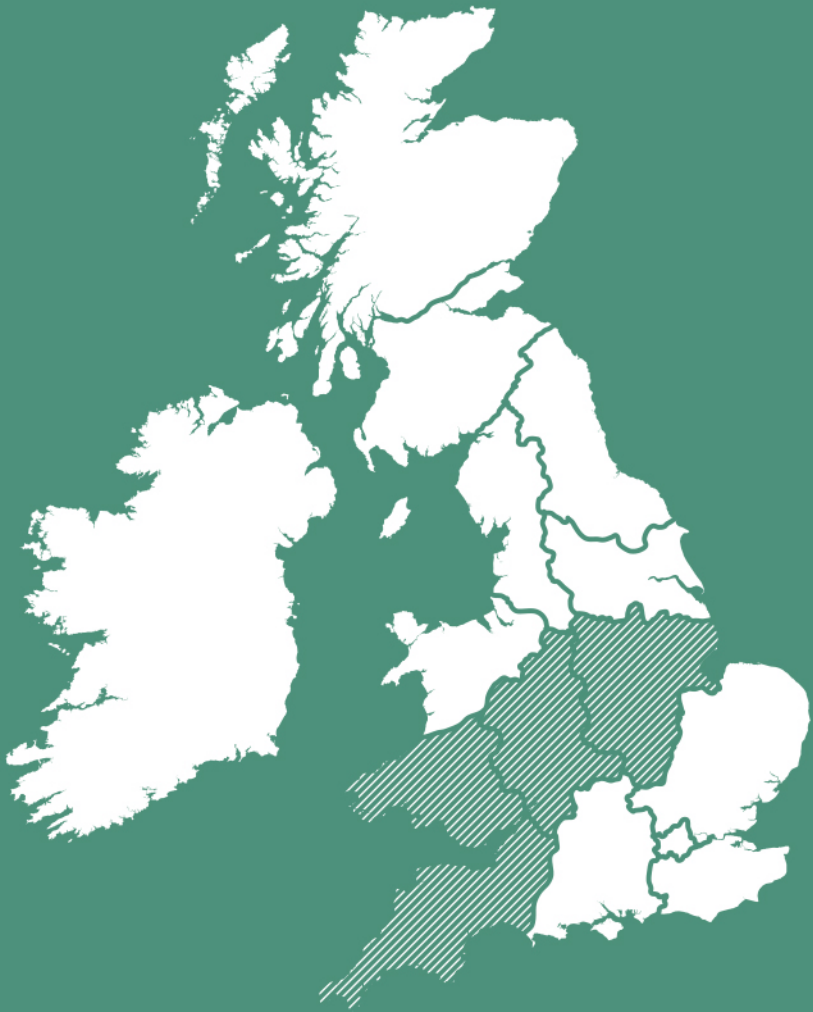
WESTERN POWER DISTRIBUTION
INNOVATION

NEXT GENERATION NETWORKS

SMART HOOKY

CLOSEDOWN REPORT



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Contents

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Executive Summary

Hook Norton is a dynamic rural community in Oxfordshire with around 2,500 residents and 800 properties. In 2009 the village was awarded £400k from DECC's Low Carbon Communities programme to help its residents 'decarbonise'. Hook Norton, like many rural villages represents a unique challenge when it comes to carbon reduction because success can only be achieved via a high level of engagement with the local community. WPD has shown this throughout all our community engagement projects.

One of the key challenges faced by communities, such as Hook Norton is the lack of visibility of their energy usage at a personal and community level. Through the Smart Hooky project this visibility was achieved through a combination of substation and consumer energy monitoring.

The project explored customer engagement and incentive programmes alongside community wide energy monitoring. From a technology perspective, the project deployed a Power Line Carrier (PLC) communications network at scale within the low voltage (LV) network, illustrating its potential capabilities for enabling smart grid end point measurement and data aggregation. An in-house designed substation monitoring solution was also developed utilising off-the-shelf components with a trial UHF radio backhaul system to gather information on the performance of the LV network.

Substation monitoring was installed in 11 substations with 46 load monitoring nodes installed in customer premises. Radio communications were established between the substations and the WPD communications network allowing data to be backhauled into the control system. Data was exported from the WPD PowerOn system via an FTP link to the National Energy Foundation every 15 minutes where it was in turn published on the customer portal. Power line carrier communications were successfully used between customer nodes, and distribution substations. Learning from the project was shared at a number of events, including knowledge dissemination events with local residents and wider industry in Hook Norton.

Smart Hooky highlighted the need for good data storage within monitoring solutions and the need for simple and replicable installation practices. We were able to demonstrate that PLC communication can work on UK LV networks with an average success rate of 70-75%. The backhaul communications solution used for this scheme was also a success with reliability in excess of 95%. From a customer engagement perspective, a wide range of recruitment techniques were trialled, although overall customer participation in the trial was lower than expected.

Given the pace of technology development, any future substation monitoring installed by WPD will be based on off the shelf solutions. A wider deployment of UHF radio will be used to support additional applications within WPD.

1. Project Background

Hook Norton is a dynamic rural community in Oxfordshire with around 2,500 residents and 800 properties. In 2010 the village was awarded £400k from DECC's Low Carbon Communities programme to help its residents 'decarbonise'. The Hook Norton Low Carbon group and the limited company which they have set up, spent the money on a variety of different projects which, over time, it is intended will return money back into the community. Initiatives undertaken at the time of this report included home retrofits (£5 to £40k interest free loans), a school makeover (including a 17.5kW PV installation) and a small automatic metering deployment. Plans were underway to obtain planning consent and funding for a community wind turbine (330kW) to the North East of the village.

Hook Norton, like many rural villages represents a unique challenge when it comes to carbon reduction because success can only be achieved via a high level of engagement with the local community. Given the fantastic work that has already gone on in Hook Norton, Western Power Distribution aims to develop a range of tools and techniques that can be used to support the low carbon transition within rural communities.

In order to progress their aspirations, Smart Hooky was agreed as a good basis with which to start to develop capability within the community as well as test measures and incentives for influencing customer behaviour.

2. Scope & Objectives

The following objectives were set at the start of the project and we have updated their status accordingly. More commentary on the exact achievements is provided within Section 6:

Objective	Status
To develop and explore customer engagement and incentive programmes. This aspect will include a small scale domestic demand response trial.	✓ ✗[1]
To develop community data measurement and display capabilities (e.g. to ascertain the total electricity consumption of the village by installing measurement devices at various locations. Subsequently, to provide this and other relevant information back to the local community via a web portal/customer interface (which if successful, could then be used for other villages))	✓
To deploy Power Line Communications (PLC) technology at scale within the low voltage (LV) network, illustrating its potential capabilities for enabling smart grid end point measurement and data aggregation.	✓
To test an 'off the shelf' asset monitoring solution for HV/LV pole-mounted and ground-mounted substations.	✓
To test and demonstrate a miniature smart grid telecommunications network (with multiple technologies) that will enable both local and remote network visibility	✓
To explore the changes that could be made to a network control system for enabling simple forms of Low Voltage (LV) network monitoring and	✓

[1] It should be noted that whilst we were not able to complete a DDSR trial this later transferred into a new project, ECHO.

management	

3. Success Criteria

The project had a number of key measures of success; these are highlighted below with their status. More information is provided on the detail within Section 6.

Success Criteria	Status
To develop and explore customer engagement and incentive programmes. This aspect will include a small scale domestic demand response trial	✓
To develop community data measurement and display capabilities (e.g. to ascertain the total electricity consumption of the village by installing measurement devices at various locations. Subsequently, to provide this and other relevant information back to the local community via a web portal/customer interface (which if successful, could then be used for other villages))	✓
To deploy Power Line Communications (PLC) technology at scale within the low voltage (LV) network, illustrating its potential capabilities for enabling smart grid end point measurement and data aggregation.	✓
To test an 'off the shelf' asset monitoring solution for HV/LV pole-mounted and ground-mounted substations.	✓
To test and demonstrate a miniature smart grid telecommunications network (with multiple technologies) that will enable both local and remote network visibility	✓
To explore the changes that could be made to a network control system for enabling simple forms of Low Voltage (LV) network monitoring and management	✓

4. Details of Work Carried Out

The electricity supply for Hook Norton is delivered through a mix of overhead and ground mounted distribution substations. One of the key aims of the project was to identify and trial methods for monitoring the low voltage network to provide improved information detailing the energy consumption of the village. This was undertaken through a combination of monitoring at substations and energy consumption readings at domestic properties, via smart nodes. Power Line Carrier (PLC) communications were also trialled on this project to provide the last mile of communications between domestic properties and substations. The gathered consumption data was passed on to customers for their own information via an online portal provided by the National Energy Foundation (NEF).

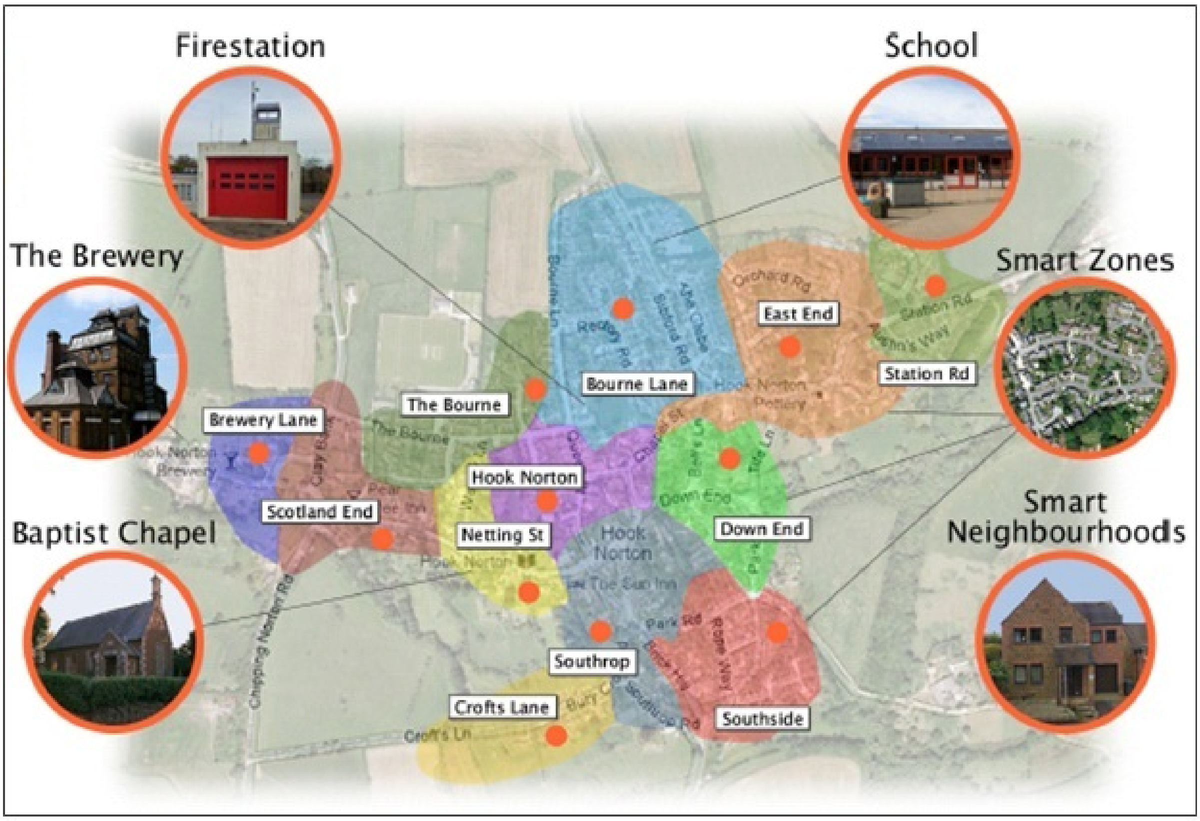


Image 1: Map of Hook Norton with substation boundary areas overlaid

The following table outlines the requirements for each site. The substations in the village range from pole mounted transformers with a single LV feeder, up to a ground mounted site with four LV ways. This meant that the substation monitoring solution developed had to be suitably flexible to account for the range of variations found across the trial area. All of the substations in Hook Norton are outdoors requiring monitoring apparatus to be sited in weatherproof cabinets. For pole mounted sites, a modified communications cabinet was utilised, and GRP pillars and meter boxes for ground mounted sites.

