WESTERN POWER DISTRIBUTION

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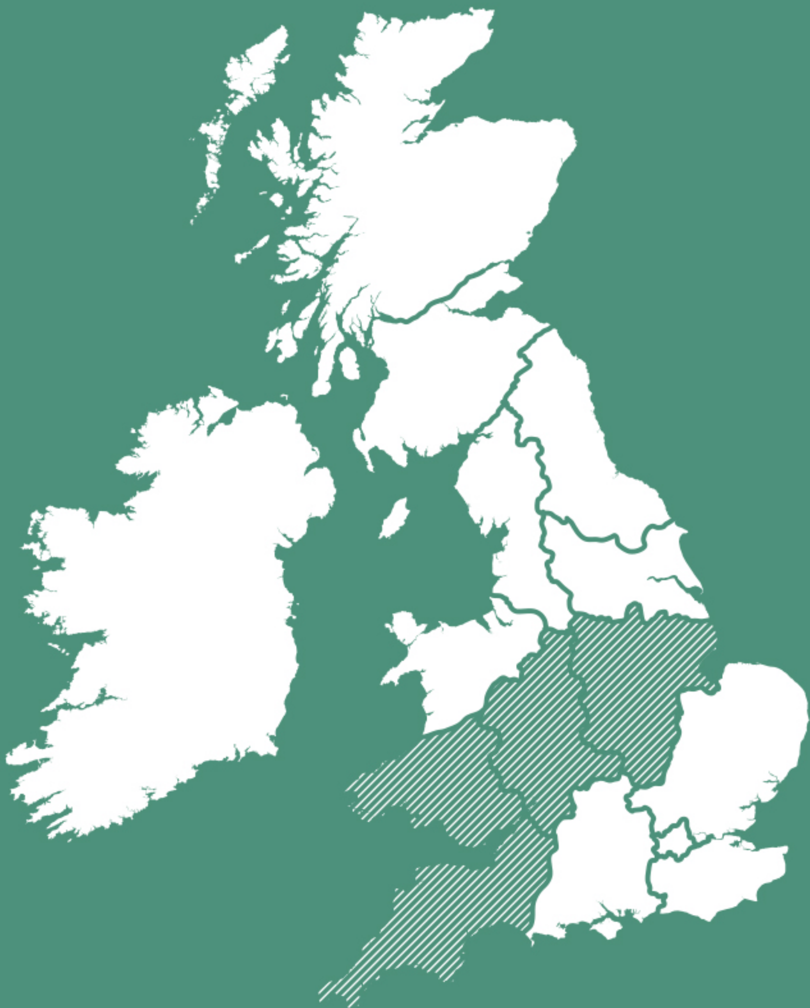
NEXT GENERATION NETWORKS

NETWORK MANAGEMENT ON THE ISLES OF SCILLY

CLOSEDOWN REPORT



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Contents

Executive Summary

The Isles of Scilly is a small cluster of islands off the coast of Cornwall that have a stated intention of becoming energy self-sufficient. The climate afforded by its location provides a large potential for this energy to be supplied using renewable low carbon technologies, such as photovoltaic (PV) generation, wind turbines or tidal power schemes.

This project has deployed and assessed several technological solutions to form an overarching smart grid covering every substation on the Isles. On completion it has produced a platform for further low carbon related research and development activities.

Due to its islanded position, the Isles of Scilly provides a discrete platform to study the effect of low carbon technologies on an electrical network and learning from this can be applied on other electrical networks in the UK.

This report details the work undertaken as part of the LCN funded Tier 1 project Network Management on the Isles of Scilly. The project had three aims which were covered across the project lifespan:

- Establish a real-time monitoring system on all the distribution substations
- Maximise existing generation facilities
- Control the generation using new methods

Under the project, all the substations on the Isles of Scilly were fitted with low voltage monitoring to determine the aggregate load across all phases. This has allowed the distribution of load across the network to be more accurately assessed and will aid in informing future network investment. The implemented system was a bespoke design due to limited available off-the-shelf systems when the project was initially scoped.

High Voltage automation wasinstalled adjacent to the off-island generation so that the load sections they supply can be altered for maximum benefit. Sequenced switching routines within the GE PowerOn Fusion Distribution Management System enable this to be an automated process and also enable routines to be configured to respond to monitored network changes. This provided flexibility for when the load and generation balance in the area changes.

Synchrophasor generator control algorithms have been developed to allow the generation sets to keep aligned to each other and the mainland without a direct electrical connection. This learning has the potential to allow the same generator control signal to be applied to multiple generator sets without the risk of dynamic stability issues. This could enable a larger amount of future low carbon generation to be accommodated, displacing the need for conventional Distribution Network Operator (DNO) owned diesel generation.

Broadband over Powerline (BPL) has been trialled on the 11kV network, allowing fast, low latency communications to be conducted over existing assets.

Other communication links on the Isles were completed using a mixture of low power UHF radios, enabling flexible low speed connections to be deployed with limited disruption to the electrical network. Some interference with the availability of the radios has been experienced due to atmospheric conditions, which occur more frequently on the islands, due to their position.

1. Project Background

Electricity supplies to the Isles of Scilly comprise a single 33kV undersea cable from the mainland supplemented by an island based diesel generating station. There are also remote, locally controlled generators on two outer islands available for use in certain circumstances.

The islands provide an effective self-contained microcosm of an 11kV and LV electricity distribution system that can be monitored and controlled to provide measurement of impact and capability to accommodate DG and other low carbon initiatives.

The Isles of Scilly Council has a published goal of the islands being energy self-sufficient To this end, the council is examining methods of localised generation such as waste disposal and the islander's themselves are keen to exploit PV and wave power on and off the smaller islands. Throughout this project WPD worked in conjunction with the islanders to ensure full support for their desire to be energy self-sufficient. The community level interest in energy management was demonstrated in their 2009 "e-day" initiative which received national BBC TV coverage.

The Project partners were the Duchy of Cornwall, IGE, Islanders on St. Agnes, Isles of Scilly Council, Power Electrics, PowerPlus Communications, Radius and Transition Scilly.

1.1 Electrical Network on the Isles of Scilly

The Isles of Scilly is situated around 30 miles off the west coast of Cornwall and is formed from five main inhabited islands and a number of smaller rocky islets. Electricity to the Isles is provided by a single 33kV submarine cable from the mainland to the largest island, St Mary's.

From here, an 11kV ring featuring a mix of overhead, underground and subsea cables connects St Mary's with the next two largest islands, Tresco and St Martin's. The other two inhabited islands, St Agnes and Bryer, are connected by a further two 11kV subsea cables teed off the ring.

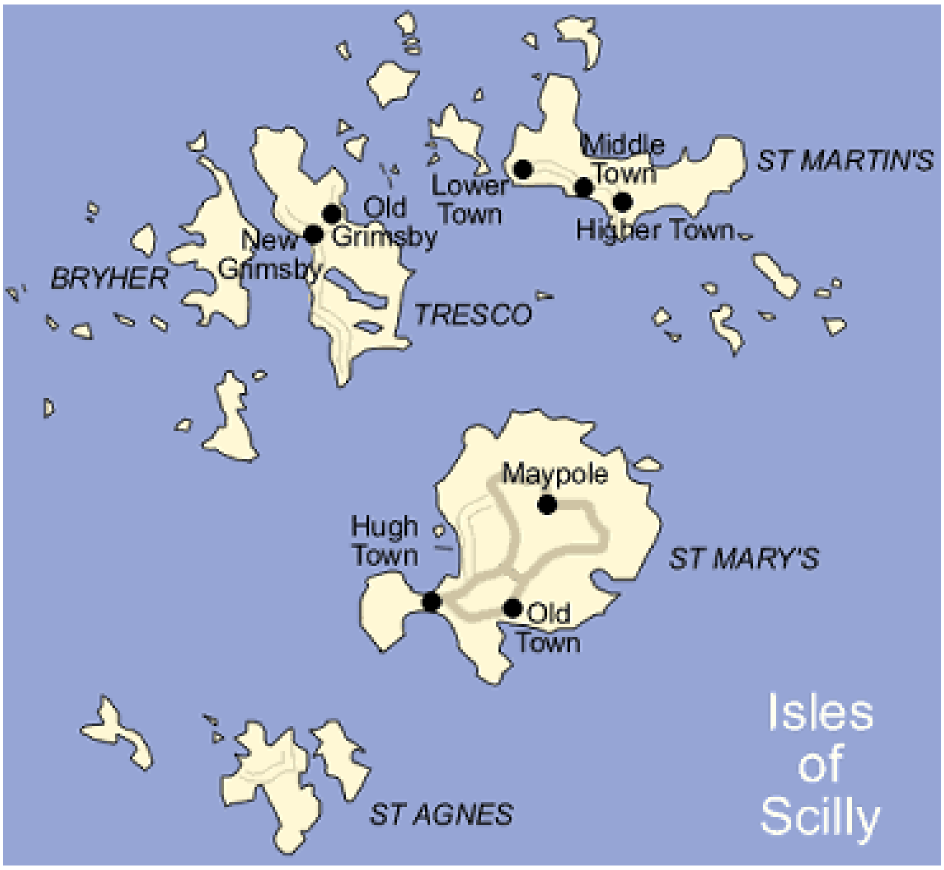

Figure 1 - The Isles of Scilly

The 11kV circuits supply power to all 63 substations on the Isles of Scilly which compromise of a mixture of overhead and underground mounted transformers and these supply the low voltage cables connected to over 1600 customers.

Seven diesel generators feed in to the main 33/11kV Primary Substation, so that in the event of a power cut affecting the undersea cable, they can support the entire network for a sustained period. The generation is also arranged so that it can supplement the supply to the islands should demand on the isles exceed the import capacity of the cables. Conversely, if the embedded generation on the isles were ever to exceed local demand, the cables can export power back onto the mainland network.

The 11kV undersea links to St Agnes and Bryer are supported by diesel generators which operate solely to support local HV outages for faults and maintenances.

1.2 Project Overview

During 2009, the Isles of Scilly played host to E-day 2009, which attempted to co-ordinate the efforts of the islanders in reducing their electricity consumption, and record the effects in real-time. Following the sense of engagement found on the islands and the local council's aims for self-sufficiency, Western Power Distribution undertook a project to establish the feasibility of gathering data on the network loadings around the islands, as well as the total aggregate loads coming in from the mainland.

