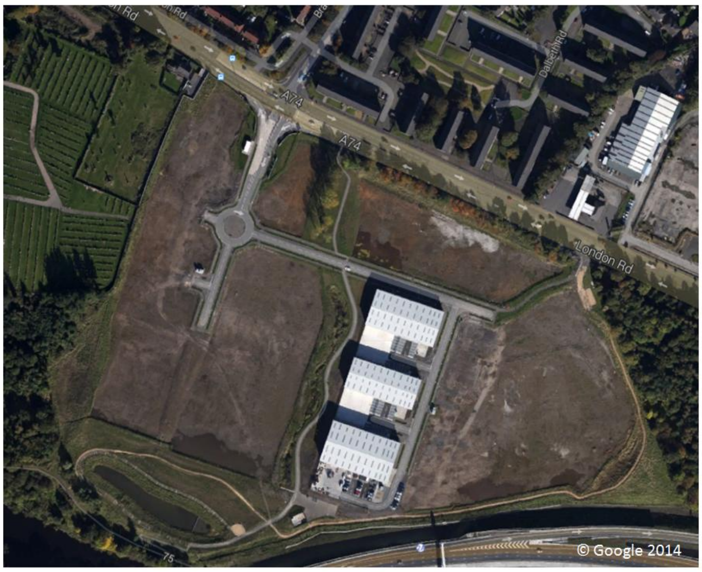
Clyde Gateway LR1 (London Road 1)



Final Close Down Report

SPT1003
Clyde Gateway LR1
(London Road 1)

April 2014

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Executive Summary

Scottish Power Energy Networks (SP Energy Networks) has developed a high voltage (HV) automation system that is used throughout its distribution network.

This project proposed to integrate the work carried out under SP Energy Networks' Innovation Funding Incentive (IFI) projects, on low voltage (LV) automation and LV fault-finding, with the HV automation system to gain more understanding and control of the LV and HV networks.

The project aimed to demonstrate the integration of a number of smart grid components within an established infrastructure and aimed to facilitate the development of solutions in a number of areas including power quality, HV/LV automation, auto-sectionalising and load-transfer. The application of the latest technologies on various smart grid components on a relatively small network was expected to:

- Assist with the development of efficient and effective solutions;
- Provide learning outcomes, not only on the smart aspects of the grid infrastructure, but on design standards, network voltages and utilisation of assets; and
- Inform industry and the supply chain on smart grid challenges and solutions.

The trialling of the following Methods formed the success criteria for the project:

- Voltage Optimisation - Simultaneous measurement of voltage at various points on the network will inform design and operational practice with respect to voltage limits.
- Asset Management - Monitoring of HV circuit breaker operating times to provide trigger for maintenance and to prevent unnecessary interruptions to supply.
- Losses - LV monitoring and automation, identification and elimination of phase imbalance.
- Distributed Generation - Simultaneous measurement of voltage at various points on the network will inform design and operational practice with respect to impact of generation and allow more generation to be accommodated.
- Outages - Automation and system monitoring will reduce unnecessary outages and identify potential network problems before fault occurs.

In 2010, the Clyde Gateway LR1 (London Road 1) site was identified as having major potential for trialling the proposed HV/LV automation solutions. With the selection of Glasgow to host the Commonwealth Games in 2014, the Clyde Gateway area would be a high profile brown-field site, providing a 'blank canvas' for deploying the HV/LV automation system infrastructure and trialling the proposed solutions with a number of customers, including high-tech manufacturers.

The steps of the planned trialling methodology are outlined below:

1. Conceptual design of the HV/LV automation system;
2. Production of a functional design specification for the HV/LV automation system and its components;
3. Specification and identification of a trial site;
4. Development of the detailed system architecture;
5. Detailed design of the HV/LV automation system in the trial site;
6. Procurement, installation and commissioning of the electrical infrastructure;

7. Procurement, installation and commissioning of the HV/LV automation system;
8. Trialling of the five Methods, as described above, based on demand and distributed generation connected to the trial area;
9. Data gathering and analysis of the HV/LV automation system performance;
10. Capturing lessons learnt and recommendations on business adoption.

Due to two key factors the five Methods, which were due to be trialled in Step 8 of this methodology, could not be trialled at the Clyde Gateway site. These key factors were:

- The lack of take-up of demand and generation in the trial area, due to the economic recession;
- Supply chain issues with the major solutions provider, Radius, going into administration during the early stages of the LCN Fund project.

A major outcome of this project was the successful installation of HV and LV network infrastructure on the London Road site. As a result, Steps 1 – 6 and 10 of the planned trialling methodology were successfully completed during the LCN Fund project timescales. However, Steps 7, 8 and 9 could not be completed.

Although there was potential for 74 businesses to develop on the Clyde Gateway site, only two small and medium enterprises (SMEs) and the site office were connected during the LCN Fund project timescales. The lack of take-up of demand and generation in the trial area was attributed to the economic recession. The site has a supply capacity of 2000kVA (two 1000kVA transformers). Due to lack of take up of load demand in the trial area, demand was only recorded on a single phase of one distribution transformer, representing approximately 1% of the capacity of the distribution substation and 0.5% of the potential supply capacity of the site.

Supply chain issues (with the major solutions provider, Radius, going into administration during the early stages of the LCN Fund project) resulted in significant delays to the development of the LV automation system and its integration with the HV automation system.

Due to the economic recession and supply chain issues, there was not the envisioned development of smart grid technologies (generation, demand and storage) at the trial site. Therefore, due to circumstances outside of SP Energy Networks' control, the project did not completely fulfil the aim of integrating smart grid technologies into a conventional network.

The HV/LV automation system architecture was developed in this project. The architecture is, conceptually, very sound and desirable, providing a useful reference guide for other distribution network operators (DNOs).

The project succeeded in delivering the installation and integration of the HV and LV network infrastructure, providing an automation-ready distribution system. During the project, practical experience was gained by SP Energy Networks in the development of HV/LV network infrastructure and automation systems.

This project has succeeded, greatly, in informing the industry and supply chain of smart grid challenges. The following key points are noted:

- Judicious site selection is required for trialling new technologies. External factors, on which the success of the project relies, need to be identified and managed effectively by the DNO and contingency measures need to be put in place for the key deliverables on the critical path of the project.
- Judicious selection of project partners is required and early warning signs of supplier difficulties should be identified.
- Through this project and the fore-running IFI projects, the industry is informed that the effective monitoring, control and automation of LV networks is possible. It is possible to install effective communications across LV networks and that the necessary LV infrastructure and power quality monitoring devices are available on the market. However, further development is required to deliver a fully functioning LV automation switch with full automation and interruption capabilities.
- The costs and efforts on the DNOs' part, associated with the integration of smart grid technologies into LV networks, do not outweigh the benefits at presents.

Due to the lack of take up of demand and generation in the trial area, the Clyde Gateway project did not produce any reportable outcomes against its original success criteria.

The following modifications were required during the course of the project:

1. Replacement of the major solutions provider;
2. Development of the LV automation switch through the IFI mechanism;
3. Re-evaluation of the trial network location;
4. Relocation of the power quality recording equipment.

The project was successful in delivering some of its initial objectives and, as a result, succeeded in providing some, but not all, of its intended benefits.

The learning has been categorised as that pertaining to HV/LV automation system deployments, learning outcomes which are transferrable to other innovation projects and other learning outcomes from the project that have merit in being reported.

Key learning points in deploying HV/LV automation systems:

- Systems should be trailed in an established network, where there is sufficient connected load;
- LCN Fund projects support SMEs, which are, potentially, more agile in terms of delivering innovation and accelerating the technology readiness level (TRL) of projects than original equipment manufacturers (OEMs);
- The LV system is complex and requires significant investment, in comparison to higher voltage systems, for less return.

Recommendations for other projects:

- Understanding and managing risks of working with SMEs;
- Technology Readiness Level of equipment must be suitable for the planned implementation;

- The trialling environment must be able meet the necessary performance requirements in order to achieve the success criteria;
- DNOs have to invest significant time and capital to facilitate connection of DG in LV networks.

At present, SP Energy Networks does not have plans to modify its Distribution System based on outputs of the Clyde Gateway project. This is because the trials did not progress as far as originally intended and limited quantifiable data was available from site, on which to make informed decisions about Distribution System modifications.

If the need case returns at London Road, and new low carbon technologies are connected at the Clyde Gateway, the electricity network infrastructure is already in place to accommodate demand and generation, and new HV/LV automation solutions could be efficiently and effectively trialled on the site. SP Energy Networks would look to continue trials of the HV/LV system through alternative funding mechanisms in RIIO-ED1, such as the Network Innovation Allowance (NIA).

The maturity of alternative LV automation technologies has increased, significantly, during the timescales of this LCN Fund project. Therefore, SP Energy Networks has aspirations to utilise these technologies, and build on the learning from other DNOs, to demonstrate and implement HV/LV automation solutions in the future.

A number of actions have been identified, for DNOs and equipment suppliers, before the HV/LV automation system can be implemented at scale. In addition, an overview is given of alternative LV automation approaches, which were developed by other manufacturers during the LCN Fund project timescales.

Details of the knowledge, products and services required to replicate the outcomes of the project have been provided. Furthermore, potential suppliers and points of contact have been identified to enable other DNOs to access the knowledge, products and services required to replicate the HV/LV automation system.

1 Project Background

Scottish Power Energy Networks (SP Energy Networks) has developed a high voltage (HV) automation system that is used throughout its distribution network.

This project proposed to integrate the work carried out under SP Energy Networks' Innovation Funding Incentive (IFI) projects, on low voltage (LV) automation and LV fault-finding, with the HV automation system to gain more understanding and control of the LV and HV networks.

1.1 Project Overview

Scottish Power Energy Networks (SP Energy Networks) has developed a high voltage (HV) automation system that is used throughout its distribution network.

This project proposed to integrate the work carried out under SP Energy Networks' Innovation Funding Incentive (IFI) projects, on low voltage (LV) automation and LV fault-finding, with the HV automation system to gain more understanding and control of the LV and HV networks.

The project aimed to demonstrate the integration of a number of smart grid components within an established infrastructure and aimed to facilitate the development of solutions in a number of areas including power quality, HV/LV automation, auto-sectionalising and load-transfer. The application of the latest technologies on various smart grid components on a relatively small network was expected to:

- Assist with the development of efficient and effective solutions;
- Provide learning outcomes not only on the smart aspects of the grid infrastructure but on design standards, network voltages and utilisation of assets; and
- Inform industry and the supply chain on smart grid challenges and solutions.

The solution consists of several tiers of control and monitoring. On the high voltage system:

- Additional automation in feeder circuits with load optimisation on each feeder to minimise losses;
- Power quality devices to monitor voltage quality, feeder breaker condition and loading.

On the low voltage system:

- Specially equipped LV substations to monitor loading/power quality and fault activity;
- LV network automation points to monitor voltage and control loads.

The project was part-funded through the Smart Grid Capital Grant Programme of the Department of Energy and Climate Change (DECC) and originally involved Radius as the LV automation (LVA) solution provider and equipment supplier.

The DECC Capital Grant funded the installation of the LV network infrastructure in order to develop the Clyde Gateway Brown Field site in the London Road 1 (LR1) District.

The LVA solution, provided by Radius, comprised of two main components: (i) a power line carrier (PLC) communications system, for monitoring voltages and controlling switchable points in the new LV network; and (ii) LV vacuum switches with magnetic actuators (controllable LV switches) installed in pillar boxes (above ground level). Radius subcontracted the development of the controllable LV switches to a third party supplier, EPS.

In November 2011, Radius went into administration and was acquired by Netcontrol. Although Netcontrol acquired the Intellectual Property and PLC solution offering of Radius, the delay in reconstructing Radius and the necessary rework to the inherited design meant that the complete LVA solution was not available to SP Energy Networks within the project timescales. Moreover, in order to demonstrate the benefits of the LVA solution, the trials were reliant on the connection of a sufficient number of demand and generation customers into the new LV network in the LR1 District. The required number of connections did not materialise during the project timescales and, therefore, the benefits of this project were not fully realised.

Following Netcontrol's acquisition of Radius, SP Energy Networks worked with EPS directly (through the IFI funding mechanism) to develop the controllable LV switch. This switch has subsequently been developed further and trialled by Electricity North West (ENW) as a link box solution (below ground level).

The original Project Registration Pro-forma is given in Appendix A.

2 Scope and Objectives

The project aimed to demonstrate the integration of a number of smart grid components within an established infrastructure and aimed to facilitate the development of solutions in a number of areas including power quality, HV/LV automation, auto-sectionalising and load-transfer. The application of the latest technologies on various smart grid components, on a relatively small network, was expected to:

- Assist with the development of efficient and effective solutions;
- Provide learning outcomes not only on the smart aspects of the grid infrastructure but on design standards, network voltages and utilisation of assets; and
- Inform industry and the supply chain on smart grid challenges and solutions.

The power quality solution was expected to allow SP Energy Networks to understand the imbalance of loads and voltages within the LV and HV networks, at the London Road trial site, in real-time. This solution was also expected to allow SP Energy Networks to pinpoint disturbances in the LV network caused by various smart grid technologies connected to the network. At HV, the solution was expected to allow SP Energy Networks to monitor the speed of operation of circuit breakers.

Building on SP Energy Networks' scheme of Network Controllable Points (NCPs), the HV / LV automation solution was expected to embed controllable points in the LV network and coordinate the operation of controllable switching points in the HV and LV networks.

The auto-sectionalising solution was expected to allow SP Energy Networks to automatically segregate different load demands, minimising the propagation of power quality disturbances introduced novel smart grid technologies and manufacturing plant. This solution also allows LV faults to be isolated and supplies restored to more customers, and more quickly, than with current conventional solutions.

In normal operation, the expected outcome of the load transfer solution was to allow the LV demand to be balanced across two distribution transformers (using the monitoring of load demand in the power quality solution and the switching controls of the HV / LV automation solution). This was expected to introduce network operation efficiencies and reduce the on-load losses of the distribution transformers. In outage conditions, the load demand from one distribution transformer could be transferred to another, thereby restoring supplies to customers more quickly and efficiently.

3 Success Criteria

The trialling of the following Methods formed the success criteria for this project:

- Voltage Optimisation - Simultaneous measurement of voltage at various points on the network will inform design and operational practice with respect to voltage limits.
- Asset Management - Monitoring of HV circuit breaker operating times to provide trigger for maintenance and to prevent unnecessary interruptions to supply.
- Losses - LV monitoring and automation, identification and elimination of phase imbalance.
- Distributed Generation - Simultaneous measurement of voltage at various points on the network will inform design and operational practice with respect to impact of generation and allow more generation to be accommodated.
- Outages - Automation and system monitoring will reduce unnecessary outages and identify potential network problems before fault occurs.