Substation Name	LV Ways	OH / UG Site	Size (kVA)	Customers	Smart Hub	Housing
Bourne Lane	3	UG	500	166	Yes	GRP
East End	2	UG	315	126	Yes	Meter Box
Station Rd	3	UG	500	66	Yes	GRP
Southside	2	UG	200	69	No	Meter Box
Southrop	2	OH	200	69	Yes	Pole Cab
Crofts Lane	1	OH	315	15	No	Pole Cab
Scotland End	2	UG	200	29	No	GRP
Hook Norton	4	UG	100	94	No	GRP
Netting Street	1	OH	200	40	No	Pole Cab
The Bourne	2	OH	200	91	No	Pole Cab
Down End	1	OH	200	66	No	Pole Cab

Table 2: Range of substation variations within the Hook Norton village

At four sites, additional smart hubs were added. These were essentially data concentrators that allowed load readings from domestic properties to be collected and passed to the communications medium.

4.1 Monitoring Layout

The monitoring kit was installed as follows:

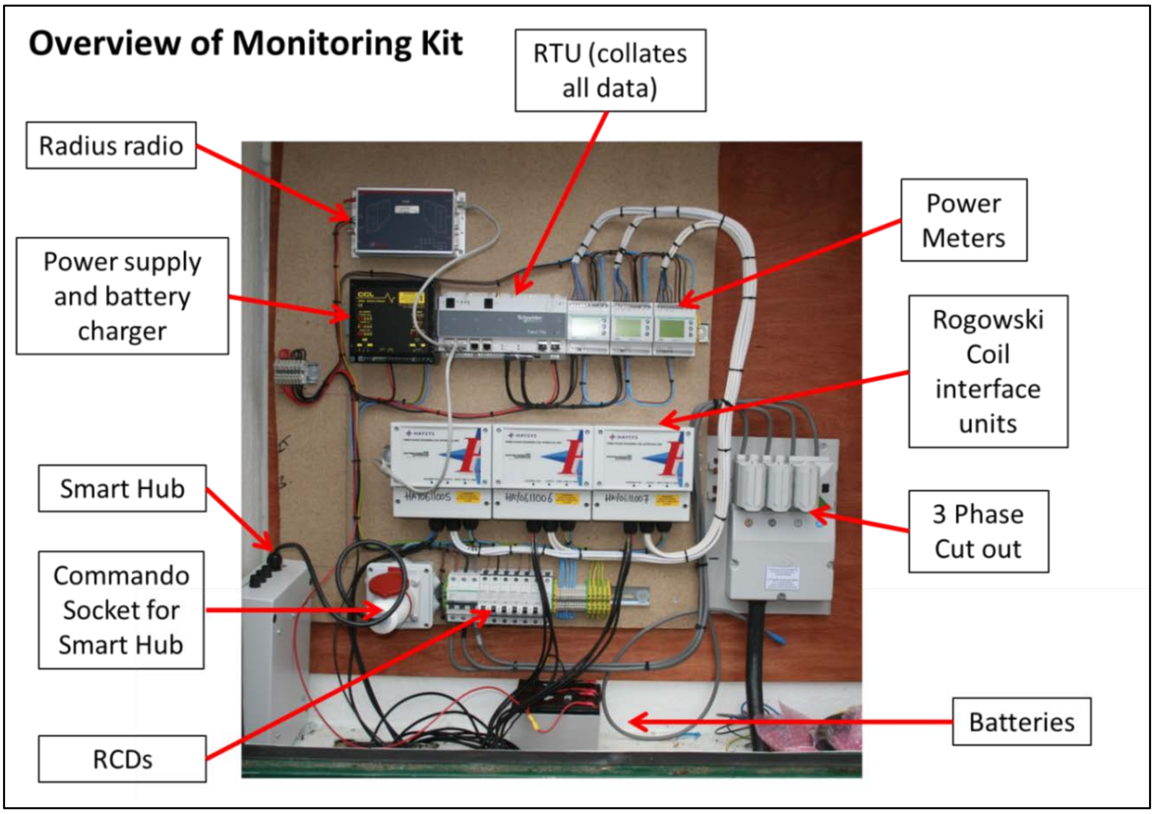


Diagram 1: Overview of Substation Monitoring Kit

Each substation monitor was constructed from a range of off-the-shelf products including:

- Rogowski coils for current measurement (3 for each LV feeder)
- A Haysys Rogowski coil interface to convert the current signal for each LV Feeder
- A Schneider PM9 Power meters to consolidate and display measurement information for each LV feeder.
- A Schneider Talus T4E RTU to process readings and package data for transmission
- A Radius 221e UHF radio to backhaul the data to the WPD control centre
- 12v power supply with battery backup

The components were all powered through a 3 phase power supply which in turn fed a 12v transformer and battery charger for the lower power items. From ground mounted sites this was achieved by jointing a new 3 phase supply onto existing mains cables in the ground. The whole solution was protected through a bank of RCD switches mounted in the cabinet. All devices were connected using small wiring that was installed by an electrical contractor.

The three phase supply was also utilised as a source for voltage readings as a proxy for direct measurement on the LV busbar.

Rogowski Coil Current Measurement

Rogowski coils were chosen for this project to measure current passing through each cable core. At the time of the project design, these had not been used extensively for substation monitoring, but were chosen due to their flexibility and ability to be installed around cables without the need for an interruption of supply. This was in contrast with other methods of monitoring previously deployed such as split core CTs around the substation busbars, which required de-energisation of the LV busbars for installation.

For each LV feeder, a Rogowski coil was installed around each individual phases to allow detailed current monitoring. The Rogowski coils were terminated into the Haysys Rogowski interface units by bringing the tails from the coils through ducting into the external cabinets.

Picture 2: Rogowski coils around LV cable cores

4.1.1 Monitoring Housings and Construction

For the underground sites a combination of different housings has been utilised. For larger sites a GRP cabinet has been installed to house all the monitoring equipment. At East End and Southside substations, two large meter boxes were added due to space constraints.

Images 3 & 4.: Meter boxes and GRP housings used for installing ground mounted monitoring

At a number of sites additional wayleave agreements were required, as the GRP housings had to be sited on private land associated with the substation.

The same monitoring equipment was also installed in metal cabinets which were then utilised for pole mounted installation. Due to the amount of components required, a number of configurations were tested to ensure that all items could be fitted into the boxes. This was a particular challenge for sites measuring two LV feeders and power meters had to be mounted on top of the Rogowski interface units.

Image 5: Example of power meters mounted on top of Rogowski Interface units

To make the installation process simpler, much of the small wiring was completed in a workshop environment. For the pole mounted monitors, components were installed directly into the metal housing and transported to site as complete units. For the larger GRP installation, all components were screwed to a MDF board and then wired together. The board was then taken to site and final connections made.

Once on site the Rogowski coils were connected to the interface units. This was a time consuming process and fiddly with 9 small wiring connections required for each LV leg. For the installations on pole mounted sites, this was even trickier as the work had to be completed working off a ladder.

Image 6: Small wiring connections

Final connections were made to power the devices and commissioned for usage.

For each site that was monitored, current data was measured for each phase of each LV leg along with the incoming three phase voltage at 15 minute intervals. In total, data was received from 17 LV legs and a total of 51 individual phases. Parameters collected included :

- Current,
- Frequency
- Voltage (of the incoming supply)
- Active Power
- Reactive Power

This arrangement allowed other parameters such as neutral current and power factor to be calculated.

At the Hook Norton and Scotland End substations, monitoring could not be commissioned. This was down to a combination of hardware faults, poor communications signal and installation issues.

4.2 Customer Energy Monitoring

In combination with the substation monitor, a domestic energy measurement system was created by AND Technology and deployed within the village. The initial development work for this system was funded through the Innovation Funding Initiative (IFI). It featured a Smart Node installed at the customers meter point, which made current readings. Data from the node was transmitted via Power

Line Carrier (PLC) communications, back to a Smart Hub data concentrator sited with the monitoring solution in the substation.

4.2.1 Smart Nodes

Smart Nodes were installed across 4 substation zones at 46 domestic properties via a spare way at the cut-out position. These allowed total household current to be measured via a clip on CT attached around a live conductor. Installation was completed by WPD's Smart Metering team, with appointments scheduled with customers through NEF. A dual pole isolator switch was also installed to allow easy isolation. Installations took approximately 30 minutes at internal meter positions and external meter boxes.

Images 7 & 8: Smart Node with power lead and CT (left) and installed in outside meter box with dual pole isolator switch (Right).

Prior to installation works, a sample of properties in the village were surveyed to ensure nodes could be fitted. At a number of meter positions, space constraints meant that installations could not be completed.

The smart node contained a Power Line Carrier (PLC) communications module capable of returning data gathered to the substation along the mains cables. As with all equipment on this project, the nodes utilised the DNP3 protocol.

The use of a clip on CT was chosen as a compromise between cost and accuracy. A number of devices were tested by AND Technology and the chosen component provided a good level of accuracy. On site testing was used to verify the current at the meter point matched that recorded and sent to the smart hub.

Image 9: CT Clip used to verify current at meter point

In a number of instances, a recent meter change had occurred and the meter tails upgraded to 25mm^2 conductors. In these instances the CT would not fully clamp around the cable and a tie wrap was employed to secure the CT. This had a limited effect on the overall accuracy of the device.

Each smart node was configured to collect consumption information at 15 minute intervals and data sent to the smart hub at the substation via the PLC communications. This was done by analysing the power usage and incrementing a counter, much in the same way as an electricity meter functions. Every 15 minutes, the incremental reading was updated allowing a load profile to be generated.

The PLC system used with this project was based around a narrowband solution to maximise the potential of messages being correctly transmitted. The data packets generated by the nodes were particularly small, which again suited the application of narrowband PLC.

Each node installed included the Renesas PLC chip, meaning that any node could act as a repeater. This essentially allowed remote nodes towards the end of feeders to send messages through nodes nearer the smart hub. In practice, nodes automatically configured themselves once connected to the network to send messages through nearer neighbours with a high level of success. Further information regarding this element of the project can be found in Appendix B

Data from the smart nodes was made available to each customer through individual accounts on the Smart Hooky website. However the quality of the data available to customers was particularly variable due to the inconsistent nature of the power line carrier.

Details of the processes used for customer engagement and recruitment can be found in Section 4.6.

4.2.2 Smart Hubs

The Smart Hub data concentrator was designed to gather data from smart nodes, and pass it on to the Talus T4E RTU to be then sent to the head end systems. These units were installed in three ground mounted substations and one pole mounted site where there was the highest concentration of interested customers. To create the PLC connection the Smart Hub was connected to via a 3 phase commando socket to the mains(shown in Image 10). This allowed PLC signals to propagate down the mains cable, onto the busbars and out through the LV network.

Image 10: Smart Hub with commando socket attachment

4.3 Telecommunications and System Configuration

The backhaul data solution used for this project was delivered through a Radius PDR221 UHF radio system, now distributed by Netcontrol(shown in Image 11 below). This system allowed a direct Ethernet feed from the Schneider RTU and was also capable of transmitting data in the DNP3 protocol. A base station was installed at an existing WPD radio site 3km from Hook Norton at Whichford Hill.