In the future, the increase in visibility achieved through the collection of LV monitoring data will allow WPD planners to build more accurate models when designing connections and also share this information with strategic authorities on the islands. The potential constraint areas of the network will be able to be identified, avoided or mitigated against when planning new load connections or integrating embedded low carbon generation. By more accurately understanding the power flows within the network, the conventional generation currently securing the power supplies on the main island, St Mary's and the two electrically spurred islands, St Agnes and Bryer, could be allowed to support any future increases in load.

WPD worked with GE and PPC to design and deploy a complete network monitoring scheme across the entire network. The network monitoring scheme was implemented using a range of radio telecommunication technologies, as well as trialling broadband over the 11kV powerline (BPL).

The combination of communication technologies has allowed comparisons between the competing technologies to be drawn, such as the differences in installation requirements, the stability of the channels and the latency of the links. By understanding these differences, future innovation projects can benefit from picking a communication method that is most suitable for the application.

The project formally registered a change in September 2012 to increase the scope of works and adjust timescales. As a result the use of phasor measurement devices has also been investigated, with a system being designed to analyse the variances in standard generation control and also 33kV submarine connections. WPD worked with Alstom and Psymetrix in order to establish real-time monitoring of phasor vectors in a number of locations across the network.

The original Project Registration pro forma is given in Appendix A1 and the amended Project Registration pro forma is included under Appendix A2.

2. Scope and Objectives

The scope and objectives of the project, as detailed in the original LCNF Tier-1 pro forma, were to:

- Establish a real-time monitoring system on all the distribution substations
- Maximise existing generation facilities
- Control the generation using new methods

The business case for replacement of network operator-owned generation plant follows the same methodology used for upgrading or replacing any conventional asset, in that investments are based on large step changes in forecasted capacity over the asset's entire life.

Due to the fixed nature of the generator's output, but also the changing variations in the local load connected, the generators can supply a larger area of network in times of low consumption, compared to the peak times. By changing the networks being fed at different times of the year, there can be efficiency savings gained through a reduction in losses and a reduction of generator operating hours.

The scope of this project was to monitor the network on the Isles of Scilly and allow the existing generator facilities to be controlled in order to maximise their capacity. The objective was to affect the control of the off-island generation on the Isles of Scilly using new methods. This was achieved using local generator management software instigated and coordinated by automated remote control. Adaptation of the network based upon the monitored load levels was achieved using supplementary network automation on a number of strategic devices.

By monitoring the differing load in the vicinity of the off-island generators and allowing remote changes to be made to the network topology, the generator's ability to feed different substations can be altered flexibly. This could allow for future integration of embedded generation in the off-islands without interfering with the assumed load levels the existing generators were design for.

Six key project objectives were identified the original Tier 1 pro forma, more information on the precise nature of their achievement is provided within Section 6:

Objective	Status
To establish real time monitoring on all of the distribution substations on the Isles of Scilly.	✓
The use of the generation facilities on the islands can be maximised to secure supplies to the islands.	✓
To determine whether the control and management of the generation on the off islands will be effected using methods that have not been used in WPD before.	✓
Monitoring to be supplemented by controls where appropriate to manage and accommodate localised generation.	✓
Support localised generation (including Photovoltaic)	✓
To support the council's published goal of energy self-sufficiency.	✓

3. Success criteria

From the original Tier 1 Project Registration Form, two success criteria were identified:

- The effective management of off island generation and monitoring & control of various PV installations on a remote and therefore potentially weak connected network.
- Use of Power Line Carrier techniques on higher voltage networks

Following an amendment to the originally submitted Tier 1 Project Registration Form, an additional success criterion was identified:

- Demonstration of Synchrophasor Generator Control

The WPD internal change mandates associated with this amendment are included in Appendix A3.

4. Details of the work carried out

The project design was carried out by GE Digital Energy including the design of the LV monitoring and communication methodology. Their brief was to develop a system capable of responding to new network requirements that arise from a low carbon economy and to encourage low carbon solutions.

The design recommended by GE Digital Energy also recognised DECC's key principles for a Smart Grid, which include the following four characteristics:

- **Observable** – it is possible to measure, quantify and visualise a wide range of operating values in real time
- **Controllable** – it is possible to manipulate, manage and optimise the power system to a far greater extent than is possible today.
- **Automated** – the network has a certain level of 'intelligence', being able to make, for example, certain unaided demand response decisions. It can also respond to the consequences of power fluctuations or outages by, for example, being able to reconfigure itself in the event of a circuit or equipment failure
- **Fully integrated** – the components that make up or extend smart grid capabilities must work with the existing legacy systems, as well as other new smart devices.

In order to fully implement the project, a number of parallel activities had to be carried out and co-ordinated. These can be broken down into the following categories:

- LV monitoring,
- Radio Communication,
- Broadband over Powerline,
- Off-island generators,
- Synchrophasor Control and
- HV control.

4.1 LV Monitoring

The requirement for understanding low voltage power flows on the network was achieved by installing low voltage monitoring on all the transformers which supplied power to customers. This project created a platform for WPD to more accurately measure the aggregated customer consumptions at each substation, establish annual trends and assess daily peaks and troughs. This information was fully integrated in WPD core business systems with additional interrogation of more granular data possible over the communication links. It helped planners to more accurately plan and manage the local network as customer adopted low carbon technologies. It is anticipated that this platform will continue to form the basis of our network management activities for the Isles.

The variety of transformers on the Isles of Scilly has historically been wide-ranging, with ground mounted units varying in size from single phase 50kVA up to three phase 800kVA and overhead mounted units from single phase 16kVA to three phase 200kVA. With this in mind, the LV monitoring equipment was designed to be modular and cover all current ranges with the use of different current transformers (CTs). The CTs were installed directly onto the outgoing transformer LV tails, which to ensure the safety of WPD technicians required an outage due to the nature and location of the CTs fitted.

This was decided as the best approach as the age and compact nature of the equipment on the Isles did not lend itself to fitting CTs on each individual LV feeder. As the majority of the data analysis from the monitoring was to be undertaken with respect to the HV network, point load information at a substation was felt to be sufficient for the application, rather than each individual LV feeder.

Analogue inputs from the CTs and fused voltage connections were taken into SM300 and KV2C smart meters supplied by GE in order to provide time-stamped measurement data for the substation consumptions. As well as being able to collect voltage, current and power factor, the smart meters were able to gather data on a number of variables such as reactive power consumed and total harmonic distortion present. These meters were capable of being remotely configured depending on requirements, though for this project we concentrated on the recovery of voltage, current and power consumption data.

The meters for all the substations were polled by WPD's main network managements system (GE's PowerOn product used widely within GB DNOs) to retrieve the instantaneous power consumption. GE Digital Energy's smart meter allowed data to be collected to IEC 62053, Class 0.5 S accuracy.

The meters and the enclosures supplied by GE also included a battery back-up which could power the meter and communications equipment for a minimum of 6 hours should there have been any low voltage interruption. Figure 2 shows a photograph of a typical enclosure installed on the islands, identifying the components used.

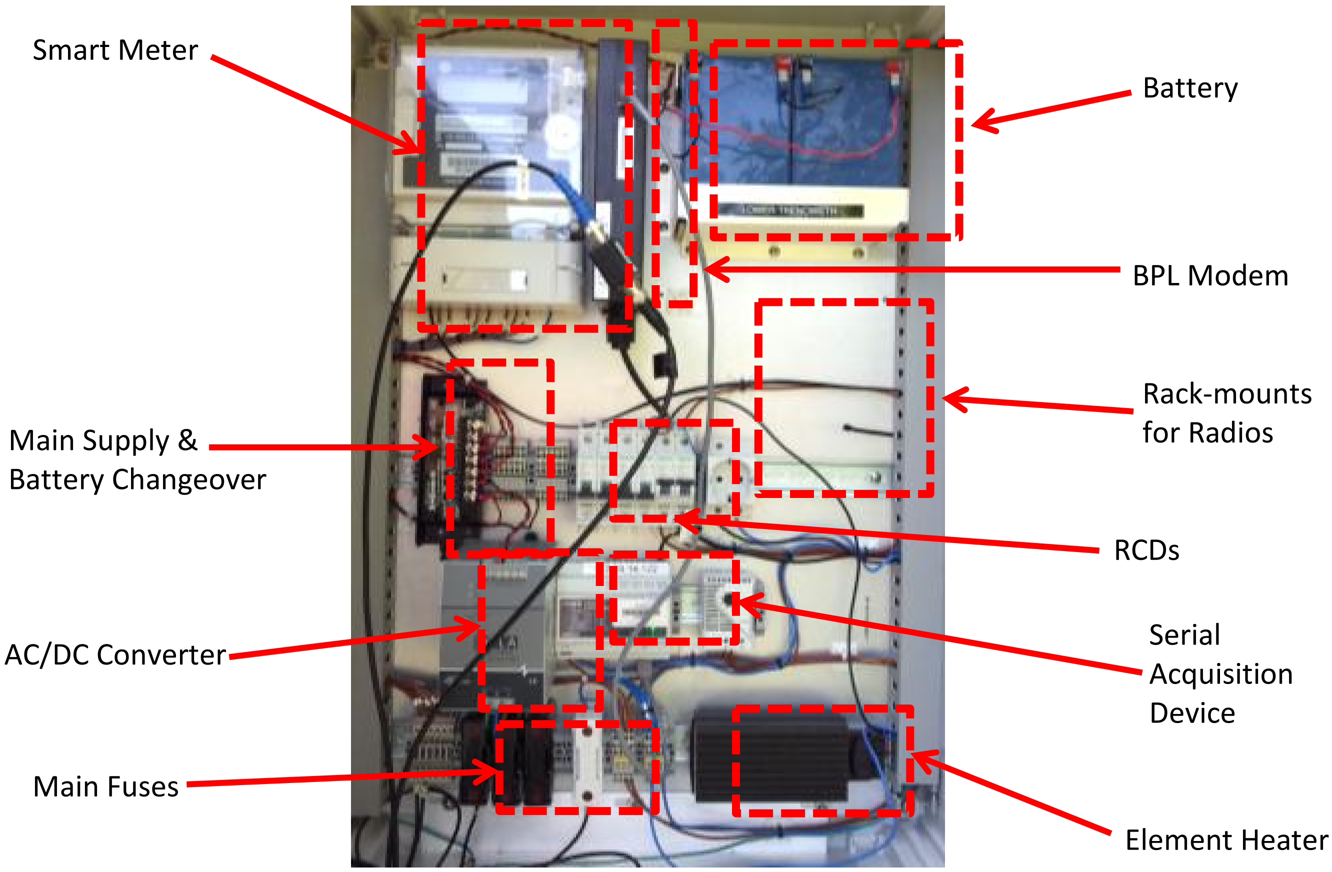

Figure 2 - Typical Metering and Communications Enclosure

The enclosures for the all the equipment were IP66 rated to provide a weatherproof and dustproof housing for both indoor and outdoor substations.