4 Details of Work Carried Out

Prior to the LCN Fund First Tier project "Clyde Gateway", SP Energy Networks had successfully created a beneficial HV automation system. In addition to this, SP Energy Networks built on the successful outputs of a number of IFI projects. The focus of the Clyde Gateway LCN Fund First Tier project was to integrate the LV components, developed at IFI level, and trial the combined HV / LV automation system.

In 2010, the Clyde Gateway LR1 (London Road 1) site was identified as having major potential for trialling the proposed HV/LV automation solutions. With the selection of Glasgow to host the Common Wealth Games in 2014, the Clyde Gateway area would be a high profile brown-field site, providing a 'blank canvas' for deploying the HV/LV automation system infrastructure and trialling the proposed solutions with a number of customers, including high-tech manufacturers.

Five Methods were identified for trialling in this project:

1. Voltage Optimisation.
2. Asset Management.
3. Reduction of Losses.
4. Integration of Distributed Generation.
5. Reduction of Outages.

The steps of the planned trialling methodology are outlined below:

1. Conceptual design of the HV/LV automation system;
2. Production of a functional design specification for the HV/LV automation system and its components;
3. Specification and identification of a trial site;
4. Development of the detailed system architecture;
5. Detailed design of the HV/LV automation system in the trial site;
6. Procurement, installation and commissioning of the electrical infrastructure;
7. Procurement, installation and commissioning of the HV/LV automation system;
8. Trialling of the five Methods, as described above, based on demand and distributed generation connected to the trial area;
9. Data gathering and analysis of the HV/LV automation system performance;
10. Capturing lessons learnt and recommendations on business adoption.

Due to two key factors the five Methods, which were due to be trialled in Step 8 of this methodology, could not be trialled at the Clyde Gateway site. These key factors were:

1. The lack of take-up of demand and generation in the trial area, due to the economic recession;
2. Supply chain issues with the major solutions provider, Radius, going into administration during the early stages of the LCN Fund project.

4.1 Justification of the Planned Approach

4.1.1 Building on previous successful projects

Prior to the LCN Fund First Tier project "Clyde Gateway", SP Energy Networks had successfully deployed Network Controllable Points (NCPs) across its HV network and created a beneficial HV automation system. In addition to this, SP Energy Networks built on the successful outputs of the IFI 0607 project "LV Network Automation" and the IFI 1006 and 0409 "LV Fault Location" projects. In these projects, SP Energy Networks worked with Radius (an SME) to develop the key components of the LV automation system. The focus of the Clyde Gateway LCN Fund First Tier project was to integrate the LV components, developed at IFI level, and trial the combined HV / LV automation system. The LV automation system was referred to as "LVA071", by Radius, in supporting documentation.

The LVA071 system comprised one modified Central Control Unit (CCU), found in traditional network control systems, and a novel single-phase LVA switch. The trials were largely successful and the switch was able to be repeatedly operated using local PLC signalling from the CCU through a live LV circuit. Using mechanical operation and control concepts for a miniature vacuum switch (LVA switch), the functionality would be delivered for sectionalising LV feeders and transferring loads between secondary substations, balancing the loading on distribution transformers to minimise losses.

The trailing and validation of Power Line Carrier (PLC) signalling took place on three different sections of the Glasgow LV network. PLC communication provides a medium for the transfer of data within live circuits across electrical networks. The integration of PLC signalling into the communications architecture for the LV network removes unnecessary costs and disruption associated with the installation of additional hard-wired infrastructure. Packets of data are imposed onto a modulated carrier signal and transmitted / received through the network using PLC modems which are connected through power electronics between phase and neutral.

The PLC circuit board comprises two modems which operate at different frequencies:

- Cenelec A-band (32-95kHz)
- Cenelec BC-band (95-140kHz).

Frequency bands are selected based on transfer distances along circuits and background noise on the LV network and are optimised for signal quality by tuning the gain of the filter.

The original specification of the PLC communications was to transfer data over a maximum distance of 500m. It is anticipated that the LVA pillars will operate as 'repeaters' for PLC signals where LV feeders exceed 500m in length.

PLC communication was trialled over a short distance across a single LV phase under the IFI 0607 project and was largely successful; however, some results indicated that data transfer was not always reliable due to disturbances on the LV network. As an additional precaution, the control system in the LVA pillar was designed to support communication over radio links as an alternative medium.

Whilst the PLC testing was actually carried out under IFI funding, because it was a vital component of this LCN Fund project it is discussed in some detail in this subsection.

Radius and SP Energy Networks carried out trials of the prototype power line communication (PLC) in early 2011 at three different SP Energy Networks sites. The aim of the trials was to gain experience of using the PLC on a live network, using different Cenelec bands, communication modes, and transmission gains and to understand the types of disturbances that would be encountered. In all, 24 tests were carried out. The test sites were selected to be as representative as possible of SP Energy Networks' system so that the effects of noise and distance on the PLC could be accurately judged.

Firstly, the PLC communication was tested between two modems at a distance of less than two metres on a desk inside the SP Energy Networks building to ascertain that all of the components were functioning as expected and that the test procedure worked.

The PLC was tested with a communication distance of around 300m between modems situated at Sardinia Lane and Vinicombe Street in Glasgow. This area contains a mixture of residential and commercial properties. It was found that in this case, the Cenelec Band BC (95-140kHz) was more prone to interference, especially during office hours. Figure 4-1 shows some results from the PLC testing at Sardinia Lane using Cenelec Band A in normal mode with varying levels of gain.

The PLC was tested for a communication distance of 100m on Cedar Street in Glasgow. In this case, the testing was carried out on modems located a cable with no branches and no load, meaning that any disturbances in the communication would be induced from nearby electrical or electronic circuits. It was found that communication worked well for both Band A (32-95kHz) and Band BC (95-140kHz) if the circuit gain was set above 0dB, although Band A also worked with a gain of -6dB during the night.

The PLC was also tested for a communication distance of 500m on Hillington Industrial estate in Glasgow. It was found that both Bands were seriously affected by interference during working hours and communication was not possible.

From the tests carried out, it was found that generally Cenelec Band A in Robust mode with a gain of 6dB worked the best, but in some instances Band BC was better. Communication was not possible on the Hillington Industrial Estate due to noise and interference. Solutions suggested to overcome this problem were the use of repeaters to increase the signal-to-noise ratio, the use of a radio link between the modems, or that SP Energy Networks find the source of the disturbance and filter it. Figure 4-2 shows some results from the PLC testing at Sardinia Lane using Cenelec Band BC in robust mode with varying levels of gain

Overall, the PLC concept was proved to work: it allowed data to be transmitted and recovered, and thus could be used for control and automation of the networks. It was found that large amounts of data can be transmitted over short distances, or small amounts of data can be transmitted over long distances. It was also found that the modem bandwidth may need to be altered for different operating conditions, due to noise and interference.

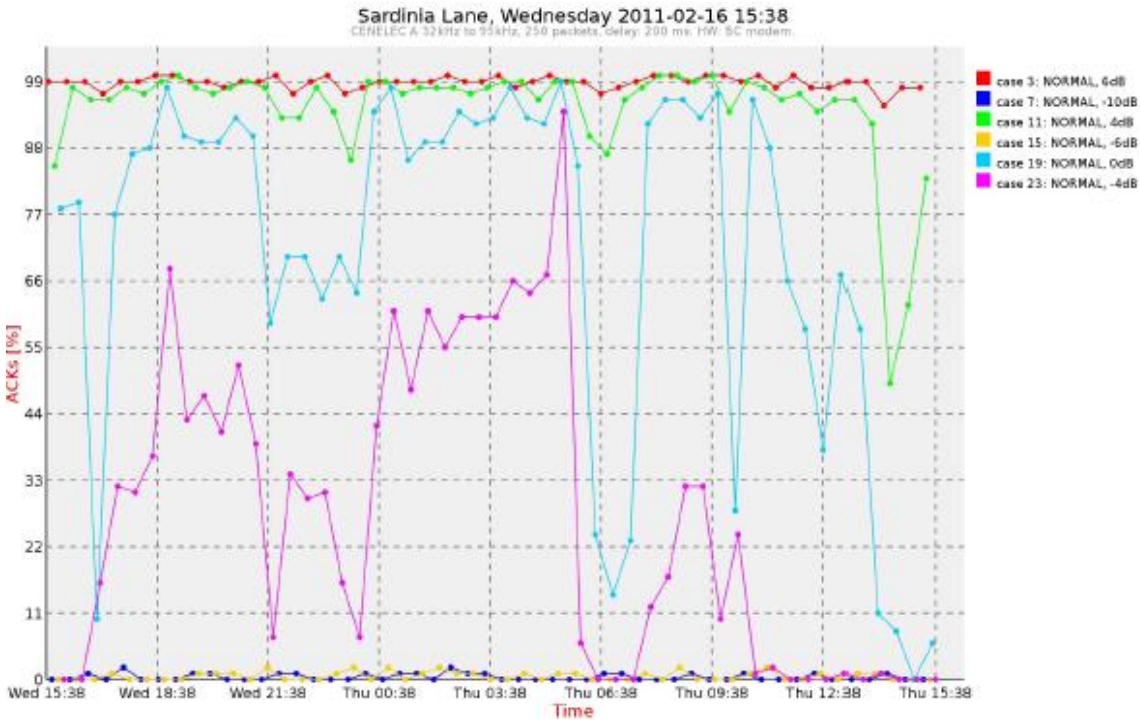

Figure 4-1 Sardinia Lane PLC testing results

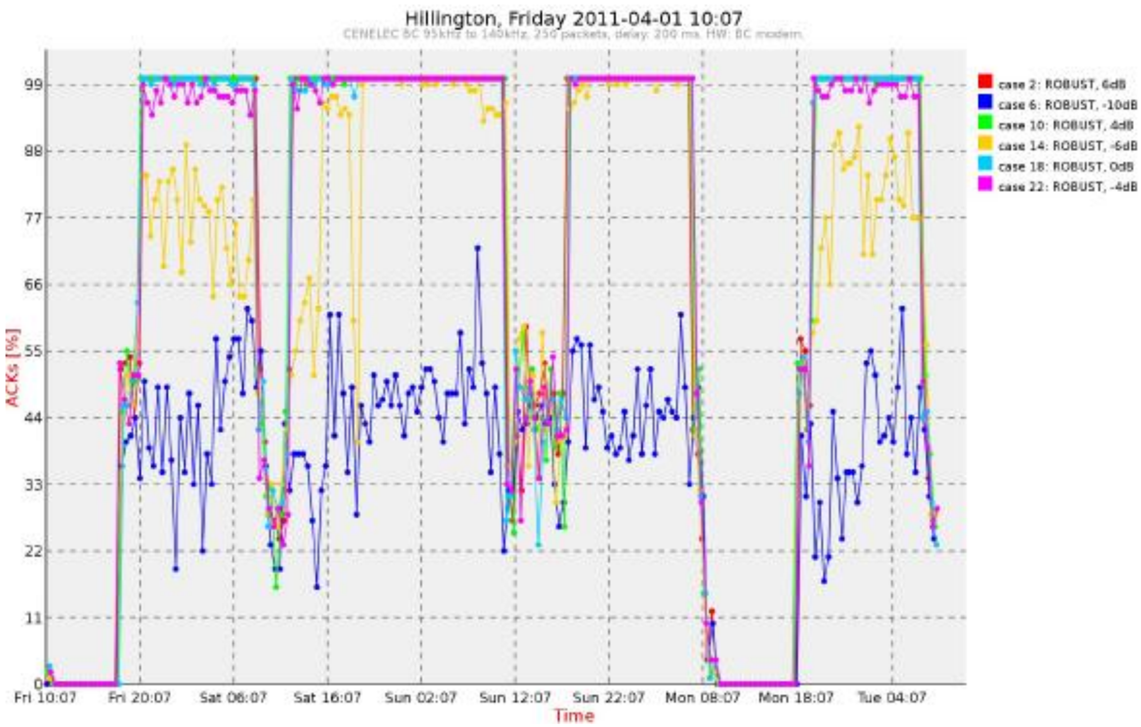

Figure 4-2 Hillington PLC testing results

Further results of the PLC testing are detailed in the Radius document 'LVA101 Power Line Communication Tests at SP Energy Networks February to April 2011' (see Appendix E).

The Clyde Gateway project has been completed in parallel with the on-going activities of the IFI project and has sought to expand on the single LVA switch / CCU prototype by introducing multiple LVA switching devices in three-phase pillar boxes, and CCUs at secondary substations for control and reconfiguration of the LV network. The project was developed in collaboration with major solutions provider, Radius.

4.1.2 Clyde Gateway: A site with major potential for trialling the proposed solutions

In 2010, the Clyde Gateway LR1 (London Road 1) site was identified as having major potential for trialling the proposed HV/LV automation solutions. This was based on the following reasons:

1. With the selection of Glasgow to host the Commonwealth Games in 2014, the Clyde Gateway area would be a high profile brown-field site, which incorporates residential and commercial redevelopment and the 'blank canvas' to develop a modern utility infrastructure. The site was expected to become a 'science park' for show-casing Smart Grid technologies.
2. The LR1 district was expected to accommodate high-tech manufacturers, who would be connected, primarily, to the LV network. This would provide a suitably variable load demand environment for trialling the HV/LV automation system technologies and generating important learning outcomes.
3. The new infrastructure would provide an ideal testing platform for the HV/LV automation system to be able to pinpoint power quality issues, associated with operation of manufacturing equipment and Smart Grid technologies.

The geographical areas of the Clyde Gateway site are shown in Figure 4-3, 4-4 and 4-5.

