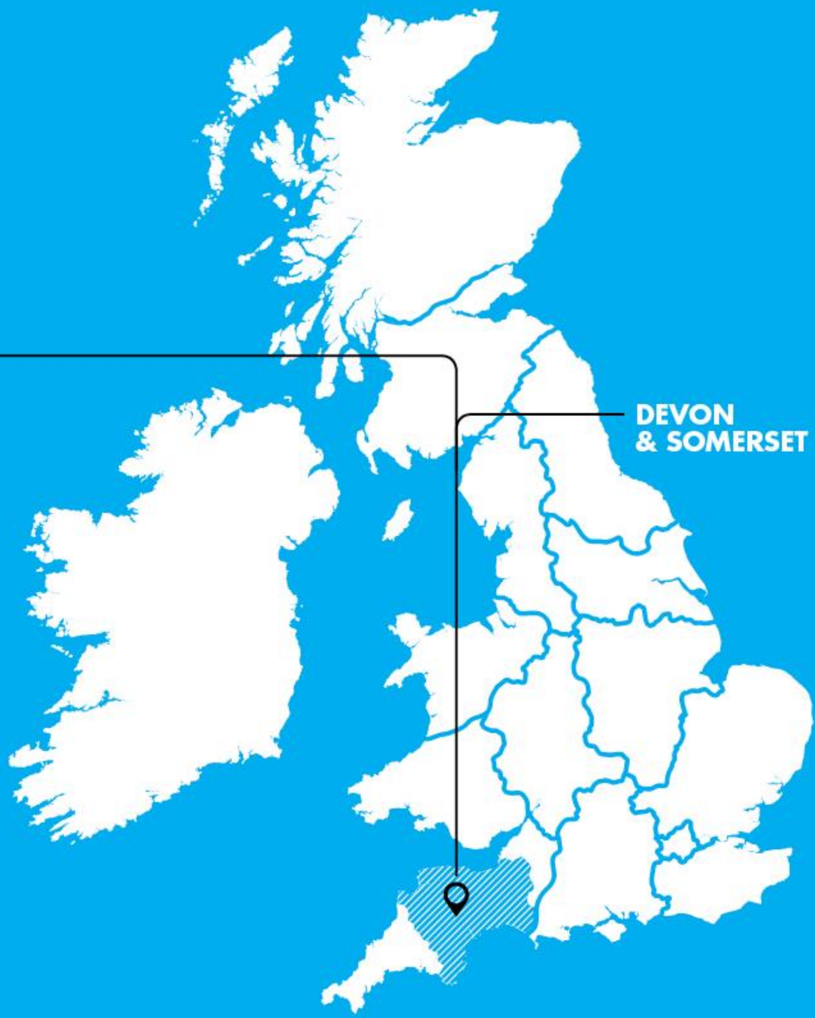
WESTERN POWER DISTRIBUTION

NETWORK EQUILIBRIUM

BALANCING GENERATION AND DEMAND



LCN Fund Tier 2 Bid 2014

WPDT206/2R

LCN Fund
Low Carbon Networks

Project Code/Version No:
WPDT206/2

Low Carbon Networks Fund
Full Submission Pro-forma
Section 1: Project Summary

1.1 Project Title:

Network Equilibrium

1.2 Funding DNO:

Western Power Distribution (WPD) South West

1.3 Project Summary:

The focus of Network Equilibrium is to balance voltages and power flows across the distribution system, using three Methods to integrate distributed generation within electricity networks more efficiently and delivering major benefits to distribution customers.

The Problem that *Network Equilibrium* addresses is that electricity infrastructure in the UK was originally designed and developed for passive power distribution requirements. As a result, the integration of significant levels of low carbon technologies (LCTs) within our present electricity networks can cause voltage management and thermal issues. For business as usual (BAU) roll-out we need to develop solutions, which take a strategic engineering approach, considering the whole system and not solving constraints on a piecemeal basis. The Problem will be investigated using three Methods, and their applicability to 33kV and 11kV distribution networks assessed. Each will involve testing within South West England:

(1) Enhanced Voltage Assessment (EVA);
(2) System Voltage Optimisation (SVO); and
(3) Flexible Power Link (FPL).

By 2050, Western Power Distribution conservatively estimates that *Network Equilibrium* will release 11.3 GW of capacity for LCTs across GB, at a cost saving of £1.5bn when compared to the most efficient traditional solutions, such as network reinforcement, presently in use. The Solution will enable DNOs to: (i) plan complex networks more effectively for LCTs; (ii) optimise voltages and power flows to utilise, fully, the existing electricity network; and (iii) balance generation and demand more efficiently, increasing the resilience of networks and securing electricity supplies for more distribution customers during outages (maintenance, new connections and fault restoration).

1.4 Funding

1.4.1 Second Tier Funding Request (£k): 11,480

1.4.2 DNO Compulsory Contribution (£k): 1,310

1.4.3 DNO Extra Contribution (£k): 0

1.4.4 External Funding - excluding from NICs (£k): 0

1.4.5 Total Project cost (£k): 13,090

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Section 1: Project Summary continued

1.5 Cross industry ventures: If your Project is one part of a wider cross industry venture please complete the following section. A cross industry venture consists of two or more interlinked Projects with one Project requesting funding from the Low Carbon Networks (LCN) Fund and the other Project(s) applying for funding from the Electricity Network Innovation Competition (NIC) and/or Gas NIC.

1.5.1 Funding requested from the Electricity NIC or Gas NIC (£k, please state which other competition):

1.5.2 Please confirm if the LCN Fund Project could proceed in absence of funding being awarded for the Electricity NIC or Gas NIC Project:

☐ YES – the Project would proceed in the absence of funding for the interlinked Project

☐ NO – the Project would not proceed in the absence of funding for the interlinked Project

1.6 List of Project Partners, External Funders and Project Supporters:

Project collaborators, service providers and equipment suppliers will be selected using a competitive tendering process.

No External Funders have been identified.

Project Supporters include:

- National Grid;
- Scottish Power Energy Networks;
- Newcastle University; and
- Parsons Brinckerhoff.

Letters of support are included in Appendix H.

1.7 Timescale

1.7.1 Project Start Date:	1.7.2 Project End Date:
1st March 2015	14th June 2019

1.8 Project Manager Contact Details

1.8.1 Contact Name & Job Title: Philip Bale, Innovation and Low Carbon Networks Engineer	1.8.3 Contact Address: Western Power Distribution Pegasus Business Park Castle Donington Derbyshire DE74 2TU
1.8.2 Email & Telephone Number: pbale@westernpower.co.uk 01332 827 448	

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Section 2: Project Description

This section should be between 8 and 10 pages.

2.1 Aims and Objectives

2.1.1 Aims

Network Equilibrium will demonstrate how novel voltage and power flow management approaches can improve the utilisation of DNOs' electricity networks. The Methods will unlock capacity for increased levels of low carbon technologies (LCTs), during normal operation and outage conditions (maintenance, new connections and fault restoration), which disrupt the electricity network.

For ease of readability, *Network Equilibrium* has been shortened to *Equilibrium* throughout this Full Submission Pro-forma. A glossary of terms is given in Appendix Q.

The trial location encompasses 33kV and 11kV electricity networks in South West England, across the counties of Somerset and Devon. Maps and network diagrams of the trial location are given in Appendix C.

The aims of *Equilibrium* are to:

- Increase the granularity of voltage and power flow assessments, exploring potential amendments to ENA Engineering Recommendations and statutory voltage limits, in 33kV and 11kV networks, to unlock capacity for increased levels of low carbon technologies, such as distributed generation (DG);
- Demonstrate how better planning for outage conditions can keep more customers (generation and demand) connected to the network when, for example, faults occur. This is particularly important as networks become more complex, with intermittent generation and less predictable demand profiles, and there is an increased dependence on communication and control systems;
- Develop policies, guidelines and tools, which will be ready for adoption by other GB DNOs, to optimise voltage profiles across multiple circuits and wide areas of the network;
- Improve the resilience of electricity networks through flexible power link (FPL) technologies, which can control 33kV voltage profiles and allow power to be transferred between two, previously distinct, distribution systems; and
- Increase the firm capacity of substations, which means that the security of supply to distribution customers can be improved during outage conditions, leading to a reduction in customer interruptions (CIs) and customer minutes lost (CMLs).

Equilibrium is timely because it will build on the learning and technology readiness level (TRL) of other Tier-2 LCN Fund projects (such as ENW's "CLASS" and "Smart Streets", and UKPN's "Flexible Urban Networks" and "Flexible Plug and Play"), as detailed in Appendix K and M. These projects have demonstrated the technologies in a network environment but often at lower network voltages. Scaled trials are needed to further advance the technologies, overcoming issues that are preventing the technologies from being rolled out. *Equilibrium* will deliver the required level of development, needed for critical network infrastructure solutions, in readiness for full business roll-out.

2.1.2 The Problem which needs to be resolved

The electricity infrastructure in the UK was originally designed for passive power distribution. Historically, this was the most economical way of developing electricity networks. Network demands have been relatively predictable, had little or no reliance on IT/communications systems and the demand profiles have been relatively flat. However, passive operation of electricity networks is not well-suited to accommodating high levels of intermittent DG, electric vehicles or heat pumps.

DNOs are significantly affected due to the high volume of customer connection applications: As an example, WPD South West is typically receiving 145 HV and EHV DG connections per month. This figure is continuing to increase. The HV or EHV generation applications are from a mixture of DG sources, currently dominated by solar PV. WPD already has 3.5 GW of distributed generation connected within the South West.

Integrating significant levels of DG has caused voltage management and thermal issues within electricity distribution networks, as evidenced by the IET's Power Networks Joint Vision report "Electricity Networks – Handling a shock to the system" and supported by a recent external study for WPD (focusing on the South West network). These problems are worsened during outage conditions and as the levels of LCTs increase.

If WPD 'does nothing' or continues to use conventional solutions, generation customers will face higher connection costs, associated with conventional network reinforcement across larger areas, and it will take longer for them to connect. The level of DG, already connected to existing networks in the Trial area, has saturated the capacity to accommodate new connections if networks continue to be operated passively. Therefore, the ultimate cost for distribution customers will be higher than if innovative solutions are used. Also, there will be a slower uptake of low carbon technologies, which will not support the Carbon Plan.

Equilibrium will overcome this Problem by demonstrating new design and operating processes, which will transform passive distribution networks to active distribution systems through the use of new technologies, including monitoring and control systems. This will allow increased levels of DG to be accommodated in the Trial area.

DECC's forecasts predicted that, by now, the UK would see a rapid take up of electric vehicles and other LCTs, such as heat pumps. This has not yet manifested itself but is expected with the continued implementation of the Carbon Plan. The outputs from *Equilibrium* will be timely in addressing this aspect of the Carbon Plan. The Methods, being demonstrated to accommodate DG in the Trial area, can also be used to solve voltage and thermal issues associated with electricity demand increases.

2.1.3 The Methods and the Trials to solve the Problem

Recent advances in the power of computing and communication systems means that there is now an opportunity to create real-time control systems, using artificial intelligence to deal with existing and future complexities associated with electricity networks. For example, these systems can be used to accommodate intermittent (highly variable) generation and demand profiles, and to cope with system outages which can be unpredictable.

Low Carbon Networks Fund
Full Submission Pro-forma
Project Description continued

The Problem outlined above will be addressed using three technical Methods, which will be trialled in 33kV (EHV) and 11kV (HV) distribution systems:

1. The Enhanced Voltage Assessment (EVA) Method;
2. The System Voltage Optimisation (SVO) Method; and
3. The Flexible Power Link (FPL) Method.

These Methods and their Trials are described below. A simple Project and Method overview is included in Appendix I.

Enhanced Voltage Assessment (EVA) Method

What happens currently? WPD, like all UK DNOs, operate 11kV and 33kV networks within the ±6% statutory limits and the voltage step change limitations. The statutory voltage limits for 33kV and 11kV electricity networks were specified for passive operation and have remained unchanged since the introduction of the “Electricity Supply Regulations, 1937: For Securing the Safety of the Public and for Insuring a Proper and Sufficient Supply of Electrical Energy”. The existing network contains a range of assets installed over many years; these were designed to operate within the existing voltage requirements. At present, the safe and effective operating ranges of electrical equipment, beyond the existing limits, are not clear. Neither is it clear which DNO or customer equipment types are limiting the amendment of both the upper and lower statutory limits.

DNOs also plan customers’ connections for the most onerous conditions during normal operation and electricity network outages. Once customers are connected, passive operation is assumed and this can lead to underutilisation of the present network capacity. Outage planning requires complex studies to assess the continued connection of DG during outage conditions. During abnormal and unexpected constrained operation (for example, following faults) existing DG customers are usually switched off until normal operation is resumed. Current planning tools have been designed for passive network operation. Using these tools, it is very challenging to model complex network conditions accurately and integrate innovative technologies.

What is the EVA Method? WPD will comprehensively research DNOs’ and customers’ equipment to understand if there are any historical or current equipment types, which are limiting the amendment of voltage limits. The Method will identify which changes may be required to the existing network equipment, or current equipment specifications, before statutory limits could be amended. If necessary, WPD will champion a change in ENA Engineering Recommendations related to operational voltage limits within 33kV and 11kV electricity networks.

WPD will also demonstrate a planning and operational tool for 33kV and 11kV networks, extending the functionality of the software that is currently used by DNOs across GB. This tool will allow DNOs to represent all network conditions more accurately and with increased granularity (due to seasonal, daily, hourly and minute-by-minute variations).

How will the EVA Method be Trialled? WPD will engage GB DNOs and the wider electricity industry in the ENA Recommendation consultation process.

As the DNO sponsor, WPD will provide the necessary resource to carry out the review of ENA Engineering Recommendations and current regulations. WPD will work with other GB DNOs to establish the Terms of Reference for the review and lead an open consultation process. The EVA Method may include network monitoring and estimation, specific to *Equilibrium*, or using other LCN Fund project data. This could culminate in a Working Group to review, recommend and implement changes. A recent example of this was the review of Engineering Recommendation P2/6 (Security of Supply) resulting from ENW's LCN Fund project, "Capacity to Customers".

The planning and operational tool will be demonstrated for normal operation and outage conditions by simulating increased levels of DG and LCT demand connections within the Trial area. The tool will incorporate models of the technologies for the SVO Method, the FPL Method and include models for DG operating in a number of different voltage control modes.

What outputs will the EVA Method deliver? The EVA Method will result in a report to the ENA, detailing limitations with current Engineering Recommendations, which may result in amendments to existing standards and/or the creation of new standards for the management of voltages and power flows within 33kV and 11kV networks.

The SVO and FPL technologies will be modelled, together with DG, and incorporated into a planning and operational tool, which will be transferrable to other GB DNOs and will allow them to accommodate increased levels of LCTs.

WPD anticipate that the TRL of this Method will be increased from TRL 5 to TRL 8.

Further details of the outputs from the EVA Method form part of the measureable evidence for *Equilibrium's* Successful Delivery Reward Criteria (as given in Section 9.1 and 9.4).

What are the benefits of the EVA Method? As described in Section 4.1.4, 4.1.5 and Appendix A, within the Trial area, the EVA Method is expected to deliver a financial benefit of about £10m, unlocking approximately 81 MW of capacity for DG connections.

System Voltage Optimisation (SVO) Method

What happens currently? The voltage in 33kV and 11kV electricity networks is regulated by automatic voltage control (AVC) relays, which control the tap changers of substation transformers. The target control voltage for these relays is based on assumed passive operation of the electricity network and has been specified to keep the network within permissible voltage limits based on maximum demand conditions. This means that for large parts of the year, electricity networks are not operated as optimally as they could be.

What is the SVO Method? Whereas previous LCN Fund projects (such as ENW's "CLASS" and "Smart Streets") have focused on voltage control for demand reduction, *Equilibrium* will use the coordinated control of voltages to unlock capacity for DG connections.

The SVO Method will demonstrate how novel algorithms can be used to optimise distribution system voltage profiles over a wide area, encompassing a significant part of WPD's South West licence area.

The settings for AVC relays will be updated in real-time and used to optimise voltage profiles, creating extra headroom for DG to connect to the network whilst keeping demand customers' voltages within permissible limits.

The voltage control system will be designed to accommodate electricity network, communication system and control system outages. These aspects of the demonstration have not been included in the scope of previous LCN Fund projects and are a priority to be addressed before BAU roll-out can take place.

How will the SVO Method be Trialled? The SVO Method trials will encompass eight bulk supply point (BSP) substations (132/33kV) and the associated 33kV and 11kV networks (see Appendix C for Network Diagrams).

The voltage control system will use historical generation and demand profiles to forecast future short-term network profiles to establish optimal voltage targets for the AVC relays. Updated voltage target signals will be communicated to AVC relays in real-time, optimising the system voltage to release capacity for DG connections.

Communication system outages will be deliberately introduced, under controlled conditions, as part of the Trial. This will allow WPD to demonstrate the integrity of the SVO Method for dealing with system failures. No distribution customers will be affected during this Trial.

What outputs will the SVO Method deliver? The SVO Method will result in detailed technical specifications and policies for the coordinated control of voltages, as well as design considerations and an implementation guide. The Method will also quantify the capacity unlocked for DG connections when compared to the present passive method of operating the electricity network.

WPD anticipate that the TRL of this Method will be increased from TRL 6 to TRL 8.

Further details of the outputs from the SVO Method form part of the measureable evidence for *Equilibrium's* Successful Delivery Reward Criteria (as given in Section 9.2 and 9.5).

What are the benefits of the SVO Method? As described in Section 4.1.4, 4.1.5 and Appendix A, within the Trial area, the SVO Method is expected to deliver a financial benefit of about £26m, unlocking approximately 194 MW of capacity for DG connections.

Flexible Power Link (FPL) Method

What happens currently? Sections of the distribution network, which are supplied from different points of the transmission system, cannot currently be operated in parallel because they are interconnected at higher voltage levels. For example, the electrical current flowing from one system to the other system during fault conditions would become too high and the systems could not be operated safely. At present, due to this constraint, DNOs' distribution systems are often interconnected at 132kV but rarely at lower voltages (such as 33kV).

What is the FPL Method? The FPL Method will install innovative power electronic devices to control real and reactive power flows between previously unconnected networks. These devices provide simultaneous power flow and voltage management capability and allow the power from one distribution system to be efficiently transferred to another.