4.2 Radio Communications

The communications backhaul for this project was an IP-based hybrid comprising of two radio technologies at different frequencies and a broadband over 11kV powerline (BPL) system. These communication systems allowed data to be transmitted back to a single point on the island network, which was then taken by a series of optical fibre and microwave links back to the WPD mainland network.

GE designed the network topology after an initial site survey to determine the suitability of radio across the topology of the islands with BPL used to connect to the remaining substations not reachable by radio.

The radios supplied by GE were SD4 450MHz and EntraNet 2.4GHz units, with the SD4 devices providing long haul links between the islands at 19.2kbps and the EntraNet devices providing shorter links at a maximum of 106kbps. The two different radio systems were deployed so that the longer sections of links and the smaller hops were not competing for the same channel space or bandwidth.

Whilst a similar outcome could have been achieved through programming the same radio types to use different frequency channels, this approach allowed us to compare the two technologies within this project.

The SD4 radio technology operated within an existing spectrum secured from the JRC by WPD, whilst the EntraNet radios utilise unlicensed frequencies. This had the benefit of being able to be deployed without using valuable licensed spectrum, though it did have the potential to suffer from interference. The interference risk was somewhat mitigated on the Isles of Scilly due to their remote location.

Omni-directional and directional Yagi antennae were installed at a reduced height close to the substations in order to keep visual impact to a minimum as agreed with the local authority and Duchy. As the radios only required a low voltage supply to power the electronics, there was no requirement for a supply outage to fit the communication devices.

Each substation was equipped with at least one radio or BPL device to connect to the next adjacent substation in the topology. Certain substations were installed with more than one type of communication technology dependant on how many substations they interfaced with. Figure 3 shows a geographic diagram depicting the communication lines and technologies used.

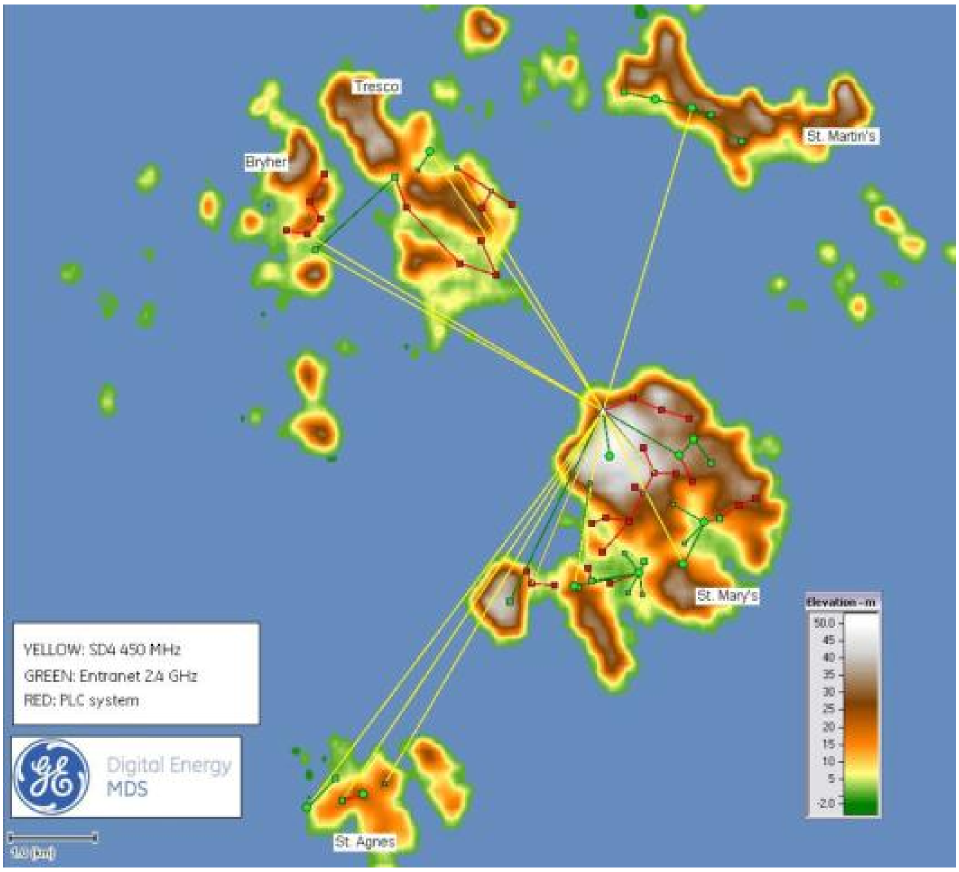

Figure 3 - The Isles of Scilly Network Management Communications Topology

4.3 Broadband over Powerline

The BPL devices supplied by PPC operated in the 2 to 30 MHz frequency band as per IEEE1901, so in addition to the 50Hz or 60Hz "signal" which was used to transmit power on the power grid, the BPL signal was modulated in several frequencies ranging from 2 to 30 MHz. The BPL system implemented in the PPC devices is named "Aranuka".

The Aranuka uses a digital multi-carrier modulation method called Orthogonal Frequency Division Multiplexing (OFDM) to modulate the signal. In OFDM a large number of closely spaced orthogonal sub-carrier signals, also called tones, are used to carry data. The data is divided into several parallel data streams or channels, one for each sub-carrier. In OFDM each sub-carrier is modulated with a conventional modulation scheme, achieving total data rates similar to conventional single-carrier modulation schemes in the same bandwidth. Within the frequency range of 2 to 30 MHz, the system uses up to 916 individual sub-carriers to transmit data.

Using the transmitted data, the BPL systemwas able to permanently determine the signal to noise ratio for each of the 916 sub-carriers and individually compute the optimal carrier for each one, out of 6 possible modulation schemes.

The sub-carrier modulation schemes differed in modulation density, with the more robust modulation schemes using a lower possible number of predefined modifications of amplitude and phase. The higher the number of predefined amplitude and phase variations, the higher the number of possible bits transmitted per time interval. However high modulation density made the signal less robust to noise and therefore required a higher signal to noise ratio in the sub-carrier.

The BPL system was installed in two different configurations depending on whether it was attached to an overhead or underground section of network.

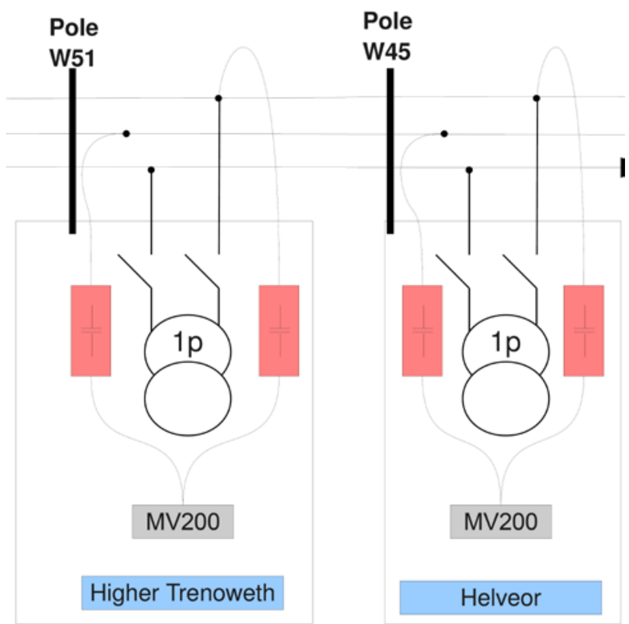

Figure 4 - Overhead BPL Configuration

The overhead implementation of BPL is shown in Figure 4 and uses two phases of the network, with a single modem attached to two couplers per site emitting a differential signal. The underground implementation uses a single modem and coupler per site attached between a phase and earth to achieve a signal (Figure 5).

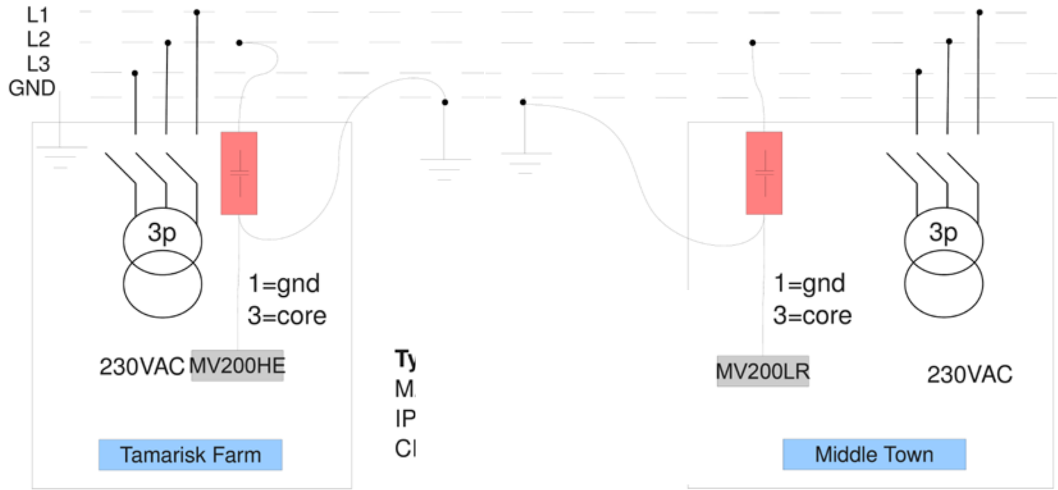

Figure 5 - Underground BPL Configuration

For the underground installations, attaching the BPL equipment to the existing HV phases was completed by breaching the flexible XLPE of the couplers into a new joint position a few metres outside of the substation. Separable connectors were used to provide an easy method of isolation should the BPL equipment need to be disconnected. For the overhead installations, the couplers were directly connected to the bare overhead conductor using wedges. For both of these types of installations, HV outages were required.

The net topology in Figure 6 shows the initial planned mixture of communication technologies used and the number of hops to each substation.

