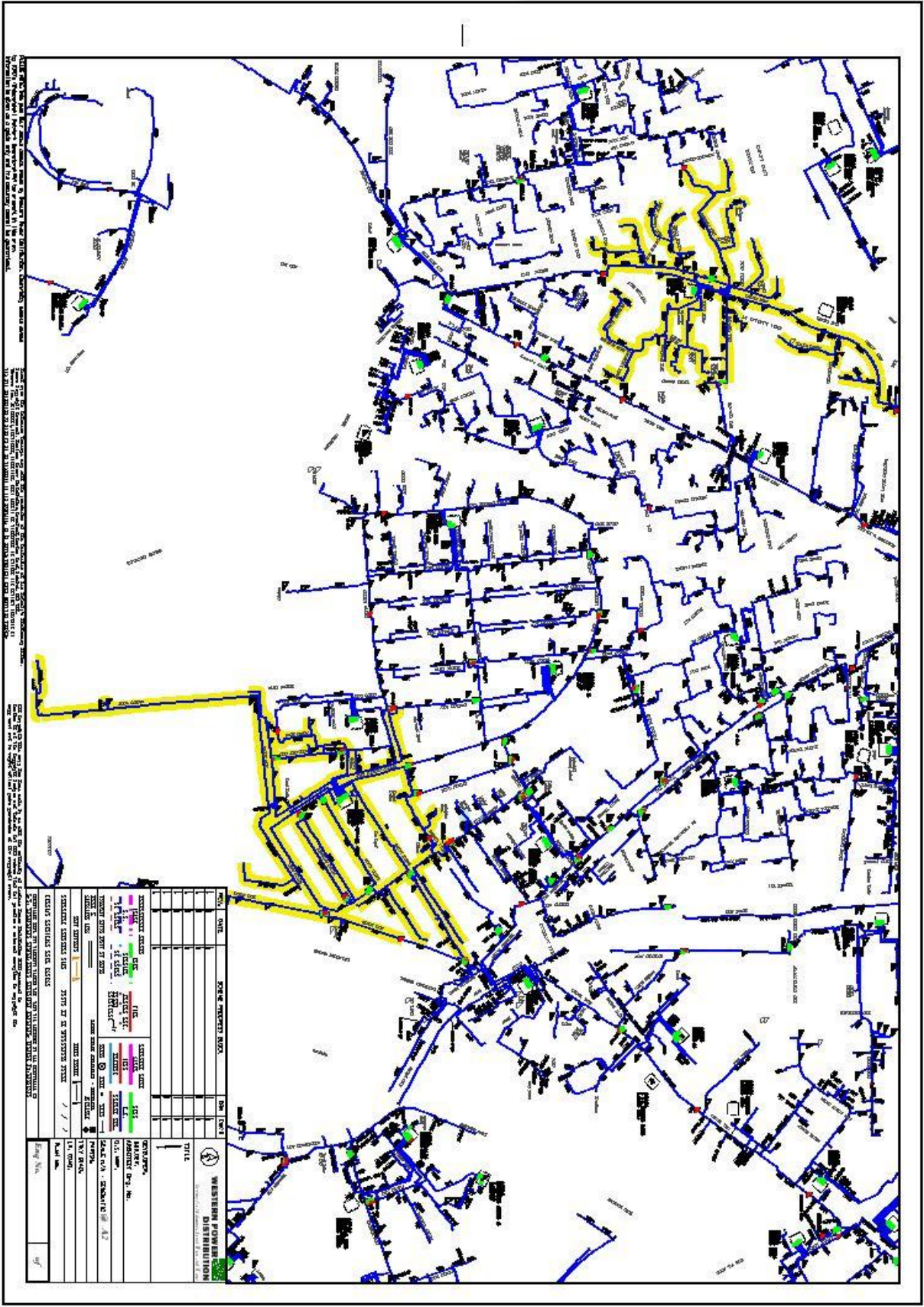
Philip Bale

Future Networks Manager

Roger Hey

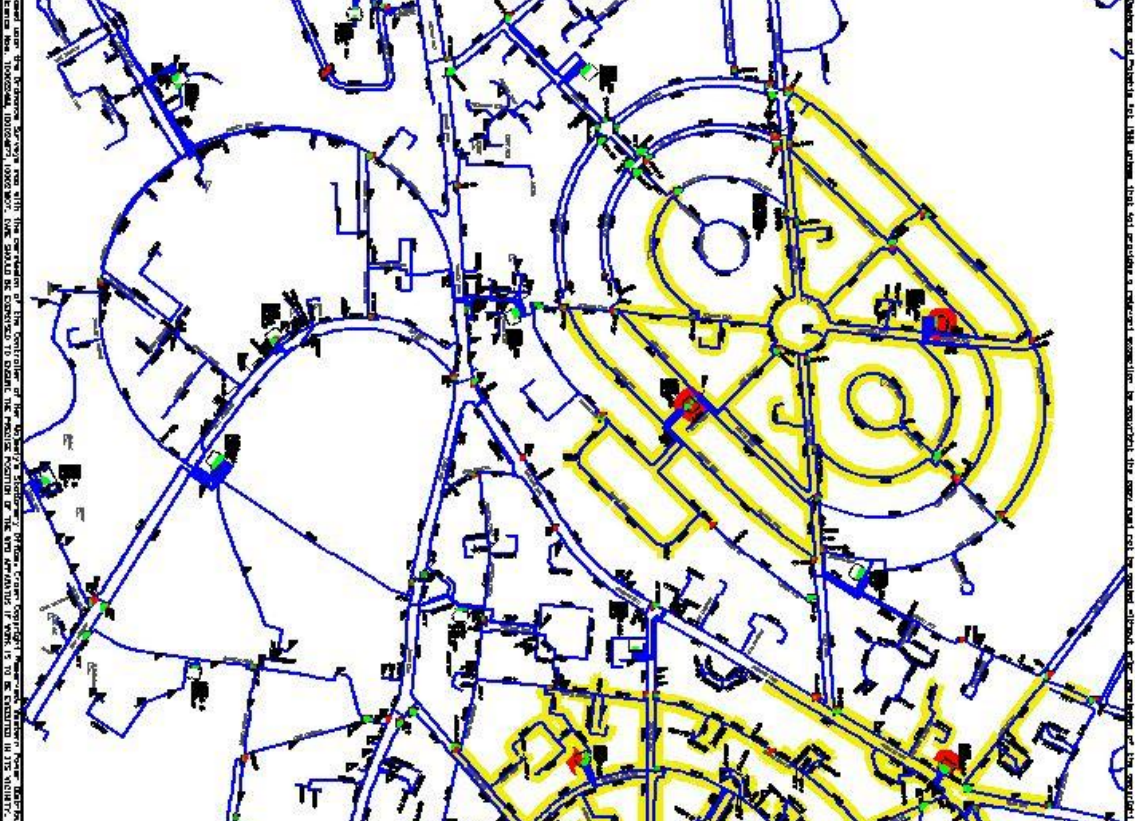
Date :

28/09/12



PLEASE NOTE: This plan ONLY shows assets owned by Western Power Distribution. Electricity assets owned by IONIA Independent Network Operator(s) may be present in this area.

Information is given as a guide only and its accuracy cannot be guaranteed.



REV.	DATE	SCOPE / PROGRESS BLOCK	PREP.	CHK'D.

UNDERGROUND CABLES 33KV 15KV 10KV STREET LTO L.V. SERVICE L.V. SERVICE L.V. SERVICE L.V. SERVICE	OVERHEAD LINES 33KV 15KV 10KV L.V. STREET LTO L.V. SERVICE L.V. SERVICE L.V. SERVICE
TRAFFIC SENSITIVE ROAD (TSR)	WORKS TO BE DISAPPOINTED SHOW
PLANT CHANGING	P
PLANT CHANGING	P

<p>WESTERN POWER DISTRIBUTION Energy & Assets Level 11, 250 Sturt Street, Perth WA 6000</p>	<p>DEVELOPER: BULLBEN ARCHITECT DRG. NO. O.S. MAP: SCALE 1:100 - SCHEMATIC @ A3</p>
<p>PLANNING NO. _____</p> <p>ENVIRONMENTAL NO. _____</p> <p>PLANNING NO. _____</p>	<p>PLANNING NO. _____</p> <p>ENVIRONMENTAL NO. _____</p> <p>PLANNING NO. _____</p>

Appendix F – Installing monitoring with no network outages

The following approach to installing network monitoring in each substation. Network outages were avoided through site visits to each location, the selection of the most appropriate components and following existing good practice and techniques developed through the retrofitting of network automation to secondary ring main units.

1. Installation of the Monitoring equipment in a suitable location.

The installation of network monitoring followed existing good practice and techniques developed through the retrofitting of network automation to secondary ring main units. Site visits identified the most suitable location for a meter board; this was affixed in each substation, brick built or GRP enclosure near to the LV feeder. The network monitors were installed on the meter board.

2. Installation of cable ducting, maintaining the IP rating of the WPD package substations

Enclosed LV feeder cabinets had glanded flexible cable ducting installed into Pre-existing cable holes, again following the existing good practice and techniques developed through the retrofitting of network automation to secondary ring main units.