This will also allow National Grid system groups to be connected together at a DNO's network level, without significantly increasing the electrical current flowing between the systems during fault conditions.

How will the FPL Method be Trialled? One location will be selected to demonstrate the FPL technology, coupling two separate 33kV distribution systems together for the first time. 33kV FPLs have been selected for demonstration as they release greater capacities for DG and LCTs when compared to 11kV and LV devices.

Whereas previous LCN Fund projects (such as UKPN's "Flexible Urban Networks") have used power electronics to create "soft normally open points" in LV networks, *Equilibrium* will use the technologies for a completely different application in 33kV networks.

What outputs will the FPL Method deliver? The FPL Method will result in a detailed technical specification for the technologies, as well as design considerations (for example, where the FPL technologies can be located) and an implementation guide. The Method will also assess the capability of the FPL technologies for transferring power and supporting voltages between the two distribution systems. As a result, the capacity unlocked for DG connections will be quantified, together with the impact of FPLs on the security of supply to distribution customers. In addition, the scope for avoiding reinforcement in 33kV, 132kV and transmission networks will be established.

WPD anticipate that the TRL of this Method will be increased from TRL 6 to TRL 8. Currently, only one-off trials in niche industrial applications, transmission and weaker system integration (such as between North America and Mexico) have taken place. Trialling the technologies on a GB distribution network at 33kV will significantly improve the TRL level.

Further details of the outputs from the FPL Method form part of the measureable evidence for *Equilibrium's* Successful Delivery Reward Criteria (as given in Section 9.3 and 9.6).

What are the benefits of the FPL Method? As described in Section 4.1.4, 4.1.5 and Appendix A, within the Trial area, the FPL Method is expected to deliver a financial benefit of about £9.4m, unlocking approximately 36 MW of capacity for DG connections.

2.1.4 The Equilibrium Solution

The *Equilibrium* Solution provides DNOs with novel voltage and power flow management approaches to improve the utilisation of electricity networks. Significant additional capacity will be unlocked within electricity networks to accommodate increased levels of low carbon technologies, during normal operation and outage conditions.

The granularity of voltage and power flow assessments will be increased and, if proven successful, *Equilibrium* could result in amendments to ENA Engineering Recommendations and statutory voltage limits, in 33kV and 11kV networks. This will unlock capacity for increased levels of low carbon technologies, such as DG.

DNOs will be able to plan, more effectively, for outage conditions thereby keeping more generation and demand customers connected to the network when, for example, faults occur.

This will become increasingly important as networks become more complex, with intermittent generation and demand profiles, and there is an increased dependence on communication and control systems.

Policies, guidelines and tools will be ready for adoption by other GB DNOs, to optimise voltage profiles across multiple circuits and wide areas of their networks.

The resilience of electricity network will be improved through FPL technologies, which will allow DNOs to control 33kV voltage profiles and allow power to be transferred between two, previously distinct, distribution systems including between DNOs.

Equilibrium will deliver a Solution to increase the firm capacity of substations, which means that the security of supply to distribution customers can be improved during outage conditions, leading to a reduction in customer interruptions and customer minutes lost.

2.2 Technical Description

A detailed technical description of *Equilibrium* is provided in Appendix J (Project Methods).

2.2.1 Background

At present, DNOs design their electricity networks for passive operation. As a result, standards are currently in place for operating the network passively. However, with the recent advances in powerful computation and communication systems, there is now an opportunity to create real-time control systems, using artificial intelligence to deal with existing and future complexities associated with electricity networks. For example, these systems can be used to accommodate intermittent (highly variable) generation and demand profiles, and for coping with system outages, which can be unpredictable.

Equilibrium will challenge some of the design assumptions related to voltage management (EVA Method), demonstrate system-wide voltage control techniques (SVO Method) and develop FPLs at 33kV (FPL Method). The FPLs will allow network interconnection at points which were previously not possible, such as between grid supply point (GSP) groups.

2.2.2 Enhanced Voltage Assessment

In the EVA Method, increased voltage rise and voltage drop scenarios can be accommodated within the electricity network if statutory voltage limits are amended, under controlled conditions, from ±6% to ± 8%, for example (see Figure 2 in Appendix J). The UK has exceptionally tight bandwidths for our operational voltages. WPD is leading work to harmonise UK voltages at LV with the rest of Europe, based on learning from LV Network Templates (LVNT).

This Method will also explore and challenge the assumptions that underpin the existing voltage standards (defined in Electricity Supply, Quality and Continuity Regulations, Engineering Recommendation P28 and Engineering Recommendation P29, and DNO internal policies) to ensure they are still relevant. Also, assessing whether modifications could facilitate increased connection levels of LCTs.

The Method will deliver the tools to enable DNO planners to design and commission a new generation of voltage control technologies and will also establish new operating procedures.

Power system analysis software plug-in tools will be developed for modelling the SVO approach, FPL technologies and voltage control modes of DG. The Method will demonstrate the automation and adaption of a PSS/E model, a commercially available power system nodal analysis software for EHV and HV networks used by many DNOs.

The model will accurately calculate the effects that the SVO and FPL Methods have on the distribution system under normal and abnormal network operations, at all times of the year and under all operating conditions.

Why is this Method innovative? Based on LVNT learning, LV statutory limits are currently being investigated by the industry to harmonise the UK with the rest of Europe. However, 11kV and 33kV statutory limits have not been investigated or revised since 1937. The most recent change to GB's Electricity Supply Regulations was in 1994. It is not clear, at present, why we use the limits that we do and why they cannot be extended with appropriate controls in place.

This Method will look at data (some from other LCN Fund projects, some from SVO) and, for the first time, this Method will give DNOs visibility of the historic and current real-time profiles of voltages across the whole system so the DNO can quantify how close the system is operating to its limits.

2.2.3 Technical overview of System Voltage Optimisation (SVO)

In the SVO Method, excessive voltage rise and voltage drop conditions can be managed by adjusting the target voltage set point of the transformer AVCs. For example, from 104% to 102% during the excessive voltage rise (high generation coincident with low demand) network conditions and from 102% to 104% during excessive voltage drop (low generation coincident with high demand) network conditions (see Figure 1 in Appendix J).

The SVO Method will take into account both normal and abnormal network conditions; take into account a loss of network communications from monitoring points and AVC relays; produce representative models for power system analysis packages that can be rolled out to network planners to facilitate future generation and demand connections; and facilitate advanced controls using existing hardware.

Equilibrium will demonstrate a solution and provide guidelines that could easily be rolled out at scale across an entire licence area. The Project will clearly document how this could be achieved by other DNOs.

Why is this Method innovative? For the first time, voltage control techniques will be deployed at scale and integrated together to provide SVO across whole feeders. This moves away from piecemeal deployments of voltage control solutions, which only solve the voltage issue at one particular voltage level or location, and do not provide the flexibility to be extended to solve future voltage issues if the need arises.

No previous LCN Fund projects have tackled the challenging issues of voltage and power flow management during outage and abnormal conditions (whether as a result of electricity network, communications or control systems outages, or combinations of all three).

2.2.4 Technical overview of Flexible Power Links (FPLs)

In the FPL Method, voltage control functionality will be achieved by adjusting the target operating conditions of the voltage source converters on either side of the power link. Also, two distribution systems, with phase angle differences, can be coupled.

The FPLs can transfer power across DNO normal open points without creating the fault level and circulating current issues that prevent the open point from being run normally closed. These flexible power devices can solve voltage issues across the feeders, provide reactive power compensation, reduce losses and solve thermal issues across networks. This can be achieved by transferring the excess generation to the high demand networks at the distribution level. FPLs also provide additional security of supply with a controllable back-feed from another network.

What is a FPL and how does it work? A FPL comprises two AC-to-DC Voltage Source Converters (VSCs), with four-quadrant operation to manipulate real and reactive power flows, on a dynamic basis, between previously unconnected networks. The devices will be installed between normally open points within existing substations to manipulate power flows between substations. These can be located large distances away from each other, efficiently transporting power via MVDC cable links, or they can be connected together with a short section of bus bar, creating a 'back-to-back' system.

In this Project we will install one 'back-to-back' system, comprising two AC-DC VSCs at 33kV. Future possible projects or demonstrations could include a range of applicable positions for the installation of both 33kV devices and 11kV devices, this will include:

- At 33kV substations or switching stations to transfer power between grid groups;
- At 11kV substations as a bus section to control power flows between different grid groups; and
- Along 11kV feeders to transfer power between different primary and grid groups.

Why is this Method innovative? This Method will facilitate the coupling together of two distinct GB distribution systems at 33kV. These systems could not be connected previously due to fault level issues, phase angle differences or excessive circulating currents.

The Method provides a new way of managing voltages and power flows in the distribution network, which could result in upstream benefits. For example, allowing National Grid to avoid costly reinforcements associated with integrating voltage control reactors into the 400kV and/or 275kV transmission network in the South West of England.

An ancillary benefit of the FPL technology is balancing power flows in the three phases of the electricity network (for example where single phase induction generators are connected to downstream systems and unbalance the voltages upstream).

2.2.5 How do these Methods work together?

All three Methods would enable DG and demand customers to remain connected to the electricity network during outages (maintenance, new connections and fault restoration, which disrupt the electricity network).

Combining all the Methods together will, for the first time, create modelling tools for SVO and FPLs within 33kV and 11kV distribution systems. In addition, a highly innovative output will be to demonstrate the integration of a FPL within system-wide voltage optimisation schemes. Moreover, the demonstration of a FPL will pave the way for cross-border DNO connections, which do not exist at 33kV as they would be unmanageable.

Other innovative aspects include the automation of analysis and control procedures, as well as the co-simulation of electricity network and communications / control system behaviour to deal with normal running conditions and outage conditions. The Project will also create a platform for other studies, an example being the impact of FPLs on system inertia.

2.3 Design of trials

Trials Design: The Trial area has been sized to provide a sufficiently large area for the scaled demonstrations required to accelerate the TRL of the EVA and SVO Methods in readiness for BAU roll out. The Trial area includes a mixture of urban, suburban and rural distribution customers. In summary:

- Ten bulk supply points and associated 33kV and 11kV electricity networks will be used for demonstrating the EVA Method. This represents the current number of sites within the Trial area with voltage constraints on 33kV circuits during normal and abnormal operation.
- Eight bulk supply points and associated 33kV and 11kV electricity networks will be used for demonstrating the SVO Method.
- One location will be selected to demonstrate the FPL technology by coupling two 33kV distribution systems.

The methodology for selecting the SVO and FPL Trial locations is given in Appendix L. This is based on anticipated levels of DG connections and the suitability of substations for the inclusion of the SVO and FPL technologies.

Robust to capture the learning: `Learning Reviews' will be an agenda item at monthly project review meetings. The learning will be captured using the same robust methodology, already employed on existing Future Networks projects in WPD's Programme of Work.

2.4 Changes since Initial Screening Process (ISP)

2.4.1 The scale of the Project, funding required, other partners or External Collaboration

The Method names have been updated to reflect, more accurately, what is being demonstrated; For trademark reasons, the official project title has changed from ***Equilibrium*** to ***Network Equilibrium***; and the proposed number of FPL deployments has been reduced from three to one. This preserves the Project learning, whilst reducing cost.

2.4.2 Cross Industry Venture (No changes)

2.4.3 IPR arrangements (No changes)

2.4.4 Ofgem feedback following the ISP

WPD have addressed the key areas, highlighted by Ofgem's feedback, in Section 4.

Section 3: Project Business Case

This section should be between 3 and 6 pages.

The Project Business Case is constructed in the following way:

1. Reasons:- A description of the triggers for *Equilibrium*;
2. Business Options:- A description of the different business options for WPD when considering the triggers for this Project and supporting the Carbon Plan;
3. Expected Benefits:- A summary of the benefits that will be achieved by the Project;
4. Timescales:- The periods over which the Project costs will be incurred and Project benefits will be accrued;
5. Investment Options:- A description of the different funding options for this Project;
6. Risks:- A summary of the major risks to Project costs and benefits; and
7. Business Changes:- A summary of how this Project links to the changes WPD wants to make to its business in the next 5 – 10 years.

3.1 Reasons

The integration of low carbon technologies (LCTs), such as distributed generation (DG), electric vehicles (EVs) and heat pumps (HPs), will result in far more complex electricity systems. Moreover, the operation of these networks is becoming increasingly reliant on communication and control systems. There are a number of technical constraints (voltage rise, thermal overloads and excessive fault levels), which are a current barrier to the rapid and cost-effective integration of LCTs (in particular, DG). Directly related to this, it is timely to review ENA Engineering Recommendations and GB's statutory voltage limits (which have remained unchanged in 11kV and 33kV systems since 1937) as these were originally developed for the passive operation of electricity networks. DNOs need more advanced planning and operational tools (and updated engineering standards) to overcome these technical constraints, integrate increased levels of DG and extract maximum benefits from the existing electricity network infrastructure. This has led to the formation of the Enhanced Voltage Assessment (EVA) Method.

Other LCN Fund projects have advanced voltage control technologies through site-specific trials or by focusing on demand reduction benefits across the distribution system. Most Solutions are not yet ready for Business-as-Usual adoption and roll-out by other GB DNOs. There is a need to demonstrate voltage control for DG integration, in a strategic and coordinated way, across wider areas of the distribution system. There is also an increasing need to demonstrate the operation of the distribution system to accommodate outages in communications and control equipment. The readiness of voltage control solutions for BAU adoption must be demonstrated through scaled trials. This has led to the formation of the System Voltage Optimisation (SVO) Method.

Areas of DG and demand are often geographically close together but electrically distant. At times, this can result in reverse power flows through the distribution and transmission networks causing issues in both. To address this, there are a number of emerging power electronic converter technologies, which can be used to couple distribution systems at 33kV voltage levels via AC-DC-AC links. These technologies are at the right level of maturity for LCN Fund trials. This has led to the formation of the Flexible Power Link (FPL) Method.

A summary of how *Equilibrium* differentiates from other LCN Fund projects (in terms of the technical challenges addressed and voltage level of Trials) is given in Figure 3.1 and Appendices N and O. Further details of the differentiators and learning from other IFI and LCN Fund projects, triggering the need for *Equilibrium*, are given in Appendices N and M respectively.

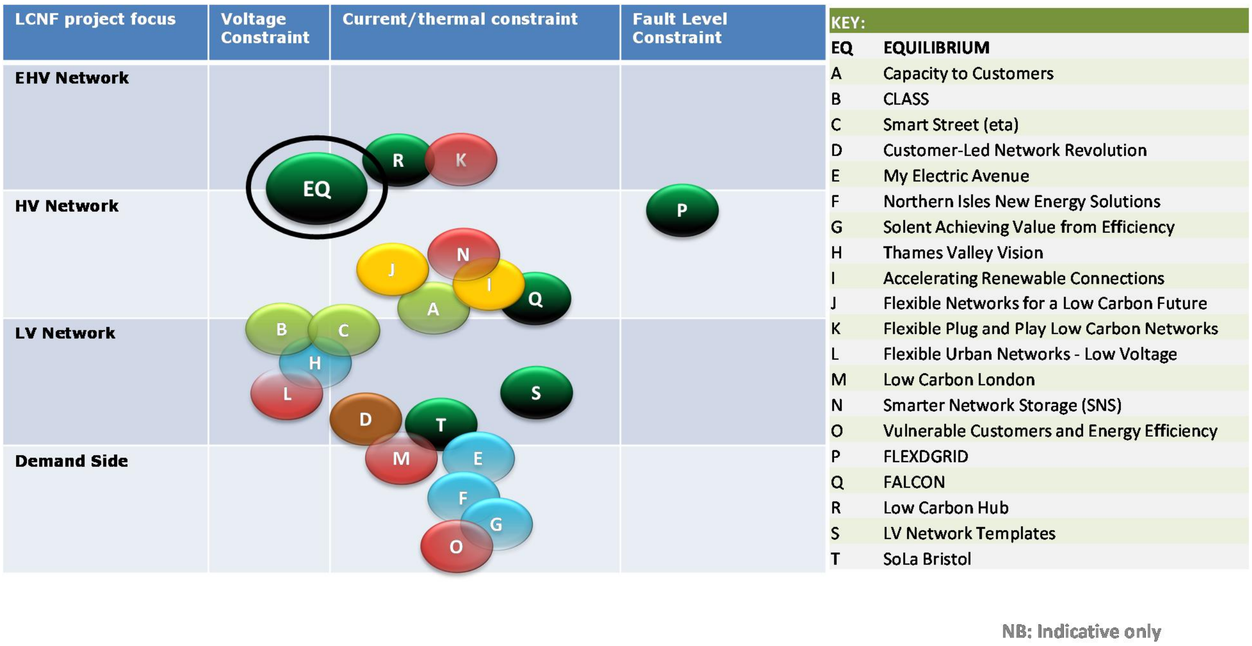

Figure 3.1: Differentiating Equilibrium from other LCN Fund projects

3.2 Business Options

A description of the different business options for WPD is given below, when considering the reasons for this Project and WPD's important position in supporting the Carbon Plan.

3.2.1 Funding Option 1: Do nothing

If WPD 'does nothing' or continues to use conventional solutions, the ultimate cost for distribution customers will be higher than if innovative solutions are used. For example, there will be a slower update of low carbon technologies, which will not support the Carbon Plan. Generation customers will face higher connection costs, associated with conventional network reinforcement across larger areas, and it will take longer for them to connect. The cost of conventional network reinforcement solutions will result in higher Distribution Use of System (DUoS) charges, which will mean that all customers' bills will increase more rapidly than if *Equilibrium*'s Solution is adopted.

3.2.2 Funding Option 2: Equilibrium's three Methods

As described in Section 2 and Section 3.1, *Equilibrium* has significant potential to address the integration of LCTs within electricity networks, delivering time efficiencies and cost savings to DG developers.

Equilibrium will challenge some of the design assumptions related to voltage management and develop new tools to deal with the future complexities of planning and operating electricity networks (EVA Method), demonstrate system-wide voltage control techniques (SVO Method) and develop FPLs at 33kV (FPL Method). The FPL device will allow network interconnection at a point which was previously not possible.

The scope of the Project is challenging but realistic, delivering value for money for distribution customers. The Trials have been designed to ensure that they are sufficiently sized and robust to capture learning, which will be transferrable and applicable to other GB DNOs.