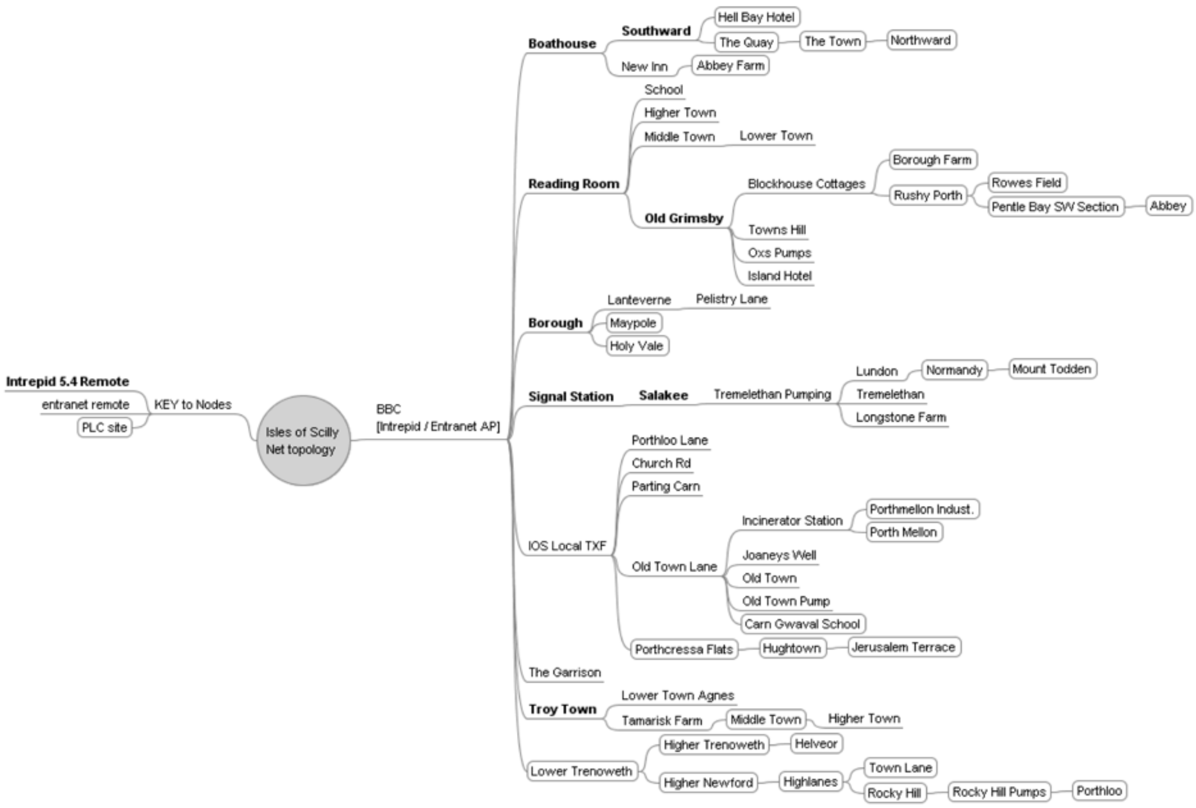

Figure 6 - Isles of Scilly Net Topology

4.4 Off-Island Generators

Off-Island generators at the The Quay substation on Bryer and at Lower Town on St Agnes had recently been replaced with two new sets, each comprising of 2 x 200kVA FG Wilson diesel generators as part of Western Power Distribution's standard asset replacement programme.

Figure 7 - 200kVA FG Wilson Gen-set

Each generator is fitted with a Comap InteliGen controller which enables the pair of generators to be connected and share load together. The outgoing LV from the generators are connected to a 500kVA Yy11 transformer which has a removable neutral earth link in order to supply a neutral reference point for the 11kV when the system is backfeeding onto the HV network.

The generators, neutral earth link and circuit breakers are all controllable through WPD's PowerOn network management system, providing complete remote control for starting and synchronising. This removes the need for any short interruptions to the customers when changing from main supply to the generators.

4.5 HV Control

Additional automation has been installed on the HV switchgear adjacent to the generator sets in order to provide remote sectionalisation points which enable the HV network to be split up at strategic points. The extra flexibility of running arrangements afforded by this investment allow the generators to supply different amounts of HV network dependent on the customer loads and embedded generation present.

Under fault conditions, the network will be able to be split up and fed directly by the off-island generators, reducing the amount of centrally located generation required to secure supplies and also reducing the distribution losses incurred when supplying the load by diesel generation. By viewing the substation metering loads before the fault occurred, the maximum amount of network capable of being supplied by each generator set can be quickly established.

4.6 Synchrophasor Control

Phasor Measurement Units (PMUs) are traditionally used on the transmission network to provide accurate monitoring of the individual voltage and current waveforms at strategic points. These captured signals are time-stamped to a Global Positioning Satellite (GPS) time signal which enables data from different strategic points to be compared along a single time domain.

Data from the PMUs can allow more accurate monitoring of the load distribution and also aid state-estimation of network open points and switch positions.

The PhasorPoint system for the Isles of Scilly has four main functions:

- Receive phasor data streams from Phasor Measurement Units
- Provide an analogue synchronised voltage waveform to the local generation controller
- Perform synchronisation check and feedback to PowerOn
- Manage different islanding states

Figure 8 - PhasorPoint Topology for the Isles of Scilly

By understanding the phasor data from the PMUs that are connected to the rest of the system and comparing these to the generator phasor data, a difference in phase can be quantified and corrective action applied. The first action would be to not allow the generation to directly resynchronise to the network, with the second being to send appropriate controls to the mis-aligned generator so that it can be brought into line and ready for synchronisation.

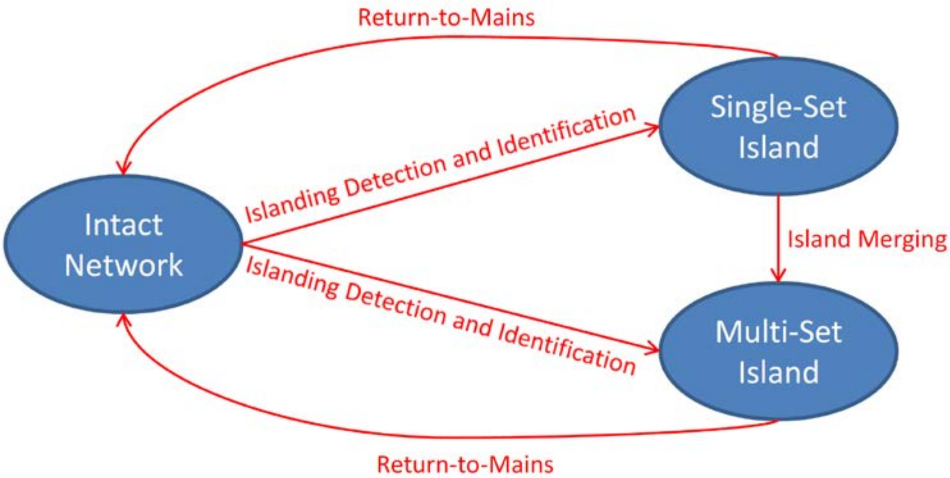

Figure 9 - Islanding states and transitions

A number of different states of network operation can be achieved using multiple generation sets and their relationships are displayed in Figure 9 above.

5. The outcomes of the Project

5.1 LV Monitoring Performance

The installation principles for the LV monitoring were based on established WPD business processes and off the shelf equipment. This meant fixed ring CTs were used and they were fitted onto the outgoing transformer tails, which required a shutdown of the transformer and number of staff hours to complete. This work was carried out from September 2011, with all 63 substations being installed by February 2012.

Having real-time information on the transformer load profiles will enable future initiatives on the islands to be fully informed and supported.

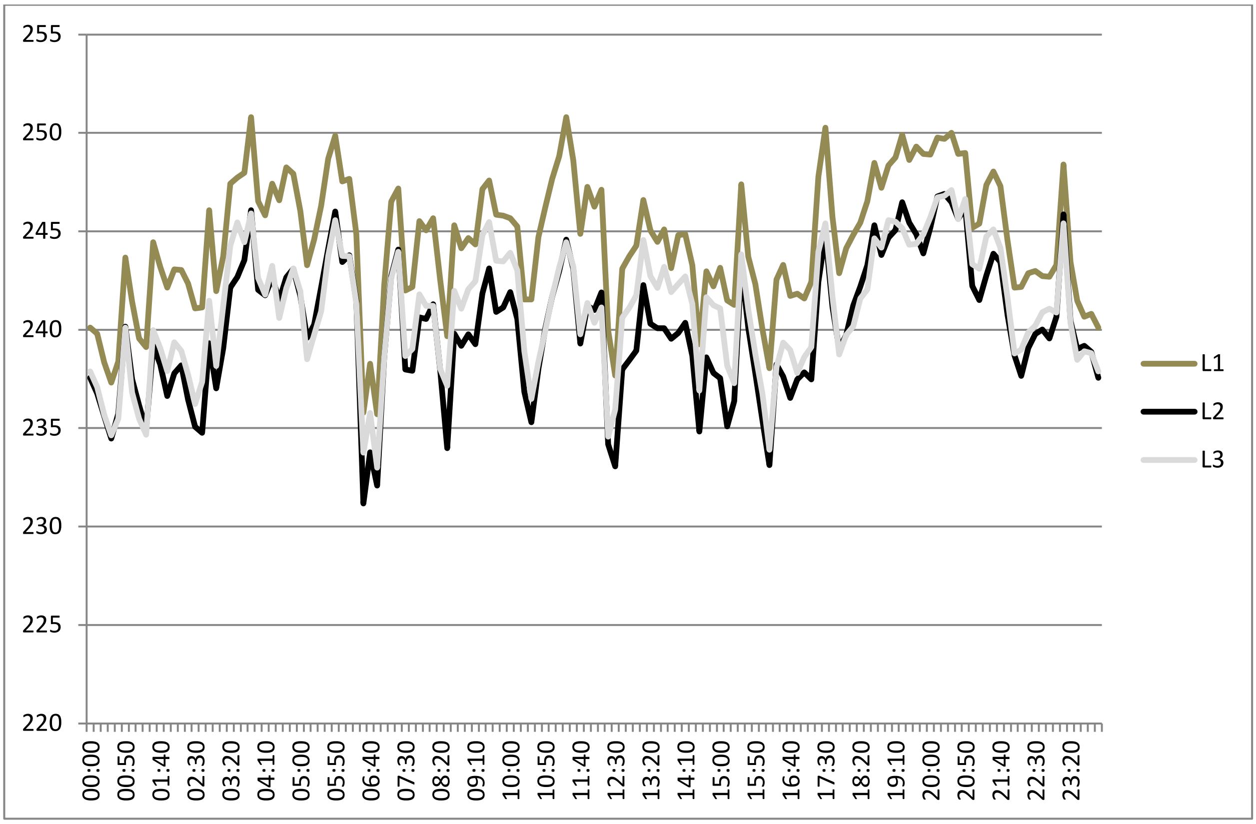

Figure 10 - Three Phase Voltage Waveform for The Garrisson

The fixed ring CTs do give a high level of accuracy within the range specified by the CT ratio, but due to the fact standard stock items were used, in some instances the 400/5 CTs were over specified for the output of the smaller 16kVA single phase transformers. This mismatch between current measured and CT capability also impacted upon the reliability of the results for some of the substations, as the resolution of the meters is spread evenly over the full scale deflection of the CT output. Similar issues were encountered on the WPD Tier 2 LV Network Templates project where an amplification unit was developed to resolve any data issues encountered.