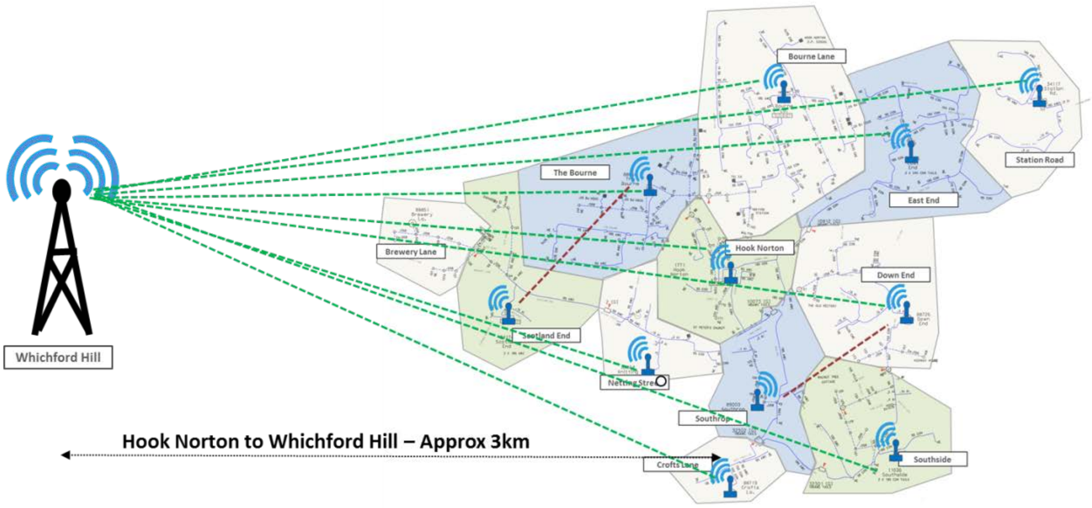
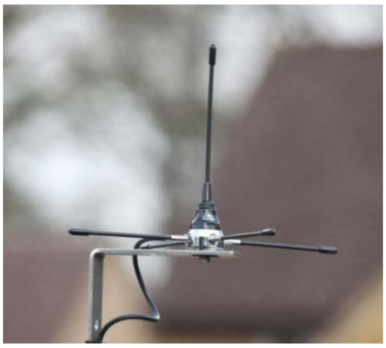


Diagram 2: Whichford Hill base station

At each substation a spider aerial mounted on an external bracket was installed(this is shown below in Image 12).

The UHF radios were licensed for 454.55 mhz. running at 9600 baud. During configuration the radios were set up to make sure they have a receive level of -80db or better, as we found due to the terrain and foliage the receive signal strength varied during the course of the year and this seemed to be the optimal value. To achieve this level of performance a number of sites including the base station have had to be run at 5 watts which is the maximum output for the PDR221 radios.



Images 11 & 12:. PDR221 radio (left) Spider Aerial (right)

	Radio					
Site Name	**Sys addr**	**Net addr**	**Radio Type**	**Tx (dbm)**	**Tx (Watts)**	**Rx (dbm)**
Whichford Hill	1	1	Master	+37dB	5 Watts	
	1	3				
	1	5				
	1	7				
	1	9				
Netting Street	1	17	**Slave with Delay for Repeater**	+37dB	5 Watts	-75
Crofts Lane	1	19	**Slave with Delay for Repeater**	+37dB	5 Watts	-82
Southrop	1	21	**Slave from Repeater**	+37dB	5 Watts	-65
Down End	1	23	**Slave and Repeater**	+37dB	5 Watts	-77
Southside	1	25	**Slave with Delay for Repeater**	+37dB	5 Watts	-96
The Bourne	1	27	**Slave with Delay for**	+33dB	2 Watts	-62

			Repeater			
Bourne lane	1	29	**Slave with Delay for Repeater**	+33dB	2 Watts	-79
East End	1	31	**Slave with Delay for Repeater**	+33dB	2 Watts	-81
Station Road	1	33	**Slave with Delay for Repeater**	+33dB	2 Watts	-82

Table 3: Transmit (Tx) level set for each site along with its receive (Rx)level.

Site surveys were carried out to establish signal strength and initial installations completed at East End, Bourne Lane and Station Road. However, following a site survey at Southrop it became apparent that there was no direct line of site to Whichford Hill. This was primarily due to the substation being sited in a hollow and surrounded by tall trees. To overcome this issue, the radio at Down End was used as a repeater and the signal from Southrop relayed on to Whichford Hill. This required a reconfirmation of all the radios already commissioned allowing the repeater functionality to be trialled. A similar issue with Scotland End was also experience with no direct line of site. However due to additional hardware issues with the substation monitor, the radio link with the Bourne was never established.

The original testing and installation at site was carried out with the radio system using IP communications. A further development period was required when the IP based system could not be configured into the WPD PowerOn network. This was primarily driven by security concerns and a serial RS232 solution was successfully configured and implemented.

4.4 Site Commissioning

Due to the number of individual components at each substation site (Rogowski coil interfaces, RTUs, power meters, radios etc), considerable effort was required to get all the devices to talk to each other. It was decided at an early stage of the project to use the DNP3 protocol. Although all devices were capable of communicating via DNP3, configuration work was required to ensure the correct data points were created and then passed through the various devices. This included several days' worth of lab based work testing the DNP3 protocol through a mocked up installation.

DNP3 configuration was not a core skill widely held within WPD, and required a number of specialists to learn how to configure each site. This process was time consuming and often required interventions from manufacturers to overcome obstacles. AND Technology produced the required DNP3 mapping for the nodes and hubs. Additional input was then required by Schneider to map points onto the RTU and power meters. Further work was also undertaken to trouble shoot communication issues between the individual components.

From a commissioning perspective, the communications required specialist skills to set up. WPD were able to utilise Surf telecom, WPD's in-house telecommunications company. In many cases the configuration and testing of each site took several hours due to line of sight issues with the communications and complexities associated with the monitoring set up.

The method used for gaining current readings relied on data being relayed to a Schneider PM9c power meter. For each site additional configuration was required to set CT ratios, communications rates and input channels for every power meter. While not particularly time consuming, this process added another layer of configuration adding to the overall commissioning time. To simplify this process, a commissioning guide was created which allowed installations to be completed by the local line teams for the pole mounted sites.

4.5 Data Management

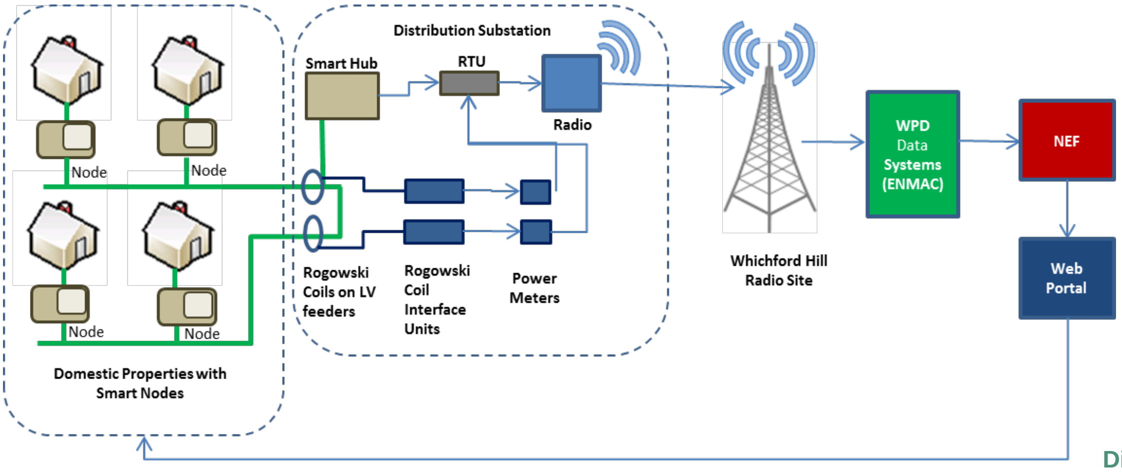
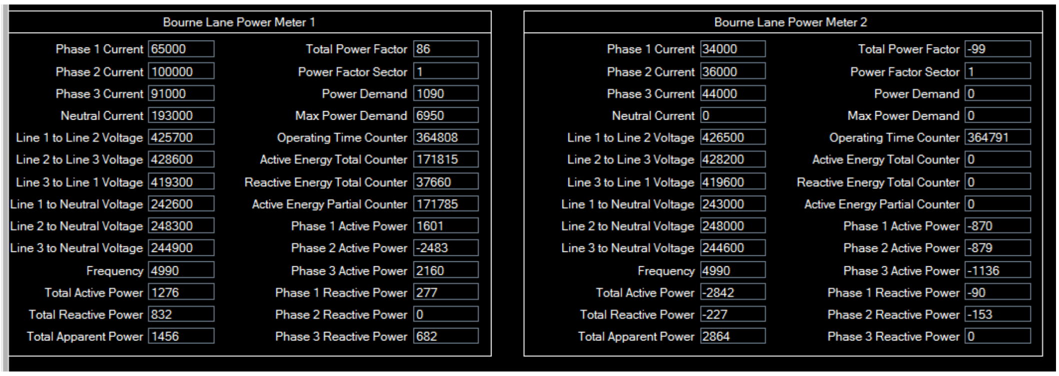


Diagram 3: The end to end system architecture applied in Smart Hooky.

Smart nodes installed at 46 domestic properties across the village and communicated via narrowband Power Line Carrier (PLC) to a Smart Hub situated at a distribution substation. Additional data substation data was measured via Rogowski coil units, measuring the 3 phase current on the LV feeders.

Readings were fed through a Rogowski coil interface unit and then onto a series of power meters. All data from the smart hub and power meters was consolidated in DNP3 format at the RTU and transmitted through the UHF radio system to the local radio tower at Whichford Hill. The data passed into the WPD network to a trial specific PowerOn control system which was being used as a data collector. Customer consumption data and substation data was packaged in an XML file at 15 minute resolution and passed to NEF via a FTP link. The data was then processed by NEF and was made available for viewing on the web portal by individual customers using a secure login.

As well as data being passed to NEF, node and substation data was displayed in the PowerOn test system, to allow live visibility of the LV network. XML files were archived at 15 minute intervals. Further analysis of the data was undertaken using Excel, the results of which can be found in Section 4.



Bourne Lane Power Meter 1			
Phase 1 Current	65000	Total Power Factor	86
Phase 2 Current	100000	Power Factor Sector	1
Phase 3 Current	91000	Power Demand	1090
Neutral Current	193000	Max Power Demand	6950
Line 1 to Line 2 Voltage	425700	Operating Time Counter	364808
Line 2 to Line 3 Voltage	428600	Active Energy Total Counter	171815
Line 3 to Line 1 Voltage	419300	Reactive Energy Total Counter	37660
Line 1 to Neutral Voltage	242600	Active Energy Partial Counter	171785
Line 2 to Neutral Voltage	248300	Phase 1 Active Power	1601
Line 3 to Neutral Voltage	244900	Phase 2 Active Power	-2483
Frequency	4990	Phase 3 Active Power	2160
Total Active Power	1276	Phase 1 Reactive Power	277
Total Reactive Power	832	Phase 2 Reactive Power	0
Total Apparent Power	1456	Phase 3 Reactive Power	682

Bourne Lane Power Meter 2			
Phase 1 Current	34000	Total Power Factor	-99
Phase 2 Current	36000	Power Factor Sector	1
Phase 3 Current	44000	Power Demand	0
Neutral Current	0	Max Power Demand	0
Line 1 to Line 2 Voltage	426500	Operating Time Counter	364791
Line 2 to Line 3 Voltage	428200	Active Energy Total Counter	0
Line 3 to Line 1 Voltage	419600	Reactive Energy Total Counter	0
Line 1 to Neutral Voltage	243000	Active Energy Partial Counter	0
Line 2 to Neutral Voltage	248000	Phase 1 Active Power	-870
Line 3 to Neutral Voltage	244600	Phase 2 Active Power	-879
Frequency	4990	Phase 3 Active Power	-1136
Total Active Power	-2842	Phase 1 Reactive Power	-90
Total Reactive Power	-227	Phase 2 Reactive Power	-153
Total Apparent Power	2864	Phase 3 Reactive Power	0

Image 13: Example of data display in PowerOn

4.6 Customer Engagement

This section outlines the customer engagement aspects of this Smart Hooky project. Further details can also be found in Appendix A produced by the National Energy Foundation (NEF).

The National Energy Foundation was appointed to work alongside the Hook Norton Low Carbon Club (HNLC) to lead on the consumer engagement aspects of the project. Specifically, NEF's role was to:

- Recruit residents willing to participate in the trial by having a smart node installed; the target was to get 150 nodes installed in clustered areas in the village;
- Organise the installation of the nodes with WPD;
- Engage with the residents to encourage a change of behaviour depending on the data received;
- Communicate with the residents on the progress and findings of the project;
- Develop all communication materials needed for the engagement part of the project, i.e. leaflets, posters, blogs, newsletters, press releases, etc.;
- Develop the online customer interface for residents to logon to view the total village electricity consumption and individual data for those selected in the trial.