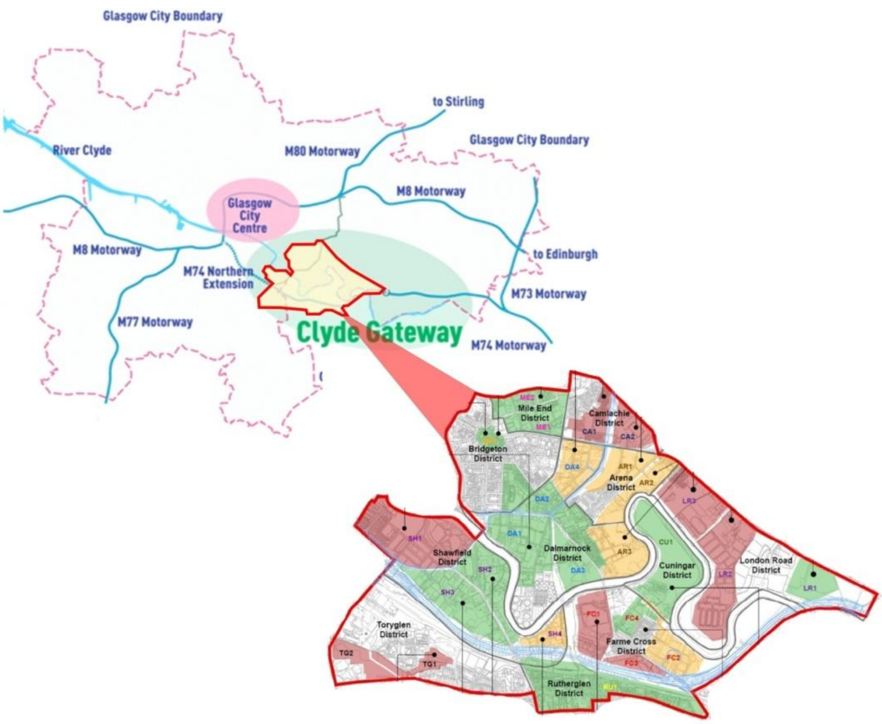

Figure 4-3 Geographical location of the Clyde Gateway site

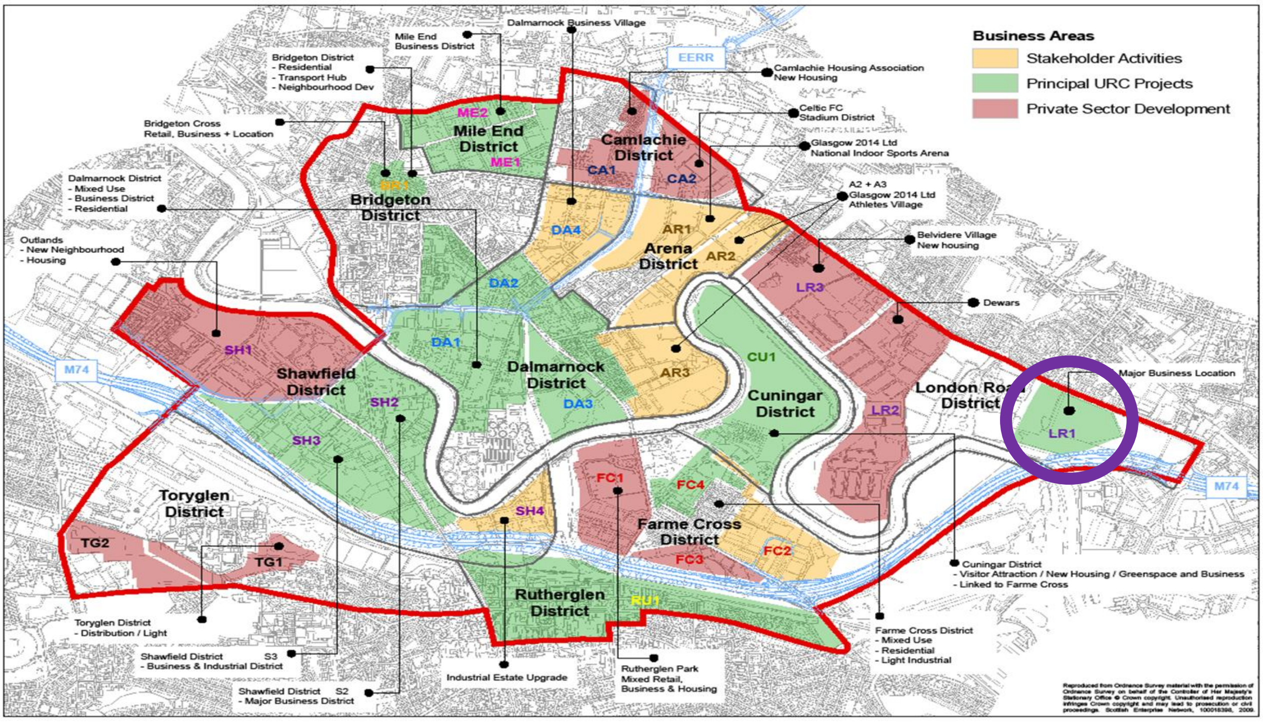

Figure 4-4 Geographical location of the LR1 district within the Clyde Gateway site

Figure 4-5 Re-development of the LR1 district within the Clyde Gateway site

4.2 Details of the Methods Trialled

Five Methods were identified for trialling in this project:

1. Voltage Optimisation: The simultaneous measurement of voltage at various points on the HV and LV network, in order to inform design and operational practices with respect to voltage limits.
2. Asset Management: The monitoring of HV circuit breaker operating times to provide a trigger for maintenance and to prevent unnecessary interruptions to supply.
3. Reduction of Losses: The deployment of the LV monitoring and automation systems, in order to identify and eliminate phase imbalance.
4. Integration of Distributed Generation: The simultaneous measurement of voltage at various points on the network, in order to inform design and operational practices with respect to the impact of generation and to allow more generation to be accommodated within the trial network.
5. Reduction of Outages: The deployment of automation and monitoring systems to reduce unnecessary outages, interruptions to customers' supplies and to identify potential network problems before faults occur.

Due to two key factors, these Methods could not be trialled at the Clyde Gateway site:

1. The lack of take-up of demand and generation in the trial area, due to the economic recession;
2. Supply chain issues with the major solutions provider, Radius, going into administration during the early stages of the LCN Fund project.

These factors are explained in more detail in the Project Outcomes (Section 5) of this report, the steps that SP Energy Networks took to progress with trials are explained in the Modifications to Planned Approach (Section 7) and the lessons learnt are captured in Lessons Learnt for Future Projects (Section 9).

4.3 Overview of the Planned Trialling Methodology

The steps of the planned trialling methodology are outlined below:

1. Conceptual design of the HV/LV automation system;
2. Production of a functional design specification for the HV/LV automation system and identification of its components;
3. Specification and identification of a trial site;
4. Development of the detailed system architecture (including the electrical infrastructure, HV/LV automation components and ICT infrastructure);
5. Detailed design of the HV/LV automation system in the trial site (specifying equipment types and quantities);
6. Procurement, installation and commissioning of the electrical infrastructure (this was part-funded by DECC's Smart Grid Capital Grant Programme);
7. Procurement, installation and commissioning of the HV/LV automation system;
8. Trialling of the five Methods, as described in Section 4.2, based on demand and distributed generation connected to the trial area;

9. Data gathering and analysis of the HV/LV automation system performance;
10. Capturing lessons learnt and recommendations on business adoption.

4.4 Methodology for the Location of Control Equipment

The control equipment is located within the LV automation pillars, the secondary substations and at the Primary Substations. Two secondary substation-based CCUs were specified under the scope of the LVA101 project, which were designed to control remotely seven LVA pillars. The substations were identified in the LR1 district under the scope of the project to demonstrate automated control of the local LV network. The CCU is designed to be contained in a wall-mounted box in the switchroom of the substation where the LV cables terminate at the LV busbars. The PLC communications hardware is connected between phase and neutral where the cable terminals meet the busbars. The control equipment is powered from the substation supply.

4.5 Methodology for the Location of LV Switching Equipment

The LV switching system is secured inside a bespoke pillar. This design provides a weather-proof enclosure and access for inspection and local data collection. The pillar conforms to the relevant standards for design and installation of LV street infrastructure.

The LV network has been newly established in accordance with the SP Energy Networks LV design policy, which provides guidance on the location of open points along feeders. The LV automation pillars have been installed where open points would normally be located in the traditional radial system. Additional LV automation pillars have been installed to provide flexibility to segregate feeders. This allows SP Energy Networks to understand the network conditions and the operation of the various loads in the LR1 area.

4.6 Methodologies for the Installation of Equipment

The LV pillar enclosures were procured during the on-going redevelopment of the Clyde Gateway site. The LV automation pillars have been installed on plinths adjacent to pavements at various locations on the network in the LR1 district. The installation of the enclosures coincided with the work programme for establishing the LV network in the LR1 district.

Delivery of the LV switching and control equipment did not materialise due to unforeseen problems with the supply chain which are discussed in more detail in Section 6. It was therefore not possible to implement any validation or testing procedures for the system.

4.7 Equipment Testing Methodologies

Factory acceptance tests and site acceptance tests were unable to be completed as the products were not finalised due to problems with the suppliers of the system. These are discussed in more detail in Section 6.

5 The Outcomes of the Project

A major outcome of this project was the successful installation of HV and LV network infrastructure on the London Road site. As a result, Steps 1 – 6 and 10 of the planned trialling methodology were successfully completed during the LCN Fund project timescales.

However, Steps 7, 8 and 9 could not be completed, due to two key factors:

1. The lack of take-up of demand and generation in the trial area, due to the economic recession;
2. Supply chain issues with the major solutions provider, Radius, going into administration during the early stages of the LCN Fund project.

Although there was potential for 74 businesses to develop on the Clyde Gateway site, only two SMEs and the site office were connected during the LCN Fund project timescales. The lack of take-up of demand and generation in the trial area was attributed to the economic recession. The site has a supply capacity of 2000 kVA (two 1000 kVA transformers). Due to lack of take up of load demand in the trial area, demand was only recorded on a single phase of one distribution transformer, representing approximately 1% of the capacity of the distribution substation and 0.5% of the potential supply capacity of the site.

Supply chain issues (with the major solutions provider, Radius, going into administration during the early stages of the LCN Fund project) resulted in significant delays to the development of the LV automation system and its integration with the HV automation system.

5.1 Overview of the Outcomes of the Project

The steps of the planned trialling methodology are outlined below:

1. Conceptual design of the HV/LV automation system;
2. Production of a functional design specification for the HV/LV automation system and identification of its components;
3. Specification and identification of a trial site;
4. Development of the detailed system architecture (including the electrical infrastructure, HV/LV automation components and ICT infrastructure);
5. Detailed design of the HV/LV automation system in the trial site (specifying equipment types and quantities);
6. Procurement, installation and commissioning of the electrical infrastructure (this was part-funded by DECC's Smart Grid Capital Grant Programme);
7. Procurement, installation and commissioning of the HV/LV automation system;
8. Trialling of the five Methods, as described in Section 4.2, based on demand and distributed generation connected to the trial area;
9. Data gathering and analysis of the HV/LV automation system performance;
10. Capturing lessons learnt and recommendations on business adoption.

Part-funded by DECC's Smart Grid Capital Grant Programme, a major outcome of this project was the successful installation of HV and LV network infrastructure on the London Road site. As a result, Steps 1 – 6 and 10 of the planned trialling methodology were successfully completed during the LCN Fund project. However, Steps 7, 8 and 9 could not be completed, due to two key factors:

1. The lack of take-up of demand and generation in the trial area, due to the economic recession;
2. Supply chain issues with the major solutions provider, Radius, going into administration during the early stages of the LCN Fund project.

5.1.1 Lack of electricity demand and generation in the trial area

Although there was potential for 74 businesses to develop on the Clyde Gateway site, only two SMEs were connected during the LCN Fund project timescales. The lack of take-up of demand and generation in the trial area was attributed to the economic recession. The site has a supply capacity of 2000kVA (two 1000kVA transformers). Due to lack of take up of load demand in the trial area, demand was only recorded on a single phase of one distribution transformer, representing approximately 1% of the capacity of the Auchenshuggle No.1 distribution substation and 0.5% of the potential supply capacity of the site.

The distribution network in the Clyde Gateway was new at the beginning of the project, so there was no existing load or generation connected to it. Due to the economic recession, there were virtually no customers (consumers or generators) wanting to connect to the new Clyde Gateway area network. This meant that it was not possible to test the proposed automation system for identifying and eliminating phase imbalance, accommodating distributed generation, or monitoring potential faults to reduce outages.

5.1.2 Supply chain issues delaying the development of the solution

Supply chain issues (with the major solutions provider, Radius, going into administration during the early stages of the LCN Fund project) resulted in significant delays to the development of the LV automation system and its integration with the HV automation system.

Radius, the company that developed the communication and control system went into administration shortly after carrying out the PLC testing. This obviously had an adverse impact on the project. Radius was then acquired by another company, Netcontrol. Some of the staff, familiar with the project, were lost during the acquisition, resulting in a lack of continuity. Further staff were recruited and significant rework of the equipment was then undertaken by Netcontrol. Coupled with the issues relating to the EPS prototype this resulted in an 18-month delay. No further testing on the communications and control part of the project was possible during the LCN Fund project timescales. The remit of Radius was, originally, to integrate and provide the complete HV/LV automation solution (including the PLC communications solution and the LV switch solution). However, after Radius went into administration, SP Energy Networks worked directly with EPS (the manufacturer of the LV switch) to develop this solution through the IFI funding mechanism.

5.2 Detailed Project Outcomes

The following sections provide the detailed project outcomes resulting from the implementation of each step of the trialling methodology.

5.2.1 Conceptual design of the HV/LV automation system

The HV / LV automation system is intended to provide intelligent control to determine the location of normally open points on the HV / LV network to maximise the performance of the network for customers. The application of the automation technology will significantly improve the reliability of HV and LV networks, delivering better performance to customers in terms of a reduction in regulatory customer minutes lost (CMLs).

The installation of power quality monitoring devices, and analysis of the results, could increase the asset life of circuit elements. Furthermore, benefits are realised by DNOs in both cost and time reductions during fault finding operations.

The three conceptual stages of the HV/LV automation system design are given in Figure 5-1, resulting in the development of a 'Smart Network'.

Stage 1 represents a traditional network design with distribution substations A and B connected to the existing distribution network and supplying customers' loads along LV radial feeders. As part of the system, the HV substations A and B are equipped with infrastructure to provide full automation functionality.

In Stage 2, the LV network is looped and meshed to provide alternative routes for power supplies to customers' loads if a fault occurs on an LV feeder. In addition, LV automation pillars are installed to allow each load customer to be sectionalised, in the case of network faults, and to allow automated load transfers to take place in the network during normal operation.

In Stage 3, the novel system accommodates increased levels of low carbon technologies (LCTs) in the form of load demand, generation and storage.

5.2.2 Functional design specification for the HV/LV automation system

The functional design specification for the HV/LV automation system was developed, based on the voltage level of the system components.