Future applications of Flexible Power Links (FPLs)

As well as demonstrating a 33kV to 33kV FPL within WPD's South West licence area, the FPL section of *Equilibrium* could be used to demonstrate the following applications:

- Incorporating a FPL demonstration between two different DNO licensees, at 33kV. For example, Scottish Power Energy Networks has expressed interest in this type of demonstration for coupling their distribution system in North Wales with WPD's distribution system in South Wales.
- In niche applications, FPLs could be used to couple two different voltage systems together to increase capacity and resilience, for example, between 33kV and 66kV networks.
- Incorporating energy storage within the DC link to provide independent real and reactive power control on both sides of the FPL.
- If the technology continues to evolve and further cost reductions are realised (for example, when manufacturers offer direct coupled FPLs without transformers), FPLs could be used to link 132kV systems.

3.3 Expected Benefits

3.3.1 Benefits of Equilibrium's three Methods

The major benefits that will be achieved by *Equilibrium* are:

- The Carbon Benefit (expressed in terms of DG capacity released), which results from each Method, the Project, and GB as a whole, is given in Section 2, 4 and Appendix A;
- There will be lower Distribution Use of System (DUoS) charges for distribution customers, due to lowering the socialised part of DG connections. This will result in lower bills for electricity consumers, when *Equilibrium*'s Solution is installed instead of conventional (network reinforcement) solutions;
- The additional resilience of the electricity network and increased security of supply to distribution customers can be measured through reductions in customer interruptions (CIs) and customer minutes lost (CMLs);
- The avoidance / deferral of network reinforcement (particularly the new build of overhead line infrastructure) within distribution and transmission networks will result in benefits to the GB Environment, such as in Areas of Outstanding Natural Beauty;
- The avoidance of upstream network reinforcement in the transmission system is a quantifiable benefit for National Grid and other transmission system operators (TSOs);
- GB DNOs will benefit from the amendment and/or creation of new standards for voltage

control and power flow management within electricity networks;
- WPD will create design specifications, procurement specifications and other policy documents which will be of direct benefit to other GB DNOs;
- Existing DG customers will benefit from reduced downtime, due to electricity network outages;
- Future DG customers will receive improved connection offers, they will be able to connect to the network more quickly and more cost-effectively than by conventional solutions; and
- The Equilibrium Solution will be equally as applicable to existing and/or future demand customers, particularly those looking to integrate LCTs into electricity networks.

The baseline measures for these quantifiable benefits will be assessed as part of the EVA Method.

3.4 Timescales

The Project costs will be incurred during the period from March 2015 to June 2019.

Once in place, the different components of the Equilibrium Solution (planning tools, voltage control technologies and FPLs) could be in operation for many years, particularly as it is WPD's intention to advance these technologies in readiness for Business-as-Usual roll out. With the periodic maintenance, replacement and upgrade of the Equilibrium Solution components, WPD conservatively estimates the benefits will be accrued by distribution customers over a 45-year period (in line with standard practice). The benefits to DG customers will be accrued from 2019 onwards, over a 25-year lifetime, depending on the type of DG technology.

3.5 Investment Options

Within the RIIO-ED1 period, WPD believe the savings of rolling out innovation instead of conventional network reinforcement will save more than £128m of demand reinforcement costs to accept the connection of new LCTs.

The Base Case Costs for the conventional solutions, against which Equilibrium's Methods can be compared, are set out in Table 3-1 and detailed in Appendix A.

WPD is seeking £11.48m funding from the LCN Fund (as given in Appendix B). The Project costs for Method Trials are given below and detailed in the Full Submission Worksheet.

- EVA Method: [redacted]
- SVO Method: [redacted]
- FPL Method: [redacted]

The three Methods are interlinked and would result in fewer benefits if demonstrated as separate Trials. When combined together, efficiencies are introduced, unlocking additional benefits, which would not otherwise be uncovered.

For example, the EVA Method will demonstrate the tools by which the SVO and FPL technologies can be planned and operated effectively and efficiently. The voltage control functionality of the FPLs can be used as part of the SVO Method to coordinate voltage control across wide areas of the distribution system.

Method	Base Case Costs	Equilibrium Post-Trial costs	Financial benefit by 2030
Enhanced Voltage Assessment	[redacted]	[redacted]	£9.9m
System Voltage Optimisation	[redacted]	[redacted]	£25.9m
Flexible Power Link	[redacted]	[redacted]	£9.4m

Table 3-1: Financial Benefits of Equilibrium

The financial benefits, which will result from this level of funding are set out in Table 3-1 and detailed in Appendix A.

At a GB scale, the estimated financial benefits delivered by the Equilibrium Solution are approximately £1.5bn as detailed in Appendix A.

3.6 Risks

The major risks to Project costs and benefits are summarised in Table 3-2 and detailed in Appendix E.

The major risks associated with the Project are understood, they can be tracked, controlled and mitigated to ensure the Project can be delivered on time and to budget, delivering the outlined benefits.

3.7 Business Changes

Equilibrium is specifically designed to provide solutions, which can be incorporated into a DNO's business quickly and effectively. The timely learning and deliverables from each Method will enable all DNOs to quickly roll out Equilibrium's Methods across their licence areas. WPD will, as outlined in our Innovation Strategy, quickly roll out innovative solutions when they are ready.

WPD already has a track record of accelerating new developments to TRL 8 and then rolling them out across the business at TRL 9. The Equilibrium Methods will also be accelerated so they can be used as an alternative solution to conventional network reinforcement in RIIO-ED1 and RIIO-ED2 to provide quicker and cheaper connections for generation and demand customers.

Risk Ref. No.	Details of the Risk	Impact (score 1-5)	Probability (score 1-5)	Proximity (score 1-5)	Rating
R007	Project team does not have the knowledge required to deliver the project	5	3	3	45
R003	No SVO available from the contracted supplier	5	2	4	40
R002	Project cost of high cost items are significantly higher than expected	5	2	4	40
R004	No FPL available from the contracted supplier	5	2	4	40
R009	Selected sites for technology installations become unavailable	3	3	3	27

Table 3-2: Major risks to Project costs and benefits

We anticipate that some LCTs could also see a high level of uptake influenced by Government subsidies or incentives. The strength of incentives on EV, HP and micro generation will alter the speed and volume of uptake. It is therefore imperative that when this uptake is seen, we have the innovative solutions that are flexible to accommodate increased load and generation quickly. This is expected to be a key challenge towards the end of RIIO-ED1 with DNOs seeing clusters, rather than mass uptake, of LCTs.

Section 4: Evaluation Criteria

This section should be between 8 and 10 pages.

4.1 Criterion (a): Accelerates the development of a Low Carbon energy sector and has the potential to deliver net financial benefits to future and / or existing customers

4.1.1 Facilitating the Carbon Plan

The Carbon Plan aims to deliver carbon emission cuts of 34% on 1990 levels by 2020. This national target is devolved, in part, through local government carbon emission reduction targets as set out in their strategy planning documents. The Carbon Plan sets out ways to generate 30% of the UK's electricity from renewable sources by 2020 in order to meet the legally binding European Union (EU) target to source 15% of the UK's energy from renewable sources by 2020.

The UK Government has identified distributed generation (DG) as a major low carbon energy enabler and an important part of the future electricity generation mix. By solving voltage and thermal issues, *Equilibrium* facilitates the integration of DG within electricity networks. This Project accelerates the development of a low carbon energy sector.

The UK Government has identified the adoption of electric vehicles and heat pumps as key aspects when meeting the UK's carbon emission reduction targets. By broadening voltage limits and using FPLs for flexibility, increased levels of LCTs can be accommodated within 11kV and 33kV networks, facilitating the development of a low carbon energy sector.

4.1.2 Aspects of the Carbon Plan, which the Solution facilitates

Low Carbon Electricity: The three Methods being tested in this Project will unlock capacity to facilitate the integration of low carbon technologies (both demand and generation). The distribution electricity sector will need to deliver an increase of 30 - 60% of electricity demand flow in order to facilitate the electrification of heating, transport and industrial processes. This Project could support the integration of significant levels of low carbon generation and demand across large portions of DNO licence areas.

Low Carbon Buildings: This Project supports the Carbon Plan aim to decarbonise heating and cooling of buildings through the integration of low carbon technologies, such as heat pumps. The Methods could also alleviate voltage and/or thermal constraints related to CHP plant, to support the development of district heating networks, particularly in urban areas. This will enable the long-term delivery of heat from low carbon sources.

Low Carbon Industry: The *Equilibrium* Solution will lay the foundation for industry to play a more active role in future energy markets through demand side management and the integration of DG within industrial sites.

Low Carbon Transport: The demand for electricity will significantly increase with the continued uptake of electric vehicles. This Project will support this demand increase and, in addition, the *Equilibrium* Methods could facilitate the integration of DG close to large demand centres, and hence close to the point of need.

Agriculture, Land Use, Forestry and Waste: This Project prioritises networks that have voltage constraints and/or thermal constraints, such as the electrically 'weak' networks in rural locations. The agriculture sector is a major contributor to the UK's overall carbon emissions. The Methods will create capacity in rural networks for increased electrical power demand to support decarbonisation of agriculture and forestry sectors, such as anaerobic digestion. In addition, the Methods will create capacity in both urban and rural networks for generation plant, such as Energy from Waste, to connect.

4.1.3 Contribution made by the roll-out of the Methods to the Carbon Plan

At present, the initial capital outlay incurred by the developers of low carbon generation (as a result of network reinforcement requirements) can be prohibitive to timely and cost-effective integration. Developers are consequently opting to install generation in areas which are less rich in natural resources, based on a cheaper and quicker grid connection. *Equilibrium* aims to unlock capacity in more suitable locations.

The roll-out of the proposed Methods across GB has significant potential to facilitate the early and cost-effective integration of customers' generation and demand connections. The Methods could provide new solutions for DNOs to overcome the barriers to delivering the Carbon Plan.

Once fully deployed, the roll-out of the Methods across GB could unlock over 11.3 GW of capacity for the connection of low carbon generation and demand technologies. The basis of the calculation and a breakdown of this figure is provided in Section 4.1.6 and Appendix A.

4.1.4 Quickly releasing capacity

The Enhanced Voltage Assessment (EVA) Method could release up to 81 MW of capacity for DG connections in the Trial area. This capacity could be released at least 24 months more quickly than the most efficient method currently in operation on the GB distribution system.

The System Voltage Optimisation (SVO) Method could release up to 195 MW of capacity for DG connections in the Trial area. This capacity could be released at least 18 months more quickly than the most efficient method currently in operation on the GB distribution system.

The Flexible Power Link (FPL) Method could release up to 36 MW of capacity for DG connections based in the Trials area. This capacity could be released at least 12 months more quickly than the most efficient method currently in operation on the GB distribution system.

The combined EVA, SVO and FPL Methods are expected to release up to 344 MW, in the Trial area, based on the summation of these benefits plus additional benefits from their combination. The additional capacity will be quantified as part of the trials and is released during conditions when maximum diverse generation sources are not coincident with the minimum network demand (based on the conclusions of the Strategic Technology Programme (STP), Module 5 Project S5267_2). The detailed outline of the capacities released by each Method and the timescales for release are given in Appendix A.

4.1.5 *Financial benefit of Equilibrium*

The total financial benefit of *Equilibrium* is £45.2m. This is made up as follows:

The financial benefit of the EVA Method is £9.9m.

The financial benefit of the SVO Method is £25.9m.

The financial benefit of the FPL Method is £9.4m.

The financial benefits of *Equilibrium's* Methods have been calculated, as required by the latest LCN Fund Governance Document. Costs of delivering the Solution have been estimated (at the scale tested within the Project) through the most efficient method currently in use on the GB distribution systems – the Base Case Costs. The Base Case Costs have been compared to the costs of replicating the Method, once it has been proven successful, at the scale being tested in the Project – the Method Costs. The difference between the Base Case Cost and the Method Cost is the financial benefit of the Project.

Further details of the financial benefits of *Equilibrium* (including a breakdown of the Base Case Costs and Method Costs) are given in Appendix A3.

4.1.6 *Potential for replication*

Equilibrium's Methods have significant potential for replication across GB. The details of this are contained in Appendix A3, which sets out the number of sites across GB where each Methods can be rolled out. In summary, the capacity released by each of the Methods by 2050 is:

- 2.7 GW through the EVA Method;
- 7.1 GW through the SVO Method; and
- 1.5 GW through the FPL Method.

When the Methods are combined together, the complete *Equilibrium* Solution could release 11.3 GW of capacity across GB by 2050.

The *Equilibrium* Solution could release this capacity across GB significantly more quickly when compared to the most efficient method (network reinforcement) currently in operation on the GB distribution system. There would also be major disruption to distribution customers and the environment which would be caused by the scale of network construction required to release the same level of capacity. Network reinforcement can meet with strong local opposition and sometimes takes years to obtain the necessary planning consents.

4.2 Criterion (b) Provides value for money to distribution customers

4.2.1 The role that WPD is playing in facilitating a lower carbon economy

Innovation has always been a key part of WPD's development strategy. During DPRC5, we have received funding for five Tier-2 projects through the LCN Fund. The projects investigate a range of network issues from 132kV active network management to rewiring customer homes with DC systems. These demonstration projects have already paved the way for major advances in the UK's transition to a lower carbon economy.

WPD has a proven track record in this area. This is demonstrated by the following, which have already been rolled out across the business:

1. "Policy Relating to Revision of Overhead Line Ratings" – including the introduction of rating based on real-time weather data and a policy for applying it to other 132kV OHLs;
2. "Policy Relating to the Retro-Fitting of Monitoring Equipment In Live LV Cabinets" – A policy for how and when to fit monitoring equipment to LV cabinets, increasing the visibility of the LV network where new LCT are installed;
3. "Policy Relating to Automation Scheme Communication Design" – A policy outlining the communications solutions being deployed by WPD, supporting smart grids;
4. "Policy for Specification, Operation, Control and Maintenance of DStatcom" – A policy outlining how a Statcom is used in an existing distribution network;
5. "Policy for Alternative Connections including Timed, Soft intertrip and ANM" – A policy outlining how alternative connections are offered to DG customers;

These demonstrate how previous investments through innovation are leading to business change.

4.2.2 Size of Project benefits versus the funding requested

Benchmarking *Equilibrium* against other LCN fund projects:

- Lincolnshire Low Carbon Hub is taking voltage control technologies to TRLs 7 and 8. The project is costing £3.5m and 42 MW of DG capacity is being released in the Trial area;
- FlexDGrid is taking fault level mitigation technologies to TRL 8. The project is costing £17m and 250 MW of DG capacity is being released in the Trial area; and
- Flexible Plug and Play is taking voltage control technology to TRL 7. The project is costing £7m and 230 MW of DG capacity is being released in the Trial area.

Equilibrium is taking voltage control technologies to TRL 8 and, importantly, developing the design and operational standards needed by other DNOs to adopt the technologies into BAU. The Total Project cost is £13.1m and 344 MW of DG capacity will be released in the Trial area.

Equilibrium is ranked well above a number of other LCN Fund projects in terms of the benefits delivered (see Section 3.3) for the value of funding requested. In this case, the Project has requested a large value of funding but the benefits are significantly larger too.

The same level of benefits could not be delivered at a lower cost because:

- Scaled trials of the EVA Method and the SVO Method are needed to advance the TRL of these Methods, beyond anything any other DNO has achieved previously, in readiness for BAU roll out. A reduction in the size or scope of the trials would result in lower capacities released; and
- *Equilibrium* includes the trialling of a small number of high value assets (the FPL technologies). WPD has distributed a Request for Information (RfI) to establish the market value of these technologies and used the average quoted prices from suppliers to form the Project costs.

The primary benefits are applicable to the distribution network and DUoS customers.

4.2.3 Resulting learning based on the funding requested

Why could the same level of learning not be achieved at a lower cost?

The Project costs reflect our best estimate of the Project costs including contingency. Each Method has been developed at a scale which is essential to ensure it will deliver the required learning. This learning will be captured and disseminated in such a way that other DNOs can adopt these Methods quickly and effectively.

The EVA Method is at the appropriate scale to thoroughly evaluate the limiting factors to amending network limits. A lower funding level would reduce the amount of information analysed and result in less reliable recommendations. This may impede BAU adoption.

The EVA Method must extend across the Project area to allow the SVO and FPL Methods to be demonstrated and operated at the scale necessary for credible results. Ten BSPs represents approximately 1% of the total number within the GB system.

The SVO Method will generate system-level learning, which would not be achieved without system-wide demonstration. Decreasing the number of sites would significantly reduce the learning from this Project under both normal and abnormal network operations.

The FPL Method will only generate learning with the comprehensive trial of technology at 33kV, which WPD is proposing. In future applications, the technology could be used in at least five different positions: Across 33kV normally open points (NOPs); across 11kV bus sections; across 11kV feeder NOPs; coupling two different voltage levels; and across DNO licensee borders. With the trial, we will create a template for deploying the FPL in any position.

4.2.4 Demonstrating an open and competitive procurement process & providing value for money.

WPD have developed this bid with the support of Parsons Brinckerhoff through an existing framework agreement. During this time, WPD has identified the requirement for several suppliers to support the delivery of this Project. These support roles are given in Appendix G.

During the preparation of the Full Submission Pro-forma, WPD has distributed Requests for Information (RfIs) to suppliers in the following areas:

- Specialist support services, such as power system modelling and design;
- System voltage control technologies, including suppliers' previous experience; and
- FPL technologies.

The RfI responses have been used to identify potential companies that will be invited to tender for supplying equipment or providing services. In addition to this:

- As a utility, WPD is governed by the EU Directives and in particular the Utilities Contract Regulations 2006 (UCR). Any procurement requirement over the current EU threshold value needs to be tendered in line with these regulations. This is standard for all LCN Fund projects;

- WPD follows the negotiated procedure, which allows for negotiation to take place with potential suppliers during the tender process, and ensures that the best value for money is achieved at all times. WPD always aims to award a contract that provides the "Most Economically Advantageous Tender", to ensure performance of the product as well as the best price;
- In order to increase competition Western Power Distribution uses the Achilles Utilities Vendor Database (UVDB) to source suppliers. WPD, as a company, does not preclude SMEs for any purchase to ensure that the market is as wide as possible. WPD worked with the Achilles UVDB to include new innovation codes for Smart Grid suppliers;
- WPD also utilises the ENA database and web portal for publicising Requests for Information (RfIs) and Invitations to Tender (ITTs). These routes into the DNO marketplace are proven paths for SMEs (50% of the current suppliers into the LCN Fund are SMEs); and
- The procurement of non-standard services and goods will be procured using both the ENA portal and the Achilles Utilities Vender Database.