For future projects the requirement for amplification could be avoided by the specification of CT ratios on a site by site basis. However advances in other sensing technologies have, in effect, made the use of CTs obsolete for load monitoring functions. WPD's LV Sensors project provides more information on this.

http://www.westernpowerinnovation.co.uk/Tier-1-Projects/Low-Voltage-Current-Sensor-Technology-Evaluation.aspx

5.2 Radio Performance

The initial radio survey completed by GE for the links used on the Isles of Scilly was completed using an assumed antennae height of 25ft, however after consultation with the local council planning officers, it was felt that this height was too great and the antennae should be installed at heights as low as possible to minimise the visual impact.

The adjustment of the anticipated antennae heights rendered the radio survey results redundant and so installation and commissioning of the links was primarily completed on location. Progress using this method was fairly quick and the heights were able to be reduced considerably in line with the Council's wishes. Measured link strength was a lot higher than anticipated due to the topology of the Isles and the lack of tall, dense vegetation. Because of this, many of the links were able to be fed directly from the main transmitter at the BBC Station substation which reduced the number of hops and equipment required. For future projects WPD would still advise the use of computer based planning tools, but with additional field surveys so that local conditions can be more effectively incorporated.

In some circumstances where other communication technologies were not able to be installed as originally proposed due to the extra disruption they entail, radio has been able to fill the gap and provide backhaul communications. On Tresco, the best solution was to use radio instead of a BPL link as the outages required for BPL connection were hard to achieve during peak summer months (due to the high load experienced due to the influx of tourists). Working on the islands outside of the summer months is more costly and less flexible as the transportation services return to an off-peak schedule. The key learning is that having a range of telecommunication solutions (as in this project) allows for plans to be adapted to local conditions without impacting on the project timescales or effectiveness.

The system availability of both types of radio has been proved to be very good, with only limited interference from atmospheric conditions experienced. The bandwidth and latency of the devices was sufficient for metering data retrieval, but the limitation of the 9.2kbps SD4 radios mean that any further applications on the network that need mass data retrieval will lead to upgrades in the system.

Figure 11 is a table showing collected data on the performance of the SD4 radio repeaters during a single month.

172.29.14.

Health	Device Name	Device Model	IP Address	Roundtrip Time (ms)		RSSI (dBm)		SNR (dB)		Availability (%)	Health History	Maintenance
				Current	Average	Current	Average	Current	Average			
	24017	4710_	172.29.14.17	144	140	-62.0	-62.0	27	27	100		
	24020	4710_	172.29.14.20	139	151	-68.0	-68.5	27	27	100		
	24027	4710_	172.29.14.27	142	139	-69.0	-68.2	23	23	100		
	24040	4710_	172.29.14.40	149	136	-62.0	-62.0	23	23	100		
	24053	4710_	172.29.14.53	147	148	-63.0	-63.0	27	27	100		
	24055	4710_	172.29.14.55	118	136	-62.0	-62.0	22	23	100		
	24063	4710_	172.29.14.63	148	148	-75.0	-74.8	24	24	100		
	24074	4710_	172.29.14.74	143	140	-62.0	-62.0	27	27	100		

Figure 11 - SD4 Radio Performance over 30 days

The radio showing downtime during this month locked out and required a local hard-reset before it was able to transmit data again.

The main learning points were:

- That unlicenced radio is an effective solution for backhaul (noting the previous comments on the remote nature of the islands)
- That the SD4 radios using allocated power industry spectrum have limited data throughput capabilities. This learning has been fed back through ENA telecommunications groups to Ofcom.
- That whilst computer aided radio planning tools provide a good "first pass", nothing can beat field surveys to ensure local issues are factored in

5.3 Broadband over Powerline Performance

The BPL devices required HV outages for each installation and due to the network being predominantly rural without LV backfeeds, generators were used to maintain supplies and avoid inconveniencing customers. The increased complexity and technical specialists involved in installation meant that progress was slower than the radio installation. But this would probably be reduced if the technology was deployed in a city-centre environment.

Although the BPL devices required extra civil works in order to install the couplers onto the underground HV network, the works can be hidden from view and all equipment can be housed in a standard substation kiosk. For the overhead installations, the couplers can be attached neatly to the pole and do not protrude as much as a directional Yagi antenna.

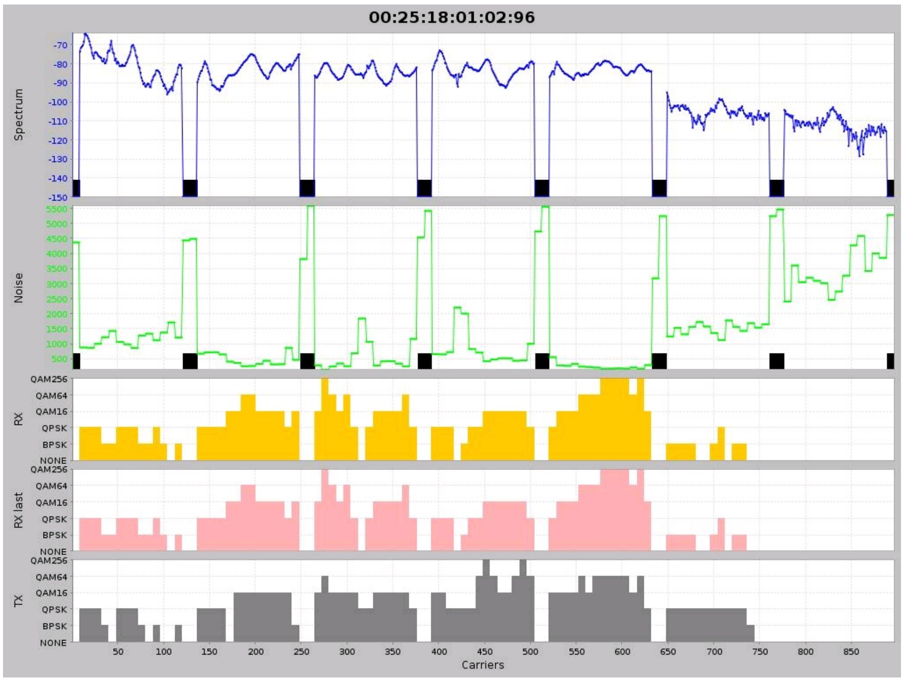

Figure 12 - BPL Link Performance – Underground Cables

There is a significant difference between the ability of certain electrical links to deliver BPL data across from node to node. Figure 12 shows a number of charts from top to bottom: the available spectrum in the cable, noise received, total received bandwidth channels, latest received bandwidth channels and sent bandwidth channels.

Underground cables tend to have more carrier paths spread across the total frequencies implemented in the BPL protocol. Overhead conductors tend to attenuate the lower frequencies and have carrier paths in the middle of the range, as observed in Figure 13.

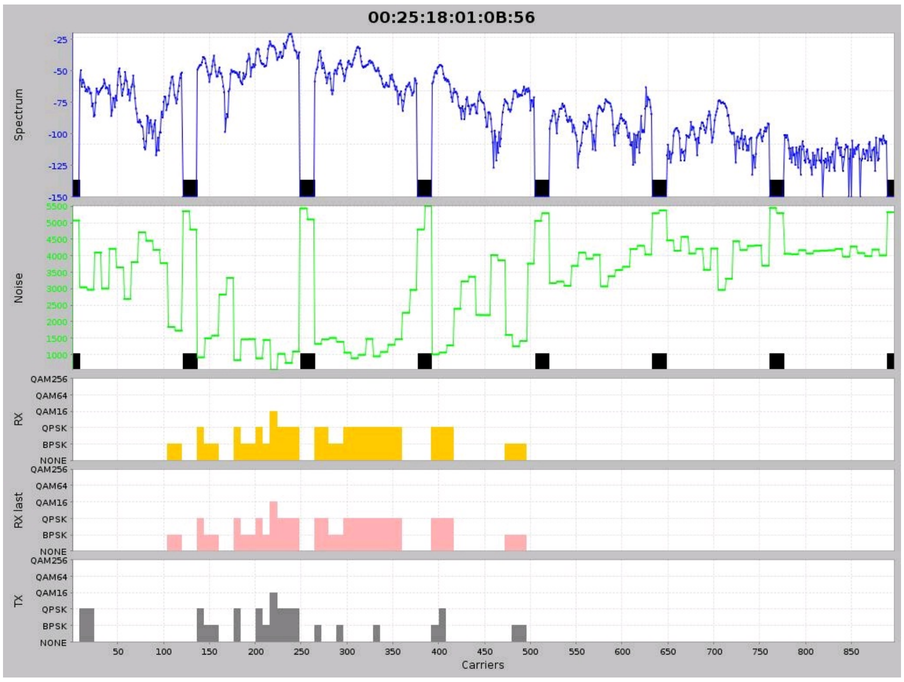

Figure 13 - BPL Link Performance – Overhead Conductors

The noise observed in the cables and conductors was also shown to change across different periods of time; however it was not possible to determine why this occurred. Presumably this was in line with the total non-resistive load or a certain type of disturbing load, but these factors are hard to isolate on a distribution network. Further analysis of these recorded results may identify certain cable types or noise signatures which preclude the use of BPL and might help pre-determine its effectiveness before installation. The learning from the project has been shared through ENA forums and through our partners with the broader PLC industry. In publishing this closedown report we invite academic or industry experts to provide additional commentary or feedback.