5.2.2.1 Primary substation components

Three system components were specified for installation in primary substations (33kV / 11kV) on the HV (11kV) side of the substation:

1. Power quality devices, with the function to monitor voltages, currents, harmonics, sequence components and to allow SP Energy Networks to assess the operating times of HV circuit breakers;
2. Remote terminal units (RTUs), with the function of providing a radio communications link between a Primary substation (33kV / 11kV) and a secondary substation (11kV / 0.4kV) for data transfer, and for communicating data to SP Energy Networks' SCADA system;
3. Central control units (CCUs), with the function to monitor the data transferred from the RTU and control the HV circuit breaker in the primary substation.

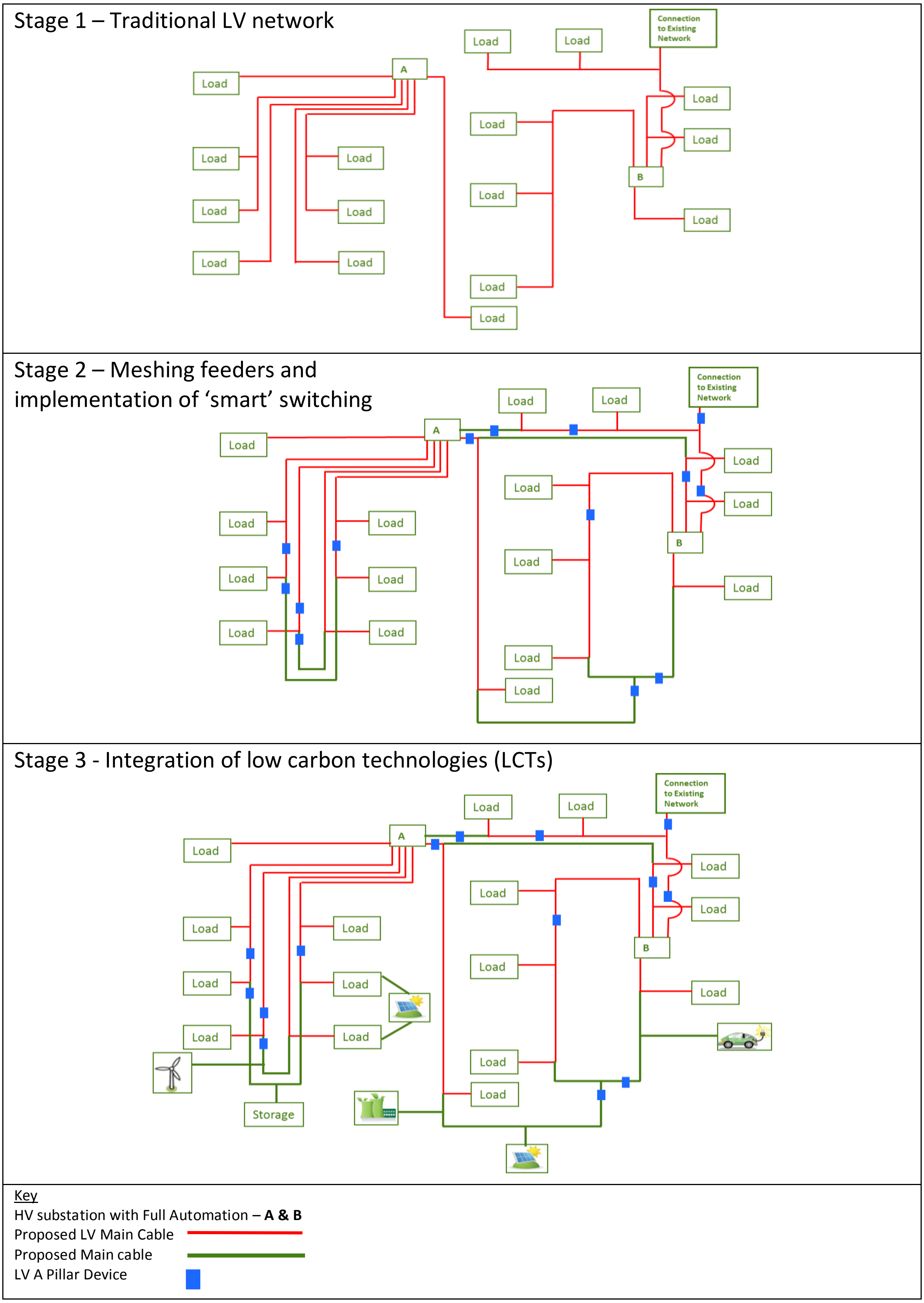

Figure 5-1 'Smart' network development

5.2.2.2 Secondary substation components

Six system components were specified for installation in secondary substations (11kV / 0.4kV):

1. Network controllable points (NCPs), with the function to allow HV circuit breakers to be remotely and automatically switched;
2. Remote terminal units (RTUs), with the function of providing a radio communications link between a secondary substation (11kV / 0.4kV) and a primary substation (33kV / 11kV) for data transfer;
3. Central control units (CCUs), with the function to monitor the data transferred from the RTU, PLC and to control the HV circuit breaker in the Secondary substation;
4. Power line carrier (PLC) communications, with the function of providing a PLC communications link between the secondary substation and the LV pillars;
5. Advanced maximum demand indicators (ADMIs), located in LV distribution boards, with the function of monitoring voltages and currents in real-time, as well as digitally recording peak values;
6. Power quality monitoring devices, with the function of monitoring the impact of smart technologies and devices on power quality.

5.2.2.3 LV automation (LVA) pillar components

Three system components were specified for installation in LV automation (LVA) pillars:

1. Power line carrier (PLC) communications, with the function of providing a PLC communications link between the LV pillars and the secondary substation;
2. Three single-phase LV switches, with the function of remote and automatic switching to change the topology of the LV network;
3. Fault-finding devices, using time domain reflectometry to pinpoint the location of disturbances in the network.

The LV automation pillars provide a broad solution for remote switching units which can be deployed on three-phase LV networks. An LVA pillar comprises the following equipment:

- Weather-proof metal pillar enclosure;
- Three single-phase LVA switches;
- Control system for operating LVA switches, communications and monitoring network conditions;
- Interface panel with local / remote control, manual override buttons and status indicators for the switches;
- Power supply unit (connected to local 240V electrical phase with transformation to supply electronics);
- Battery for backup power supply.

The LVA switch, which was developed and prototyped by EPS under the IFI project is designed to switch single-phase load currents, and has a continuous rating of 400A.

The switch is able to interrupt currents of up to 2kA for a period of less than 3 seconds, beyond which the switch is protected by a fuse. The switch has a maximum short circuit current withstand capability of 8kA, although EPS have been developing a device which has the full 16kA operating capability required by DNOs.

The LVA switch can be split into two major parts, mechanical and electrical. The mechanical part comprises a capsule enclosure which accommodates a vacuum switch, a fuse and the power electronics required to operate a magnetic actuator. The electronics comprises several circuit boards which operate the vacuum switch and provide interfaces to the main control circuitry.

The functional design specification of the LV automation system is given in Appendix C.

5.2.3 Specification and identification of a trial site

In 2010, the Clyde Gateway LR1 (London Road 1) site was identified as having major potential for trialling the proposed HV/LV automation solutions. This was based on the following reasons:

1. With the selection of Glasgow to host the Commonwealth Games in 2014, the Clyde Gateway area would be a high profile brown-field site, which incorporates residential and commercial redevelopment and the 'blank canvas' to develop a modern utility infrastructure. The site was expected to become a 'science park' for show-casing Smart Grid technologies.
2. The LR1 district was expected to accommodate high-tech manufacturers, who would be connected, primarily, to the LV network. This would provide a suitably variable load demand environment for trialling the HV/LV automation system technologies and generating important learning outcomes.
3. The new infrastructure would provide an ideal testing platform for the HV/LV automation system to be able to pinpoint power quality issues, associated with operation of manufacturing equipment and Smart Grid technologies.

The planned redevelopment zones of the London Road District, within the Clyde Gateway site, are given in Figure 5-2.

Figure 5-2 Re-development of the LR1 district within the Clyde Gateway site

5.2.4 Development of the detailed system architecture

This section describes the system architecture, communications architecture, software and control architecture and system data requirements.

5.2.4.1 System architecture

Based on the functional design specifications of the HV/LV system components and the specification of the London Road District for the trial site, the detailed system architecture was developed and is given in Figure 5-3.

The project encompasses two newly established secondary substations (Auchenshuggle No.1 and No.2) and the associated HV and LV networks. The LV network was developed with 300mm^2 main cables throughout the network, which are larger, in sections, than the traditional tapered design. This is a smart network enabler, facilitating the auto-sectionalising and load transfer functions of the LV automation system. The substations are looped into an existing 11 kV circuit which interconnects Eckford Street and Maukinfield Road Primary Substations. The area is supplied from SP Energy Networks' 33kV distribution system.

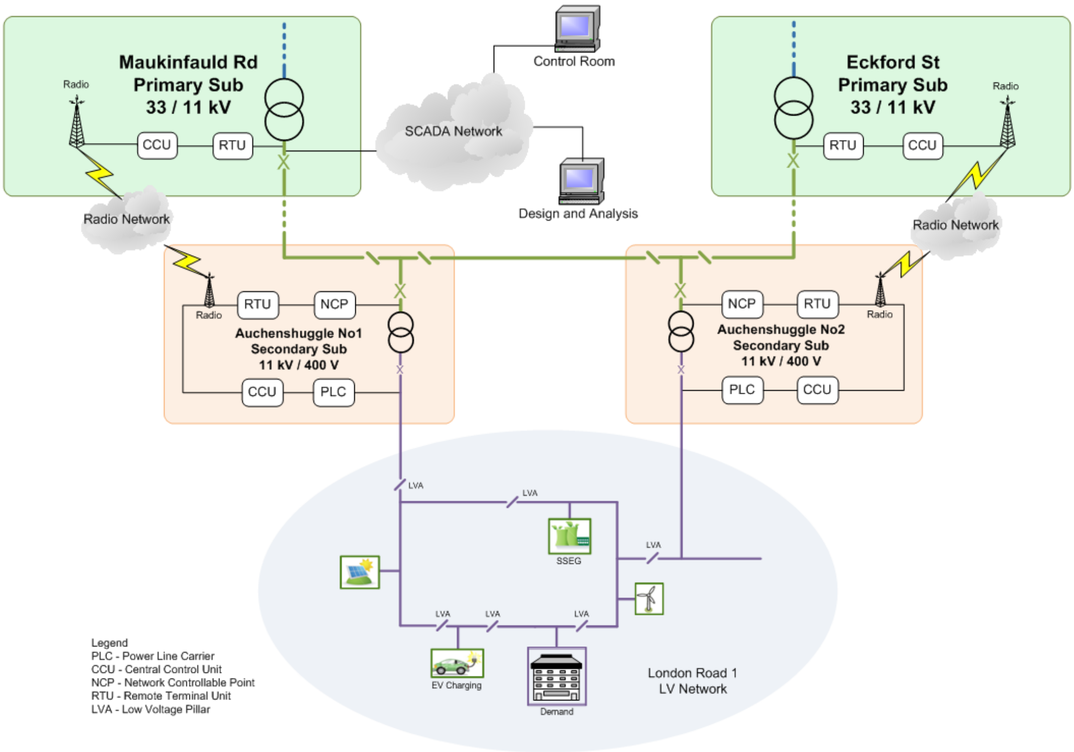

Figure 5-3 HV / LV automation system architecture

The architecture of the original LVA071 prototype system has been extended to include several three-phase switching units and a centralised control system for use by control engineers. To achieve this, LVA pillars would be installed at various points on the LR1 LV network. The pillar provides a weather-proof enclosure for measurement devices, communications equipment LVA switches, one switch per phase. The LV cables which interconnect the secondary substations are terminated at the switches, which act as remotely operated normally open points to provide flexible reconfiguration of the network. Power quality recording equipment is also installed in the Primary and Secondary substations.

The two secondary substations accommodate central control units (CCUs) to monitor activity on the LV network communicated from the LVA pillars and transfer data back to CCUs at the primary substations. The LVA pillars and the secondary substations communicate via power line carrier (PLC) signalling, and the data transfer to the primary substations is via radio links. The CCU at the primary substation has an integrated touchscreen HMI and an interface to the SCADA network.

5.2.4.2 Communications architecture

The system utilises three communication mediums for data transfer between the LV network and the control room. The setup is as follows:

- LVA Pillar -> Secondary substation (PLC communication)
- Secondary substation -> Primary substation (Radio link)
- Primary substation -> Control room (SCADA network)

PLC communication provides a medium for the transfer of data within live circuits across electrical networks. The integration of PLC signalling into the communications architecture for the LV network removes unnecessary costs and disruption associated with the installation of additional hard-wired infrastructure. Packets of data are imposed onto a modulated carrier signal and transmitted / received through the network using PLC modems which are connected through power electronics between phase and neutral.

The PLC circuit board comprises two modems which operate at different frequencies:

- Cenelec A-band (32-95kHz)
- Cenelec BC-band (95-140kHz).

Frequency bands are selected based on transfer distances along circuits and background noise on the LV network and are optimised for signal quality by tuning the gain of the filter.

The original specification of the PLC communications was to transfer data over a maximum distance of 500m. It is anticipated that the LVA pillars will operate as ‘repeaters’ for PLC signals where LV feeders exceed 500m in length.

PLC communication was trialled over a short distance across a single LV phase under the IFI project and was largely successful, however some results indicated that data transfer was not always reliable due to disturbances on the LV network. As an additional precaution the control system in the LVA pillar was designed to support communication over radio links as an alternative medium.

Radio communications between the primary and secondary substations for access to the SCADA network are considered an extension of the scope of the project, for future implementation.

5.2.4.3 Software and control architecture

The overall design of the control system is such that the reconfiguration of the LV network is discrete and can be observed from SP Energy Network’s control room with little or no manual intervention.

The LV automation control architecture of the system is presented in Figure 5-4. The system can be extended to include a radio link to the primary substation to facilitate interfacing with the SCADA network.

The content of the data transmitted over PLC from the LVA pillar to the CCU is as follows:

- Electrical parameters (maximum voltage, current and real / reactive power)
- Position of switches (open / closed)

Similarly, the reverse flow from the CCU to the pillar is as follows:

- Control signals (for operation of switches)

The system was designed such that the software could be loaded into the CCU at the secondary substation and pushed to downstream hardware at the LVA pillars. This provides a fully automated solution without requiring the operator to visit the remote LVA pillars.

In addition to the software control the system design incorporates additional control features:

- Local connections at the substation-based CCUs for software upgrades;
- Local connections at the LVA pillars for data collection and monitoring;
- Interfaces at the LVA pillars and substation-based CCUs for manual intervention (i.e. switching).