All the required services and equipment are available from multiple sources, making competitive selection the most appropriate route for this Project.

Equilibrium will create the required confidence amongst DNOs to adopt system-wide voltage control technologies and FPLs into BAU processes. The Project will also serve to stimulate the supply chain and ensure a competitive market, providing best value for money for distribution customers in the long term.

4.2.5 Justification that the Project is innovative and evidence that it has not been tried before

Equilibrium is highly innovative, as detailed in Sections 2.2.2 to 2.2.5, Appendix N and Appendix O. None of the proposed Methods are currently being used by DNOs, at a licence-area scale or relevant voltage levels, to unlock capacity for future and/or existing customers.

4.2.6 Demonstrating that significant new learning will be developed

This Project will deliver significant new learning, which is required before the EVA and SVO Methods can be safely and effectively rolled out by DNOs in their Business as Usual processes.

Appendix M provides the details of what WPD has learnt from other LCN Fund projects and how this has informed the development of *Equilibrium*. The additional learning that *Equilibrium* will deliver is given in Section 4.3.

Appendix K provides an overview of FPL technologies and explains how the components and network design considerations of the FPL technology are different to those at lower voltages.

4.2.7 Why can the Project only be undertaken with the support of the LCN Fund?

The LCN Fund provides DNOs with the space to innovate and access to more speculative project funding (which would not be funded by shareholders). The Methods proposed for trial in *Equilibrium* align with the funding criteria set out in the LCN Fund governance document.

Appendix E contains the details of the Project-specific risks, which would prevent the deployment of the Equilibrium solution without such a trial.

Appendix K provides details of the specific risks associated with the FPL aspect of the Project, which would prevent it from being carried forward without LCN Funding.

4.2.8 Outline of person days and rates

WPD has provided the number of person days and day rates for labour in the Full Submission Spreadsheet.

4.3 Criterion (c): Generates new knowledge that can be shared amongst all DNOs

4.3.1 Outline of incremental learning

The EVA Method will generate new knowledge in the following areas:

- Detailing the merits of amending statutory voltage limits for 33kV and 11kV electricity networks, including any technical and procedural restrictions to making the amendments;
- Understanding how to model the SVO and FPL components and evaluate their performance using power system analysis (PSA) software;
- Updating and/or creating design and operational standards for voltage control; and
- Voltage control models for DG, including the most appropriate control settings.

The SVO Method will generate new knowledge in the following areas:

- How to strategically deploy voltage control technologies at scale to maximise access to the electricity network for DG customers and ensure value for money for demand customers;
- How to operate SVO in the real world, not just in test conditions; and
- How to operate the electricity network to maximise benefits for different types of customers during outage conditions (planned maintenance, new connections and fault restoration) and when communications or control systems fail.

The FPL Method will generate new knowledge in the following areas:

- How to plan, integrate and operate electricity networks with FPL technologies coupling two distribution systems together. For example, this will include the impact of the technologies on protection systems, power quality and security of supply to customers; and
- Using artificial intelligence to configure FPL technologies for voltage support and optimum power flows. This will be explored by WPD in *Equilibrium*.

4.3.2 Applicability of new learning to other DNOs

Each Method, deployed by itself, will provide valuable learning for other DNOs. When all three Equilibrium Methods are combined and operated together, there is considerable system level learning.

The new knowledge generated by WPD in *Equilibrium* will be applicable to other DNOs in the following ways:

- Every DNO adheres to the same statutory voltage limits and set of ENA Engineering Recommendations. Any changes to operational voltage limits, resulting from the EVA Method, will be directly applicable to all the other GB DNOs;
- The toolkit created in the SVO Method for dealing with electricity network, communication and control system outages will be directly transferrable to other DNOs. This toolkit could also support DNOs rolling out active network management (ANM) schemes; and
- The FPL Method will provide knowledge, policies, standard techniques and specifications relevant to planning, control and field staff from all DNOs. Different distribution systems could be coupled at 33kV, overcoming voltage and power flow management issues at the network peripheries. DNOs border each other, however, there is no significant interconnection between companies. For example, WPD has boundaries with Northern Powergrid, Electricity North West, Scottish Power Energy Networks, UK Power Networks and Scottish and Southern Energy. Each border has a high number of potential points of interconnection. Also, there are boundaries between different licence areas within the same DNO licensee group. For example, WPD West Midlands has boundaries with the East Midlands, South Wales and South West.

4.4 Criterion (d): Involvement of other partners and external funding

4.4.1 Selection of Project Partners and External Funders

The Organogram for *Equilibrium's* delivery is given in Appendix G.

As set out in 4.2.4, WPD will select Project suppliers after the 2014 LCN Fund award announcement by Ofgem. This ensures that time and resource are not wasted and all parties are aware of the potential supplier opportunities to ensure the best value is achieved.

WPD has identified the scope of services needed to deliver the Project, which will be selected via a competitive tender. The scope of each service is detailed in Appendix G. These categories are appropriate given the scope of *Equilibrium's* deliverables and what the Project is aiming achieve.

4.4.2 Reasonable endeavour to attract External Funding

Between the Initial Screen Process and completion of the Full Submission Pro-forma, WPD distributed a Request for Information (RfI) to service providers and equipment suppliers across the electricity industry. The RfI contained a specific section, which invited suppliers to outline any offers of contributing to the Project. On the basis of the RfI responses, WPD did not receive any offers of External Funding.

4.4.3 Systems and Processes for identifying potential Project partners

How the DNO has made interested parties aware of the LCN Fund?

Our project website www.westernpowerinnovation.co.uk sets out the work being delivered through the LCN Fund and provides contact details. Further to the information submitted in the ISP, WPD has distributed separate "Requests for Information" (RfIs) for specialist modelling and analysis support, FPL device providers and SVO equipment and algorithm providers. Each RfI was posted on the Achilles vender database. The RfI responses have been received and used to shape the *Equilibrium* Full Submission Pro-forma. Project suppliers will be selected through a competitive process, in line with WPD purchasing procedures (approved by Ofgem as part of the FlexDGrid project) and EU regulations.

How the DNO has actively sought ideas for projects and what process did WPD go through to decide which ideas it takes though to Tier-2?

WPD followed the now-established process for selecting ideas for ISP. This year, three potential projects were identified as worthy of consideration and evaluation. Our evaluation process tests:

- The quality of the idea;
- How well developed the idea is;
- The quality of the documentation/research;
- The value the Solution may deliver;
- The appropriateness for Tier-2 (particularly the scale of the project)
- How likely it is that the Solution would become a normal business solution (for example, ease of implementation and need for legal or regulatory changes);
- Project risk; and
- Timeliness.

In 2014, three potential projects were developed from concepts identified by WPD colleagues. This year no ideas from third party organisations were evaluated in detail under the Tier-2 process, as they were discounted at initial evaluation. *Equilibrium* was selected after careful evaluation and challenge by WPD senior management. Of the other ideas evaluated in detail, one will no longer be progressed through the LCN Fund (as other funding sources may be more appropriate) and one is now being scoped for a potential Network Innovation Allowance project.

4.5 Criterion (e): Relevance and timing

4.5.1 Overcoming current obstacles to a future low carbon economy

The management of voltage is a growing concern with the potential increases in demand, especially localised clusters of low carbon technologies. This was recently highlighted by the IET in their Power Network Joint Vision "Electricity Networks – Handling a shock to the system". These problems are exacerbated during outage conditions. Large areas of the distribution networks are already limited by voltage rise and thermal restrictions, caused by the high power output from DG during periods of minimum demand. The low carbon capacity trend looks set to continue with DECC and National Grid estimating that an additional 46 – 81 GW will be connected over the next 21 years, based on a recent report

"UK Future Energy Scenarios" (published by National Grid in 2014). The three Methods proposed for trials in Network Equilibrium will overcome voltage and power flow management obstacles by developing alternative solutions to network reinforcement in readiness for Business as Usual roll out by DNOs.

4.5.2 Trialling new technologies that could have a major low carbon impact

The system voltage optimisation and power electronics devices being trialled will make a significant difference in areas that have already seen (or expected to see) a large take-up in DG and LCTs. Rather than relying on customer engagement to deliver low carbon benefits, WPD will use Network Equilibrium to demonstrate how electricity networks can evolve to be fit-for-purpose and ready to support a low carbon economy as and when this occurs. For example, the trialling of the innovative technologies will unlock capacity for DG (for example using FPLs to balance high load demand areas with excesses of DG). Once proven, the technologies will facilitate further capacity for Electric Vehicles and Heat Pumps, when these LCTs become more prevalent.

4.5.3 Demonstrating new system approaches that could have a widespread application

Network Equilibrium has applications in a number of areas including system planning, the development of design standards, system operation and outage scenario planning. The project outcomes will be particularly relevant to other GB DNOs but also of interest to a number of other stakeholders including TSOs, the manufacturers of voltage control and FPL devices, the academic community, and standards / electricity network code developers. Furthermore, the learning and experience will be of interest to international organisations (such as CIGRE, CIRED, the IET and the IEEE). This is evidenced by the recent formation of CIGRE working groups, which are focusing on the control of voltages and application of power electronics to distribution systems.

4.5.4 Applicability to future business plans (regardless of uptake of LCTs)

WPD has a track record of taking projects to TRL 8 and deploying them into BAU. Equilibrium is the same. The EVA, SVO and FPL Methods will reduce the need for network reinforcement, this will be reflected in the business plan in terms of reduced requirements for conventional asset investment and will contribute to the savings in WPD's Innovation Strategy. If Network Equilibrium proves to be cost effective at releasing latent capacity in electricity networks and lays the foundation for national design / operation standards, it can be reasonably expected to form part of the business plans of other GBs DNO when considering capacity constraints in their EHV and HV networks.

Equilibrium is timely for the reasons given in Sections 2.1 and 3.1, and because power electronic devices are now regarded as a major enabling technology for the low carbon transition: These devices are a prominent solution in DECC/Ofgem's Transform model. The capabilities and costs of power electronic devices have significantly improved. (for example, voltage ratings have increased from 1.2kV to 10kV and conversion losses have reduced by 50% in the past 10 years.

Section 5: Knowledge dissemination

This section should be between 3 and 5 pages.

☐ Please cross the box if the Network Licensee does not intend to conform to the default IPR requirements.

5.1 Learning and dissemination

Knowledge capture is a fundamental element of the Project and requires a robust methodology and plan for delivery. In order to achieve this, we plan to use the proven approach for knowledge capture and dissemination developed and utilised on other WPD LCN Fund projects. Due to the nature of the project, new knowledge will be produced that relates to various stakeholders. A stakeholder map will be produced, which will then be mapped onto the overall project plan so that knowledge can be disseminated in a timely manner. Knowledge will generally be of two forms: planned and unplanned. The approaches for capturing these types of learning are detailed below.

5.1.1 Plans for learning dissemination to other DNOs

Planned learning:

- The learning outcomes for the overall project and each project area will be clearly identified by the relevant project team member and documented during Work Package A (Detailed Design).
- The learning outcomes will be integrated into the plan for each project area to ensure knowledge capture is seen as an integral part of each team member's role.
- The knowledge gained throughout the project will be shared through reports published on WPD's innovation website (www.westernpowerinnovation.co.uk) and the ENA Smarter Networks Portal (www.smarternetworks.org).
- Access to data supporting the learning will available to third parties to access and analyse independently in order to stimulate the generation of additional learning.

Unplanned learning:

- It is very difficult to anticipate the nature of these lessons learnt and, as such, issuing a standard template would be counterproductive. Instead, the learning lead for the Project will conduct regular meetings with Work Package (and Project) leads to identify all lessons learnt. The advantage of having a project team together is that the discussion brings out a far richer context which, when captured in a coherent manner, can be very valuable. Interviews will be integrated into the Project Plan and take place at regular intervals. This will make it a part of normal Project activity, thus highlighting the importance of knowledge capture.
- This means that it will be a relatively quick process to capture knowledge and lessons learnt with the majority of the work in post-processing and collating the information.
- These commentaries will be organised into a coherent structure, as described in the following section, and any recurring issues will be investigated where necessary. At agreed stages in the project, learning will be collated and shared amongst the Project participants to enable implementation of any relevant lessons learnt.
- This will capture issues that occur on an on-going basis but would otherwise be forgotten.

5.1.2 Knowledge capture methodology

To enable the rapid collation of detailed learning, planned or unplanned, we have designed a simple hierarchy structure to manage the knowledge gained. This structure will allow integration of all levels of knowledge and learning, no matter how high or low level they may be. Much of the detail will form wide learning topics. This list will never be exhaustive and certainly, as the project develops, will expand at all levels.

Learning will be categorised across seven learning categories: Customer Engagement; Project Management; Construction Process; Technology & Equipment; IT & Telecommunications; People & Culture; Industry Process & Regulation; Stakeholder Analysis.

Each Project area has ten learning (parent) topics and will form the content of the final Project report:

1. Amending 11kV and 33kV voltage limits;
2. Unlocking capacity using amended voltage limits;
3. How to implement enhanced planning tools for planning and operational purposes;
4. Unlocking capacity using enhanced planning tools;
5. Maintaining customer connections using enhanced operations tools;
6. How to implement System Voltage Optimisation (SVO) at a system level;
7. Ability to unlock capacity using SVO;
8. How to implement a Flexible Power Link (FPL);
9. Ability to unlock capacity using FPLs; and
10. Implementing and unlocking capacity (generation and demand) as a combined project.

The knowledge management structure is shown in Figure 5.1.

Terminology explanation:

Learning Topic – Parent:

- A high level learning topic, made up of several learning outcomes which will be a combination of planned and unplanned learning outcomes.
- Example: *How to implement SVO at a system level.*

Learning Outcome – Planned:

- Belonging to a Learning Topic (Parent) each planned learning outcome is one of those we set out to learn either during the development of the bid, or one we have identified during the design phase– there will be several of these per learning topic.
- Example: *Planned Learning: Forecasted voltage profiles using historic demand and generation data, corrected with environmental data to forecast power flows and subsequently voltage profiles is accurate within 0.5% for 98% of the times. The profile can be above 0.5% pessimistic when estimating voltage profiles across networks due to unplanned generation connection outages which cannot be forecasted.*

Knowledge dissemination continued

Learning Outcome – Unplanned:

- Belonging to a Learning Topic (Parent), each captured learning outcome is one of those we will capture or collect as the project progresses. There will be several of these per learning topic.
- Example: *Network control engineers now assess the outage window for each Bulk Supply Point (BSP) due to the implementation of SVOs, network maintenance and construction activities can now be extended by an average of 3 months with no additional network risk.*

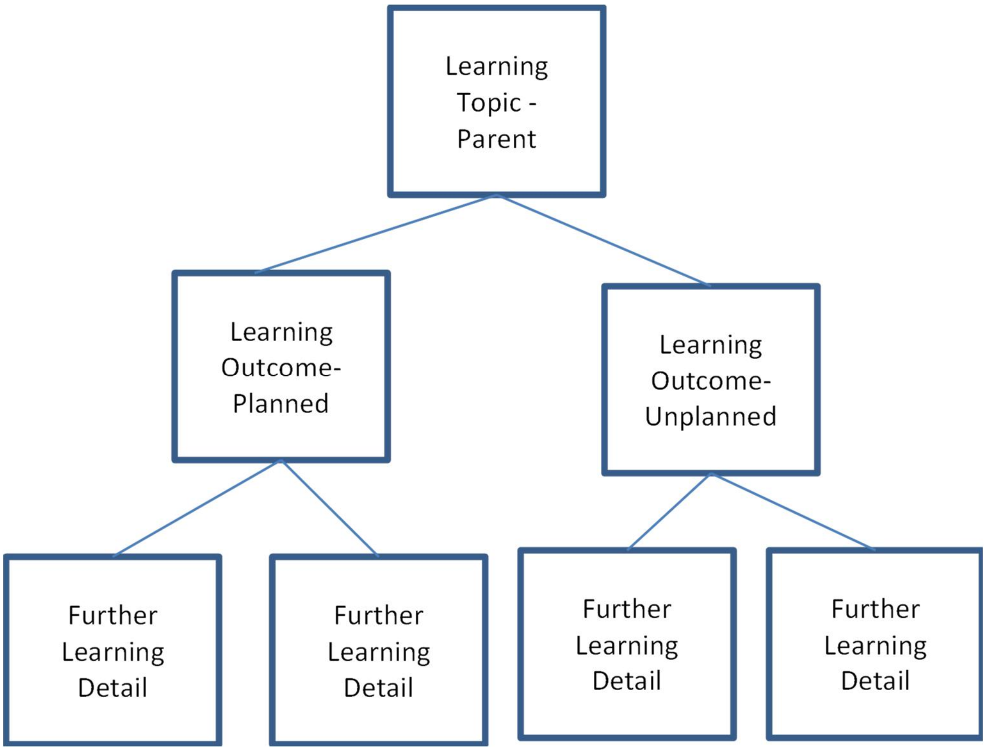

Figure 5.1: Knowledge management structure

Each of the individual learning outcomes, either planned or unplanned, will potentially contain more than one learning document. The learning document captures the detail behind that outcome, the catalyst for the learning, the owner and a method of dissemination, where applicable. It also captures any correlation to other areas of learning across the Project.

The purpose of the hierarchal structure and supporting documentation is to capture a historical footprint of each area of learning for the business to retain as a library. It will also form much of the content towards the final Project report.

Whilst the learning will be captured by the Project Manager as much as possible, it will be the responsibility of each Work Package lead to own their areas of knowledge and commit to regular review periods to ensure the detail remains in date and valid.

Knowledge dissemination continued

As the Project progresses, it is expected that much of the detail will either grow or alter, as is the case for innovative projects.

As part of capturing learning, regular interviews with Work Package leads (or teams, if appropriate) will be integrated into the Project Plan. This ensures that learning objectives remain a priority throughout the Project. The regular interviews will focus around what issues the project teams faced and how they dealt with them, as well as what aspects have gone well and what factors contributed to this. This type of experience will be very valuable to other parties interested in rolling out similar projects (e.g. DNOs, service providers and equipment suppliers). Combining this with periodic written reports (throughout the project), collating experiences and evidence across different sub-projects, will make it easier for other parties to learn from WPD's experience.