To support the project, Smart Hooky branding was developed in keeping with the feel of the village, along with leaflets and posters to explain the project objectives and support customer recruitment for the installation of smart nodes.

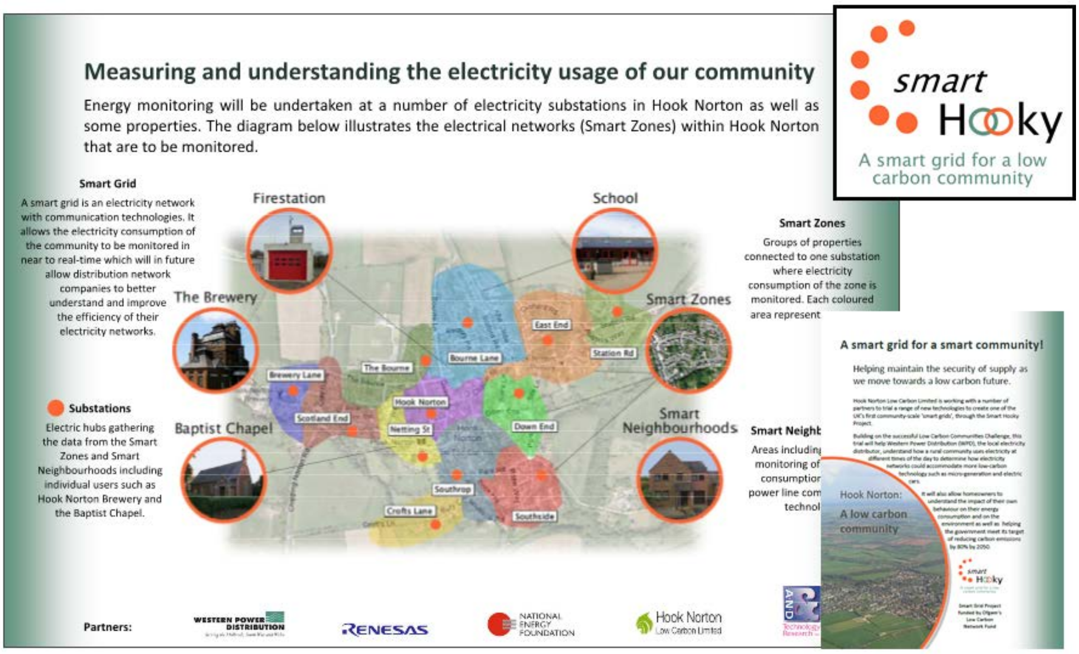


Image 14: Smart Hooky Branding

4.6.1 Customer Recruitment

One main reason to select Hook Norton for trialling this new technology was because the village was already very active in terms of lowering their carbon footprint, led by a dynamic group of people who set up the Hook Norton Low Carbon Club to lead on all initiatives.

Due to HNLCs previous engagement with the community, the project benefited from a 'warm' audience to talk to and engage with the Smart Hooky project. The initial presentation of the project at a HNLC meeting resulted in 38 residents expressing an interest. Further publicity was created through the local newsletter, leaflets placed in the local library and shops and a stall at the Crossroad music festival.

A number of methods were utilised to register interest including a postal form attached to the leaflet and a dedicated web address.

By the end of September 2011, we had gathered interest from 70 residents across the village as follows (38 of which were members of HNLC):

- 24 through the newsletter
- 25 at the Crossroad event
- 21 through HNLC meeting

For the PLC function of the Smart Node to work, it needed to be associated with a Smart Hub. In addition, it was important to achieve density to be able to test the repeater functionality. Therefore it was decided to focus the PLC trial activity on four sites. These are shown below:

Sub-stations	Interested residents	Total residents	% Interest	Selected
East End	15	126	12%	Yes
Southrop	12	67	18%	Yes
Bourne Lane	12	166	7%	Yes
Southside	9	66	14%	No
Hook Norton	7			No
Station Road	4	62	6%	Yes
Other 5 substations	*11*			
Total	**70**			

Table 4: Substations with interested residents

The four substations with the most interest were East End, Southrop, Bourne Lane and Southside. However, due to its ease of access and some work already underway to install equipment, Station Road was favoured for the installation of a smart hub. This meant not installing hub and node equipment at Southside as a result. The four chosen substations (shaded in orange on the map below) had a total interest from 43 residents.

Image 15: Location of chosen substations

Further recruitment was undertaken in the specific substation areas using a range of methods. These included;

- Door-to-door knocking
- Leaflets/Posters
- Newsletter
- Incentives through further prizes
- News/blogs and press releases

The door-to-door approach was very time consuming resulting in an average of 5 customers signed up in 2 hours of door knocking. This process however did provide an opportunity for customers to ask a few more questions about the project before they signed up.

In order to encourage residents to sign up for the trial, we promoted a prize draw offering the following prizes to three residents who were picked at random:

	Prize	Value
1st Prize	Eurostar voucher	£150
2nd Prize	Restaurant vouchers	£70
3rd Prize	Village shop vouchers	£30

By March 2012 a total of 65 residents in the target substations had signed up for the project, broken down as follows.

- 46 installations completed (roughly 1/3 of target)
- 7 could not be completed due to lack of space for the equipment
- 12 installations left to do

The remaining 12 installations were not completed, due to a mix of technical issues and lack of confirmation from the customer regarding project participation.

A final wave of customer recruitment was planned towards the end of the project, along with a village wide energy event. With the customer node data, gaps in the data set did not allow for reliable 15 minute resolution load profiles to be produced for each customer. Given difficulties in recruiting the first 70 interested participants, it was anticipated to be too stretching to achieve a further 100 installations. While improved density of nodes would have inherently improved data quality, the lack of data storage was an issue that could not be circumvented. Given that nodes close to the substation failed to communicate 100% of the time highlighted this further and additional recruitment plans were cancelled.

4.7 Customer Workshops

In March 2013 workshops were run by WPD and NEF for local residents to coincide with the launch of the community website. The purpose of the evenings was to allow project participants to find out more about the project, and discuss some of the issues around reducing energy use. The events were attended by 20 project participants and included brainstorming sessions associated with energy reduction and moving peak load.

Image 16: Customer workshop at Hook Norton Brewery Visitors Centre

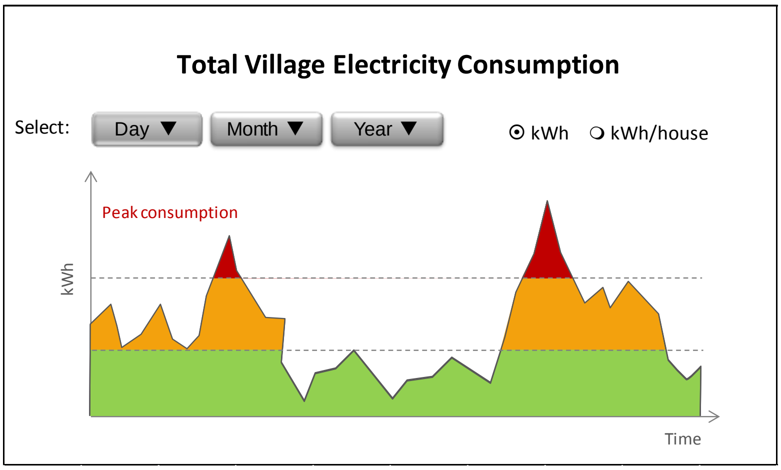
4.8 Data Display Capabilities

During the project, initial system designs were reconsidered to ensure delivery complied with WPDs IT policies. As a result responsibility for delivering the web portal element of the project was moved to NEF.

NEF established www.smart-hooky.net and setup the framework of the website based on the Drupal7 CMS, ready for further development. Drupal required a MySQL database for its own use, within which new tables were added with fields to store incoming values from transmitted XML files. A customised Drupal module was written in PHP for the project. This handled two major areas relevant to the project success; importing readings from XML files and rendering data as charts. This was later moved over to a virtual server with greater resources to allow for larger MySQL databases to store more data.

After trialling several potential charting libraries (Google API, Dygraphs, PChart and finally Fusion Charts), the website was established using the Fusion Charts package. This was due largely to performance and ease of use, but also due to the many available charting formats.

The website and went live with substation data in November 2012. Further testing was undertaken with a number of project participants in January 2013. Following sucessful trials, the full portal went live in March 2013, with user name and password details given to individual project members.



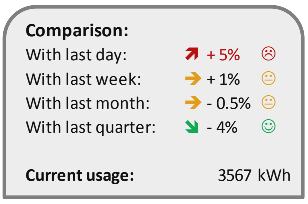


Image 17:Illustration of a possible graph highlighting peak consumption in the village

4.9 Knowledge Dissemination

The information gained from the Smart Hooky project has been shared at a number of forums including the 2012 Low Carbon Network Fund Conference. At this event a keynote presentation was given by a Hook Norton resident and project participant. Additional learning was also shared at the same conference in 2013. In February 2013 an event was run at Hook Norton Brewery to showcase the findings from the project and allow delegates to view actual installations. The event was attended by about 20 people including representatives from energy charities, universities and 4 other network operators.

The morning featured presentation from all project partners, followed by a site visit and workshops in the afternoon.

The workshops aimed at gaining insight into a number of key questions for this project, and others schemes of a similar nature including customer engagement, incentives and energy reduction techniques.

Image 18: Selection of Photos taken during the February 2013 Dissemination event at Hook Norton Brewery

5. Outcomes

This section outlines the findings from substation monitoring, PLC trials and customer engagement. Further information can be found relating to the customer interactions and PLC in the appendices prepared by NEF and AND Technology attached at the end of the document.

5.1 Substation Monitoring

5.1.1 Hardware Performance and Maintenance

This project has been able to demonstrate that a substation monitor can be developed using off-the-shelf products. At the time of the project design, Rogowski coils had not had extensive use for LV current monitoring applications on UK networks. Utilising them within this trial demonstrated a positive application of the technology as part of an accurate and fit for purpose monitoring solution. Since the project started, many new substation monitoring solutions have been developed by third parties and widely deploy Rogowski technology.

While the data returned from the monitors provided vastly improved network visibility, there were a number of performance issues from the hardware that required further investigation and on-site rectification. In some cases sites had to be visited multiple times to rectify problems.

To protect the installations, a number of RCD devices were used on the small wiring. In a number of circumstances, these were very sensitive and tripped, cutting the power to the monitor. On one occasion, three sites tripped at the same time, leading us to the conclusion that a transient fault on the network had occurred causing the RCDs to operate. This led to a high number of site revisits to rectify problems and reset devices. This was a particular issue with overhead mounted sites where overhead line teams were required to reset the devices.

The design of the monitoring did not include any elements of data storage. As a result, any temporary loss of communications resulted in lost data packets. This led to a number of gaps in the data sets for both substation monitoring and contributed to the incomplete data from customer nodes. This is of course valuable learning for the future.

Utilising a number of components resulted in installation problems that led to onsite troubleshooting work. This included wiring errors that were made in the workshop configuration resulting in the monitoring solution not functioning. At one site a fault was found on all 4 Rogowski coil interfaces where all the units would not power up. It was thought at the time that an error in commissioning was to blame resulting in the failure of the unit's power supplies.

At the Hook Norton and Scotland End substations, monitoring could not ultimately be commissioned. This was down to a combination of hardware faults, poor communications signal and installation issues.

5.1.2 Substation Data Analysis

The substation monitoring utilised for this trial provided a good data set of current and voltage data for the Hook Norton network. However, due to the recent advances in substation monitoring, power quality, harmonic analysis and the setting of alarm thresholds are now common place measurements on up-to-date systems, allowing a deeper analysis of network conditions.

Due to the way the data was collected, each LV feeder produced over 10,000 data points per year for current alone. This highlighted the need for further analytical tools to help assess the data and identify anomalous situations. For the purpose of this trial, data analysis was undertaken manually using techniques such as databases and MS Excel.

On the whole the monitoring demonstrated that given the present load conditions, the network is very lightly loaded with spare capacity in the system. For a number of sites there was over 1 years' worth of data, which gave a high degree of confidence when assessing the network. The following load profile curves summarise the duration of loads on a specific substation. The red line represents the overall capacity of the specific substation.