5.2.4.4 System data requirements

In order to achieve the success criteria, the HV/LV automation systems require measurements to be sampled from the HV and LV networks in real-time.

The flow of data is from the measuring equipment in the LVA pillars to the CCU at the secondary substation. The LVA pillar stores a permanent log of the data which can be accessed via a serial link connected to a mobile PC.

Advanced maximum demand indicator (ADMI) metering units were installed to feed measurements into the control system. The units include current transformers (CTs) and voltage transformers (VTs) to measure voltage and current at the live cable terminals of the LV distribution board in the secondary substation.

Power quality recording units, installed in the primary and secondary substations, provide the following measurements for the HV / LV automation system:

- Voltage;
- Frequency;
- Current;
- Harmonics;
- Flicker.

The intention was to record the information over a trial period of two years, for off-line analysis, to develop an understanding of the performance and influence future LV network design.

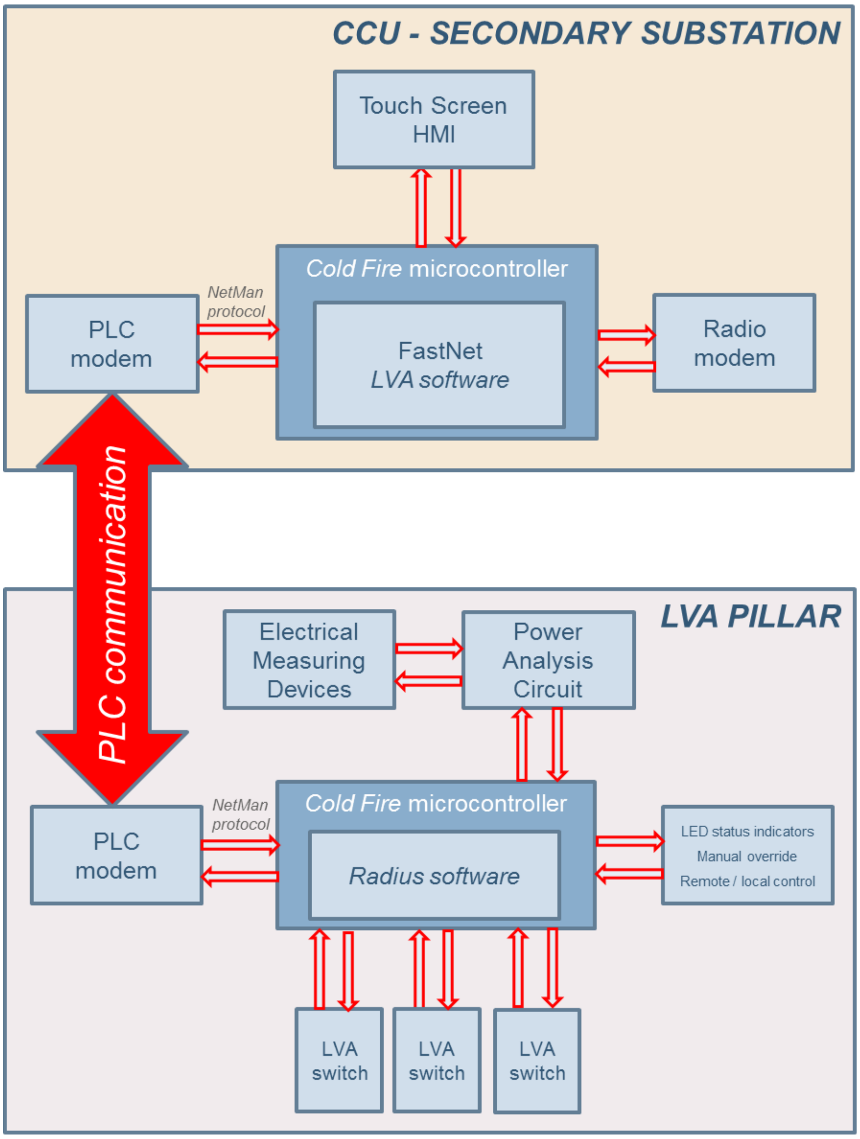

Figure 5-4 LVA control architecture

5.2.5 Detailed design of the HV/LV automation system in the trial site

The secondary substation locations, the HV and LV cable routes and the LV automation pillars locations were specified, as given in Figure 5-5.

In total, seven LV automation pillars were installed on the pavements in the London Road site. The location of LV automation pillars was specified in order to provide the functionality to sectionalise the LV demand customers on the London Road site.

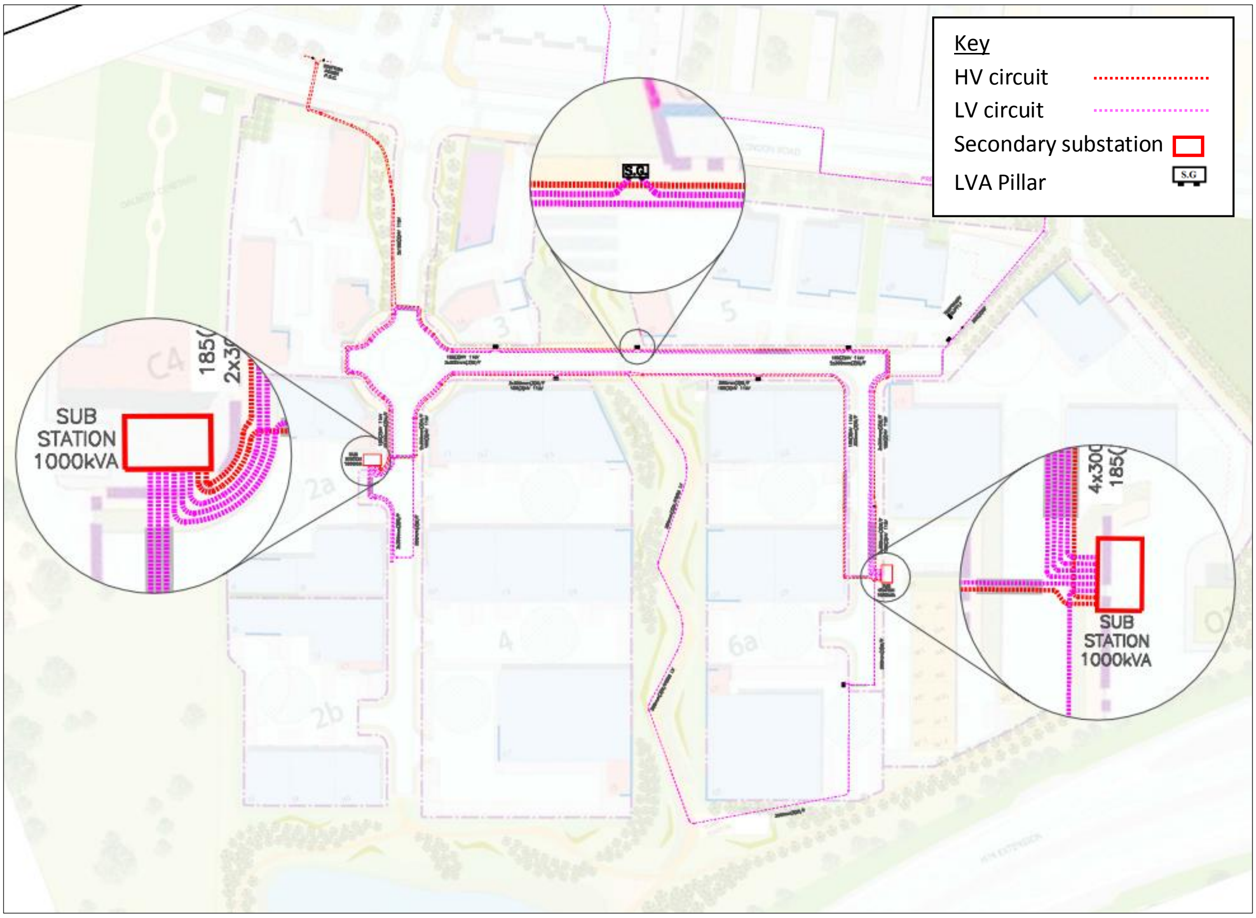

Figure 5-5 Layout of the HV and LV network within the LR1 district

5.2.6 Procurement, installation and commissioning of the electrical infrastructure

Part-funded by DECC's Smart Grid Capital Grant Programme, a major outcome of this project was the successful installation of HV and LV network infrastructure on the London Road site. Auchenshuggle 11/0.4kV Substations 1 and 2 were installed to supply the London Road LV network (as shown in Figure 5-5). Also, in total, seven LV pillars were installed at the Clyde Gateway site along with all of the associated cable work. The installed pillars can house three single-phase switches and communications and monitoring equipment, with associated controls systems for operating them.

Figure 5-6 shows the LVA Pillars at different stages: 5-6a shows a pillar in the factory prior to installation on site; 5-6b shows a pillar during installation on site; 5-6c shows a complete pillar as installed on the Clyde Gateway network.

a) Prior to installation | b) During installation | c) Complete pillar installed

Figure 5-6 LVA Pillars

Figure 5-7 shows Auchenshuggle 11/04kV secondary substation both during installation and as the substation is now, operational on the network.

a) Substation during installation | b) Operational substation

Figure 5-7 Auchenshuggle 11/0.4kV Secondary Substations

Figure 5-8 presents a single-line diagram of the SPEN distribution network in the east of Glasgow. The diagram shows how the secondary substations and LV network installed as part of this LCN Fund project are connected to the rest of the distribution network.

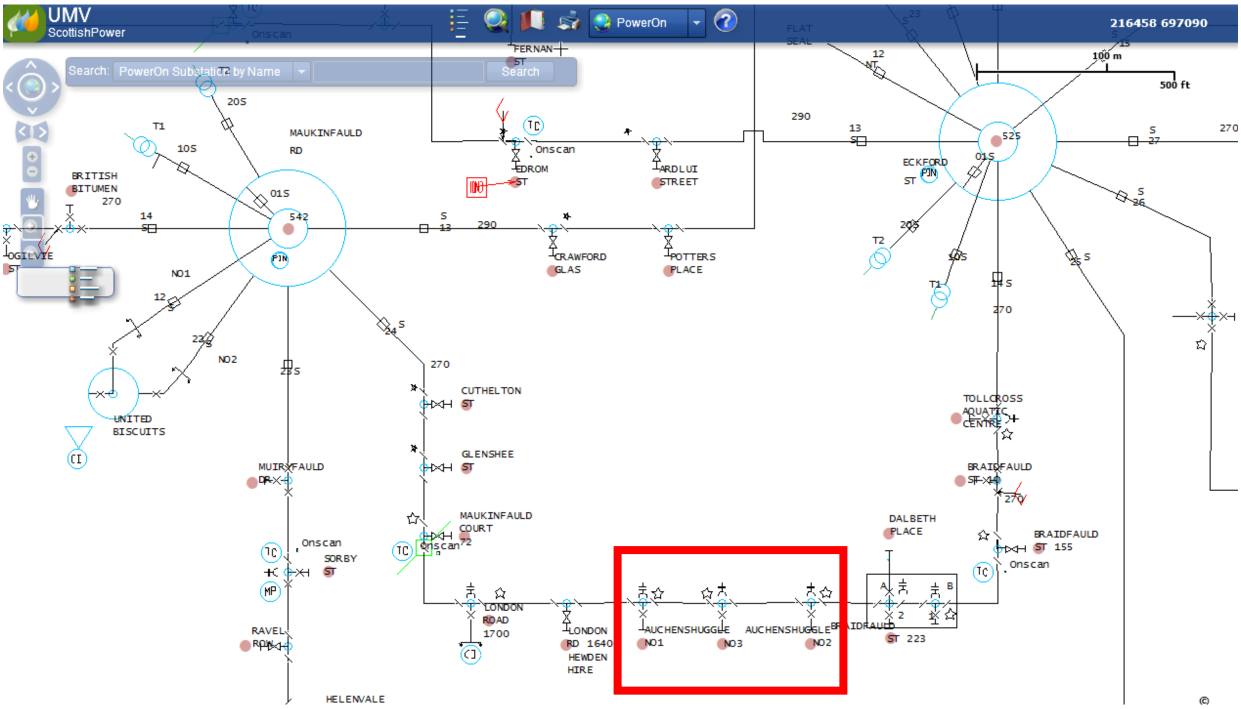

Figure 5-8 Single-line diagram of distribution network in Glasgow, incorporating the Clyde Gateway site

5.2.7 Procurement, installation and commissioning of the HV/LV automation system

The following suppliers were identified for provision of the complete HV / LV automation system and its components:

- Ametek, supplying the quality monitoring devices for installation in the Primary Substations;
- Radius, supplying the CCUs and PLC communications solution, and sub-contracting EPS to provide the LV automation switch;
- Schneider, supplying the LV distribution board with advanced maximum demand indicators (AMDIs);
- EMS, supplying Sub.net units for monitoring the impact of smart devices on the power quality of the HV network;
- Kehui, supplying TP22 fault-finding devices for pinpointing the location of disturbances and faults using time domain reflectometry (TDR).

Other equipment, such as the RTUs and NCP infrastructure, was procured through SP Energy Networks' established supply chain.

An example Bill of Materials for the HV/LV automation system is given in Appendix D.

The Ametek power quality monitoring devices were procured and successfully installed in the Maukinfauld and Eckford Street Primary Substations.

The Schneider LV distribution boards, with the ADMIs, were procured and successfully installed in the Secondary Substations (Auchenshuggle No.1 and No.2).

5.2.8 Trialling of the HV / LV automation methods

As seen in Figure 5-9 and Table 5-1, despite the potential for re-development at the Clyde Gateway site, only two SMEs connected to the site.

The site has a supply capacity of 2000kVA (two 1000kVA transformers). Due to lack of take up of load demand in the trial area, demand was only recorded on a single phase of one distribution transformer, representing approximately 1% of the capacity of the Auchenshuggle No.1 distribution substation and 0.5% of the potential supply capacity of the site.

Table 5-1 Potential and actual load demand customers at the Clyde Gateway LR1 site

Type of Premises	Number of Units	Number of Units Occupied to Date
Business Centre	1	1
Commercial/Office Unit	12	0
Industrial Unit	28	2
Workshop	30	0
Workshop Office	3	0
Total	**74**	**3**

Figure 5-9 Aerial view of the Clyde Gateway site at the project close down

Figure 5-10 is a photograph showing the units that are occupied at the Clyde Gateway site. Figure 5-11 shows a photograph of a meter installed at the Auchenshuggle No.1 Secondary Substation. The meter is showing the peak demand on each phase of the LV network at LR1. It can be seen that there is a peak demand of 2 Amps on Phase A, 2 Amps on Phase B and 30 Amps on Phase C.