Figure 5.2 shows the overarching strategy to achieve the learning objectives of *Equilibrium*. Key themes, as described earlier, cut through the entire project lifecycle. Learning will be recorded in a log for ease of reference and will include analysis on whether there is an impact on DNO strategy or policies.

5.1.3 Plans for learning dissemination to other parties

Having a clear methodology and purpose for all learning activities is integral to delivering a successful project. The approach outlined here requires close communications and contact with the Project team members on a regular basis whilst ensuring that the research-based activities progress in line with the objectives of the Trial.

Learning outcomes of the Project will be formulated in terms of research questions, the results of which will be published and disseminated in the following ways:

- Technical reports made publicly available on WPD's innovation website (www.westernpowerinnovation.co.uk);
- Academic papers published in leading journals and conferences;
- Workshops with relevant participants; and
- Reports and white papers made available on WPD's innovation website.

The outcomes relating to lessons learned in the practicalities of the Project will be shared as follows:

- Updates made publically available on the Project's website and via other digital channels;
- Reports made publicly available on the programme's website;
- Workshops with relevant participants; and
- End of Project lessons learned booklet.

As part of the dissemination plans, *Equilibrium* will utilise various routes as outlined in Figure 5.3.

5.2 IPR

This project conforms with the default IPR requirements as set out in the LCN Fund Governance Document v.6.

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Knowledge dissemination continued

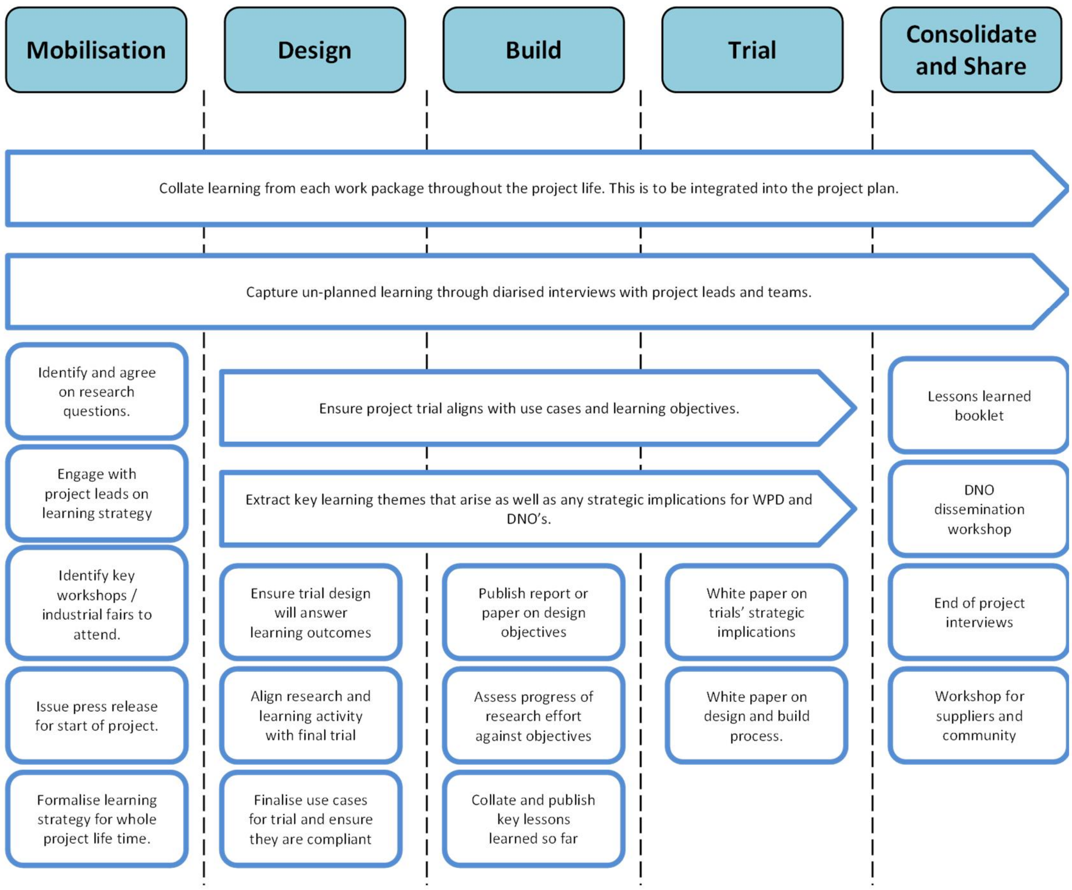

Figure 5.2: Overview of learning strategy for Equilibrium

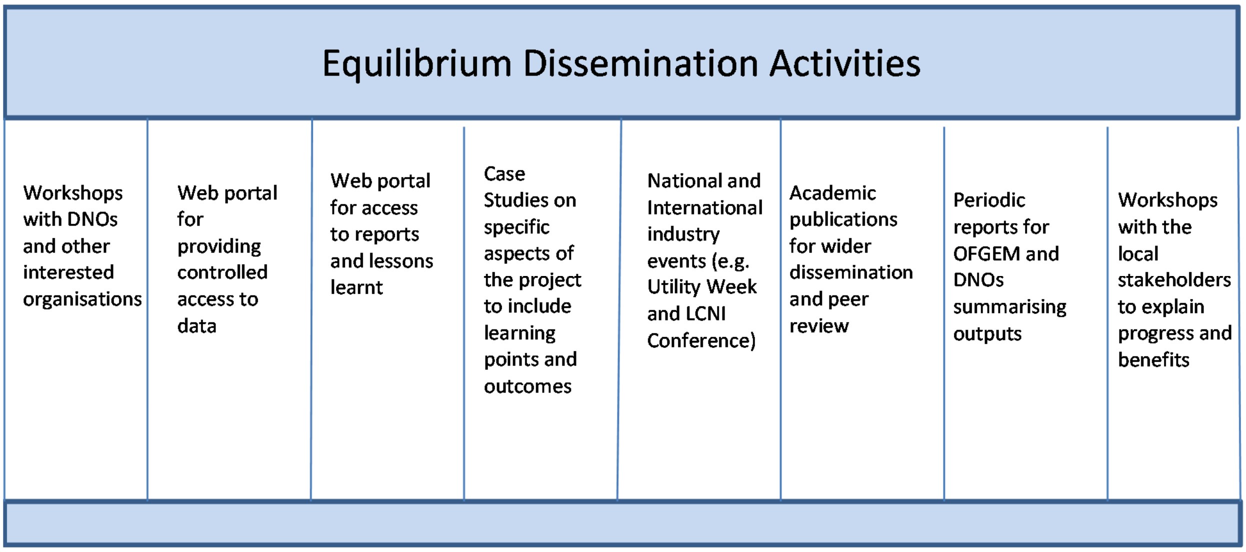

Figure 5.3: Dissemination activity outline for Equilibrium

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Section 6: Project Readiness

This section should be between 5 and 8 pages.

Requested level of protection require against cost over-runs (%): 0%
Requested level of protection against Direct Benefits that they wish to apply for (%):0%

6.1 Evidence of why the Project can start in a timely manner

Western Power Distribution is confident that the Project can start in a timely manner. This Project has potential to play a major role in the UK's transition towards a lower carbon economy, whilst simultaneously delivering service improvements for distribution customers in the South West of the UK. Outstanding customer service is a core value of WPD. Due to the expected benefits, which will be delivered by *Equilibrium* for both generation and demand customers, consideration has been given in planning this Project for a timely start. The following key focus areas provide the evidence that this Project is ready to start in March 2015:

1. Senior Management commitment and WPD's governance model;
2. Engaging with WPD's internal stakeholders;
3. Learning from the initiation of previous LCN Fund projects;
4. Building on previous IFI and LCN Fund projects;
5. Streamlined procurement process and selecting Project collaborators;
6. Experienced Project delivery team;
7. Project logistics and the Project Plan; and
8. Engaging with customers.

These elements are explained in more detail in the sections that follow. Sufficient time has been incorporated pre-mobilisation, between the funding award date and the planned start of *Equilibrium*, to ensure there is no conflict when securing specialist Project resource.

6.1.1 Senior management commitment and WPD's governance model

Western Power Distribution's Board of Directors are fully engaged with *Equilibrium*, from project inception and throughout the entirety of the bid process. Directors of Pennsylvania Power and Light, WPD's parent company, have also been briefed on the Project, its scope and drivers.

The governance model includes a Project Review Group comprising key stakeholders, including WPD's senior management. The Project Review Group will be responsible for ensuring that *Equilibrium* achieves its stated Successful Delivery Reward Criteria (Section 9). Our selected Project collaborators will demonstrate their commitment to the Project by appointing representatives to attend the Project Review Group.

6.1.2 Engaging with WPD's internal stakeholders

WPD has a low carbon and sustainability vision, focused through a single Future Networks Programme. During the bid preparation stage, key internal stakeholders have been identified and actively engaged to ensure successful project delivery.

These key Project roles are defined in the Project's organisational structure (see Appendix G). They are focussed on the key aspects of WPD's main business, such as Policy, Procurement, Primary System Design and Health, Safety and Environment.

6.1.3 Learning from the initiation of previous LCN Fund projects

WPD is the only DNO to have taken a Tier-2 project through to successful completion and final report. The roll out of the findings is in progress and we have fed valuable lessons learnt into the start of other projects, such as the inclusion of an upfront design phase and the control of changes. We are currently delivering four of the existing LCN Fund Tier-2 projects. The valuable experience gained through the successful and valuable output from these projects will help to ensure that *Equilibrium* starts in a timely way. A key learning point in the seamless transition from bid to delivery in WPD’s previous LCN Fund projects has been dovetailing the Bid Delivery team with the Project Delivery team. On this basis, the Bid Manager for *Equilibrium* has also been appointed as the Project Manager.

6.1.4 Building on previous IFI and LCN Fund Projects

As detailed in Appendix M, where appropriate the Project is building on the learning from previous IFI and LCNF projects. The new learning delivered by *Equilibrium* will facilitate the roll out of the Methods at scale.

6.1.5 Streamlined procurement process and selecting Project Partners

WPD will operate an open and competitive procurement process for the services and equipment required to deliver *Equilibrium*.

During the *Equilibrium* bid stage, separate Requests for Information (RfIs) have been used to identify and engage with service providers, equipment suppliers and other potential Project collaborators. This has given us the confidence to delay the selection of service providers, equipment suppliers and other potential Project collaborators until the funding decision has been announced.

6.1.6 Experienced Project delivery team

WPD has the resources and experience to lead the delivery of *Equilibrium*. The resources are of a sufficient size and quality to be reasonably expected to ensure *Equilibrium’s* delivery.

WPD will use the same delivery model that it has employed on other LCN Fund projects, such as FALCON and FlexDGrid. This includes specialist Work Package leads with support from Network Services, Telecoms and IT.

6.1.7 Project logistics and the Project Plan

Using project management tools, aligned with the Project Management Institute and PRINCE2, key performance indicators (KPIs) have been identified and a high-level Project Plan (containing key milestones) has been created. This plan is contained in Appendix D and provides a firm footing for detailed design activities to take place in a timely manner.

Equilibrium will be delivered with the same structure as FALCON and FlexDGrid, following the Work Packages of A (Mobilisation and Design), B (SVO Build), C (FPL Build) and D (Trial and Share).

Equilibrium will follow WPD's Innovation Project Governance Guidelines, which support the delivery and management of innovation projects in line with Ofgem requirements. The guidelines:

- Create an agreed governance structure for projects;
- Outline our common project controls for innovation projects including the internal reporting and approval processes, and the gateway review and escalation processes;
- Support the consistency of delivery across projects and allow the Future Networks Manager to have a detailed overview of projects in the programme;
- Support reporting to the senior management team and Project Sponsor; and
- Assist with the coordination between projects where appropriate, facilitating continuous improvement and ensuring compliance.

In addition, to support delivery of the Project Governance Guidelines, a suite of project templates have been created, which gives the team the ability to incorporate new governance requirements, improvements and project learning across project documentation quickly and easily and supports the consistency of documentation across projects.

Through the use of robust risk management tools, WPD understands and mitigates risks before they occur. For example, WPD has learnt that the incorporation of six-month design phase at the start of the Project significantly de-risks the construction phase of the Project, allowing the site construction and equipment installation activities to begin as scheduled and with reduced uncertainty.

6.1.8 Engaging with customers

Equilibrium's Methods will allow customers to apply for standard connections or alternative connections. The site survey and local consideration elements of the Project will mean there is a reduced risk of delay for connecting customers.

WPD will produce a Customer Engagement plan, in line with the LCN Fund Governance Document requirements.

6.2 Evidence of how costs and benefits have been estimated

6.2.1 Estimation of costs

1. Costs (as given in Appendix B) have been calculated using a bottom up and top down methodology, drawing on WPD's knowledge from other innovation projects.
2. Project suppliers have indicated prices for the majority of their equipment and services through RfI responses.
3. Conventional costs, feeding into the Base Case, have been sourced from RIIO-ED1 figures and estimated based on previous experience of implementing traditional solutions.
4. Method Costs have been estimated based on credible information from suppliers and citable sources.

6.2.2 Estimation of benefits

The benefits of the Project have been estimated using projected roll out as provided in Appendix A. In quantifying the benefits, a number of scenarios have been considered with varying levels of voltage control (see Appendix P).

WPD's best estimates have been used to model the benefits and as part of the project, the method benefits will be continually assessed, reviewed and shared (with other DNOs) for each of the networks selected for EVA, SVO and FPL methods.

Further evidence of how the costs and benefits have been estimated is supplemented in Appendix A and B.

6.3 Evidence of the measures that WPD will employ to minimise possible cost overruns and shortfalls in Direct Benefits

1. The costs have been calculated using a bottom-up and top-down methodology.
2. Costs for WPD commodity items have been used where possible to provide a greater level of certainty.
3. In line with the development and Trial of the three Methods, the Project has been broken down into separate and distinct work packages to provide a detailed overview of each area.
4. Strong governance, already in place, will be used with Project tolerances and KPIs monitored by WPD's senior management.
5. Through a detailed design phase, uncertainty in the Project will be reduced at an early stage.
6. Risk management processes will be implemented throughout the Project: In keeping with standard innovation project risk management processes, every risk will be assigned an owner, based on the risk rating and the ability of the individual to manage the risk (see Appendix E). An example contingency plan is given in Appendix F.

6.4 Verification of all the information included in the proposal

1. The Project proposal has been prepared by Western Power Distribution in conjunction with Parsons Brinckerhoff, with information provided from other potential Project collaborators and equipment suppliers.
2. The bid has been prepared by an experienced team of engineers, led by a single WPD Project Manager.
3. The proposal has been through independent checking processes and peer review processes to ensure the accuracy of information. The technical sections of the Full Submission Pro-forma have been reviewed by academic experts, which were not directly involved in the bid formulation.
4. Information from collaborators, service providers and equipment suppliers has been reviewed by WPD to ensure accuracy.
5. The Project submission has been reviewed and signed off by WPD's Operations Director.

6.5 How the Project plan will still deliver learning in the event of fewer LCTs

In the event that the take up of low carbon technologies and renewable energy in the Trial area is lower than anticipated, the Project plan will still deliver learning in the following ways:

1. The Enhanced Voltage Assessment (EVA) Method will still deliver benefits by informing WPD and other DNOs of the potential increase in precision of network modelling tools, reducing network analysis complexity across networks under abnormal conditions.
2. The System Voltage Optimisation (SVO) Method will still deliver benefits by informing WPD and other DNOs of real-time changes in network voltages. For example, how close actual operational voltages are to statutory limits and how often system voltages are operated within certain bands (± 3% of nominal voltage, ± 5% of nominal voltage, ± 7% of nominal voltage). The Method would be used in the networks where maintaining a voltage profile with passive control is a limiting factor. This could be triggered by additional demand to networks with existing high LCT penetration.
3. The Flexible Power Link (FPL) Method will still deliver learning since the back-to-back voltage source converters will allow separate 33kV distribution systems to be operated in parallel (coupled) delivering potential loss reductions by equalling the load on parallel transformers, increasing the security of supply to customers and, potentially, reducing CIs and CMLs. The Method would also still provide learning on the effectiveness and suitability of the FPL technologies. In addition, the FPL demonstration will pave the way for cross-border DNO connections, which do not exist at 33kV as they would be unmanageable. This could be triggered by additional demand growth.

6.6 Process to identify circumstances to suspend the Project

The following processes are in place to identify circumstances where the most appropriate course of action will be to suspend the Project, pending permission from Ofgem that it can be halted. This approach will give all the parties involved clarity and consistency from the outset.

6.6.1 Gateway Reviews

In order to ensure that the Project proceeds smoothly, the Project contains gateway reviews at critical stages in its lifecycle, which are clearly indicated in the Project Plan. These include review points between the Work Packages set out in Figures 5.2 and 9.1.

The aim of gateway reviews are to assess whether or not the Project can progress successfully to the next stage. They provide assurance that the Project is on track and being run in an efficient and cost-effective manner and give further assurance to stakeholders and Project team members alike that the Project can proceed.

The gateway review is a snap-shot at the point at which the review takes place. As such, recommendations are based on the documents provided and the review process is intended to be supportive and forward looking.

WPD senior management will assign a status in the form of a Delivery Confidence Assessment. This assessment will then provide the Project team recommended actions. Actions fall in the following categories:

1. Critical (Do Now): to increase the likelihood of a successful outcome, it is of the greatest importance that the Project should take action immediately;

2. Essential (Do By): to increase the likelihood of a successful outcome, the Project should take action in the near future. Whenever possible, essential recommendations should be linked to Project milestones and/or a specified timeframe;
3. Recommended: the Project would benefit from the uptake of this recommendation. If possible recommended actions should be linked to Project and/or a specified timeframe;
4. Halt the Project: the Project has exceeded the tolerances set and agreed at Project initiation and the situation is deemed to be irrecoverable. The Project is to be halted and WPD senior management will contact Ofgem to discuss and agree the way forward.

6.6.2 Regular Project Review Group meetings

WPD senior management, together with the Project Manager, will:

1. Be briefed on Project progress;
2. Review the Project Plan, cost model and the risk, assumptions, issues and dependencies (RAID) log;
3. Approve key outputs and milestones since the previous meeting;
4. Assess delivery against the Successful Delivery Reward Criteria;
5. Discuss and recommend Project changes;
6. Document and review actions; and
7. Assign an overall Red/Amber/Green (RAG) status to the Project, where red means the Project has severe delays affecting output, amber means the Project has delays affecting output or additional cost are required to deliver outputs on time and green means the Project is on time and budget.