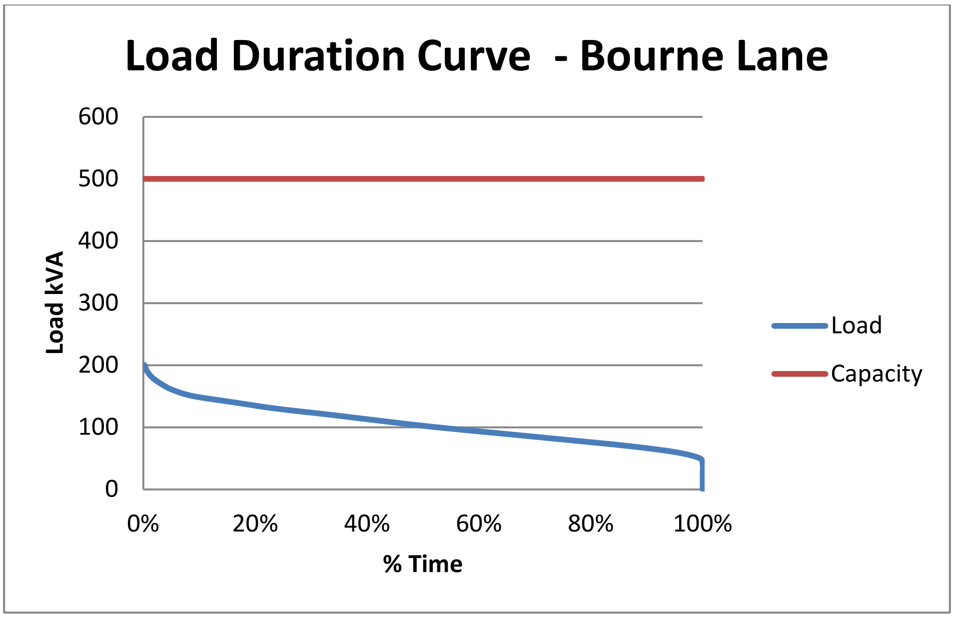


Diagram 4: Bourne Lane substation load profile

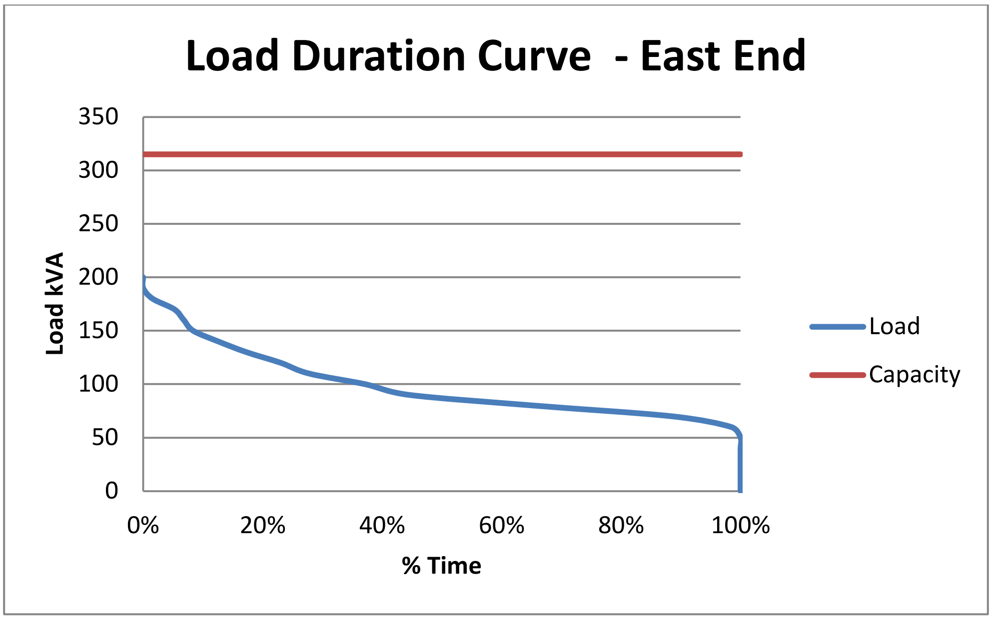


Diagram 5:East End substation load profile

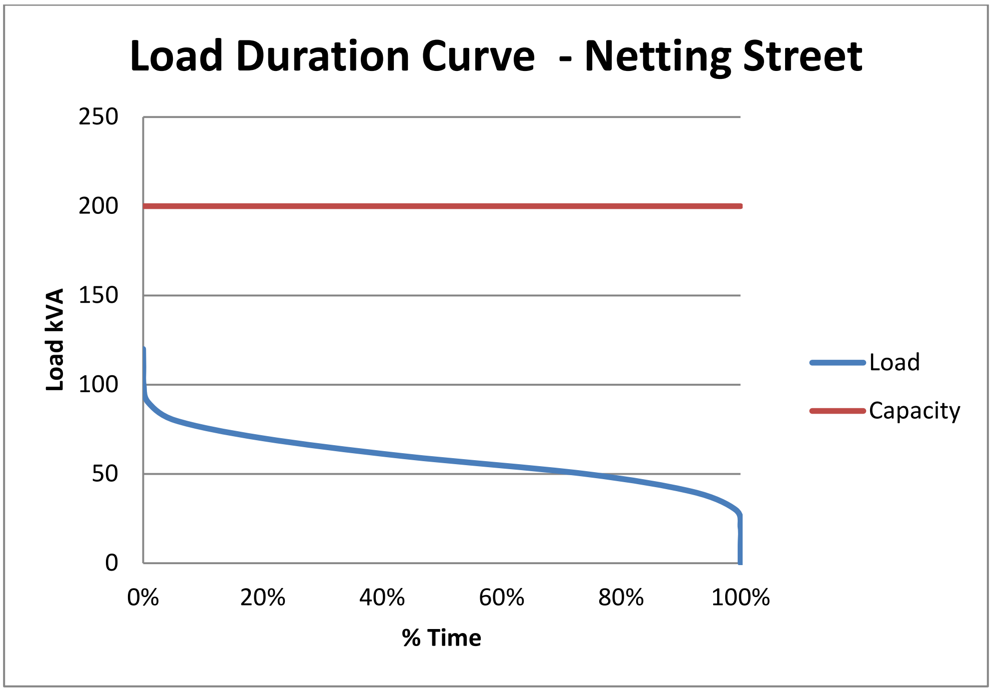


Diagram 6: Netting Street substation load profile

While this data may not highlight any particular issues on site, it demonstrates clearly the available capacity in the system across Hook Norton. We have been able to evaluate the load across the village with a greater level of clarity and this will be extremely useful when evaluating any further loads or other detailed network planning in the future.

5.2 Smart Node Performance

Smart Nodes were installed at 48 properties around the village associated with 4 substations. Initially it was anticipated that about 150 nodes would be installed but customer take up was not as high as expected.

Substation Name	OH / UG Site	Hub	Total Customers	Installed Nodes	% Of Customers
Bourne Lane	UG	Yes	166	17	10.2%
East End	UG	Yes	126	21	16.7%
Station Rd	UG	Yes	66	2	3.0%
Southrop	OH	Yes	69	8	11.5%

Table 5 : Customer node installs by substation

Below is an example of some of the data collected from a customer node associated with an electrically heated bungalow. The load profile is as expected with peaks during early morning and evening. Additional load spikes can also be observed on Sunday 27th at lunchtime.

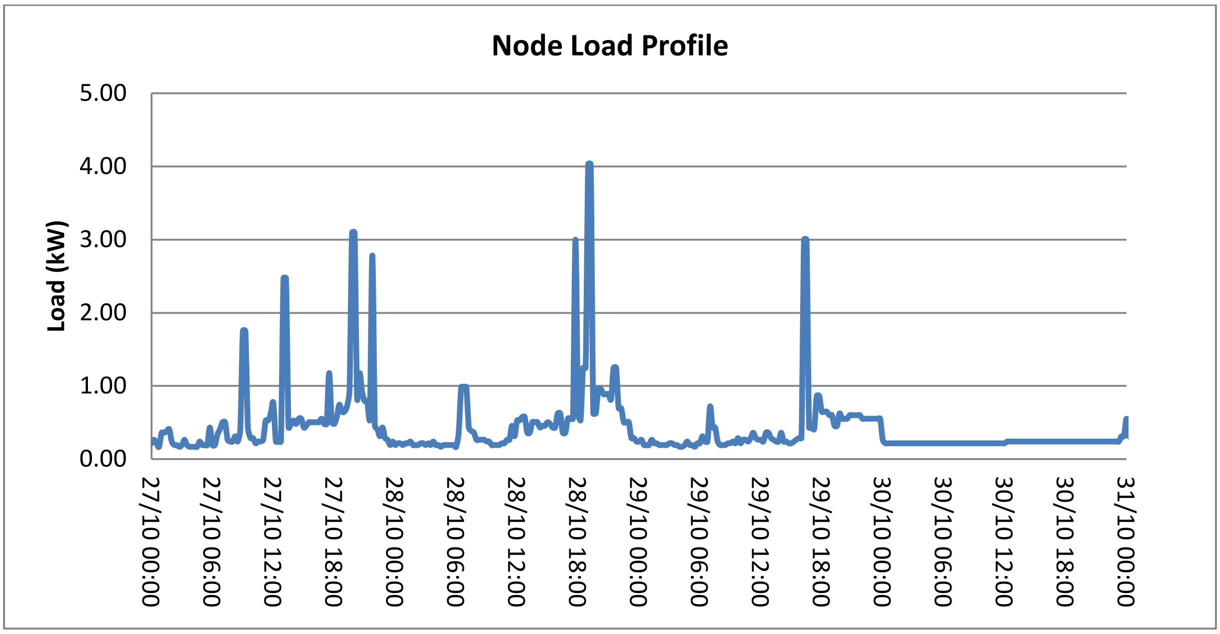


Diagram 7: Electrically heated property load profile, showing loss of PLC communications

However the load profile goes flat around midnight on 30th October and remains so for a 24 hour period. This was due to signals from the node not being returned to the head end control system. This was most likely due to a loss of PLC communications.

5.2.1 Smart Node Design

Operating the nodes for several months highlighted a number of short falls in the overall design of the smart nodes. Firstly, as with the substation monitors, no data storage was included. Subsequently if data failed to reach the head end, the packet was lost, resulting in missing data in the load profile shown above in Diagram 7.

There were a number of properties in Hook Norton that had installed photo voltaic (PV) panels. The nodes utilised a simple current transformer (CT) to measure the load flowing through the cable. However these were not capable of detecting the direction of the power flow. As a result, data exported from PV panels was shown as a load making any financial estimates of energy costs over inflated.

Since the project started, additional requirements for voltage information on the network have emerged. With additional electrical loads and export from embedded generation, modelling and managing the system voltages is expected to get more challenging. Voltage measurement was not included in the node design but could be easily added with any future development.

5.2.2 Data Quality Checks

While undertaking data quality checks, a number of load readings were identified which appeared extremely low and at other premises, extremely high. In both scenarios, visits were made to customer premises and checked with portable monitoring equipment. These checks provided a high level of confidence in the data being returned from the nodes.

At one property the internal wiring was particularly complex with more than one consumer unit in place. The CT could not be fitted around the enlarged meter tails and as another cable was identified. However it was later discovered that this cable did not carry all the power for the property as current readings returned did not match expectations.

Another property yielded exceptionally high readings indicating a significant amount of load was being drawn. Following further investigation it was found that the high load was due to the installation of a heat pump. In addition the property also benefitted from PV panels. From the data being collected by the node, it was possible to see that the heat pump was running for significant periods of time. The chart below compares the load profile with a more moderate energy usage. As can be seen, the heat pump is running at about 3.5kW during the night. It would appear that the load continues but is masked by some of the output from the PV panels during the day. This pattern of overall power usage falling in the afternoon can be seen across a number of days, suggesting that the solar panels are working at their best in late afternoon.