Exposed LV feeder had flexible cable ducts affixed to the walls or LV feeder pillar structure, again following the existing good practice and techniques developed through the retrofitting of network automation to secondary ring main units.

3. Installation of transducer cabling between the LV feeder pillar and monitoring equipment.

Doubly insulated voltage and current cables were pulled from the LV feeder pillar through the cable ducting to the network monitoring point.

4. Installation of current transducers

The project selected split current transducers and rogowski coils installed around insulated cable terminations. This allowed the installation without taking network outages, following the same methodology when installing temporary power quality monitoring discussed in section 7.1.1, selection of substation monitoring.

5. Installation of voltage transducers

The project installed two voltage transducers,

Schneider voltage handle EE:200

These voltage transducers selected for the project are a modified version of the existing fuse carrier handles, a feeder with a link box was selected and a temporary backfeed was applied, the existing fuse carrier handles were removed and replaced with the EE:200 fuse carrier handle. The process took approximately 2 minutes, but the customers supplies were not interrupted due to the availability of link boxes in urban environments.

Nylon G Clamp

These voltage transducers selected for the project were designed around existing fused voltage connectors for temporary LV supplies on open LV busbars. These devices were attached to the LV busbar using an approved live working techniques, this didn't require any network outages.

6. Commissioning monitors

This process involved configuring the monitors using a laptop to the correct transducer settings and reporting requirement.

7. Commissioning the GPRS communications

This process involved plugging in a GPRS modem and configuring the monitors using a laptop to communicate remotely using the GPRS communications.

8. Affixing a notice in the substation, providing guidance for staff unfamiliar with the project.