The results of the testing carried out show that each of the BPL links provides a latency of between 5 and 35ms and bandwidths between 400kbps and 7500kbps which show a considerable improvement on the radio technology.

```
# iperf -c 172.29.14.129 -i5 -t30
------------------------------------------------------------
Client connecting to 172.29.14.129, TCP port 5001
TCP window size: 16.0 KByte (default)
------------------------------------------------------------
[  6] local 172.29.14.137 port 1024 connected with 172.29.14.129 port 5001
[  6]  0.0- 5.0 sec  4.25 MBytes  7.13 Mbits/sec
[  6]  5.0-10.0 sec  4.28 MBytes  7.18 Mbits/sec
[  6] 10.0-15.0 sec  4.76 MBytes  7.98 Mbits/sec
[  6] 15.0-20.0 sec  4.43 MBytes  7.43 Mbits/sec
[  6] 20.0-25.0 sec  4.71 MBytes  7.90 Mbits/sec
[  6] 25.0-30.0 sec  4.75 MBytes  7.97 Mbits/sec
[  6]  0.0-30.0 sec  27.2 MBytes  7.60 Mbits/sec
#
```

Figure 14 - BPL Throughput at Porthloo to Highlanes

Availability of the strongest BPL links is high, although it has been noted that their performance changes with the load connected to the HV network and harmonic disturbances within the operating frequency can affect bandwidth and connectivity.

Data detailing the performance of the installed BPL links is presented in Figure 15.

Area	Station	Station Type (UG/OH)	Modem MAC address	Modem IP 172.29.14.	Latency to NMS [ms]	Latency previous hop [ms]	Bandwidth p. Hop [Mbits/s]	Bandwidth to HE [Mbits/s]	SEW MAC address	SEW IP 172.29.14.
St. Agnes	Tamarisk Farm	UG	04AA	80	229					
	Middle Town Agnes	UG	0710	81	232	3	2,8			
Bryer	Southward	UG	07EE	90	407					
	The Quay	UG	07E4	93	n/a	n/a	n/a	n/a	22	94
	The Town	UG	05AC	95			0,7		5B	96
	Northward	UG	0538	97	n/a	n/a	n/a	n/a	4E	98
	Hell Bay Hotel	UG	07A8	91					33	92
St. Mary's	Hugh Town	UG	0488	152						
	Porthcressa Flats	UG	0BC0	150		9	1,0	1,0	28	153
	Jerusalem Terrace	UG	0752	154		8	8,4	8,4	50	155
	Incinarator Station	UG	0346	159	999					
	Porthmellon Industrial	UG	17A0	162		10	1,1	1,1	41	163
	Carn Gwaval School	UG	090A	157		10	1,1	1,1	20	158
	Lundon	OH	081A	144						
	Normandy	OH	09C0	147	536	536	4,9	4,9	2D	148
	Highlanes	OH	0A7E	129					3F	130
	Higher Newford	OH	0B3A	127		10	1,0	1,0	1E	128
	Maypole	OH	0A7A	140		10	1,5	1,5	34	141
	Town Lane	OH	0A38	131		25	0,5	0,5	4C	132
	Rocky Hill	OH	081C	133		32	0,4	0,2	1C	134
	Rocky Hill Pumps	OH	0B36	135		8,6	4,2	0,1	47	136
	Porthloo	OH	0296	137		9,5	7,3	0,1	04	138
	Lower Trenoweth	OH	0B58	120					4B	122
	Higher Trenoweth	OH	0B40	123		9	1,7	1,7	06	124
	Helveor	OH	07E0	125		9	0,9		5F	126
	Borough	OH	0B56	139	99					
	Holy Vale	OH	0B08	142	115	16	1,1	1,1	53	143

Figure 15 - Broadband over Powerline Overview

The head-end rows highlighted in yellow designate the BPL links that filter the traffic back to the radio network. The white coloured links below communicate with the other components in the network via the headends.

The key learning points were:

- BPL does provide an effective communications path where radio options are not possible
- In some circumstances the technical performance of BPL is better than radio
- For some links the performance of BPL falls below required standards for some time periods.
- Additional research is needed to understand the impact of load types on BPL performance, and in particular the impact on BPL from the connection of low carbon technologies.

WPD intends to maintain the BPL system and track performance as customers on the Isles adopt low carbon technologies. WPD invites further research on this topic.

5.4 Communications System

The communication system installed was able to retrieve the real-time instantaneous values of the installed metering, however the bandwidth was largely limited by the SD4 radios, which have a maximum capability of 9.2kbps.

The data concentrators used within the Broadband over Powerline system are designed for usage on complete BPL systems, which are typically high-bandwidth systems. Consequently, the data structure is not optimised for delivery over narrow bandwidth radio devices, which further reduces the ability of the hybrid system to deliver data. Whilst the system is capable of delivering small amounts of real-time data for substation polling, the system could not retrieve much larger daily data downloads in this particular trial.

Although this project was focused on technology assessment it has created a platform for further research using the data collected. However the limitations of the low bandwidth radios mean that although a lot of data can be collected compared to the operation of a passive electricity network, the most granular data cannot be included in such analysis. The key learning point is to consider whether projects, in some cases, need to be over specified to support research beyond the initial stage.

5.5 Synchrophasor Control

Phasor Measurement Units have traditionally been deployed on EHV networks to monitor system disturbances with a high level of accuracy. Deploying PMUs on a distribution network required a ruggedised packaging to be developed so that these highly sensitive devices could be installed in the smaller spaces commonly available at distribution substation sites.

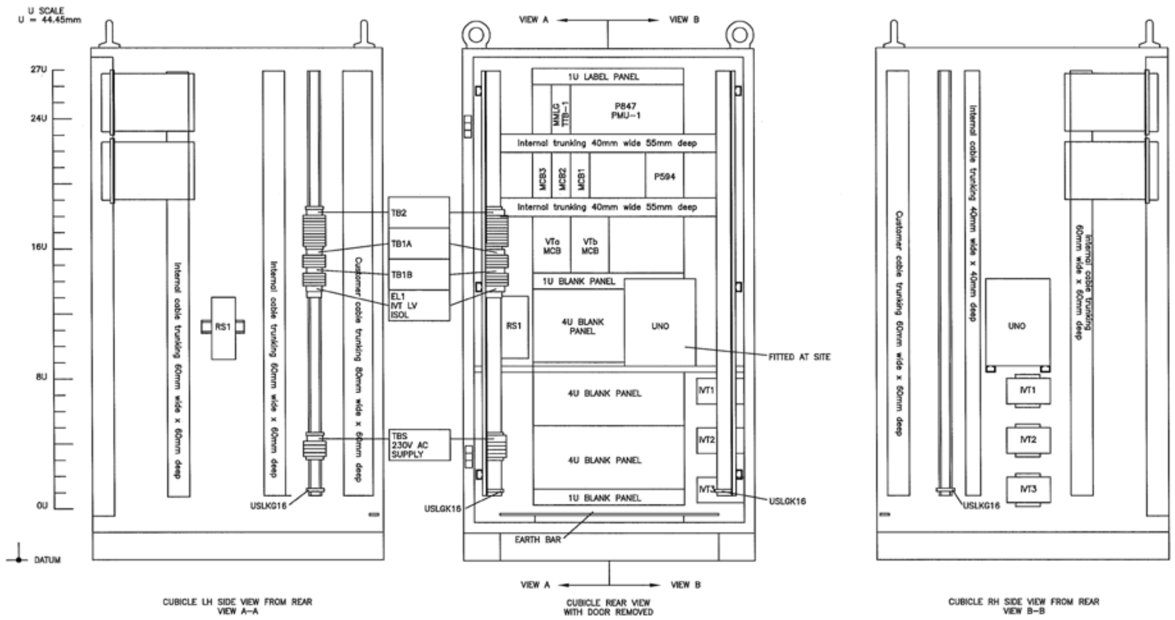

Figure 16 - PMU Cubicle

Development of this cubicle enabled the devices to be installed in both indoor and outdoor 11kV ground mounted substations, as shown in the technical drawing of the PMU arrangement (Figure 16).

In order to demonstrate the functionality of the system, a testing scenario was designed to understand the effectiveness of the synchronisation and the stability experienced during operation.

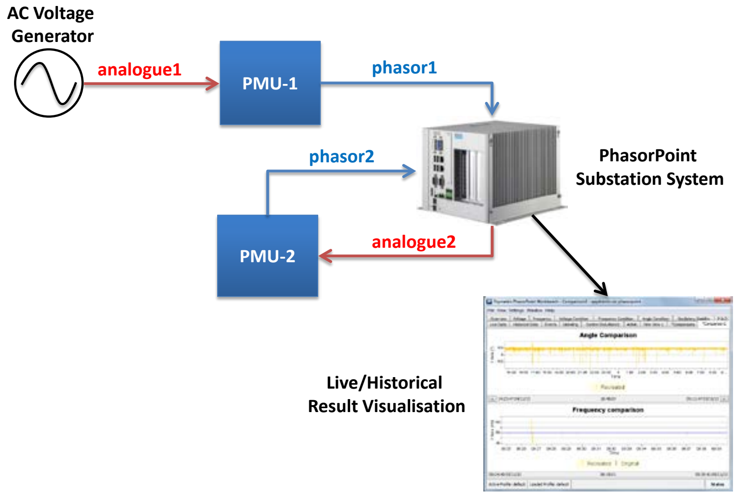

Figure 17 - Synchrophasor Demonstration Setup

A sinusoidal voltage was produced from an AC generator and measured by the first PMU (PMU-1) as a phasor. The phasor was then passed into the PhasorPoint substation system and converted back to an analogue signal. The recreated analogue signal was sent to the second PMU (PMU-2) and converted into the second phasor. The second phasor was also sent to the same PhasorPoint substation system. By altering the original sinusoidal voltage and comparing it to the second recreated phasor, the frequency and angle differences could be measured and their synchronicity calculated.

During testing, the maximum angle difference variation between the two phasors observed was about 40 degrees, as shown in the diagram below. This implies that the phase error between the original and recreated signals would be +/- 20 degrees if a proper angle offset were to be implemented.