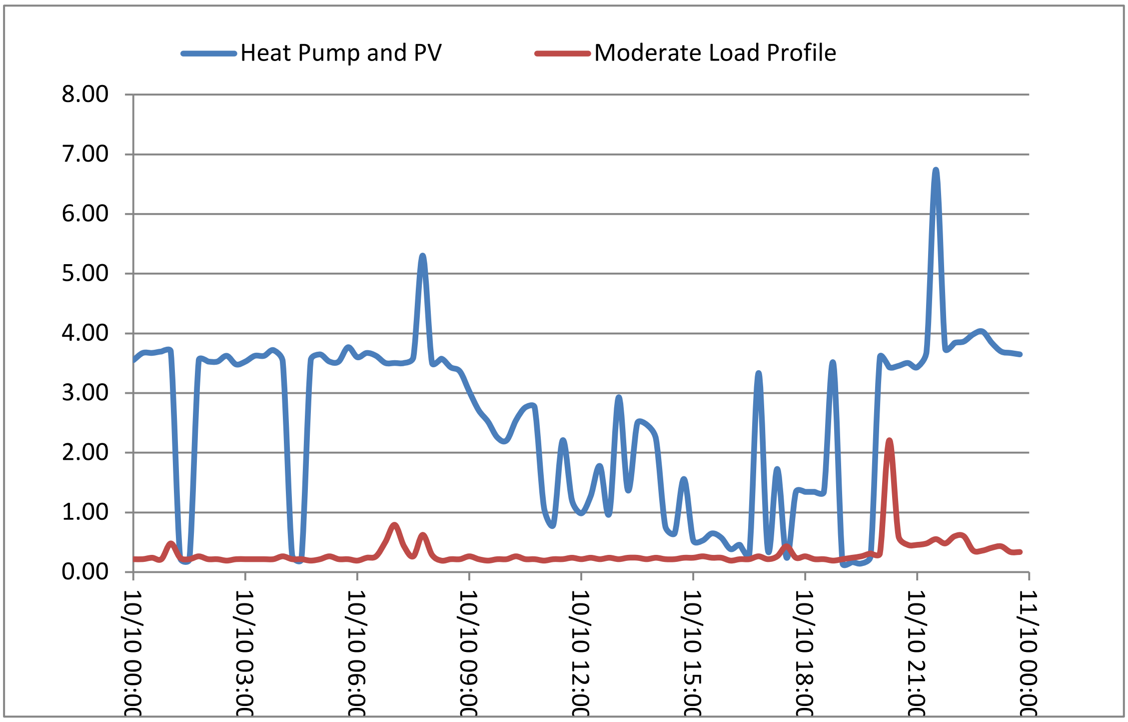


Diagram 8: Load profile of property with heat pump compared to property with a moderate energy usage load profile

5.3 PLC Performance

5.3.1 Message Transmission Success

As has already been outlined, not all the customer load data packages from smart nodes were successfully received back at the WPD control system. In a small number of cases the radio back haul dropped out causing messages to be lost, although this occurred less than 5% of the time. There are a number of factors that could have caused these problems to occur including loss of backhaul communications, application issues between the hub and the RTU or a failure of the PLC communications.

In some circumstances this can be attributed to the distances between the node and the substation. If no additional nodes were connected to that phase of the feeder, it may have proved too far for the message to be sent. However, even some of the better performing nodes did not achieve 100% data transmission rates.

On average nodes successfully transmitted data between 50% and 75% of the time. The following chart demonstrates the success rate of transmission for the time of day for 31 nodes averaged across a month (October 2013). This has been plotted against the average load profile for the associated substations for the same time period.

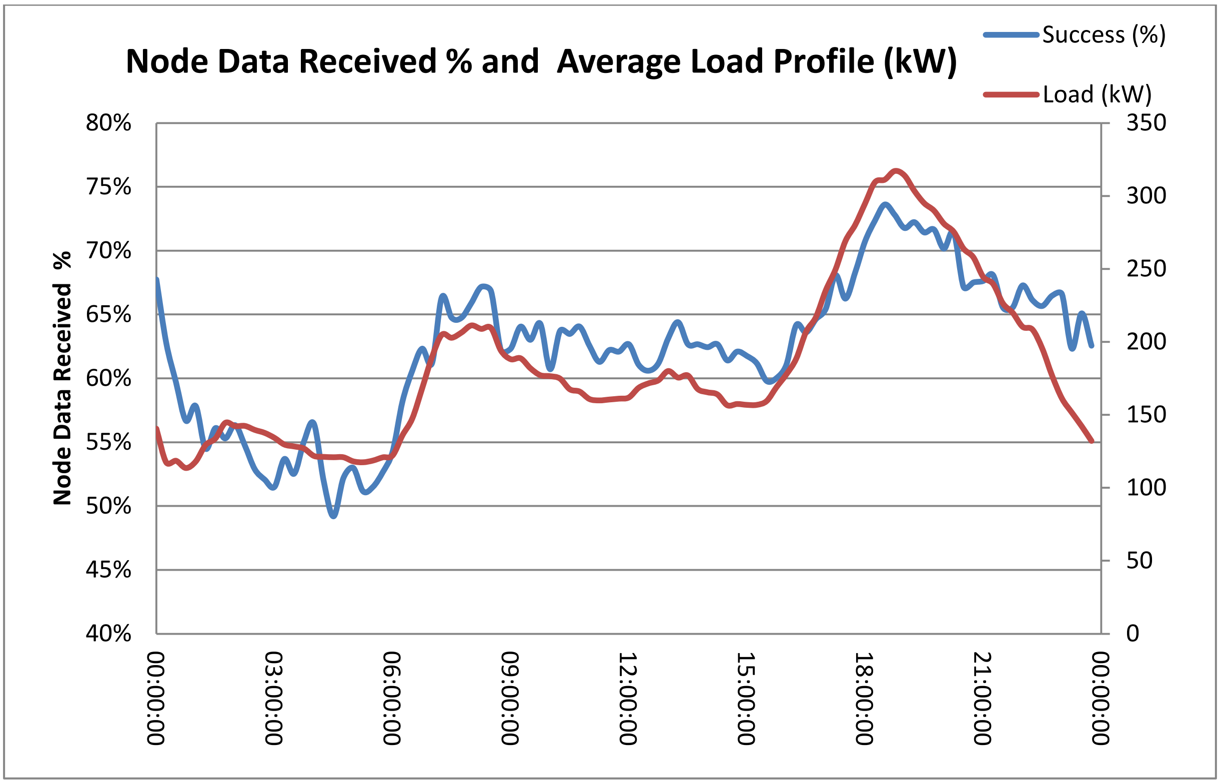


Diagram 9: Average % of data received compared to average load profile

It would appear that there is a direct correlation between the load on the network and the rate of successful data transmission through PLC.

Issues of intermittent data transmission could be mitigated with the addition of some form of data storage with the node and some form of confirmation message that the data packet has been received. In the absence of the return message, the packet could be sent again until successfully transferred.

5.3.2 PLC Performance Conclusions

It is quite difficult to separate out the PLC performance as an individual element from the end to end solution as many factors affect the overall system operation, such as the performance of the hub, RTU and backhaul comms. However is true to say that PLC performance can be considered as one of the main variables, especially as there is a variability between messages received from different nodes at the same time.

The nodes at East End and Bourne Lane represented the densest deployment of nodes in Hook Norton with 38 nodes installed within a customer base of 286; a 13% deployment.

Whilst data was being sent every 15 minutes, for many applications, such as smart metering, data would need transferring at much lower frequencies. Of the 38 nodes installed on these two sites, 75% of them managed to return a message at least once every day. Generally speaking the rate of successful data transfers diminished towards the end of feeder although this was skewed by nodes acting as repeaters. In areas with a high density of nodes, the rates of data transfer increased.

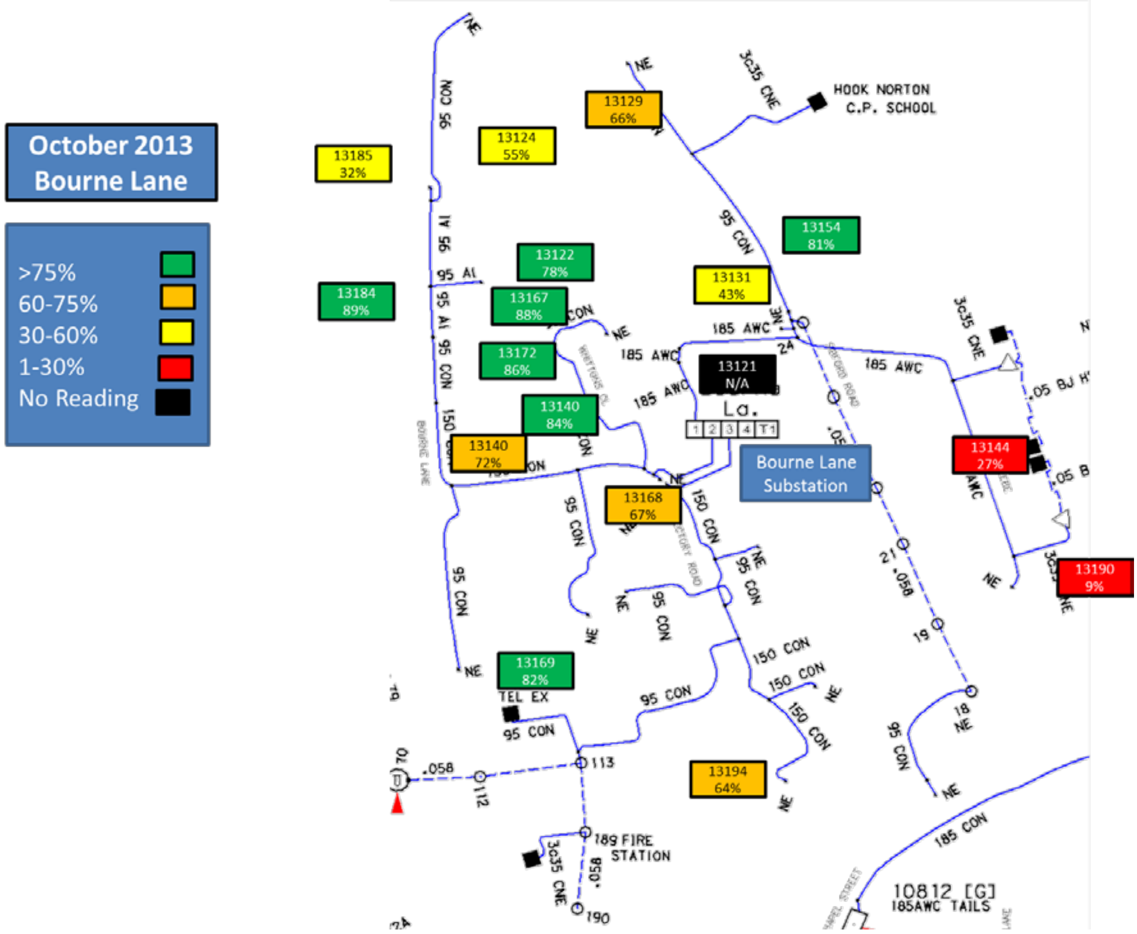


Image 19: Shows a cluster of properties with nodes associated with the Bourne Lane Substation

For East End the data is less conclusive although there is a cluster that can be observed in the South West of the area where all nodes failed to communicate throughout the month. It should be recognised that some of these nodes did connect and send messages during the trial but not with the same regularity as nearer nodes.