6.6.3 Proactive risk management

WPD maintains a number of specialised risk management strategies. The Project risk controls are a subset of the overall risk management strategy and relate specifically to the delivery of Future Networks Team projects. The risk management objectives are to:

- Ensure that risk management is clearly and consistently integrated into the project management activities and evidenced through the project documentation;
- Comply with WPD's risk management processes and any governance requirements as specified by Ofgem; and
- Anticipate and respond to changing Project requirements.

These objectives will be achieved by:

- Defining the roles, responsibilities and reporting lines within the team for risk management;
- Including risk management issues when writing reports and considering decisions;
- Maintaining a risk register;
- Communicating risks and ensuring suitable training and supervision is provided;
- Preparing mitigation action plans and contingency action plans; and
- Monitoring and updating risks and risk controls on a regular basis.

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Section 7: Regulatory issues

This section should be between 1 and 3 pages.

☐ Please cross the box if the Project may require any derogations, consents or changes to the regulatory arrangements.

7.1 Regulatory issues

7.1.1 Derogations

No derogations will be required for the Enhanced Voltage Assessment (EVA), System Voltage Optimisation (SVO) or Flexible Power Link (FPL) Methods.

Through the EVA Method, WPD will explore and document the limiting factors for the setting of 11kV and 33kV statutory voltage limits. If appropriate, the Project will suggest the amending of statutory limits through the existing channels within the ENA and DECC. This activity has already been undertaken for LV networks. Reviews are underway to assess the impact of further relaxing the limits for LV networks, bringing the UK into line with wider Europe. For the avoidance of doubt, no networks will be operated outside of statutory limits during the Project.

7.1.2 Licence consent

The Project does not require any additional Licence consents for the EVA, SVO or FPL Methods.

7.1.3 Licence exemptions

The Project does not require any Licence exemptions for the EVA, SVO or FPL Methods.

7.1.4 Changes to regulatory arrangements

The Project does not require any changes to regulatory arrangements for the EVA, SVO or FPL Methods.

Section 8: Customer impacts

This section should be between 2 and 4 pages.

8.1 Customer Impacts

8.1.1 Project

This Project, through the use of all three Methods, will reduce the way in which DNOs impact on customers. For example, by avoiding or deferring significant upstream network reinforcement (especially the building of new overhead lines) and also the installation of new underground cables, which can have a significant impact on customers.

New generation customers could benefit from having quicker connections.

Generation developers can target the most appropriate places for new developments rather than sites driven solely by the ability to gain a connection to the distribution network.

Demand and generation customers will be unaffected by changes in voltage profiles, all connections operate within statutory limits at all times. The effect on customers of changing 11kV and 33kV statutory limits will be evaluated as part of the Enhanced Voltage Assessment (EVA) Method.

The network will continue to be planned using conventional approaches until the techniques have been fully developed and accepted into BAU, reducing the risk that customers face.

8.1.2 Enhanced Voltage Assessment (EVA)

The EVA Method will produce a consultation, to be published through established channels, canvasing stakeholder's opinions on changes to statutory limits.

When the EVA Method is developed, installed, tested and accepted within WPD, with supporting policies, the Solution will be used to more effectively plan the impact of generation and demand connections, improving customer connection offers. Where non-firm connections are made, customers will be better informed of the likely impact of outages on them for different conditions such as seasonal variations and different times of day.

8.1.3 System Voltage Optimisation (SVO)

The System Voltage Optimisation (SVO) Method will automatically optimise the voltage of 33kV and 11kV networks to target the most appropriate voltage at all times whilst always staying within statutory limits.

The installation of SVO may require certain grid and primary transformer outages to install microprocessor-driven AVCs. These types of AVCs are already approved for use on WPD's networks. Supplies to customers will be maintained and network risk minimised, at all times, in line with WPD's existing policies.

Using the EVA Method, we intend to maintain connections to non-firm DG customers. Any outages necessary will be done via BAU and in accordance with connection agreements.

When SVO is developed, installed, tested and accepted within WPD with supporting policies, SVO will be used to release capacity for both standard and alternative connections at LV, 11kV and 33kV.

Customer impacts continued

8.1.4 Flexible Power Link (FPL)

A Flexible Power Link (FPL) will be used to optimise power flows between systems and different grid groups, balancing real and reactive power flows and controlling network voltages.

When an FPL is deployed at 33kV, it will either be installed in grid substations or primary substations (between two existing 33kV substations).

WPD's normal process for installing new assets will be followed to minimise any impact on customers. Site visits have already been carried out at five sites to confirm that the installations will not have any negative impact on customers.

Where new equipment is required, the normal process will be followed with an application to the Local Authority for either permitted development or planning permission.

FPLs are flexible and can often be installed in several locations to have the same effect between two systems, meaning the most appropriate site for both WPD, the Local Authority and external stakeholders can be considered before an application is made.

The installation of a FPL, as per the connection of any new equipment, may require certain 33kV outages to fit new circuit breakers. These outages will be scheduled to maintain supplies to customers and minimise the risk to the network at all times, in line with WPD's existing policies.

In line with WPD's standard practice, the installation of a new piece of equipment will be de-risked by installing additional protection breakers. The existing network operation will not be affected by the installation of the FPL.

When FPLs are developed, installed, tested and accepted within WPD (with supporting policies), FPLs will be used to release capacity for standard and alternative connections at LV, 11kV, 33kV and 132kV.

8.2 Interaction or engagement with customers or customers' premises

WPD will engage with demand and generation customers, both nationally and locally, as part of WPD's wider stakeholder engagement. Aside knowledge dissemination, the Project will have a low level of interaction with customers.

If WPD approach land owners to procure land or set up a long term lease, as part of the installation of the FPLs, this may require engagement of a wayleave officer with land owners. WPD will use their own Wayleave Officers and follow existing WPD policies, as per any other projects.

WPD will set out the methodology for releasing any additional demand or generation capacity within the first year of the project commencing. This will demonstrate a clear and transparent way of releasing any capacity generated through the Project.

8.3 Direct impact the project may have on customers

The Project will not have any Direct Impact on customers, in terms of new charging mechanisms, contractual arrangements or supply interruptions.

Customer impacts continued

8.4 Planned interruptions

The EVA Method will be used to enhance WPD's ability to schedule outages when the risk to the network is at its lowest, minimising the impact through the implementation of SVO, FPLs and further outages associated with construction, maintenance, fault restoration and new connections. The EVA Method will provide greater certainty in the most complex of networks with a large number of generation and demand customers.

In the SVO Method, WPD will make best use of existing current and voltage transducers already installed on the network. Where additional voltage transducers are required to increase granularity, the site selection based on network topology, hot stick techniques, hot glove techniques and innovative sensors will be used to avoid planned network outages.

In the FPL Method, WPD plan to install one FPL between two substations at 33kV. Based on the site selection process, existing spare circuit breakers or new circuit breakers will be installed.

WPD regularly plans network outages to undertake construction, asset replacement and new connections. 33kV networks are designed so that during any network outages a mitigation plan is put in place for if a second, unexpected, fault was to occur. This minimises the subsequent impact on customers.

Number: None

Durations: Not applicable

Power quality issues: None

Cause of interruptions: None

8.5 Unplanned interruptions

Number: None expected

Durations: Not applicable

Power quality issues: None expected

Cause of interruptions: None expected

8.6 Alternative ways to implement the project to reduce or avoid need for customer interruptions.

As discussed above, WPD have already designed the project to avoid the requirement of customer interruptions.

8.7 Protection from incentive penalties

WPD does not expect any planned or unplanned interruptions during construction or operation. Therefore, we are not requesting any protection from incentive penalties.

Low Carbon Networks Fund
Full Submission Pro-forma
Section 9: Successful Delivery Reward Criteria

This section should be between 2 and 5 pages.

A schematic representation of the Successful Delivery Reward Criteria (SDRC) milestones is given in Figure 9.1. The SDRCs are described in Sections 9.1 – 9.8.

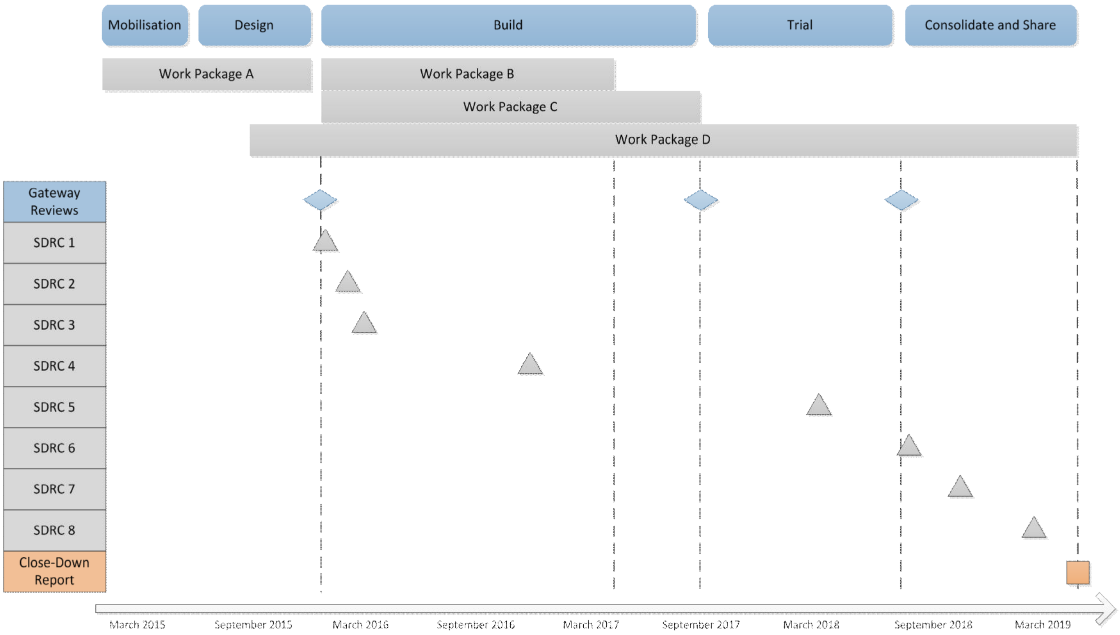


Figure 9.1: Successful Delivery Reward Criteria milestones

9.1 Criterion 1 (SDRC-1)

Specific: Detailed design of the Enhanced Voltage Assessment (EVA) Method;

Measurable: Delivery of a report on the detailed design of the EVA Method. The report will contain chapters or appendices titled: (1) Key findings from the statutory voltage limit workshop and questionnaire; (2) The limiting factors for amending 11kV and 33kV statutory voltage limits; (3) Where statutory limits for 11kV and 33kV networks could be amended; (4) Specification and Guide to implementation of an EVA power system analysis tool.

Achievable: The preliminary design process has been developed in parallel to the production of the Full Submission Pro-forma;

Relevant: This criterion corresponds to the delivery of the EVA Method;

Time- bounded: The SDRC-1 report will be submitted to Ofgem after the end of the design phase by 29th January 2016.

SDRC-1 evidence

1. Conduct a questionnaire and workshop with GB DNOs (and other relevant stakeholders) to discuss and explore amendments to existing statutory voltage limits and Engineering Recommendations;
2. Share a report with the industry detailing evidence for the limiting factors for 11kV and 33kV statutory voltage limits including new and existing transformers, tap changers,

cables, overhead lines, switchgear, CTs, VTs customer equipment, stating the limiting factors and safety margins will be detailed for future evaluations;
3. Issue a discussion paper suggesting where the statutory limits for 11kV and 33kV networks could be amended; and
4. A DNO relevant specification and guide to implementation of an EVA power system analysis tool.

9.2 Criterion 2 (SDRC-2)

Specific: Detailed design of the System Voltage Optimisation (SVO) Method;

Measurable: Delivery of a report on the detailed design of the SVO Method; The report will contain chapters or appendices titled: (1) SVO technical specification; (2) SVO algorithm design and considerations; (3) Sample SVO detailed designs (The contact details for requesting all details designs will be included with the sample designs).

Achievable: Initial scoping and design of the SVO Method has taken place in parallel to the production of the Full Submission Pro-forma. A comprehensive feasibility study of substation locations has been carried out, building on the learning from other WPD LCNF projects. The sites will be investigated in more detail to determine their suitability for the demonstration of this Method;

Relevant: This criterion corresponds to the delivery of the SVO Method;

Time- bounded: The SDRC-2 report will be submitted to Ofgem after the end of design phase by 26th February 2016.

SDRC-2 evidence

1. Create a technical specification (including performance metrics) with input from UK DNOs;
2. Sharing of the SVO algorithm design and considerations to facilitate SVO; and
3. Make detailed designs available explaining how SVO will be installed for DNOs and interested parties.

9.3 Criterion 3 (SDRC-3)

Specific: Detailed design of the Flexible Power Link (FPL) Method;

Measurable: Delivery of a report on the detailed design of the FPL Method; The report will contain chapters or appendices titled: (1) FPL tender specification; (2) FPL performance metrics; (3) System incorporation designs; (4) FPL – Installation design (The contact details for requesting all details designs will be included with the installation designs); (5) Key considerations when incorporating FPLs within 33kV networks.

Achievable: Initial scoping and design of the FPL Method has taken place in parallel to the production of the Full Submission Pro-forma. A comprehensive feasibility study of substation locations has been carried out, building on the learning from other WPD LCN Fund projects. The sites will be investigated in more detail to determine their suitability for the demonstration of this Method;

Relevant: This criterion corresponds to the delivery of the FPL Method;

Time- bounded: The SDRC-3 report will be submitted to Ofgem after the end of the design phase 25th March 2016.

SDRC-3 evidence

1. Share FPL specification used in the tender;
2. Detail the performance metrics of how FPL will be measured;
3. System incorporation design, physical and protection;
4. Sharing detailed designs of how the FPL will be installed by request of other DNOs; and
5. Define the key considerations when incorporating a FPL within 33kV networks.

9.4 Criterion 4 (SDRC-4)

Specific: Trialling and demonstrating the EVA Method;

Measurable: Delivery of a report on the trialling and demonstration of the EVA Method; The report will contain chapters or appendices titled: (1) Potential benefits of adjusting the statutory limits; (2) Evidence of EVA demonstration at Equilibrium Workshop 3; (3) Recommendations for modelling SVO control components; (4) Recommendations for modelling FPLs; (5) Capacity released from EVA, SVO and FPL.

Achievable: The completion of SDRC-1 will significantly de-risk the trialling and demonstration of EVA Method, making SDRC-4 achievable;

Relevant: This criterion corresponds to the delivery of the EVA Method;

Time- bounded: The SDRC-4 report will be submitted to Ofgem during the operation by 27th January 2017.

SDRC-4 evidence

1. A report demonstrating the potential benefits of adjusting the statutory limits;
2. Demonstration of EVA power system analysis software for planning and operational uses;
3. Recommendations to GB DNOs on how to model the SVO control components;
4. Recommendations to GB DNOs on how to model the FPL; and
5. Use the EVA power system analysis models to quantify the capacity released for each of the Methods, individually and when combined together. These will be compared to the estimates included in Section 4.1.4.

9.5 Criterion 5 (SDRC-5)

Specific: Trialling and demonstrating the SVO Method;

Measurable: Delivery of a report on the trialling and demonstration of the SVO Method; The report will contain chapters or appendices titled: (1) Photographs of SVO hardware at BSPs and Primary substations; (2) Installation of SVO equipment at BSPs and primary substations; (3) Implementation of the SVO solution; (4) Performance and capacity released by the SVO Method; (5) SVO Policies.

Achievable: The completion of SDRC-2 will significantly de-risk the trialling and demonstration of the SVO Method, making SDRC-5 achievable;

Relevant: This criterion corresponds to the delivery of the SVO Method;

Time- bounded: The SDRC-5 report will be submitted to Ofgem during the trialling phase by 20th April 2018.

SDRC-5 evidence

1. Installation of SVO across 8 BSPs and 8 primary substations;
2. Report on the installation of SVO equipment at BSPs and primary substations;
3. Report on the implementation of the SVO solution;
4. Report on the performance and capacity released by the SVO Method; and
5. Sharing of policies with other DNOs.

9.6 Criterion 6 (SDRC-6)

Specific: Trialling and demonstrating the FPL Method;

Measurable: Delivery of a report on the trialling and demonstration of the FPL Method; The report will contain chapters or appendices titled: (1) Learning from the Installation and commissioning of the 33kV FPL; (2) Guide to implementation and use of FPL; (3) Sharing of FPL policies with other DNOs.

Achievable: The completion of SDRC-3 will significantly de-risk the trialling and demonstration of the FPL Method, making SDRC-6 achievable;

Relevant: This criterion corresponds to the delivery of the FPL Method;

Time- bounded: The SDRC-6 report will be submitted to Ofgem during the trials phase by 5th October 2018.

SDRC-6 evidence

1. Installation and commissioning of the 33kV FPL;
2. A guide to implementation and use of FPL, detailed evaluation of the performance, capacity increased through the technique in the report; and
3. Sharing of policies with other DNOs.

9.7 Criterion 7 (SDRC-7)

Specific: Trialling and demonstrating the integration of the EVA, SVO and FPL Methods;

Measurable: Delivery of a report on the integration of *Equilibrium's* Methods; The report will contain chapters or appendices titled: (1) Incorporation and impacts of all three techniques; (2) Capacity released; (3) CBA of EVA, SVO and FPL Methods

Achievable: The completion of SDRC-4, SDRC-5 and SDRC-6 will significantly de-risk the integration of all Methods, making SDRC-7 achievable;

Relevant: In this criterion, WPD will quantify the benefits of integrating *Equilibrium's* Methods. This will include the financial and carbon benefits of the Methods, based on the completion of the trials;

Time- bounded: The SDRC-7 report will be submitted to Ofgem during the trials and sharing phase by 28th December 2018.

SDRC-7 evidence

Publication of a report detailing:

1. Quantification of how all three techniques can be incorporated together and the impacts;
2. Analysis of the passive and active generation and demand capacity that can be released across the eight different BSPs; and
3. Cost-benefit analysis of the Methods, deployed separately and integrated, including the capital expenditure and projected operations and maintenance costs.