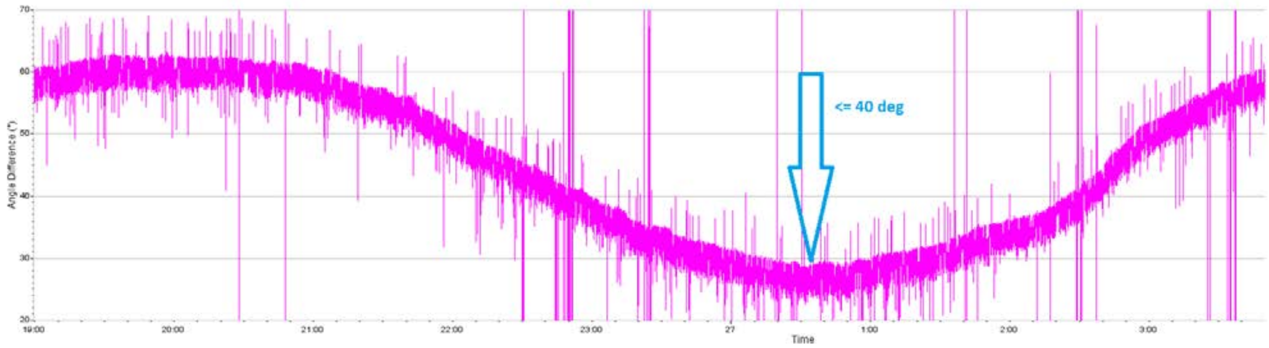

Figure 18 - Phase angle difference using NTP

Further investigation revealed that the angle variation was due to different time sources used by the PMU and the PhasorPoint substation system. The PMU time was locked into GPS, but the PhasorPoint substation system used Network Time Protocol (NTP). The 40 degree angle variation was caused by the Nano-second time difference in one direction but lasted for a considerable time period and therefore the angle error accumulated. However, eventually the error bounced back as NTP started to correct itself.

By altering the PhasorPoint substation system to also synchronise using a GPS time signal, rather than the NTP signal, a much smaller deviation between the two signals is observed

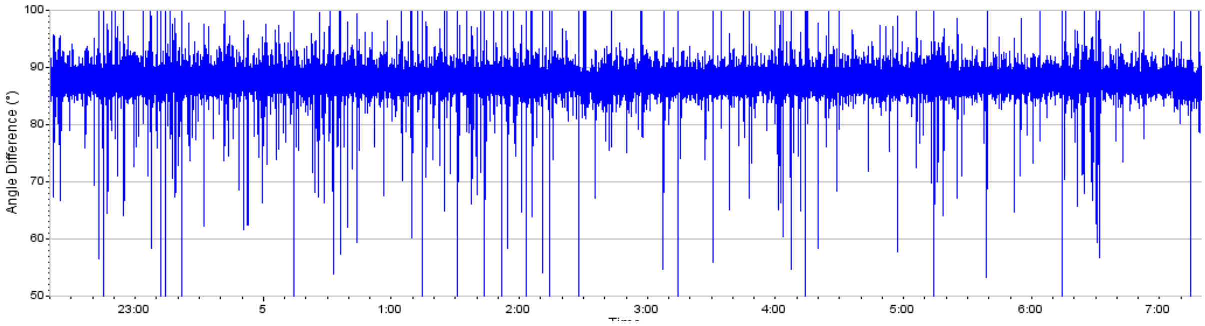

Figure 19 - Phase angle difference using GPS

The phase angle difference for an 8-hour period is shown in Figure 19 and shows that there is no obvious angle variation. The angle error was kept within +/-5 degree for most of the times, which met the IEE standard for synchronisation (+/- 10 degree). Further development of the algorithm used for synchronisation could reduce the noise experienced between the two signals.

The key learning points were:

- Packaging needs developing when transferring EHV technologies to distribution networks
- PMUs do work on 11kV
- Accuracy of the clocking source is crucial

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

For clarity, the changes made as part of this trial remain in place and so objectives that were met at the time of project closure continue to be maintained.

Objective 1: To establish real time monitoring on all of the distribution substations on the Isles of Scilly

All 63 substations that serve customers on the Isles of Scilly were and still are fully monitored on the outgoing LV tails of the transformer. Each individual meter can be polled instantaneously to retrieve the real-time measurements currently being recorded.

This objective has been met.

Objective 2: The use of the generation facilities on the islands can be maximised to secure supplies to the islands

Following the installation of the new off-island generation sets and the accompanying HV automation, sections of the network can now be remotely isolated and supplied by local generation. This secures the supplies to the islands of Bryer and St Agnes, which are each fed by a single 11kV cable. Following a HV fault on either of those cables, the customers can now be resupplied by the local generation within 3 minutes, whereas before the customers would have had a much longer return to service time.

This objective has been met.

Objective 3: The control and management of the generation on the off islands will be effected using new methods that have not been used in WPD before

Integration of the generation facilities into the Islands electrical network and Western Power Distribution's PowerOn network management system was completed. The connection of the generators on the Isles of Scilly is unique as security of supply to customers is generally afforded by the addition of an alternative connection to the network. Due to the cost and complexity of laying an additional submarine cable to the two smaller inhabited islands Bryer and St Agnes, this security is created by the generators' ability to export directly onto the 11kV network.

Traditionally, the generation units would have been sized to accommodate the maximum estimated load in the area planned to be supplied, plus extra headroom to cater for any variability of load across the whole lifespan of the assets. The new monitoring installed as part of this project can determine the real-time load on the islands and allow the network to be fed in different configurations depending on whether the network is experiencing high, medium or low load conditions. This allows the generation to be utilised at its most efficient operating level and will ensure that the units do not need replacing ahead of their expected lifespan, regardless of any changes in local load.

The control and management of the 11kV primary neutral link of the Yy11 transformers allow the same transformer to be used for supplying an earth reference on the HV system when the generators are exporting, as well as allowing the transformers to be used to supply local load from the HV network when the system is running conventionally. Having this link controlled remotely by the distribution management system allows isolation from the main network and restoration from local generation to be carried out remotely and autonomously.

The addition of monitoring for local load patterns also enables any potential reverse power situations to be identified and managed. If the aggregate amount of localised embedded generation on the off-islands were to ever exceed the amount of load supplied, then it would prohibit the diesel generation from supporting it as an islanded network. The flexibility of the new HV automation installed permits other demand sections to also be supplied, which ensures there are no net reverse power conditions.

This objective has been met.

Objective 4: Monitoring to be supplemented by controls where appropriate to manage and accommodate localised generation.

The additional HV automation installed as part of this project allowed the normal open points of the network to be moved depending on load conditions. Traditionally planned rural networks such as those found on the Isles tend to allow for more voltage drop than for voltage rise and this can limit the amount of generation export that can be accommodated. By monitoring the voltage levels around the network and the direction and magnitude of the current, the network can be reconfigured to ensure substations with high penetrations of generation are on the same HV feeder as substations with high load take off.

This objective has been met.

Objective 5: Support localised generation (Photovoltaic)

There have been a number of photovoltaic installations on the Isles of Scilly to date, covering a mixture of public buildings and domestic dwellings and ranging in size up to 16kVA. 22 of the 63 substations have one or more photovoltaic installations connected to the low voltage network. With no large scale solar farms connected, the total installed capacity is under 150kVA.

Western Power Distribution has also supported a number of proposals which seek to develop the self-sufficiency of the islands. These have included other generation technologies such as wind, wave and power from waste.

Since the monitoring has been installed, we have connected a further 15 embedded low carbon generators across the Isles. Whilst this proportion is significantly below the threshold which would start causing issues, the monitoring will allow any future load related reinforcement to be identified.

By using the monitoring information and the learning from the Tier 2 project LV Network Templates, an additional 20% network headroom has been identified, allowing for further distributed generation to be connected to the network without the need for reinforcement

This objective has been met.

Objective 6: Initiative will support the council's published goal of energy self-sufficiency.

The data collected by the monitoring systems is able to provide load information to the Council and inform where further generation or load reduction is required for the Isles to work towards being energy self-sufficient. The data will continue to be used to support regular dialogue with representatives from the Isles.

The real-time information provided by the monitoring is only available through the internal distribution management system, however this will be interpreted and fed into the distributed generation maps available at:

http://www.westernpower.co.uk/Connections/Generation/Generation-Capacity-Map/Distributed-Generation-Map.aspx.

This objective has been met.

Success criterion 1: The effective management of off island generation and monitoring & control of distributed generation on a weakly connected network.

Through monitoring all the connected LV load on the Isles of Scilly, the off-island generation is now able to be used to its fullest potential in securing customer supplies. Loads will be monitored into the future and the effects of energy efficiency and embedded LV generation (through PV or other technologies) will be identified.

Should local demand continue to reduce because of these measures, the strategic HV switching points can be altered to ensure there is always the correct balance of supporting generation and consuming load when operating as an electrical island.

This criterion has been achieved.

Success criterion 2: Use of Power Line Carrier techniques on higher voltage networks

By working together with PPC, the implementation of 11kV Broadband over Powerline was designed, installed and commissioned within the project timescales. A number of links have been in highly successful operation throughout the trial, whilst some other links have had their availability reduced due to the reasons outlined in Section 8.

The successful links have proved the technology concept for installation on both underground and overhead systems on the 11kV network. The latencies and throughput do have an advantage over comparable radio solutions, though the requirements for installation mean roll-out is not as quick. Variances in link quality would also need to be solved, potentially through pre-installation surveys, in order for this system to be considered elsewhere.

This criterion has been achieved.

Success criterion 3: Demonstration of Synchrophasor Generator Control

Following the algorithm and system development for the synchrophasor control, initial testing demonstrated that the principle of operation is sound and synchronisation should be within acceptable limits.

This criterion has been achieved.

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

7.1 Planned Communications Topology

The initial plan for roll out of the radio and BPL was completed by GE Digital Energy following a series of site surveys during the scoping phase. On receipt of the final report, it was noted that a number of BPL links were placed either side of normal network open points and that there would be no physical connection between these two points. Whilst the BPL technology does have the ability to mesh nodes together and synchronise to the nearest head end, some secondary nodes were placed on electrical networks without an adjacent head end.

To fix this, some planning was carried out internally to site additional radio backhauls in these areas and to convert the secondary nodes to head ends in order to get the meter data back. Having a better understanding of the network running arrangements and BPL limitations, would have been overcome in the initial planning stage.

7.2 Business As Usual Changes

Due to the changing load patterns and alterations to the low voltage network, a number of adjacent pole mounted substations was rationalised down into a single ground mounted unit. This replacement was not undertaken until the LV monitoring and communications network was designed and had entered production. Due to the monitoring solution having the flexibility to be installed in both overhead and underground substations, the equipment did not require any alterations, though the positioning and direction of the radio links did require on-site modification.

The new site established was a relatively short distance from the other substations it was replacing, so this did not require radical changes to the radio signal strengths. The other two communication and monitoring enclosures were kept for strategic spares and could be redeployed should any new substations be created.