Figure 5-10 Photograph showing Clyde Gateway occupancy

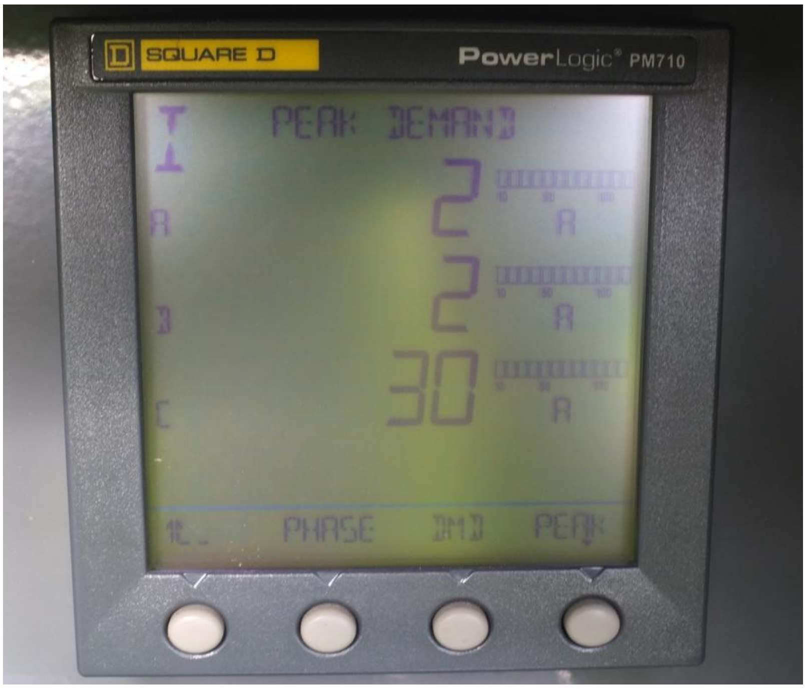

Figure 5-11 Maximum demand at Auchenshuggle No.1 Secondary Substation

Due to the lack of demand and distributed generation connected to the trial area, the five different HV / LV automation Methods, planned for trialling in this project, could not take place.

There were no faults at the Maukinfauld and Eckford Street Primary Substations, during the timescales of the LCN Fund project; therefore, it was not possible to monitor the speed of operation of the HV circuit breakers at these locations.

Alternative trial locations were identified by SP Energy Networks for the sub.net units supplied by EMS.

5.2.9 Data gathering and analysis of the HV/LV automation system performance

The recording of parameters was not developed or trialled during this project due to the lack of generation and demand data, resulting from a very low customer uptake on the network. However, it is felt that, as the communications and control parts of the project proved successful at IFI level, parameter recording would have been straight forward to carry out, had there been a need for it.

For instance, equipment was installed to monitor the operating time of circuit breakers when clearing faults. However, as there was very little network uptake by customers, and since no faults occurred during the lifetime of the project, it was not possible to monitor or record circuit breaker operating times.

5.2.10 Capturing lessons learnt and recommendations on business adoption

The lessons learnt from this project are given in Section 9. Since the trials did not progress as far as intended, SP Energy Networks does not have immediate plans to adopt the LV automation system into its Business as Usual operations. The maturity of alternative LV automation technologies has increased, significantly, during the timescales of this LCN Fund project. Therefore, SP Energy Networks has aspirations to utilise these technologies, and build on the learning from other DNOs, to demonstrate and implement HV/LV automation solutions in the future.

5.3 Technology Readiness Levels

The power quality monitoring devices and advanced maximum demand indicators that were installed at the primary substations were already well developed.

The PLC communications and CCU devices developed under the IFI 0607 project 'LV Network Automation' and the IFI 1006 and 0409 'LV Fault Location' projects require further development and trialling before they are suitable technologies for deployment in the HV/LV automation system.

The architecture used to integrate and control all of the monitoring and control equipment was developed through this project from the initial concept and design stage to being fully operation and deployed on the network.

The LVA fuse switch, supplied by EPS was developed from a prototype to the level of almost being ready to install on the network. The reasons why the LVA fuse switch was not fully functioning and deployed on the network during this project are described in detail in Section 7 (Modifications to the planned approach).

The TRLs of the HV/LV automation system and its components are summarised in Table 5-2.

Table 5-2 TRLs of the HV/LV automation system and its components

Technology	Function	TRL at project start	TRL at project completion
PLC solution	HV / LV communications	5	5
LV switch	Load transfer and sectionalising	5	8
CCU	System control	5	5
Sub.nets	Power quality monitoring	5	8
TP22s	Fault finding	5	5
HV/LV automation system	**Various functions**	**5**	**5**

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

Due to the economic recession and supply chain issues, there was not the envisioned development of smart grid technologies (generation, demand and storage) at the trial site. Therefore, due to circumstances outside of SP Energy Networks' control, the project did not completely fulfil the aim of integrating smart grid technologies into a conventional network.

The HV/LV automation system architecture was developed in this project. The architecture is, conceptually, very sound and desirable, providing a useful reference guide for other DNOs.

The project succeeded in delivering the installation and integration of the HV and LV network infrastructure, providing an automation-ready distribution system. During the project, practical experience was gained by SP Energy Networks in the development of HV/LV network infrastructure and automation systems.

This project has succeeded, greatly, in informing the industry and supply chain of smart grid challenges. The following key points are noted:

- Judicious site selection is required for trialling new technologies. External factors, on which the success of the project relies, need to be identified and managed effectively by the DNO and contingency measures need to be put in place for the key deliverables on the critical path of the project.
- Judicious selection of project partners is required and early warning signs of supplier difficulties should be identified.
- Through this project and the fore-running IFI projects, the industry is informed that the effective monitoring, control and automation of LV networks is possible. It is possible to install effective communications across LV networks and that the necessary LV infrastructure and power quality monitoring devices are available on the market. However, further development is required to deliver a fully functioning LVA switch with full automation and interruption capabilities.
- The costs and efforts on the DNOs' part, associated with the integration of smart grid technologies into LV networks, do not outweigh the benefits at presents.

Due to the lack of take up of demand and generation in the trial area, the Clyde Gateway project did not produce any reportable outcomes against its original success criteria.

In this chapter, the performance of the project is assessed against the original aims and objectives, and against the original success criteria.

Based on the planned trialling methodology in Section 4, and the outcomes in Section 5, the Clyde Gateway brown-field site was developed with the necessary HV and LV network architecture to support the automation trials. However, due to supply chain issues, the complete HV / LV automation solution was not available to SP Energy Networks within the project timescales.

Moreover, in order to demonstrate the benefits of the automation solution, the trials were reliant on the connection of a sufficient number of demand and generation customers into the new LV network in the LR1 District. The required number of connections did not materialise during the project timescales and, therefore, the benefits of this project were not fully realised.

Despite the project not fulfilling all of its initial aims and objectives, several positive outcomes can be drawn from this project. As well as the successful communications and automation testing at IFI level, on which this project was based, the project succeeded in delivering the installation and integration of the HV and LV network infrastructure, providing an automation-ready distribution system. Furthermore, power quality monitoring equipment has been installed at two Primary Substations which will supply between 50-60% of the load demand of the Commonwealth Games in 2014.

6.1 Project Performance Relative to its Aims and Objectives

The project partially succeeded in delivering some of the intended outputs to fulfil the original project objectives. This section evaluates the project performance against its original aims and objectives.

Aim 1 - Integration of different smart grid technologies in a conventional network

Due to the economic recession there was not the envisioned development of smart grid technologies (generation, demand and storage) at the trial site. Therefore, due to circumstances outside of SP Energy Networks' control, the project did not completely fulfil this aim.

Aim 2 - Assist with the development of efficient and effective solutions

The project succeeded in developing the architecture for the HV/LV automation system. The HV/LV automation system is conceptually very sound and desirable, providing a useful reference guide for other DNOs.

In addition, the HV and LV electricity network infrastructure was installed at the London Road site. If the need case returns, and new low carbon technologies are connected at the Clyde Gateway, the electricity network infrastructure is already in place to accommodate demand and generation, and new HV/LV automation solutions could be efficiently and effectively trialled on the site. Overall, the project has assisted with the development of efficient and effective HV/LV automation solutions in a limited way.

Aim 3 – Provide learning outcomes on smart grid infrastructure, design standards, network voltages and utilisation of assets

During the project, practical experience was gained by SP Energy Networks in the development of HV/LV network infrastructure and automation systems. However, the development of design standards and the learning related to network voltages and utilisation of assets did not take place.

Due to the lack of take up of load demand in the trial area and the issues with the supply chain of Smart Grid solutions, this project has resulted in extremely valuable lessons for other DNOs. These lessons are detailed in Section 9.

Aim 4 – Inform industry and the supply chain of smart grid challenges and solutions

This project has succeeded greatly in informing the industry and supply chain of smart grid challenges and, to an extent, solutions.

The following key points are noted:

- Judicious site selection is required for trialling new technologies. External factors, on which the success of the project relies, need to be identified and managed effectively by the DNO and contingency measures need to be put in place for the key deliverables on the critical path of the project. Installing the network infrastructure on a brown-field site is much easier and less disruptive to customers and the general public than in an established network and developed environment. However, brown-field sites have the distinct disadvantage of relying on customers connecting to the network once it is complete. There was not the anticipated customer uptake at the London Road 1 site, and this had a significant effect on the project.
- Through this project and the fore-running IFI projects, the industry is informed that the effective monitoring, control and automation of LV networks is possible. It is possible to install effective communications across LV networks and that the necessary LV infrastructure and power quality monitoring devices are available on the market. However, further development is required to deliver a fully functioning LVA switch with full automation and interruption capabilities.
- Through SP Energy Networks' collaboration with various project partners (Radius, Netcontrol, and EPS) it was found that the required skills, knowledge and fully functioning equipment for LV network monitoring, control and automation is not always readily available, and that development work in these areas is still needed. Therefore, judicious selection of project partners is required and early warning signs of supplier difficulties should be identified.
- It was also found that the costs currently associated with LV monitoring, control, and automation outweigh the benefits that can be gained from the system deployment.

6.2 Project Performance Relative to its Success Criteria

This section evaluates the project performance against its original success criteria, as described in the Project Registration Pro-forma.

The trialling of the following five Methods formed the Success Criteria of this project:

- Criterion 1 – Voltage Optimisation
- Criterion 2 – Asset Management
- Criterion 3 – Reduction of Losses
- Criterion 4 – Accommodation of Distributed Generation
- Criterion 5 – Reduction of Outages

SP Energy Networks was unable to trial these Methods at the Clyde Gateway site due to the two key factors, as cited previously:

1. The lack of take-up of demand and generation in the trial area, due to the economic recession;
2. Supply chain issues with the major solutions provider, Radius, going into administration during the early stages of the LCN Fund project.

As a result, the Clyde Gateway project did not produce any reportable outcomes against these success criteria.

7 Required Modifications to the Planned Approach During the Course of the Project

The following modifications were required during the course of the project:

- Replacement of the major solutions provider;
- Development of the LV automation switch through the IFI mechanism;
- Re-evaluation of the trial network location;
- Relocation of the power quality recording equipment.

The following modifications were required during the course of the project:

- Replacement of the major solutions provider;
- Development of the LV automation switch through the IFI mechanism
- Re-evaluation of the trial network location;
- Relocation of the power quality recording equipment.

Each of these modifications is described in more detail in the sections that follow.

7.1 Replacement of Major Solutions Provider

SP Energy Networks collaborated closely with Radius throughout the IFI project prior to the Clyde Gateway LCN Fund project. Under the IFI scheme Radius was responsible for the technical development, manufacturing and validation of a prototype LV automation system, consisting of one LVA CCU and one single phase LVA switch. Radius were commissioned by SP Energy Networks under the Clyde Gateway LCN Fund project to further develop this system by trialling multiple LVA switched in three-phase link boxes and multiple CCUs to implement wider radial LV network automation.

Radius went into administration during the early course of the LCN Fund project and was subsequently acquired by Netcontrol in September 2011. Radius's project responsibilities prior to the acquisition were assumed by Netcontrol who possess similar experience in developing automation and communication solutions. However, the continued development of the HV/LV automation system was not initially possible whilst Netcontrol reconstructed Radius. Moreover, there was a loss of some of the project personnel during the acquisition, which resulted in further delays until suitable replacements could be procured. As described in the following section, SP Energy Networks continued to demonstrate and develop the LV automation switch, working directly with the supplier, EPS, who was originally sub-contracted to Radius.

7.2 Development of the LV Automation Switch through the IFI

The development of the LV automation switch through the IFI mechanism was a modification to the project. Originally, Radius was procured to provide the complete HV / LV automation system integration, based on PLC communications and controllable LV switching technologies. Radius sub-contracted EPS to deliver the working prototype of the LV automation switch. The Clyde Gateway LCN Fund project dovetailed with preceding IFI projects in order to accelerate the development of technologies in the low carbon sector.

The scope of the IFI 0607 project "LV Network Automation" was to communicate from a control point to an LV automation switch via the PLC communication technique, and to validate the mechanical behaviour and control of the magnetic vacuum switch. The PLC technology was demonstrated and tested, proving it was fit-for-purpose for use in the Clyde Gateway network. The concept of the LV automation switching unit was proven, with a prototype constructed from 3-D printing technologies.

During the IFI project, it was found that the actuator component of the mechanism developed by EPS to control the switch did not work as required, and that no actuators on the market were fit for purpose. This has led to manufacturers trying to develop actuators that could be used in conjunction with such a switch for network automation. An image of the LVA fuse switch developed in this project is shown in Figure 7-1.