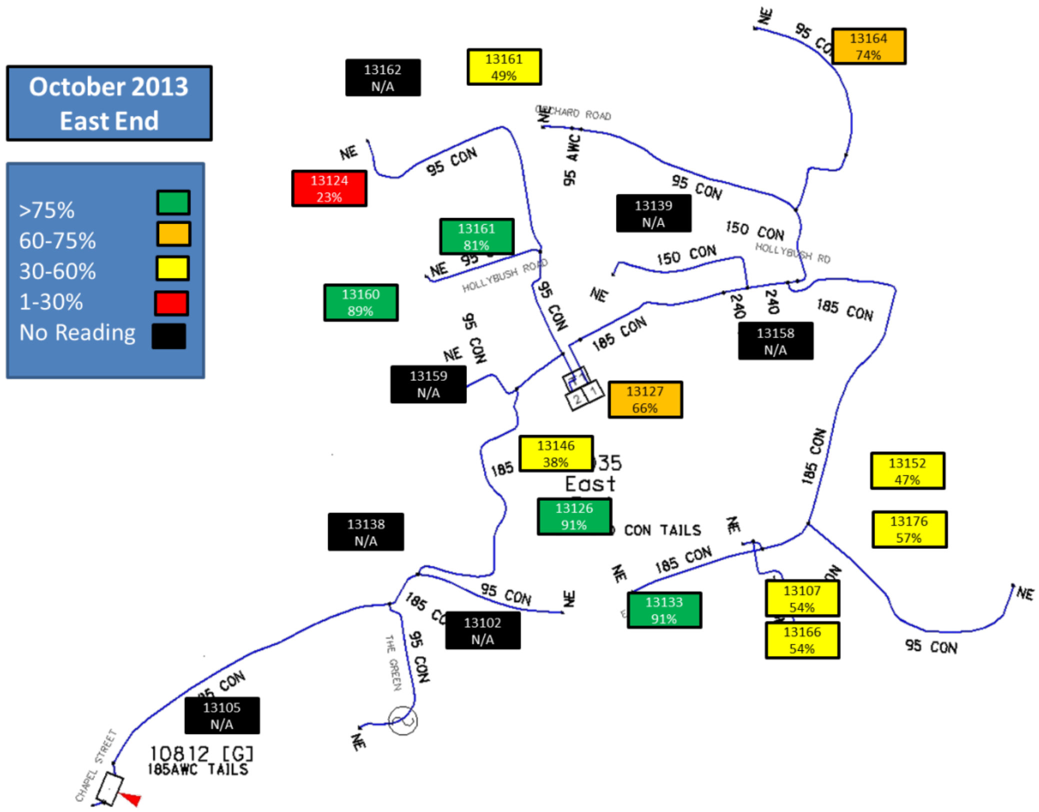


Image 20: Shows a cluster of properties with nodes associated with the Bourne Lane Substation.

In summary, the PLC seemed to perform well given the limited deployment across the village. For business as usual applications, data storage could bridge some of the intermittent communication losses experienced in this trial. The success rate of 50-75% rose when looking at 1 successful message per day to about 75% for most nodes which would be suitable for many applications. It is difficult to quantify how many further nodes would have been required to significantly improve performance further. However if nodes could have been placed strategically across all three phases, it is anticipated that many of the poorer communication links would have been improved. Initial calculations suggest an addition 20% would have been required based on 3 more nodes per feeder. More details of the PLC performance can be found in Appendix B .

5.4 Radio Backhaul

The radio system performed well with a high level of reliability. Analysis showed a few periods of time when the signal appeared to drop out and data transmission ceased. However many of these periods were attributed to work on the radio system which had temporarily interrupted the signals.

Initial configuration and commissioning of the radio at each site was a time-consuming process. This was improved through the use of pre-site survey and experience as the telecoms team became more familiar with the equipment. However, this knowledge was not transferred to local line teams allowing them to configure new installations. Instead, communications specialists attended each new install to support commissioning.

There were issues at a number of sites regarding signal strength, which could be improved by using the PDR 121 version of the radio. The PDR 121 has improved hop/relay capability possibly allowing connections to inaccessible sites.

5.5 Customer Engagement and Incentives

Initially it was anticipated that 150 customers would be recruited to take part in the project. The hypothesis was that this would have allowed for an extremely dense installation of customer nodes, and therefore a robust PLC communications system. This would have occurred due to a large number of nodes on the system able to act as repeaters improving signal propagation and reliability.

From the site surveys it became apparent that the target of 150 installations would be extremely challenging as 1 in 6 of the sites inspected could not have the nodes installed due to a lack of space. This finding was very important as it meant that to get 150 nodes installed it was likely that the project would need to recruit at least 175 interested residents amongst the 421 residents within the 4 selected areas. This represented more than 41% of the population. This was an extremely challenging task considering that, whilst the village overallwas very proactive in engaging with green issues, a large proportion of the village had elderly people who did not necessarily want to be involved in such trials.

A number of delays in the development of an end to end data solution may also have contributed to a reduced recruitment for the project. On reflection, we feel that being able to demonstrate a working solution to customers would have aided further recruitment, allowing the benefits of participation to be demonstrated.

5.6 Website

The live website provided the functionality that was required for the project; display live and historic data for customer nodes, substations and the village as a whole. However during the initial testing of the website, it became apparent that incomplete data sets would reduce the sites overall usefulness. For example, where node data was missing, the system was not able to complete the appropriate load profile. Instead the load would drop to zero and then increase in a spike when a reading was received.

Although the data contained accurate information on total load, the missing data points made it difficult to read and at sometimes misleading. It also meant that any specific customer actions to reduce demand would be invisible within missing data points. We have no direct evidence to suggest that customer behaviours and energy usage were altered as a result of this project. However the presence of the website and publicity associated with the project would have increased the awareness in the village of energy related issues.

5.7 Knowledge Dissemination

The workshops aimed at gaining insight into a number of key questions for this project, and others schemes of a similar nature. Below is a summary of the discussion questions and the responses deemed to be the most important by the participants.

- What are the benefits for customers taking part in trials (like Hook Norton)?
    - Financial benefit through reduced bills.
    - Help protect the environment and future energy supply.
    - Improved education around how to be energy efficient
- What actions could project participants take to reduce consumption?

    - Management of devices on standby
    - Scheduling of loads
    - Improve knowledge of demand of individual appliances.
- What are the most effective communication channels to engage project participant?
    - Alerts – to email, text, website portals
    - In person
    - Smart phone / tablet apps
    - Websites

6. Performance Compared to Original Aims, Objectives and Success Criteria

In the initial project registration a number of project objectives and success criteria were outlined. This section will examine the project performance against these aims.

Objective 1: To develop and explore customer engagement and incentive programmes. This aspect will include a small scale domestic demand response trial.

The project explored many different customer engagement techniques including a web presence, email campaigns, face to face interaction, leaflets, posters and use of village newsletters. Incentives were also successfully offered in the form of a prize draw, along with a demonstration of benefits for project participation. Anecdotal evidence has suggested that the prize draw did encourage some customers to sign up to the programme, but most made their decisions based on other factors, such as an interest in energy matters. Hook Norton represents a particularly engaged community, yet rates of uptake have been significantly lower than expected. Further information about the successes and issues around customer engagement can be found in Appendix A.

A number of activities were originally planned around domestic demand response whereby customer would have been asked to alter their energy usage and retrospective investigation would have looked for the effects in the data. However, due to the issues with data inconsistency, it was decided not to pursue this work as the data would have provided inconclusive results. This aspect would though be pursued in follow on projects.

Objective 2: To develop community data measurement and display capabilities (e.g. to ascertain the total electricity consumption of the village by installing measurement devices at various locations. Subsequently, to provide this and other relevant information back to the local community via a web portal/customer interface (which if successful, could then be used for other villages))

Community data measurement and display capabilities were developed through the successful monitoring of distribution substations across the village. The live web portal was developed allowing customers to see loads on the network along with individual customer load profile data. The model used for the website could be exported for use with other such community level monitoring projects subject to the appropriate data sources.

Objective 3: To deploy Power Line Communications (PLC) technology at scale within the low voltage (LV) network, illustrating its potential capabilities for enabling smart grid end point measurement and data aggregation.

The Power Line Communications element of the project was demonstrated through the installation of 4 hubs and 48 nodes. It was hoped that approximately 150 nodes would be deployed but this was limited by a lack of customer uptake. Measurement of the current at end points through the nodes was shown to work well with data being returned via the PLC last mile communications. Data aggregation at the substation was not been achieved as a more centralised approach was proposed. However, none of the nodes communicated with 100% reliability. On average the PLC solution worked between 55% and 75% of the time depending on node location, rising to over 80% when considering successful communication on a daily level.

Objective 4: To test and compare a variety of 'off the shelf' asset monitoring solutions for HV/LV pole-mounted and ground-mounted substations. The quality of the products will be assessed, alongside the installation methods.

Smart Hooky pioneered community level energy measurement through the deployment of substation monitoring. This project successfully deployed a blend of off-the-shelf products to deliver a fit for purpose substation monitoring solution. The specification and learning from this project has gone on to identify potential improvements in monitoring solutions that have inturn led to further iterations in third party equipment. Thishas also demonstrated the successful deployment of Rogowski coil technology, which up to this stage, has limited UK network deployment. Following on from this project, Rogowski coil technology has become more prevalent in the current generation of third party substation monitors on the market. This project also helped to inform further specification and procurement decisions.

From an installation perspective, a large number of lessons were learnt from the on-site fitting and commissioning elements of this scheme that have supported further monitoring deployments on additional projects.

Objective 5: To test and demonstrate a miniature smart grid telecommunications network (with multiple technologies) that will enable both local and remote network visibility

Smart Hooky project demonstrated an "at scale" PLC solution with a reliable UHF radio backhaul installation. The solution has demonstrated greater visibility of LV network performance within the village providing both control system visibility and also through the www.smart-hooky.net

Objective 6: To explore the changes that could be made to a network control system for enabling simple forms of Low Voltage (LV) network monitoring and management

For this project a trial PowerOn based solution was developed providing live visibility of the LV network in a control centre application. This data was also captured and stored to allow historic analysis of the network performance. It is envisaged that this will support assessing any future network investments and connections.

Success criteria 1: Accelerates the development of a low carbon energy sector

Through this project we have been able to deliver a range of engagements with the local community, from presence at local events, workshops with the project participants, and a presence throughout the village with a wide range of publicity. The improved visibility of the network will give greater confidence to the connection of additional loads and generation on the network.

Smart Hooky also provided:

- A framework for engaging with communities about their low-carbon aspirations
- Information technology tools that can be then used in other communities

Additional visibility was created through the web portal (www.smart-hooky.net) and enabled greater awareness of energy issues to the residents by utilising the tool. It is anticipated that this IT framework will be adopted for further projects where network data is to be published for local groups. This includes a proven technology for gathering data, processing through corporate systems and exporting to a third party in a secure way.

Success criteria 2: Has the potential to deliver net benefits to existing and/or future customers

This criteria also enabled WPD to achieve the following:

- Ability to accommodate new technologies in the knowledge that the networks are not being adversely impacted
- Will accelerate the carbon reduction in this particular community (and subsequent ones)

When Smart Hooky was developed, WPD had limited experience of substation monitoring at community level. This project developed a legacy which has help inform our future monitoring works and network wide analysis. It has also influenced the rapid development of third party substation monitors. The specifications that we are using for further monitoring is based on many of the lessons learnt from this scheme.

The success of the monitoring has also delivered a high level of confidence in the performance of the network and its capacity to absorb additional technology as it comes on line. We are therefore in a strong position to evaluate the connection of low carbon technologies as they are adopted across the community as part of the on-going carbon reduction plans of the village.

Success criteria 3: Has a Direct Impact on the operation of a DNO's Distribution System

This criteria also enabled WPD to achieve the following:

- The project will explore the benefits of added intelligence in HV and LV networks
- Will explore PLC technology for smarter LV grids
- Small scale demand side management trial to be initiated

Continuous measurement of network performance has created greater visibility of the assets in Hook Norton. Such data has helped assess the current state of the network and will support any future network investment decisions.

The trials utilising PLC have shown that this is a viable method for last mile communications across the network, subject to a suitable density of nodes.

One area that was not completed in the project was a small scale demand side management trial. This was primarily due to inconsistencies in the network data brought about through lack of data storage. This is something that is now fundamental in all monitoring solutions applied in further projects.

Success criteria 4: Generates new knowledge that can be shared amongst all

This criteria also enabled WPD to achieve the following:

- Possible reduction in longer-term capital spend on rural communities
- Greater understanding of future network design requirements for rural areas
- A range of tools and techniques that can be applied for rural areas.

Greater visibility of the network performance will lead to better informed asset management decisions. Ultimately this will manifest itself in supporting planning decisions and ensuring that efficient application of capital reinforcement can be made when required. Initial lessons have been learnt about the resilience of this rural network and we will seek to apply the learning to other similar areas.

The approach taken for substation monitoring in this project can be applied to other network areas, in both rural and urban environments. While the technology itself may not prove fully applicable for further replication, the principles gained from this project will prove vital for additional deployments.