7.3 Antennae Height

The site surveys were also carried out with a predicted aerial height of 25ft, which did not give consideration to the Isles of Scilly being an Area of Outstanding Natural Beauty. As the local planning officers required the heights to be kept to a minimum, the validity of the indicated signal strengths was also reduced, meaning many of the links had to be commissioned using signal amplitudes determined on site.

7.4 Radio Signal Strengths

During the initial site surveys and desktop studies carried out, propagation paths were analysed and signal attenuation predicted. In order to minimise the risk of interference and reduce unnecessary coverage, the output signal levels were reduced on site during the commissioning process. This enabled the levels to be fine-tuned, whilst still maintaining a good communication path between sites.

7.5 BPL Installation

The amount of HV outages required for the BPL technology proved problematic as the initial planned timetable for installation coincided with the Isles' holiday season, when occupancy is at its fullest and outages cause the greatest amount of disruption. To minimise this disruption generators have been used to maintain supplies and local staff have arranged the switchover times to fit the customers.

The results of the first survey indicated that the layout and existing infrastructure on Tresco would most suit a BPL installation, however, during initial discussions about implementation with local WPD staff, it soon became clear that the landowner and residents of Tresco would only allow limited works to be carried out on the island.

Due to the timing and duration of some of the excavation works required for BPL installation on this underground network, it left two options for successful project delivery; let the works proceed outside of the holiday season or change the communication links to a radio solution. To ensure the project ran as timetabled and with as little disruption as possible, communications on the island were changed to radio links, which required less obtrusive work and could be carried out in a shorter duration of time.

As this change was highlighted during the initial planning stage of the project, the amendments were able to be accommodated without any variation to the fixed price contract with GE.

8. Significant variance in expected costs and benefits

8.1 Costs

Description	Forecast (k)	Actual (k)	Variation (%)
Synchrophasor Control	£ 180,000	£ 179,330	-0.37%
Plant & Equipment	£ 347,000	£ 336,899	-2.9%
Monitoring & Communication	£ 760,000	£ 759,698	-0.03%
Total	**£1,287,000**	**£ 1,275,927**	**-0.9%**

Figure 20 - Cost breakdown

No significant variance was experienced across the project expenditure as the majority of the costs attributed to the project were fixed price contracts with suppliers, which allowed the project costs to be carefully controlled. In line with WPD policy at the time and as per the original budget estimation, internal labour costs were not included on the project.

8.2 Expected Benefits

No direct benefits were stated in the original registration pro forma. There were however the expected qualitative benefits from undertaking the project.

Whilst the uptake of low carbon generation in the rest of the South West has been very high, the amount of embedded generation connected on the Isles of Scilly has so far been limited to small-scale photovoltaic installation. The islanders have been developing plans for other diverse generation technologies and money from the Energy Savings Trust has been received by the Isles of Scilly Renewable Energy Cooperative (ISREC) to carry out a feasibility study into the islands' suitability for small-scale wind turbines.

Developers have also been looking at the potential for the Isles of Scilly to become a wave hub and invest in tidal or wave powered energy harvesters. Despite the interest, there has been little development of large scale renewable generation on the isles, but for the generation capacity already on the network, the measured effects have been measurable, but small and certainly below the level able to be absorbed locally. The ability for the islands to become energy self-sufficient is still apparent and the equipment installed as part of this project will enable the future uptake of low carbon technologies to be managed more effectively.

The ability of phasor measurement data to act as a real-time synchronising tool for embedded generation has been developed and demonstrated. The learning from this project can be taken forward and implemented in other applications where dynamic system stability can be a problem, and where frequency deviation might be greater influenced by the number of connected generation sets.

The use of Broadband over Powerline on the 11kV network has managed to demonstrate the functionality of this technology, particularly for high-speed and high bandwidth applications. BPL technology is strictly a different implementation than the PLC mentioned in the original pro-forma, but the medium used in transporting the data is the same. Whilst BPL has a greater available bandwidth, the signal does not travel as far on the conductors. For small networks like the Isles of Scilly, this is less of a problem.

9. Lessons learnt for future Projects

Throughout the running of this project, significant learning has been created on how low voltage networks should be monitored and how communications architectures should be developed for smart grids.

The low voltage monitoring equipment deployed on the Isles of Scilly was a bespoke solution developed specifically for the project by GE. 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. The bespoke solution was also sought due to the requirements for housing radio or BPL communication equipment, as GPRS coverage on the islands was not deemed to be acceptable.

A more robust BPL implementation would be to have multiple headend units connected together by adjacent nodes, rather than relying on a single headend to reach multiple nodes. As the BPL nodes have the functionality to choose the nearest available headend unit to transmit back to, the system would communicate as intended, but the design would allow a greater resilience in the system.

The specification for an LV monitoring system was developed during the scoping for the solution delivered by GE. Following the installation of these units, further recommendations were made which have been incorporated into the tender specification for the LV sensors project, undertaken jointly with UK Power Networks.

This project also recognised that there is benefit in completing a full site survey before attempting installations, as potential difficulties can be highlighted before the activity is planned. This is particularly pertinent for the Isles of Scilly, as travel to and from the off-islands has to be carefully planned.

Many of our substations can be assumed to follow certain load patterns, as the LV Network Templates project showed. However, actual LV monitoring is particularly important for substations which include clusters of load which do not follow conventional trends found across the UK. The Isles of Scilly has a large percentage of electrically heated properties and a significant amount of load is also influenced by the peak tourist periods. Hence the maximum total demand experienced by the islands usually occurs around Easter, particularly if it coincides with a cold spell. Differences such as these increase the likelihood that the load patterns will not fit a standard template approach.

Having a greater visibility of the LV network enables more informed planning decisions to be made and allows networks to be optimised for specific operating conditions. This is of increasing importance when connecting a greater amount embedded generation on the lowest voltage levels. This becomes even more significant for networks that are limited in the amount of reverse power they can absorb, so ensuring that the load is always greater than the connected generation in areas that may be supplied by diesel generation is imperative.

Initial learning from the project has helped understand, define and manage the different types of traffic a distribution network orientated communication network needs to carry. The radio and BPL network for the Isles of Scilly does not rely on any third party intervention or services in order to operate and utilises both licensed and unlicensed spectrum. The level of resilience afforded by the licensed radios would be essential for high-priority traffic, such as control or protection. A slightly less robust availability could be tolerated for the monitoring traffic, particularly if the information is only polled in daily cycles. This was not chosen for this application due to the real-time requirements for the monitoring system.

The same levels of criticality applied to the communications backhaul was also applied to the power requirements of the equipment, with each monitoring unit being supported by DC battery backup. For future monitoring systems, the same level of resilience is not necessarily required.

Whilst the BPL technology has not fed directly into the smart metering model, the architecture developed for this project can help with the transition of distribution networks towards smarter networks requiring a greater reliance on communications. How the topological IP network was developed for the islands' communications system and how it relates to the physical electrical assets has fed into standard policies within the business.

This project demonstrated that it is possible to safely install BPL technology on the overhead and underground 11kV networks and that the equipment is fit for purpose for usage in a distribution network environment.

The requirements for a Phasor Measurement Unit system fit for installation on the distribution network has been investigated as part of this project and the final design implemented on the Isles of Scilly can be duplicated around the network. The finalised design is able to be deployed in both indoor and outdoor substations and can be powered using both AC and DC supplies.

The demonstration of synchrophasor control to enable advanced generator control has proved that by using GPS synchronised phasor measurement data, remote generators can be kept electrically separate, but synchronised to a high degree of accuracy, even with a variable and asynchronous communication delay.

10. Planned implementation

This project has created a platform to build an understanding of LV loadings in weakly connected areas that may be supplied by generation islanded from the main network. Levels of total aggregate load will continue to be monitored to ensure that reverse power conditions do not affect the security of the system.

The radio and Broadband over Powerline communication system that has been deployed on the network can act as an enabling technology in the future. Having this robust data infrastructure will allow any further advanced control of the network to be implemented and will facilitate any HV or LV active network management systems on the islands.

The use of UHF radios which use unregulated spectrum to deliver less-critical traffic piloted in the project has been proved successful, particularly in rural areas where there is less likely to be other applications using these frequencies. WPD is planning to use a similar approach to provide short-distance, low-cost communications to low carbon generators in order to bring back monitoring data to the distribution management system. The use of these radios to enable generators to be actively managed is also planned.

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.

The use of synchrophasor control for the generators will continue to be monitored whilst the generators are run under standard business procedures, to build up confidence and further data on the accuracy of the developed algorithm. Further fine tuning of the software and a larger amount of tested hours is required before the system can be operated independent of other synchronicity checking equipment.

Learning from this project has already been transferred into the Tier 2 project FALCON (Flexible Approaches to Low Carbon Optimised Networks) as it has informed best practice when installing further phasor measurement units on the network.

If the technology wants to be transferred so that multiple renewable generation sets can be co-ordinated remotely from a single monitored source, then further development work will need to be carried out by the generator control manufacturers.

11. Facilitate Replication

11.1 Knowledge Required

The knowledge required to implement a platform which supports the connection of embedded generation and is able to maximise the effectiveness of any controllable generation is outlined below:

- Electrical network topology and connectivity
- Electrical network impedance data
- Load distribution
- Geographic asset locations
- Physical terrain and relief mapping
- Communication topology
- Data flows and requirements

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 prerequisites required before the enabling platform can be fully operational. This section outlines these requirements:

- Overhead LV monitoring
- Underground LV monitoring
- Substation data aggregators
- Allocated licensed spectrum
- Licenced UHF radios
- Unlicensed UHF radios
- Broadband over Powerline
- Real-time data polling system
- Phasor Measurement Units
- Phasor data concentrators
- Generator Control systems

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, as described in sections 12 and 13.

Lessons learnt from this project have already helped form the WPD requirements for LV substation monitoring as used in the LV Current Sensors project and develop a standard for implementing Phasor Measurement on the distribution network, which has been used within project FALCON.

A method of connection for 11kV BPL devices for both the overhead and underground network has been developed and the technical policy documents 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

Appendix A1:

Pro forma

LCN First Tier Project Registration WPD.pdf

Appendix A2:

Amended pro forma

LCN First Tier Project
Registration WPD-Ch

Appendix A3:

Change mandates

WPDT1002 - CM1 (draft).pdf

WPDT1002 - CM2 (draft).pdf

WPDT1002 - CM3 (draft).pdf

Appendix A4:

BPL topology

BPL.png

Appendix A4:

Substations on the Isles of Scilly

IoS Substations.pdf

Appendix A5:

Typical overhead installations

Appendix A4:

Typical underground substation


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