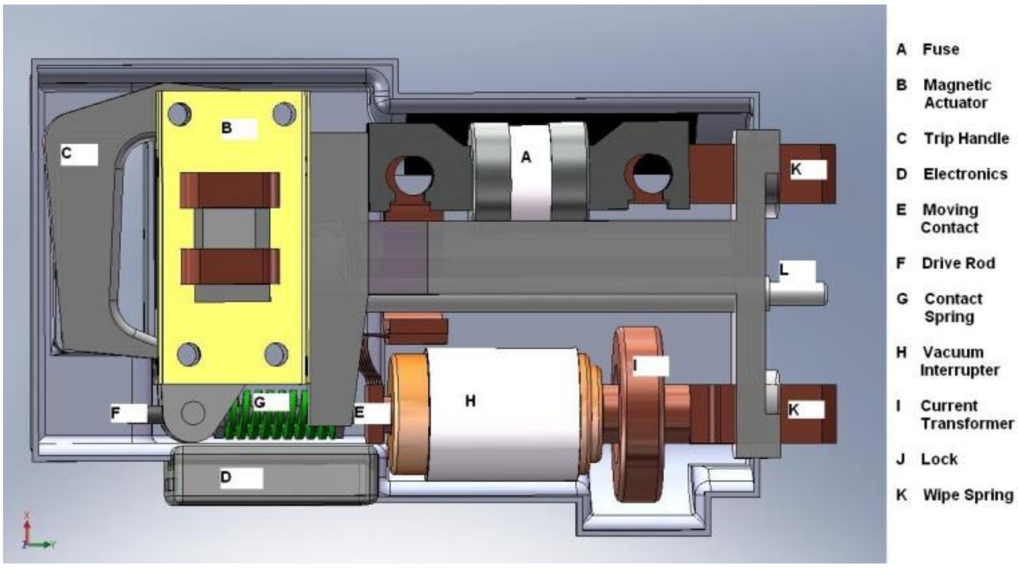

Figure 7-1 Detailed design of the LV automation switch

The main problem with the EPS switch mechanisms, which were trialled, was that they were produced by means of 3-D printing, rather than being of a moulded manufactured type. The prototype switch is shown in Figure 7-2.

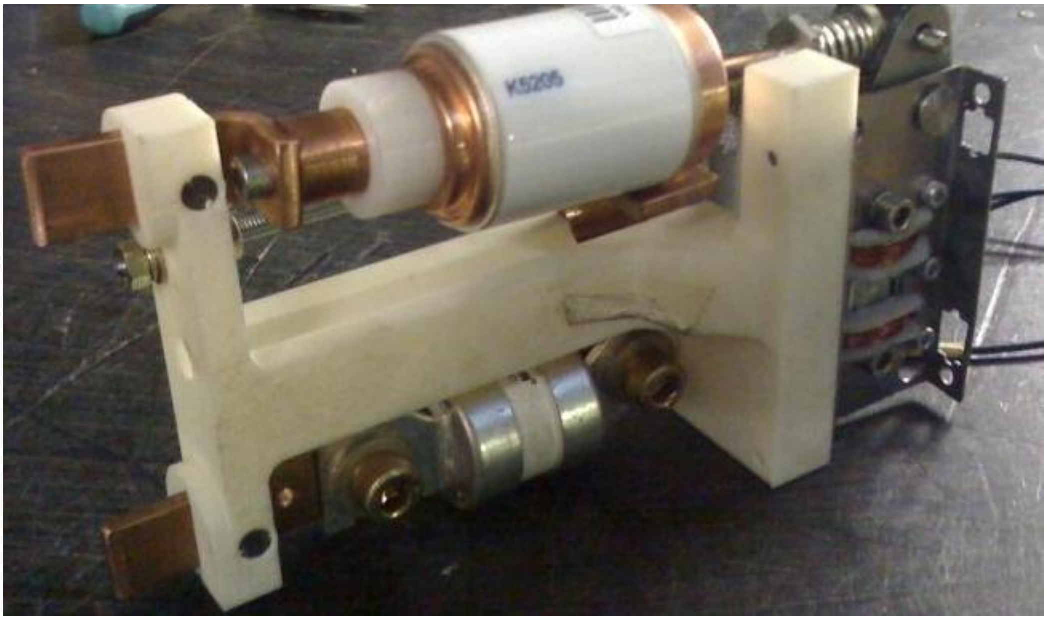

Figure 7-2 Prototype of the LV automation switch

The reason for using a 3-D printed version was cost: the 3-D printed type was significantly cheaper than the moulded type. Thus it was judged prudent to use the 3-D printed device for the LVA switch trials; however, it was found that, due to the process of producing the mechanism by 3-D printing which has relatively high dimensional tolerances leading to burrs and chamfers in the moving parts of the mechanism, the actuator did not operate smoothly or would stick in one position and was not fit for use.

When the prototype LV automation switch was tested (to coincide with the initial stages of the LCN Fund project), the switch assembly was found to be insufficiently robust for use on the live system. It was not until the 3D printing technique had been tried at tested that this limitation was discovered.

The impact of this modification, and following the acquisition of Radius by Netcontrol, SP Energy Networks continued to develop the LV automation switch, working directly with EPS. As a result of SP Energy Networks' efforts, an LV automation fuse switch was successfully developed, in parallel to the LCN Fund project, through the IFI funding mechanism.

EPS subsequently saw the value in what was being developed and, with another DNO (Electricity North West), went on to develop a design that incorporates a bespoke vacuum interrupter, in-line magnetic actuator and a housing that could be used on a live system. The EPS design built on what was learnt from SP Energy Networks' IFI and LCN Fund projects but, in this case, the switch was developed for a link box application (below ground level), as opposed to a pillar box application (above ground level). There is still scope for SP Energy Networks to work with EPS to develop an LV automation switch with sufficient maturity for trialling in pillar box applications.

It is apparent that, if the LVA fuse switch was successfully rolled out on to the network, then parts of the network, where industrial loads cause power quality issues, could be operated with open circuit points to improve quality of supply to other customers.

7.3 Re-evaluation of the Trial Network Location

SP Energy Networks invested heavily in the construction of the HV and LV network in the LR1 district, in addition to funding awarded by the Department of Energy and Climate Change (DECC) to support the investment in cable and substation infrastructure. When the economic recession occurred and the customers failed to materialise, the design of the system had been completed, and it was therefore no longer practical to change the trial location to a different site. Alternative, non-brown-field sites would have entailed disruption to customers as roads would have needed to be dug up to retrofit the looped and meshed cable infrastructure. Therefore, it was not feasible to change the project location without significantly exceeding the project expenditure.

7.4 Relocation of Power Quality Monitoring Equipment

SP Energy Networks procured power quality monitoring equipment which was to be installed in the secondary substations on the Clyde Gateway site. Since the project was halted, the power quality equipment has been trialled at other substations on the SP Energy Networks' network. The sub.net instruments were supplied by EMS and have been successfully deployed in other locations of SP Energy Networks' distribution system to assess the impact of smart technology devices on power quality.

8 Significant Variance in Expected Costs and Benefits

The original project cost was £300,000, whereas, the actual project cost was £175,636 (-41.5%). £126,636 was sourced through the LCN Fund and £49,000 was sourced through the Smart Grid Capital Grant Programme of the Department of Energy and Climate Change.

The project was successful in delivering some, but not all, of its initial objectives and, as a result, succeeded in providing some, but not all, of its intended benefits.

Due to the economic recession in the UK during the project's timescales, there was not the anticipated demand for load and generation connections in the Clyde Gateway area. This meant that the project did not deliver the full economic benefits as originally envisioned, particularly in the areas of reducing losses and outages and accommodating DG.

8.1 Variance in Costs

Table 8-1 highlights the variation between SP Energy Networks' planned expenditure at the start of the project and the actual expenditure. As a result of the issues detailed in the report, associated with the delivery and trialling of the HV/LV automation solution, there has been a significant under-spend of £124,364 on the project. This under-spend was a direct result of the difficulties encountered within the project (as detailed in Sections 6 and 7), which meant that not all of the intended contracts were placed or fully met.

Table 8-1 Variance in Project Costs

Element	Forecasted Expenditure 2010	Actual Expenditure March 2014	Variance
Contracts	£225,000	£146,116	-£78,884
IT	-	-	-
Labour	£30,000	£29,520	-£480
Materials	-	-	
Legal	-	-	
Contingency (15%)	£45,000	-	-£45,000
TOTAL	**£300,000**	**£175,636**	**-£124,364**
TOTAL with DECC Contribution (£49,000) excluded	**£251,000**	**£126,636**	**-£124,364**

8.1.1 Contracts

The bulk of the project's forecast expenditure (£225,000) was envisaged to be spent on contracts for the delivery of the proposed HV/LV automation system within Clyde Gateway, and the subsequent analysis of its performance once it was being utilised. As many of the contracts were placed for enabling technology and network infrastructure at the start of the project, the expenditure in this category (approximately £175,000) remained true to the original budget. However, there was significant under-spend (approximately £79,000) as a result of the network's underutilisation and the difficulties encountered with developing the LV automation solution. These issues resulted in a reduction in the number of the contracts placed for some of the network technologies and for the analysis / dissemination of the network's performance.

As highlighted earlier in the report, prior to the start of the project, DECC awarded funding of £49,000 for the provision of the smart grid infrastructure within Clyde Gateway. This funding was used to pay for non-standard network infrastructure, such as the introduction of larger LV mains cables, additional pillar-boxes, GRP buildings and their associated civil works. As a result of this, the actual LCN Fund expenditure for contracts was actually only £97,116.

8.1.2 IT

There was no forecast and actual expenditure on IT within the LCN Fund project. The required investment in IT had been previously covered within the IFI LV Automation and Fault-finding projects.

8.1.3 Labour

There was a marginal (£480) difference in the planned and actual expenditure in this category; however, the nature of the work undertaken by the labour was significantly different to what was envisaged, with more time dedicated to managing the supply chain difficulties encountered in the project.

8.2 Variance in Benefits

As discussed in previous sections of this report, the project was successful in delivering some, but not all, of its initial objectives and, as a result, succeeded in providing some, but not all of its intended benefits.

The integration of the PLC communications developed under the IFI project with LV monitoring equipment installed at secondary substations provided the ability to monitor voltages at different points on the network simultaneously. This has opened up new opportunities for network design and operational practice, and will in the future, along with LV control and automation equipment, lead to a much more efficiently operated LV network. Therefore, this part of the project delivered its anticipated benefits.

An additional benefit derived from the voltage monitoring part of the project. If the neutral of a piece of equipment or part of the network is lost due to vandalism, theft or installation issues, then a voltage rise on the neutral can be detected. This means that repair crews can be quickly sent to the affected part of the network, expediting repair, which in turn increases security of supply to the customer, increases network efficiency, and delivers enhanced Health and Safety benefits.

The monitoring equipment installed on the HV network is also able to provide information about the operating times of circuit breakers on the network. Through this, information can be gathered about the health of a circuit breaker and when it should be taken out of service for maintenance. Therefore this part of the project delivered its anticipated benefits.

Due to the economic recession in the UK during the project's life cycle, there was not the anticipated demand for load and generation connections in the Clyde Gateway area. This meant that the project did not deliver the full economic benefits as originally envisioned, particularly in the areas of reducing losses and outages and accommodating DG.

9 Lessons Learnt for Future Projects

The learning has been categorised as that pertaining to HV/LV automation system deployments, learning outcomes which are transferrable to other innovation projects and other learning outcomes from the project that have merit in being reported.

Key learning points in deploying HV/LV automation systems:

1. Systems should be trailed in an established network, where there is sufficient connected load;
2. LCN Fund projects support small and medium enterprises (SMEs), which are, potentially, more agile in terms of delivering innovation and accelerating the technology readiness level (TRL) of projects than original equipment manufacturers (OEMs);
3. The LV system is complex and requires significant investment, in comparison to higher voltage systems, for less return.

Recommendations for other projects:

1. Understanding and managing risks of working with SMEs;
2. Technology Readiness Level must be suitable for the planned implementation;
3. The trialling environment must be able meet the necessary performance requirements in order to achieve the success criteria;
4. DNOs have to invest significant time and capital to facilitate connection of DG into LV networks.

9.1 Summary of Learning

This section provides key learning that resulted from the project. The learning has been categorised as that pertaining to HV/LV automation system deployments, learning outcomes which are transferrable to other innovation projects and other learning outcomes from the project that have merit in being reported.

9.1.1 Key learning points in deploying LVA systems

1. SP Energy Networks have little, if any, control over when and where customers apply to connect to the network, this is a risk that has materialised in a number of LCN Fund projects (i.e. lack of uptake of customers in trial areas). Brown-field sites are an attractive option for the development of new network designs, however, contingency measures need to be developed if the trialling of the solution is reliant on the connection of demand and generation customers to the network;
2. The LCN Fund projects support SMEs, which are, potentially, more agile in terms of delivering innovation and accelerating the TRL of projects than OEMs;
3. The LV system is complex and requires significant investment in comparison to higher voltage systems for less return.

9.1.2 Recommendations for other projects

1. Understanding and managing the risks of working with SMEs;
2. Technologies must be at a suitable readiness level, and have successfully passed testing and validation procedures in order to operate effectively in a larger integrated system;
3. The trialling platform should be an established network, which possesses the necessary performance characteristics to achieve the success criteria;
4. DNOs have to invest significant time and capital to facilitate connection of DG. With the installation of the LV automation system equipment, a great deal was learnt about the possibilities open to DNOs with regard to monitoring, control and automation of their LV networks. However, it was found that, currently, the costs outweigh the benefits of LV automation.

9.1.3 Summary of other learning points

The other learning points that resulted from this project were:

- The quality of transmitted PLC signal remains an issue for reliable communications. It is possible to use the modems in the LVA Pillars in a repeater set-up, however this increases the signal to noise ratio at the receiver, and a maximum of 4 repeaters supported by the Radius communications protocol.
- Inverter connection of generation imposes a neutral current, the DC component saturates the core of the distribution transformers causing them to heat up, resulting in increased losses and potential failure;
- With DG, current flows in one phase towards the transformer and in the other two phases away from the transformer. There is therefore a requirement for complex analysis of unbalanced voltages and three-phase load flows.

9.1.4 Early Warning Signs of SME difficulties

Whilst SMEs have agility to respond quickly to innovation challenges, there are risks to DNOs of working with these companies, particularly as DNOs may have a certain amount of inertia when looking to adopt new technologies. The following early warning signs have been noted, retrospectively, and capture valuable learning, which may be applicable to other DNOs:

- Regular and frequent communications need to be established with the SME. This not only helps to steer the SME in the right direction for technology developments, but also helps the DNO to detect if the SME is experiencing difficulties. If communications with the SME become slow and responses delayed, this could be an early warning sign that the SME is experiencing difficulties;
- DNOs should investigate the business plan of the SME before proceeding to contract. If the SME is reliant on the development and sales of a sole product (as would be transparent in the SME’s order book), this could be a risk to the DNO and the SME could experience financial difficulties if the target sales and product develop are not achieved;
- DNOs should ensure there is a robust system in place to access the IPR and know-how from SMEs, if the SME was to go into administration.