Information from this project has been shared at a number of forums including the LCNF conferences in 2012 and 2013. An additional industry knowledge dissemination event was run in February 2013 in Hook Norton. Further learning from the project was also shared at a WPD Substation Monitoring event held in Leicester in June 2013

Success criteria 5: Focuses on network Solutions that are at the trialling stage

This criteria also enabled WPD to achieve the following:

- At-scale UK demonstration of Power Line Communications (PLC) technology in an LV distribution network.
- Demonstration of a smart grid telecommunications network 'access layer'

The PLC network applied in Hook Norton has included the installation of 49 smart nodes across 4 substations and has demonstrated the successful transmission of data from remote extents of the LV network. The development of the smart hub and node was undertaken through the Innovation Funding Initiative, and has been taken on with this project to a full demonstration. This has been supported by the successful application of addition backhaul communications allowing data to be returned to the WPD control system.

Substation monitoring was also at the trailing stage and has now been demonstrated as a viable option for improving network visibility.

Success criteria 6: Does not lead to unnecessary duplication

There are no UK based projects that meet the same objectives as the Smart Hooky scheme.

7. Required modifications to the planned approach during the Project

A number of modifications were made to the approach during the duration of the project. As part of the project governance, internal change mandates were completed. These can be found in Appendix C. A formal change notification was submitted to Ofgem in September 2012.

Amendments were made to the data architecture of the project to ensure that the scheme complied with WPDs IT and security policies. As a result the publication of customer and load data to www.smart-hooky.net was delayed by several months. To ensure all project learning was captured in the closedownreport, the project was extended for an additional 15 months.

An additional modification was made, removing the comparison of off-the-shelf monitoring solutions from the project. The project delivered a robust measurement system utilising a range of off-the-shelf components. It was deemed that the most efficient use of resources on this project was to concentrate on delivering one working solution, rather than developing multiple solutions across the village. Further work to compare wider application on the market has recently been completed within the LV Current Sensor Evaluation project.

Issues with data consistency led to the removal of the small scale demand response trial from the project scope. This was primarily due to the lack of confidence that changes in customer behaviour could have been accurately identified and reported on. We will continue to work with the community outside of this project to support any further initiatives where possible.

Initially it was hoped that up to 150 nodes would be installed across the village. Due to poor levels of customer sign up, only a third of this number was achieved. This has had an effect on the project learning and in particular around the required density of PLC nodes to provide a robust last mile communications network. However, engineering judgement has been applied to the learning and it is now considered that an additional 20% of nodes, if placed correctly, would have had a significant impact on the overall PLC performance.

Two substation sites, Hook Norton and Scotland End, did not have the substation monitoring commissioned due to equipment and communications issues. As these sites were not directly involved in customer engagement, this has little effect on the overall learning for the project. From a substation monitoring perspective, learning has been accrued from the other sites in terms of installation practices. It is therefore considered that this decision was not at detriment to the project's overall objectives.

8. Significant Variance to Cost and Benefits

8.1 Project Budget

Initially the budget for the project was set at £350,000 but reassessed and set to £344,000 to reflect the removal of the substation monitoring comparison works.

The following table outlines the main spend elements on the scheme:

Item	Cost
AND – Node and Hub Development	£ 131,041.26
NEF – Customer Engagement & Website	£ 107,788.75
Installation and Project Management	£ 107,569.57
Equipment and Software	£ 44,275.75
Other	£ 1,173.34
Total	**£ 391,348.66**
Budget	**£ 344,000.00**
Overspend	**£ 47,348.66**

As can be seen from the table, the project has overspent by just over £47,000. There have been a number of factors that have contributed to this. These include;

- Increased IT Development Costs
- Moving of website development from internal development and hosting to third party.
- Additional on-site support
- Project extension leading to additional project management and web site support

Initially it was envisaged that the website development would be delivered in house. A review of the IT project elements resulted in the responsibility for the website moved to NEF. This introduced additional cost into the project for development and maintenance of the website.

Additional IT project costs were incurred due to a number of delays into the scheme, ultimately resulting in the project being extended for an additional 15 months. Further cost of £3-4k would have been incurred had Scotland End and Hook Norton substations been commissioned with the monitoring solution. As the key learning associated with these installations had already been gathered, it was deemed that this represented additional unrequired expenditure.

With the project extension, further project management, customer engagement and website support was required. A number of sites experienced commissioning issues requiring further on-site support.

8.2 Project Benefits

8.2.1 DNO Benefits

This project has broadly delivered the expected level of benefits in line with the project objectives. In particular, Smart Hooky has had a significant influence over the specification and procurement of substation monitoring equipment for a number of further LCNF projects within WPD. Further lessons regarding customer engagement and recruitment are now being applied to additional schemes and supporting the development of new projects.

The PLC trials have been able to demonstrate that it is a viable method for last mile communications within a UK LV network context. Further benefit and confidence could have been gained through the installation of more nodes. However engineering judgement has been applied to the results, and concluded that with further nodes and data storage, it is a viable solution.

9. Lessons Learns

9.1 Substation Monitoring

The substation monitoring solution developed for Smart Hooky has provided a robust system of current and voltage measurement. The rollout within this project has played a significant role in informing WPDs requirements for additional deployments. It has also been used to advise third party manufacturers as to network operators requirements in this area. Subsequently the pace of these developments has ultimately meant that the more advanced stand-alone systems are now available at the same price point.

As a result of this project, a number of key technical specifications have been identified

- **Size** – Not all sites have the space to install standalone GRP housings. Smaller IP rated cabinets are therefore required.
- **Integration** – A significant amount of time was required to integrate the individual elements of the monitor and write and update the firmware for each element. This can be mitigated with an integrated solution.
- **Commissioning** – All-in-one solutions speed up and de-skill the installation and commissioning process.
- **Reliability** – Due to a number of factors, the RCD trip switches were prone to operation rendering the solution unreliable. More robust system protection is required
- **Data Storage** – Data storage is an essential element that ensures that data is not lost should the communications medium prove unreliable.

In particular the project has demonstrated the successful application of Rogowski coils in a live operational environment, bringing additional flexibility in sites with close cable cores and congested LV pillars. This is technology that has already been deployed on further projects

A number of issues were identified on site that proved challenging to rectify in the field. To overcome this, it is recommended that new equipment should undergo a process of factory acceptance.

Many of the techniques used in this project drew on core skills within the business. For example the power was supplied via a dedicated three phases supply. While this met the project requirements, alternative power solutions have now been developed including modified fuse carrier handle and busbar clamps.

9.2 Customer Energy Monitoring

While the performance of the smart nodes has been extremely positive, there have been a number of factors that have been identified that would improve a deployment in future scenarios. During the early stages of node installation it was decided to concentrate on installing nodes in customers premises with outdoor meter boxes. This ensured that if further work was required to update firmware, access to the node could be made with minimal disruption to the customer. Further work could be undertaken to assess the form factor of the smart nodes and even look to include it as part of an enhanced cut-out / cut-out fuse. This would significantly reduce the space required and remove the need for external wiring to a clip on CT.

At a number of sites the meter positions were too congested to allow installation. This was due to a number of factors including off-peak time switches, FITs meters and other ancillary equipment. This could be an issue with the deployment of smart meters as it is envisaged they will have a larger footprint than existing meters.

Any future customer energy monitoring should include data storage to mitigate for communication losses. The design employed on this project would also have benefited from a larger CT to fit around 25mm^2 meter tails. Also, with installations at sites with PV generation, it is important to identify when power is being exported to the network. It is also recommended that voltage is measured and recorded.

It is envisaged that much of the data and functionality of the smart nodes will be available from smart meters, which are due to be deployed between 2015 and 2020.

9.3 Communications

Narrowband Power Line Carrier has provided a good medium for last mile communications, and demonstrated daily message reliability of over 80%. This could be increased with a more dense installation of PLC nodes. It was observed that PLC reliability improved with increased network loads.

The UHF radio deployment provided a robust backhaul solution and has also informed future communication choices for wider applications. It is recommended that for any future installations, each radio is set up with repeater functionality enable to increase flexibility. Signal strength surveys should be conducted prior to deployment to reduce further site visits.

9.4 Customer Engagement

The recruitment of customers in the village yielded smaller numbers than was initially anticipated. This was of particular note given the engaged nature of the community in Hook Norton. The lack of certainty as to when data would be available was, in some cases, a factor that hindered recruitment. The use of incentives such as the prize draw proved popular although it is not thought that this was the deciding factor in involvement for many.

While a selection of recruitment techniques was employed, face to face engagement led to the greatest level of success. While it is recognised that this may not be practicable in all projects, the use of local groups and advocates may enhance customer engagement.

Further information on the learning associated with customer engagement can be found in Appendix A prepared by NEF.

9.5 Knowledge Dissemination

The knowledge dissemination session run in Hook Norton for industry proved to be a successful event with positive feedback received from delegates. Elements of the day have been applied to further events organised for other projects. This has included the use of a neutral and interesting venue, a mix of presentations and an opportunity to view actual project equipment.

10. Planned Implementation

There are a number of areas within this project that will be implemented for further work.

Substation monitoring has provided improved network visibility which will support local network operations and planning activity. It is envisaged that monitoring shall play a vital role in future network management. At present monitoring will continue to form an integral part of trial projects, moving into more business as usual as the costs reduce and additional business applications emerge.

The use of Rogowski coils will be used in future monitoring solutions where congestion means other sensor types cannot be deployed.

The FTP link between PowerOn and NEF proved to be a reliable and safe method of data transfer to a third party. We are currently looking into how this will be applied for further community based projects were data required transferring to outside organisations. This includes the application of the Smart-Hooky.net website tool.

The National Energy Foundation provided valuable expertise in delivering the customer engagement elements of the project, along with the website development. We are currently investigating how the website application could be utilised for further projects. In addition, we will look to maintain the links with NEF for potential future schemes.

The equipment developed by AND Technology met the defined scope and was delivered within budget and on time. On-site support was essential in achieving the project objectives and any further development work was delivered within agreed timescales. We are looking to how WPD can continue to work with AND in developing future products for network applications. However at this time we have no direct plans to apply the PLC technology, smart nodes and hub further.

There are outline plans to utilise Radius radios to replace the existing communications to all of the existing secondary automation sites in the Midlands area as per the South West and Wales. Where the Hook Norton project used the PDR221 version which allows only one hop within a system, the new automation system will use the Netlink PDR121 which allows multiple hops within a system.

11. Facilitate Replications

11.1 Knowledge Required

The knowledge required to implement a platform which supports community energy monitoring is outlined below:

- Electrical network topology and connectivity
- Electrical network asset information
- Geographic asset locations
- Physical terrain and relief mapping
- Communication topology
- Data flows and requirements
- DNP3 protocol configuration

11.2 Products/Services Required

As well as general project management and installation resources at the disposal of a distribution network operation, there are a number of separate products and services that have been identified by this project as being to deliver this functionality. This section lists these requirements:

- Overhead LV monitoring
- Underground LV monitoring
- Allocated licensed spectrum
- Licenced UHF radios
- Unlicensed UHF radios
- Power Line Carrier Nodes
- Power Line Carrier Data Concentrator
- Real-time data polling system
- Data storage capability
- Data export capability
- DNP3 configuration tools
- Customer engagement capability

More information on these elements is provided in this report, or can be provided upon request.

11.3 Project IPR

This project integrated a number of existing products and services as outlined in section 14.2 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.

Lessons learnt from this project have already helped form the WPD requirements for LV substation monitoring as used in the LV Current Sensors project, FALCON and the Community Energy Action project. Aspects of the customer engagement activity have also support the ECHO project in the recruitment process.

Appendix A outlines the approaches taken regarding customer interaction by NEF report. Appendix B provides further information as to the technical aspects of the smart hub and node designs. There is additional information as to the application of the DNP3 protocol in this section.

Technical documents relating to the installation and configuration of the substation monitors and radio backhaul systems are available on request.

This project has been reported on during both the 2012 and 2013 Low Carbon Network Fund Conferences. Design documents and specifications for the equipment developed for this project are available on request from wpdinnovation@westernpower.co.uk .

12. Points of Contact

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

Future Networks Team
Western Power Distribution
Pegasus Business Park,
Castle Donington,
Derbyshire
DE74 2TU
Email: wpdinnovation@westernpower.co.uk

Appendices

Appendix A: NEF Final Report

Smart Hooky - NEF
Final Report.pdf

Appendix B: Interim Technical Report

Smart Hooky Interim
Technical Report v1.c

Appendix C: Change Mandate

Smart Hooky Projec
Change Mandates.pd