9.8 Criterion 8 (SDRC-8)

Specific: Knowledge capture and dissemination;

Measurable: Delivery of a report to summarise the knowledge generated, learning from the project and dissemination activities within *Equilibrium*; The report will contain chapters or appendices titled: (1) Details of knowledge and learning dissemination reports and presentations (Including links to publically available documents); (2) Details of Network Equilibrium Data (The contact details for requesting data will be included); (3) Details of Six-monthly progress reports submitted (Including links to these documents); (4) and (5) Details of Equilibrium project presentations (Including links to publically available presentations).

Achievable: Time and resource has been included in the project planning activities to ensure that knowledge and learning generated by *Equilibrium* is captured in a robust way;

Relevant: The SDRC-8 report will summarise all of the knowledge capture and dissemination activities within *Equilibrium*;

Time- bounded: The SDRC-8 report will be submitted to Ofgem during the trials and sharing phase by 12th April 2019.

SDRC-8 evidence

1. Knowledge and learning dissemination reports and presentations;
2. Network data being made available for each of *Equilibrium's* Methods;
3. Six-monthly progress reports submitted to Ofgem throughout the project;
4. *Equilibrium* project presentations delivered at eight industry conferences during the course of the project from March 2015 to June 2019; and
5. *Equilibrium* project presentations delivered at each of the LCNI conferences during the course of the project.

Section 10: List of Appendices

Appendix	Description
A1. Financial Benefits Table	Explanation of how this project will provide financial benefits through the roll out of the project within WPD and GB
A2. Carbon Benefits Table	Explanation of how this project will provide network capacity release through the roll out of the project within WPD and GB
A3. Explanatory Notes	Documentation providing detail on the assumptions and method to provide the detail included in appendices A1 and A2
B. Costs	Detailed cost spreadsheet showing the complete cost of the project and the spend per regulatory year
C. Maps – Network Diagrams • Constraints Map • Heat Maps	Maps indicating project area's network and its constraints. Heat maps providing indications of the benefits to voltage and generation connection for carrying out the SVO Method
D. Project Plan	Detailed GANTT chart detailing the project activities and timelines
E. Risk Register	Document capturing the project risks and their severity
F. Contingency Plan	Document capturing the most severe project risks identified at the bid stage and provision of an appropriate contingency if the risk turns in to an issue
G. Roles and Responsibilities	Overview of the roles and responsibilities of each project supplier and an organogram of the project team's structure
H. Letters of Support • Parsons Brinckerhoff • Newcastle University • Scottish Power • National Grid	Letters of support provided by organisations that see value in this project being awarded and delivered to add knowledge and learning to the electricity network industry
I. Simple Project Overview	Document providing an overview of the project's aim and objective for a non-engineering audience
J. Project Methods	Technical description of the three project Methods
K. FPL Technology Overview	Information provided on the RfIs received relating to FPLs detailing the outline design, cost and dimensions
L. Substations and Suitability for Technology Inclusion	Document providing detail on the process undertaken to ensure that the technologies for each method can be installed in the identified substations
M. Learning from other Projects	Overview of other LCNF projects that have common themes to Network Equilibrium and the learning used to inform this project
N. Differentiators from previous LCNF Projects	Table identifying where each LCNF Tier-2 Project sits in terms of the problem each project aims to solve
O. Differentiator Table	Table identifying the voltage level and problem that each LCNF Tier-2 project is investigating, indicating where this project fills a knowledge gap
P. Generation Effect on Voltage	Overview of the effect of generation on voltage on the 33kV network. Information is provided on the change in voltage due to generation connected at points on the network
Q. Glossary of Terms	Explanations of terms used throughout the bid documentation

A1 – Financial Benefits

Financial benefit (£m)								
Scale	Method	Method Cost	Base Case Cost	Benefit 2020	Benefit 2030	Benefit 2050	Notes	Cross-references
Post-trial solution	Method 1 (EVA)	[redacted]	[redacted]	N/A	9.9	9.9	Individual deployment of the post-trial solution, at the scale of Network Equilibrium, due to commence in 2020.	Appendix A3, pages 52-53.
(individual deployment)	Method 2 (SVO)	[redacted]	[redacted]	N/A	25.9	25.9	Individual deployment of the post-trial solution, at the scale of Network Equilibrium, due to commence in 2020.	Appendix A3, pages 52-53.
	Method 3 (FPL)	[redacted]	[redacted]	N/A	9.4	9.4	One set of FPL deployments by 2030.	Appendix A3, pages 52-53.
Licensee scale	Method 1 (EVA)	[redacted]	[redacted]	N/A	49.7	79.5	Assuming EVA will be replicated in WPD's 3 other licence areas.	Appendix A3, pages 52-53.
If applicable, indicate the number of relevant sites on the Licencees' network.	Method 2 (SVO)	[redacted]	[redacted]	N/A	130.8	210.8	Two project replications in the South West, 3 replications (one in each of the other licence areas) by 2030. Three further replications in the other licence areas (assuming that the South West has had SVO deployed in all appropriate BSPs) by 2050.	Appendix A3, pages 52-53.
	Method 3 (FPL)	[redacted]	[redacted]	N/A	39.9	126.9	4 replications have been assumed till 2030, 8 sets of FPL deployments by 2050.	Appendix A3, pages 52-53.
GB rollout scale	Method 1 (EVA)	[redacted]	[redacted]	N/A	149.1	278.3	Assuming EVA will be replicated in all 14 licence areas.	Appendix A3, pages 52-53.
If applicable, indicate the number of sites on the GB network.	Method 2 (SVO)	[redacted]	[redacted]	N/A	392.5	739.0	15 deployments (two in the South West and one in each other licence area) by 2030, 13 more by 2050.	Appendix A3, pages 52-53.
	Method 3 (FPL)	[redacted]	[redacted]	N/A	89.7	448.7	9 replications have been assumed till 2030, 33 FPL deployments by 2050.	Appendix A3, pages 52-53.

A2 – Carbon Benefits

Capacity released (MVA)								
Scale	Method	Method Cost (£m)	Base Case Cost (£m)	Benefit 2020 (MVA)	Benefit 2030 (MVA)	Benefit 2050 (MVA)	Notes	Cross-references
Post-trial solution	Method 1 (EVA)	[redacted]	[redacted]	N/A	81.0	97.2	10% capacity release from this method. Individual deployment of the post-trial solution, at the scale of Network Equilibrium, due to commence in 2020. Most network low voltage limiting equipment will no longer be connected to the system post 2030, thus allowing further relaxation of the voltage limits (+/- 2%) and an additional 20% capacity release by 2050.	Appendix A3, pages 54-56.
(individual deployment)	Method 2 (SVO)	[redacted]	[redacted]	N/A	194.4	252.8	30% capacity release from this method. Individual deployment of the post-trial solution, at the scale of Network Equilibrium. A further 30% increase in capacity released is anticipated by 2050, due to the increased relaxation of voltage limits by the EVA method.	Appendix A3, pages 54-56.
	Method 3 (FPL)	[redacted]	[redacted]	N/A	36.2	36.2	A 33kV flexible power link releases 36.2MVA. No replications have been assumed till 2020, one set of FPL deployments by 2030.	Appendix A3, page 56.
Licensee scale	Method 1 (EVA)	[redacted]	[redacted]	N/A	405.1	777.7	Assuming EVA will be replicated in WPD's 3 other licence areas.	Appendix A3, pages 54-56.
If applicable, indicate the number of relevant sites on the Licencees' network.	Method 2 (SVO)	[redacted]	[redacted]	N/A	972.2	2022.1	Two project replications in the South West, 3 replications (one in each of the other license areas) by 2030. Three further replications in the other licence areas (assuming that the South West has had SVO deployed in all appropriate BSPs) by 2050.	Appendix A3, pages 54-56.
	Method 3 (FPL)	[redacted]	[redacted]	N/A	144.8	434.4	4 replications have been assumed till 2030, 8 sets of FPL deployments by 2050.	Appendix A3, page 56.
GB rollout scale	Method 1 (EVA)	[redacted]	[redacted]	N/A	1215.2	2722.0	Assuming EVA will be replicated in all 14 licence areas.	Appendix A3, pages 54-56.
If applicable, indicate the number of sites on the GB network.	Method 2 (SVO)	[redacted]	[redacted]	N/A	2916.5	7077.3	15 deployments (two in the South West and one in each other licence area) by 2030, 13 more by 2050.	Appendix A3, pages 54-56.
	Method 3 (FPL)	[redacted]	[redacted]	N/A	325.8	1520.4	9 replications have been assumed till 2030, 33 FPL deployments by 2050.	Appendix A3, page 56.

A3 - Explanatory Notes on Project Benefits

Financial Benefits

The financial benefits of the project were calculated by estimating the costs of delivering the three methods (at the scale being tested within the project) through the most efficient conventional methods currently in use on the GB Distribution System. These costs (i.e. the Base Case Costs) were then compared to the costs of replicating the project methods, once they have been proven successful, at an equal scale - the Method Costs. The difference between the Base Case Costs and the Method Costs for all three project methods has been stated as the financial benefit of the project.

Base Case Costs

The costs of delivering the EVA method through conventional techniques were calculated by assuming installations of 33kV overhead line (OHL) circuits (including conductors and poles) across an area of 10 Bulk Supply Points (BSP: 132kV / 33kV), i.e. the scale tested within the project. For the SVO method, the Base Case costs were calculated by assuming installations of 33kV underground cable circuits across the project area (i.e. 8 Bulk Supply Points). Finally, the assumptions made for the FPL deployments included the same types of installations, with the addition of costs for the installation of two 132/33kV transformers per BSP.

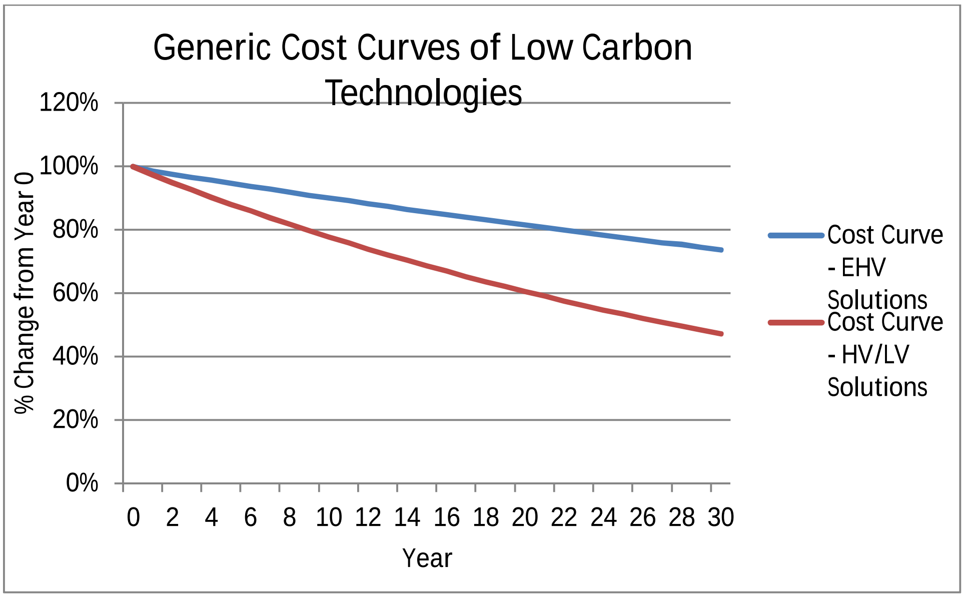
A statistical analysis of the South-West network was performed in order to calculate the average length of 33kV and 132kV feeders; 4.4km and 13.7km respectively were identified as the average values. An average number of 8 feeders per BSP was used for the calculations.

Method Costs

In relation to the costs of the 3 project methods and their reduction during the roll-out period, the following assumptions have been made:

- EVA Method - No method cost reduction has been assumed during the roll-out period 2020-2050.
- SVO Method – A method cost reduction as per the cost curve for EHV low carbon technologies has been assumed (see graph overleaf).
- 33kV FPL - A method cost reduction as per the cost curve for EHV low carbon technologies has been assumed.

A study of historic cost reductions in power electronic devices indicates that the less conservative curve of HV/LV solutions could be used in the method cost calculation for the FPL technology. This would result in a larger amount of FPL-induced financial benefits by 2050, in the region of 12%.



Smart Grids Forum – Work Stream 3, Report: *'Assessing the Impact of Low Carbon Technologies on Great Britain's Power Distribution Networks'*

Replications

It has been assumed that no project replications will occur by 2020, as the project trial is due to be completed by mid-2019. For the EVA and SVO methods, 5 replications have been assumed within licensee scale by 2030 and an additional 3 deployments by 2050. For a GB roll-out scale, 15 replications have been assumed by 2030 and 13 more by 2050.

With regard to the FPL method, one deployment per WPD licence area has been assumed by 2030 (4 in total) and two additional deployments per licence area by 2050. Up-scaling to GB roll-out, 5 replications from other DNOs have been assumed by 2030. By 2050, the high technology readiness level (TRL) of the FPL method will be expected to allow two deployments per GB licence area (28 in total), plus 5 potential inter-DNO deployments. The following table indicates the total number of replications in licensee and GB scale by 2030 and 2050.

Scale	Method	Number of Sites		
		2030	2050	Total
Licensee scale	Method 1 (EVA)	5	3	8
	Method 2 (SVO)	5	3	8
	Method 3 (FPL)	4	8	12
GB rollout scale	Method 1 (EVA)	15	13	28
	Method 2 (SVO)	15	13	28
	Method 3 (FPL)	9	33	42

Summary

The Financial Benefits for the three methods, scaled up to licensee and GB roll-out levels are presented in Appendix A1. At GB scale, a financial benefit of £278.3m is anticipated from the EVA method by 2050, while £739m of savings are anticipated from the SVO method and £448.7m from the FPL method.

Carbon Benefits

The Carbon Benefits associated with this project were calculated by assessing the MVA of generation capacity released from each of the three project methods. The impact of the three methods was modelled in power system analysis software; the methodology involved modelling of the network voltage levels and line loadings while adding new Distributed Generation into the studied system.

EVA Method

The Enhanced Voltage Assessment (EVA) method involves establishing whether modification of the existing voltage standards could increase the ability to accommodate further generation and demand connections. In order to model this method and calculate the generation capacity it would release, an indicative Bulk Supply Point (BSP: 132kV / 33kV) and its surrounding 33kV / 11kV (primary) substations were selected, while distributed generation and load in the system were assumed to be at their year highest/lowest values respectively, thus forming a worst case scenario for the system. Subsequently, additional generation was incrementally added to the system while all node voltages and line loadings were monitored for over-voltages and over-loadings.

It was concluded that, when allowing for an upper voltage limit of 7% (1.07pu) on the 33kV and 11kV circuits, as opposed to the existing 6% limit, the additional generation which could be connected to the BSP system without the addition of any significant reinforcements amounted to 10% of the existing generation level. For example, a BSP with a firm capacity of 100MVA and 80MVA of distributed generation connected around its associated primary substations could accept an additional 8MVA of generation connections without any over-voltages (above the new 1.07pu limit) or over-loadings occurring on the network.

The results from the studied BSP and surrounding substations were then up-scaled to an area of 10 BSPs within the South-West WPD network, which is the extent of the implementation area for the EVA method. The overall capacity release for that area was calculated at 81.01MVA.

The EVA method could release capacity at least 24 months more quickly than the EVA Base case. Once the design tools are proven and the design standards are in place, the critical enabler section of the EVA Method could be replicated by WPD and other DNOs within a 12-month timescale, which builds in time for the tool to be adopted and adapted. The adoption process should be relatively short when standards and policies are in place.

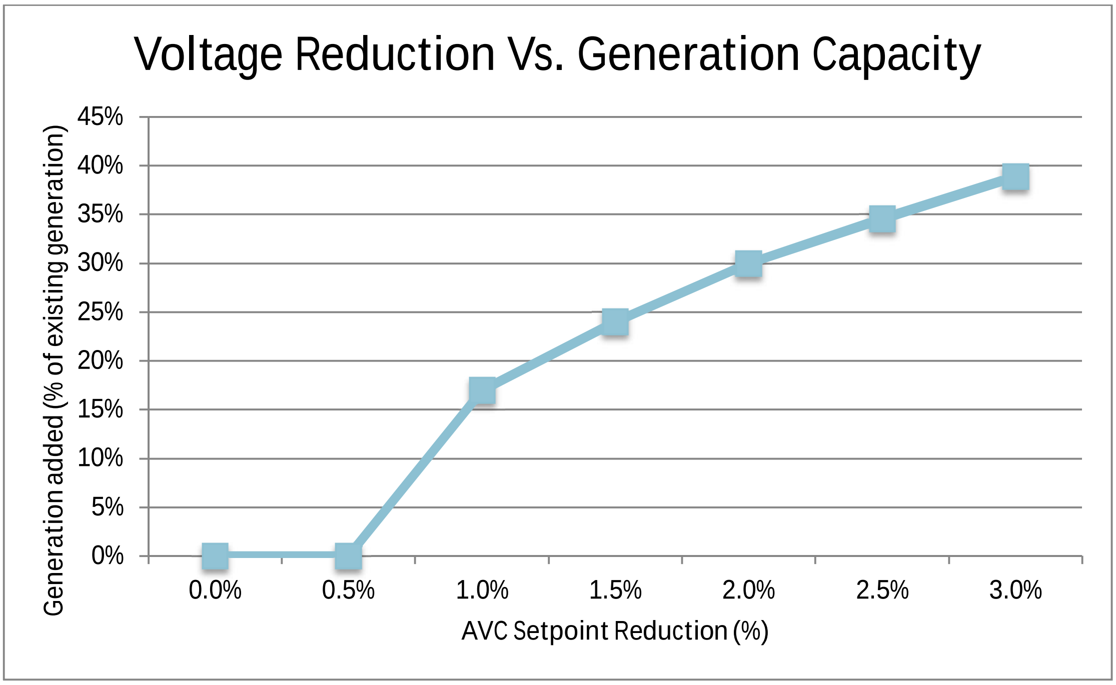
Whilst the amending of voltage limits is a binary condition, the delivery of benefits comes from applying these changes to networks when applied. The amendment of voltage limits allows for a DNO to carry out sufficient diligence in each network area, considering the network equipment and, if appropriate, amending the tap profile of distribution substations across 11kV feeders.