9.2 Discovery of Significant Problems with the Trialled LVA Method

The following significant problems were encountered:

9.2.1 Location of trial network

It was anticipated that a number of customers would connect to the LV network over the course of the project. However, due the economic recession only a small number of customer connections materialised. It was therefore considered the load was insufficient to complete any meaningful trials and observe any reliable testing results.

9.2.2 Reliability of the LVA switch

There were reliability problems with the operation of the LVA switch due to the manufacturing method. The switches were manufactured using 3-D printing technology which provided the least cost solution for development of the prototype. However, it was concluded that the printed material was too fragile for stable operation of the switch. In order to progress, the product would likely be manufactured on a commercial scale, to benefit from better processing techniques, however this would require significant investment.

9.3 Recommendations on How the Outcome of the Project can be Exploited Further

The following recommendations are made on how the outcome of the project can be exploited further:

1. The project has informed several changes to SP Energy Networks' LV network design, for example, the change in network design has facilitated wider application of Engineering Recommendation G83 which is intended to simplify the connection of DG in public distribution systems;
2. The HV/LV automation system is conceptually very sound and desirable, providing a useful reference guide for other DNOs. Moreover, there are now alternative LV automation systems available 'off-the-shelf' through alternative product suppliers.

9.3.1 System further developments

The TRL of the LVA switch has since been increased by Electricity North West (ENW) through further development and deployment on LV networks. This recognises the significant research and development (R&D) undertaken by SP Energy Networks, which provided the foundation for further development of the device to this stage.

9.4 Deployment of HV/LV automation on a Large Scale in the Future

If the need case returns, and new low carbon technologies are connected at the Clyde Gateway, the electricity network infrastructure is already in place to accommodate demand and generation, and new HV/LV automation solutions could be efficiently and effectively trialled on the site.

SP Energy Networks does not have immediate plans to trial the HV/LV automation system, at the Clyde Gateway, on a large scale. However, there have been other LV automation devices developed by other providers during the timescales of the project, namely products manufactured by Tyco Electronics and Kelvatek. It is possible that these providers could supply solutions for the Clyde Gateway project if there was a need for LVA systems in the future.

Since the maturity of alternative LV automation technologies has increased, significantly, during the timescales of this LCN Fund project, SP Energy Networks has aspirations to utilise these technologies, and build on the learning from other DNOs, to demonstrate and implement HV/LV automation solutions in other parts of its network in the future.

9.5 Effectiveness of Contractual Methods

9.5.1 Contracts with generation and / or demand customers

This project did not involve any contractual methods with generation or demand customers.

9.5.2 Contracts with project partners

The contracts with project partners worked successfully. Equipment suppliers were contracted on a milestone payment basis.

The contract in place with Radius was cancelled when they went into administration and was inherited by Netcontrol.

10 Planned Implementation

At present, SP Energy Networks does not have plans to modify its Distribution System based on outputs of the Clyde Gateway project. This is because the trials did not progress as far as originally intended and limited quantifiable data was available from site, on which to make informed decisions about Distribution System modifications.

If the need case returns, and new low carbon technologies are connected at the Clyde Gateway, the electricity network infrastructure is already in place to accommodate demand and generation, and new HV/LV automation solutions could be efficiently and effectively trialled on the site. SP Energy Networks would look to continue trials of the HV/LV system through alternative funding mechanisms in RIIO-ED1, such as the Network Innovation Allowance (NIA).

The maturity of alternative LV automation technologies has increased, significantly, during the timescales of this LCN Fund project. Therefore, SP Energy Networks has aspirations to utilise these technologies, and build on the learning from other DNOs, to demonstrate and implement HV/LV automation solutions in the future.

A number of actions have been identified, for DNOs and equipment suppliers, before the LV automation system can be implemented.

In addition, an overview is given of alternative LV automation approaches, which were developed by other manufacturers during the LCN Fund project timescales.

10.1 Distribution System Modifications

At present, SP Energy Networks does not have plans to modify its Distribution System based on outputs of the Clyde Gateway project. This is because the trials did not progress as far as originally intended and limited quantifiable data was available from site, on which to make informed decisions about Distribution System modifications.

10.2 Further Development and Trialling of LVA Systems

The following actions are required before the proposed LVA system can be implemented:

1. A suitable site would need to be selected, which has a variety of LV-connected demand and generation and the potential to retrofit LV network infrastructure (cables and LV pillars) for the LVA system. This is a DNO action.
2. A cost effective solution would need to be developed for the remote recovery of data and the control of LV switches. This is a third party supplier action (with potential support for trialling from DNOs).
3. A cost effective and reliable LV switch needs to be developed to provide the automation functionality within the network to sectionalise and transfer load between distribution substations. This is a third party action (with potential support for trialling from DNOs).
4. The communications system, control system and LV switch need to be integrated. This is a third party action (with potential support for trialling from DNOs).

5. When appropriate products are available on the market, the DNO could look to invest in the LV infrastructure (as outlined in Step 1) and the LVA system (as outlined in Step 4).

If the need case returns, and new low carbon technologies are connected at the Clyde Gateway, the electricity network infrastructure is already in place to accommodate demand and generation, and new HV/LV automation solutions could be efficiently and effectively trialled on the site. SP Energy Networks would look to continue trials of the HV/LV system through alternative funding mechanisms in RIIO-ED1, such as the Network Innovation Allowance (NIA).

If SP Energy Networks was to re-enter this project (for example through the NIA), in the Clyde Gateway location, then the spending forecast would be significantly lowered due to the infrastructure already being in place. However, alternative project locations may be preferable as trialling sites for the HV / LV automation solution (for example, locations that already have load and generation customers connected). In this case, these projects could entail infrastructure investment to put the necessary network topology in place for HV / LV automation solution.

The maturity of alternative LV automation technologies has increased, significantly, during the timescales of this LCN Fund project. Therefore, SP Energy Networks has aspirations to utilise these technologies, and build on the learning from other DNOs, to demonstrate and implement HV/LV automation solutions in the future.

10.3 Alternative LVA Approaches

An overview is given below of alternative LV automation and switching solutions. These solutions are based on the product offerings of EPS, Tyco Electronics and Kelvatek, and were developed by these suppliers during the timescales of the LCN Fund project.

10.3.1 EPS

EPS UK has developed a vacuum switch, operated by a magnetic actuator, and housed in an injection moulded unit. This makes the technology suitable for automating LV link boxes. The Link Box Switch (LBS) has many innovative features including IEC EN 61850-ready controls, and optional bluetooth operation with a Smart Phone Secure App.

An alternative version includes current and voltage measurement facilities with integral crossed phase detection.

With safety in mind, the device is fitted in the open position and has fault make and break capability. This unit can readily be coordinated with a J-type fuse and consequently can be retro-fitted into many LV fuse pillars.

10.3.2 Tyco Electronics

Tyco Electronics offer an LV network automation system which enables utilities to remotely identify location of LV faults on their networks, isolate these faults and re-energising the healthy LV circuit by remote control.

The hardware for this system is designed to be retrofitted into existing LV switchgear and panels, which enables the network changeover to be done cost effectively and with minimum interruption to the network.

The system also enables utilities to monitor load flows on the LV networks and identify circuits which are overloaded and gives control room operator options for redistribution of network load where possible. Communication within the LV network automation system is provided through PLC signals.

10.3.3 Kelvatek

The 'Bidoyng' solution is a single shot auto-recloser designed to remove intermittent faults from the Low Voltage network. Bidoyng fits into existing LV fuse positions using two LV fuses in parallel, creating a robust single-shot auto-recloser. The primary fuse carries the load current until a fault causes it to operate. Then, after a user programmed delay, the secondary fuse is switched in and the network re-energised without customer interruption.

The 'Weezap' solution is an LV vacuum circuit breaker combined with advanced measurement and protection capability. The compact retrofit design allows 'Weezap' to be fitted directly to existing LV panels in replacement of the fuse. It is not necessary to replace the LV board itself. The design allows the 'Weezap' to close and open the circuit at the LV substation either locally or remotely. The 'Weezap' can protect the network by opening the circuit breaker in overload and fault conditions. Configuration settings allow local automated re-closing; alternatively reclose control can be via the Network Management System (NMS).

The 'Lynx' solution is an LV switch designed to fit into existing UDBs allowing active network meshing and un-meshing alongside advanced monitoring capabilities. 'Lynx' is fitted directly to LV link boxes in replacement of the solid link or fuse. It is not necessary to replace the link box itself. The 'Lynx' solution has the ability to close and open the circuit at the link box either locally or remotely. The Lynx LV switch communicates with Kelvatek's 'Gateway' device, which provides a remote connection to the installed devices. This enables remote monitoring and control via the NMS.

11 Facilitate Replication

Details of the knowledge, products and services required to replicate the outcomes of the project have been provided. Furthermore, potential suppliers and points of contact have been identified to enable other DNOs to access the knowledge, products and services required to replicate the HV/LV automation system.

The knowledge required to replicate this project is contained within this report and the information provided in the Appendix.

The products required to replicate the HV/LV automation system can be categorised by voltage level and installation location as (i) primary substation equipment; (ii) secondary substation equipment; and (iii) LV automation pillar equipment.

The services required to replicate the system draw on Business as Usual skills within the DNO and can be accessed through suppliers of the HV/LV automation system equipment.

In keeping with the Objectives of the Low Carbon Networks Fund, the following points of contact are available to provide further details on the system replication:

i. Geoff Murphy, SP Energy Networks (Geoff.Murphy@sppowersystems.com);
ii. Max York, Netcontrol (Max.York@netcontrol.com);
iii. Brian McKean, EPS (bmckean@eps-uk.co.uk).

Details of the knowledge, products and services required to replicate the outcomes of the project have been provided. Furthermore, potential suppliers and points of contact have been identified to enable other DNOs to access the knowledge, products and services required to replicate the HV/LV automation system. External dissemination activities are summarised in Appendix B.

11.1 Knowledge Required to Replicate the HV/LV Automation System

The knowledge required to replicate the HV/LV automation system and deployment methodology is detailed in Section 5 (Project Outcomes) and the Appendices. The key knowledge areas for replicating the HV/LV automation system are:

- HV/LV automation system architecture and design methodology;
- HV/LV automation system and component providers;
- Previous presentations, delivered by SP Energy Networks on the Clyde Gateway project;
- DNO stakeholder map for business adoption.

On submission of this report, SP Energy Networks will circulate an invitation for other DNOs to join a WebEx. This will provide SP Energy Networks with the forum to disseminate the project and will provide other DNOs with the opportunity to seek clarifications on the information contained within this report.

11.2 Products and Services Required to Replicate the System

The products and services required to replicate the HV/LV automation system can be categorised by voltage level and installation location as (i) primary substation equipment; (ii) secondary substation equipment; and (iii) LV automation pillar equipment. These product categories are described in more detail in the following sections. In addition to this, any DNO looking to replicate the HV / LV automation system will need to develop the HV and LV network infrastructure in-line with the system architecture given in Section 5. In particular, a looped or meshed cable system is needed, together with the specification of automation switching points, as the basis for the implementation of the HV/LV automation system.

11.2.1 Primary substation equipment

Three system components are required for installation in primary substations (33kV / 11kV) on the HV (11kV) side of the substation:

1. Power quality devices, with the function to monitor voltages, currents, harmonics, sequence components and to allow SP Energy Networks to assess the operating times of HV circuit breakers;
2. Remote terminal units (RTUs), with the function of providing a radio communications link between a primary substation (33kV / 11kV) and a secondary substation (11kV / 0.4kV) for data transfer, and for communicating data to SP Energy Networks' SCADA system;
3. Central control units (CCUs), with the function to monitor the data transferred from the RTU and control the HV circuit breaker in the primary substation.

Example solution providers include Ametek, Netcontrol and Nortech Management Limited.

11.2.2 Secondary substation equipment

Six system components are required for installation in secondary substations (11kV / 0.4kV):

1. Network controllable points (NCPs), with the function to allow HV circuit breakers to be remotely and automatically switched;
2. Remote terminal units (RTUs), with the function of providing a radio communications link between a Secondary substation (11kV / 0.4kV) and a primary substation (33kV / 11kV) for data transfer;
3. Central control units (CCUs), with the function to monitor the data transferred from the RTU, PLC and to control the HV circuit breaker in the secondary substation;
4. Power line carrier (PLC) communications, with the function of providing a PLC communications link between the secondary substation and the LV pillars;
5. Advanced maximum demand indicators (ADMIs), located in LV distribution boards, with the function of monitoring voltages and currents in real-time, as well as digitally recording peak values;
6. Power quality monitoring devices, with the function of monitoring the impact of smart technologies and devices on power quality.

Example solution providers include Netcontrol, Schneider, EMS and Nortech Management Limited.

11.2.3 LV automation pillar equipment

Three system components were specified for installation in LV automation (LVA) pillars:

1. Power line carrier (PLC) communications, with the function of providing a PLC communications link between the LV pillars and the secondary substation;
2. Three single-phase LV switches, with the function of remote and automatic switching to change the topology of the LV network;
3. Fault-finding devices, for example using time domain reflectometry to pinpoint the location of disturbances in the network.

Example solution providers include Netcontrol, EPS, Tyco Electronics, Kelvatek, Kehui and Nortech Management Limited.

11.2.4 Service requirements

The following services could be provided by the above named suppliers:

- Support with the development of the site-specific system architecture;
- Development of functional design specifications for the equipment;
- Development of factory acceptance and site acceptance testing schedules;
- Equipment installation and commissioning support;
- Post-commissioning system support including training, maintenance and system diagnostic services.

11.3 Summary of Intellectual Property Rights

A summary of background IPR and relevant foreground IPR is given in Table 11-1.

Table 11-1 IPR

Background IPR	Access route	Relevant foreground IPR	Access route
PLC communications solution	Via Netcontrol	HV / LV automation system architecture	Via this report and SP Energy Networks
Controllable LV switch	Via EPS, Tyco Electronics or Kelvatek		
LV fault finding devices	Via Kehui		
Power quality monitoring	Via EMS or Ametek		

11.4 Summary of Points of Contact

In keeping with the Objectives of the Low Carbon Networks Fund, the following points of contact are available to provide further details on the system replication:

i. Geoff Murphy, SP Energy Networks (Geoff.Murphy@sppowersystems.com);
ii. Max York, Netcontrol (Max.York@netcontrol.com);
iii. Brian McKean, EPS (bmckean@eps-uk.co.uk).

Appendices

Appendix A: LCN Fund First Tier Registration Pro-forma

Appendix B: LCN Fund Dissemination Activities

Appendix C: Functional Design Specifications

Appendix D: HV / LV Automation Example Bill of Materials

Appendix E: IFI Data Results for PLC and HV Switch Operation