SVO Method

The System Voltage Optimisation (SVO) method involves monitoring and controlling of the distribution system voltage profiles downstream of eight BSPs, in real time, based on group demand, feeder demand and Distributed Generation output. Modelling of this method was performed by modifying the AVC set-point of the grid transformers in a selected BSP in various steps and recording the voltage profile alterations induced downstream in the network, i.e. on the primary substation bars and the 11kV and 33kV circuits. The additional amount of generation available for connection could then be calculated by incrementally increasing the level of generation within the studied subsystem and monitoring the voltage and loading levels, ensuring that the current statutory voltage limits and circuit/transformer ratings are not exceeded.

The 'Maximum Generation, Minimum Load' scenario was again selected as the worst case for this modelling exercise and a BSP was studied for which the level of connected Distributed Generation has reached a saturation point (based on the firm capacity of the BSP and of the primary substations fed from it). It was observed that for a 2% voltage drop of the AVC set-point at the secondary of the grid transformers of the selected BSP, an additional 30% of generation could be connected to the BSP subsystem (i.e. 130% in total). The effect of different voltage set-point reductions, across the range of 0.5% to 3% was modelled and the associated capacity released for each scenario was recorded. Note: In order to measure the capacity released for each AVC set-point setting, the output of the existing generators in the BSP system was uniformly increased in PSS/E in steps of 1-2%, with the exception of certain generators for which major over-voltages and/or circuit over-loadings were observed. The output of these generators was set at its nominal value while generation in the remaining parts of the network was increased.

Up-scaling to an area of 8 BSPs and associated substations, also taking into account the average firm capacity and connected generation for BSPs across the project area, the overall capacity release for this method was calculated at 194.43MVA.



It is estimated that the combination of the EVA and SVO methods (i.e. reduction of the AVC setpoint along with an increase of the allowable voltage limits) would result in at least 10% further increase of the overall capacity release, as compared to the separate implementation of the two methods.

The SVO method could release capacity at least 18 months more quickly than the SVO Base case. The deployment of SVO has been estimated as being within an 18 months' timescale, this timescale to deploy SVO based on early adoption. The timescale includes planning, site visits, lead time for ordering equipment, installation and commissioning. Once the SVO control system is in place, new customers could be connected much more quickly (the timescale dominated by the lead time for the customer to purchase their new generation set).

FPL Method

The Flexible Power Link (FPL) method will manipulate real and reactive power flows, on a dynamic basis, between previously unconnected 33kV networks. Modelling of the 33kV FPL was performed by selecting one of the 4 potential FPL sites (i.e. a normal open point on a 33kV feeder). The voltage on both ends was then monitored in order to identify what the effect of transferring the existing real and reactive power across the normal open point was, for different operating conditions of the flexible power link. It was thus concluded that an operating condition where the FPL transferred 50% of its MVA capacity as real power (MW) across the normal open point and contributed the other 50% of its capacity as reactive power (MVAr) absorbed on each end (25% on each end) was the optimal in terms of the voltage profile across the normally open (N/O) point of the feeder. 20MVA of total capacity was assumed for the 33kV FPL.

Optimising the voltage profile across the 33kV feeder (i.e. on both ends of the normal open point) allowed the addition of new generation on the side of the N/O point from where active power was extracted, as well as in the surrounding primary substations and feeders. The maximum value of additional generation was limited by the incurrence of over-voltages and/or over-loadings within the studied network.

The FPL method could release capacity at least 12 months more quickly than the FPL Base case. The deployments of FPLs have been estimated as within 24 months; this is heavily dominated by the current worst case lead time for the equipment. It is expected that when designs and standards are created for these devices, this timescale will reduce. Detailed planning and design can take place in parallel with equipment ordering.

Summary

Modelling results for the studied areas of BSPs and Primary S/S are summarised in the following table.

Method	New Setting/Network Condition	Capacity Release (MVA)
EVA	+/-1% Voltage limit	81.01
SVO	-2% AVC set-point	194.43
33kV FPL	20MVA transfer	36.2

The Capacity Release for the three methods, scaled up to licensee and GB roll-out levels is presented in Appendix A2. The assumptions related to project replications by 2030 and 2050 are explained in the first part of the present appendix; the same replications are also applicable for the calculation of Capacity Release.

Appendix B – Costs

B - Costs

Second Tier Funding Request		2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	Total
Cost	*From Project Cost Summary sheet*							
	Labour	21.75	351.21	443.31	271.28	130.75	43.67	1,261.97
	Equipment	-	2,617.00	3,475.00	598.67	-	-	6,690.67
	Contractors	-	1,149.77	1,295.63	708.40	175.26	10.25	3,339.32
	IT	-	220.00	76.33	100.00	-	-	396.33
	IPR Costs	-	-	-	-	-	-	-
	Travel & Expenses	-	74.10	57.71	12.88	13.60	1.02	159.31
Payments to users & Contingency		2.18	441.21	535.87	170.99	33.83	6.03	1,190.09
	Decommissioning	-	-	-	-	-	-	-
	Other	-	-	10.66	18.65	18.65	5.33	53.29
	Total	23.93	4,853.28	5,894.52	1,880.86	372.09	66.30	13,090.97
External funding	*Any funding that will be received from Project Partners and/or External Funders - from Project Cost Summary sheet*							
	Labour	-	-	-	-	-	-	-
	Equipment	-	-	-	-	-	-	-
	Contractors	-	-	-	-	-	-	-
	IT	-	-	-	-	-	-	-
	IPR Costs	-	-	-	-	-	-	-
	Travel & Expenses	-	-	-	-	-	-	-
Payments to users & Contingency		-	-	-	-	-	-	-
	Decommissioning	-	-	-	-	-	-	-
	Other	-	-	-	-	-	-	-
	Total	-	-	-	-	-	-	-
DNO extra contribution	*Any funding from the DNO which is in excess of the DNO Compulsory Contribution - from Project Cost Summary sheet*							
	Labour	-	-	-	-	-	-	-
	Equipment	-	-	-	-	-	-	-
	Contractors	-	-	-	-	-	-	-
	IT	-	-	-	-	-	-	-
	IPR Costs	-	-	-	-	-	-	-
	Travel & Expenses	-	-	-	-	-	-	-
Payments to users & Contingency		-	-	-	-	-	-	-
	Decommissioning	-	-	-	-	-	-	-
	Other	-	-	-	-	-	-	-
	Total	-	-	-	-	-	-	-
Initial Net Funding Required		*calculated from the tables above*						
	Labour	21.75	351.21	443.31	271.28	130.75	43.67	1,261.97
	Equipment	-	2,617.00	3,475.00	598.67	-	-	6,690.67
	Contractors	-	1,149.77	1,295.63	708.40	175.26	10.25	3,339.32
	IT	-	220.00	76.33	100.00	-	-	396.33
	IPR Costs	-	-	-	-	-	-	-
	Travel & Expenses	-	74.10	57.71	12.88	13.60	1.02	159.31
Payments to users & Contingency		2.18	441.21	535.87	170.99	33.83	6.03	1,190.09
	Decommissioning	-	-	-	-	-	-	-
	Other	-	-	10.66	18.65	18.65	5.33	53.29
	Total	23.93	4,853.28	5,894.52	1,880.86	372.09	66.30	13,090.97
Direct Benefit	*from Direct Benefits sheet*							
	Total	-	-	-	-	-	-	-
DNO Compulsory Contribution / Direct Benefits			*from Project Cost Summary sheet*					
	Labour	2.18	35.12	44.33	27.13	13.07	4.37	126.20
	Equipment	-	261.70	347.50	59.87	-	-	669.07
	Contractors	-	114.98	129.56	70.84	17.53	1.02	333.93
	IT	-	22.00	7.63	10.00	-	-	39.63
	IPR Costs	-	-	-	-	-	-	-
	Travel & Expenses	-	7.41	5.77	1.29	1.36	0.10	15.93
Payments to users & Contingency		0.22	44.12	53.59	17.10	3.38	0.60	119.01
	Decommissioning	-	-	-	-	-	-	-
	Other	-	-	1.07	1.87	1.87	0.53	5.33
	Total	2.39	485.33	589.45	188.09	37.21	6.63	1,309.10
Outstanding Funding required		*calculated from the tables above*						
	Labour	19.58	316.09	398.98	244.15	117.67	39.30	1,135.77
	Equipment	-	2,355.30	3,127.50	538.80	-	-	6,021.60
	Contractors	-	1,034.80	1,166.07	637.56	157.74	9.22	3,005.38
	IT	-	198.00	68.70	90.00	-	-	356.70
	IPR Costs	-	-	-	-	-	-	-
	Travel & Expenses	-	66.69	51.94	11.59	12.24	0.92	143.37
Payments to users & Contingency		1.96	397.09	482.28	153.89	30.44	5.42	1,071.08
	Decommissioning	-	-	-	-	-	-	-
	Other	-	-	9.59	16.79	16.79	4.80	47.96
	Total	21.53	4,367.96	5,305.06	1,692.77	334.88	59.67	11,781.87
balance	11,477.54	0.00	7,088.06	1,968.65	366.44	54.91	(0.54)	11,477.54
interest		0.00	185.66	90.57	23.35	4.21	0.54	304.33
								11,781.87

Bank of England interest rate		0.5%	SECOND TIER FUNDING REQUEST £				11,477.54		
interest rate used in calculation		2.0%							
RPI adjustment	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/2022	2022/2023
Index	259.5	267.6	275.9	284.4	293.2	302.3	311.7	321.4	331.3
Annual inflation	3.10%	3.10%	3.10%	3.10%	3.10%	3.10%	3.10%	3.10%	3.10%

nab the Second Tier Funding Request calculation should use the Bank of England Base rate plus 1.5% on 31 June of the year in which the Full Submission is made.

C – Maps & Network Diagrams

C1 – Constraint Map

This map shows the Network Equilibrium project area, Somerset and Devon, and provides an overview of the constraints that are present on the existing 33kV and 132kV network. The types of constraints identified are voltage, thermal overload and fault level.

C2 - Existing Sample Network Voltage Heat Map

Provided in this map is the voltage at a BSP and through the network to its connected primary substations, represented as a heat map. The scale for this and all the heat maps in this appendix is; Blue indicates a voltage of 1pu and through to Red representing 1.06pu (statutory voltage limits).

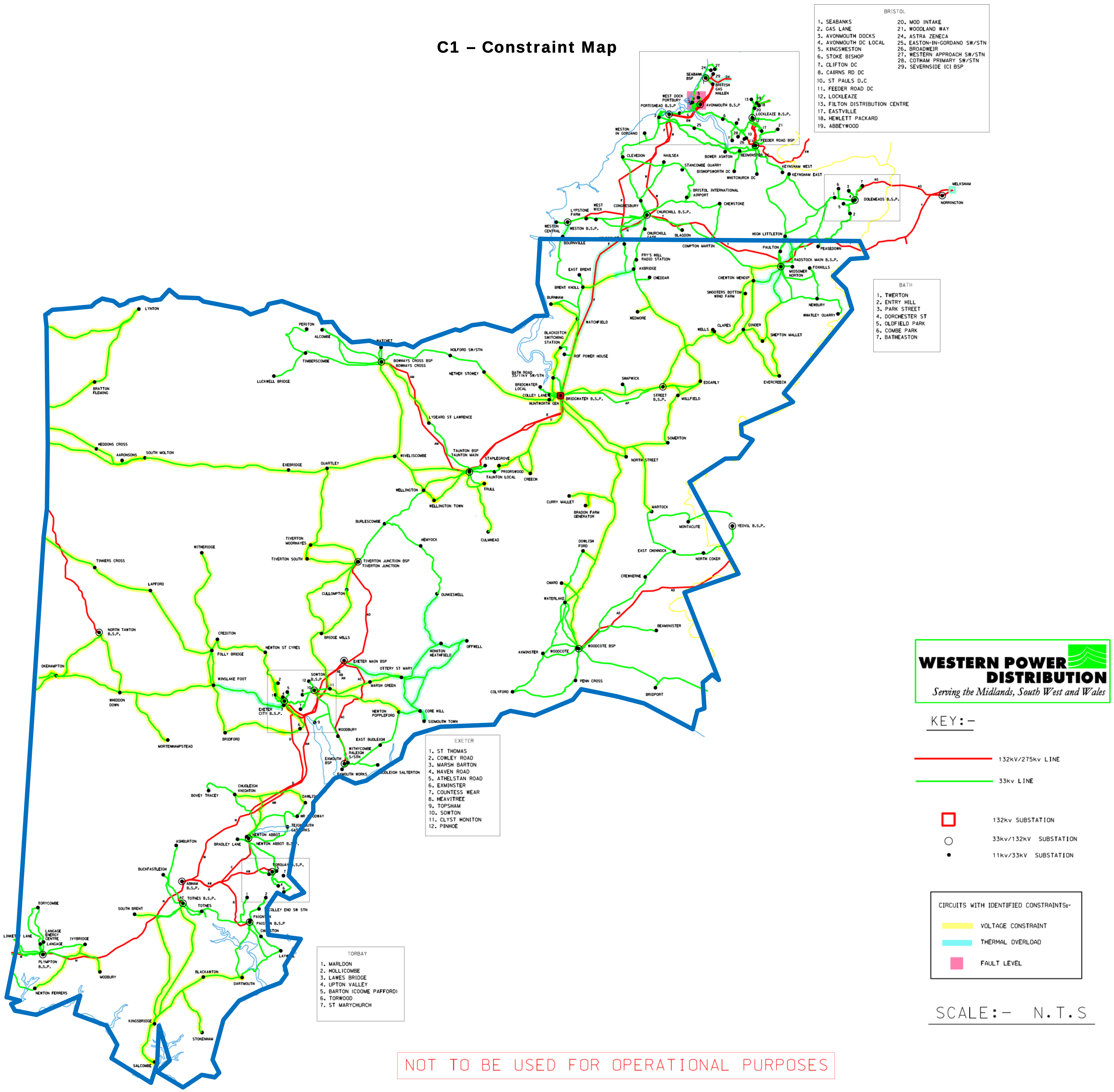
C3 – Proposed SVO Control Sample Network Voltage Heat Map

This heat map represents the same network as in C2, however, the voltage at the BSP has been reduced by 2% by utilising the SVO Method. The effect is that a significant amount of the network now has reduced its voltage and therefore moved down the heat map scale.

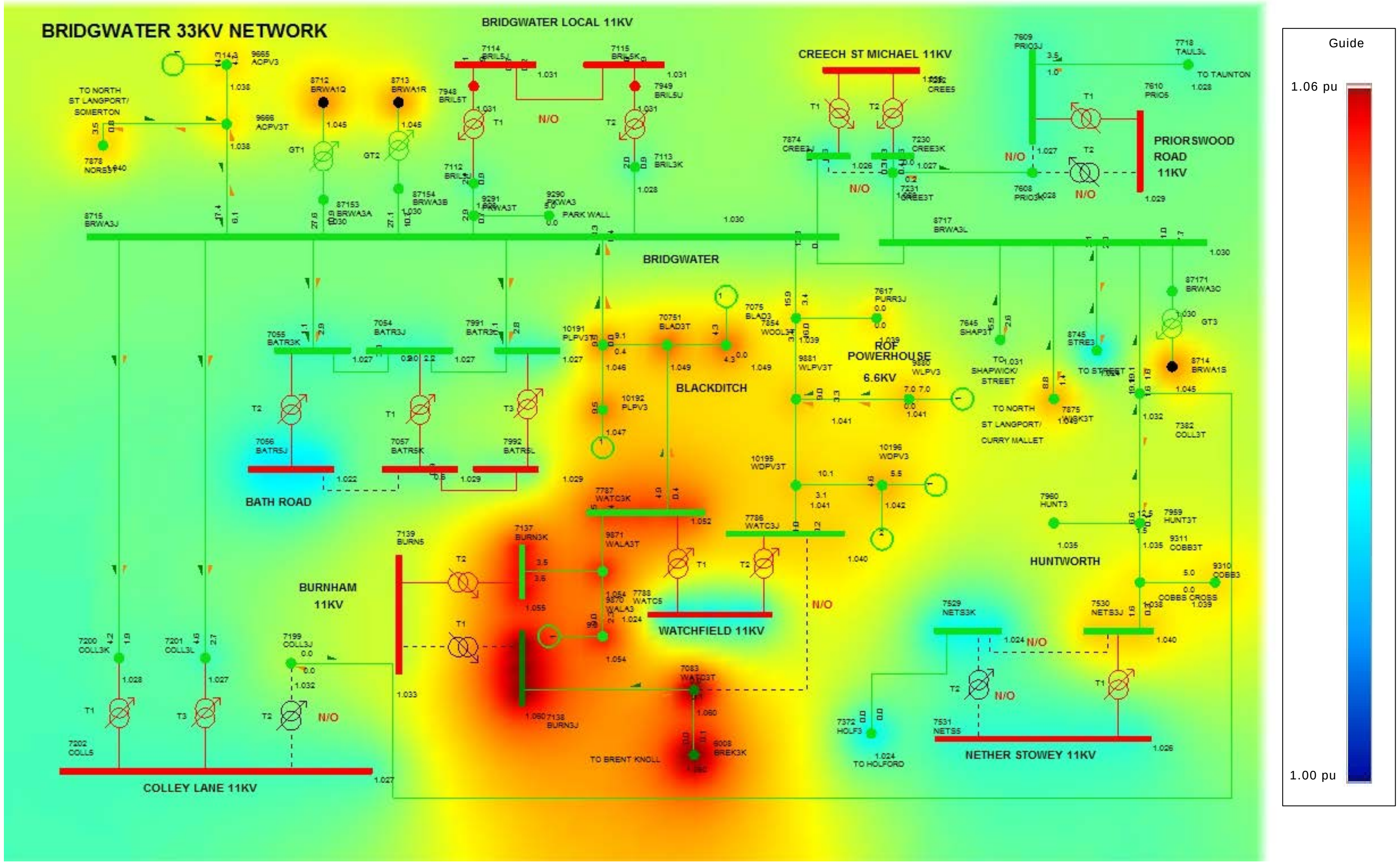
C4 – Proposed SVO Control with 30% additional Generation Sample Network Voltage Heat Map

Using the map provided in C3, this map shows the voltage, in heat map form, when a further 30% (33MVA in this instance) of generation is connected to the system. It can be seen that this heat map is lower down the scale than the original, provided in C2, meaning that by deploying the SVO Method at least 30% of additional generation can be added to the existing system utilising its existing assets

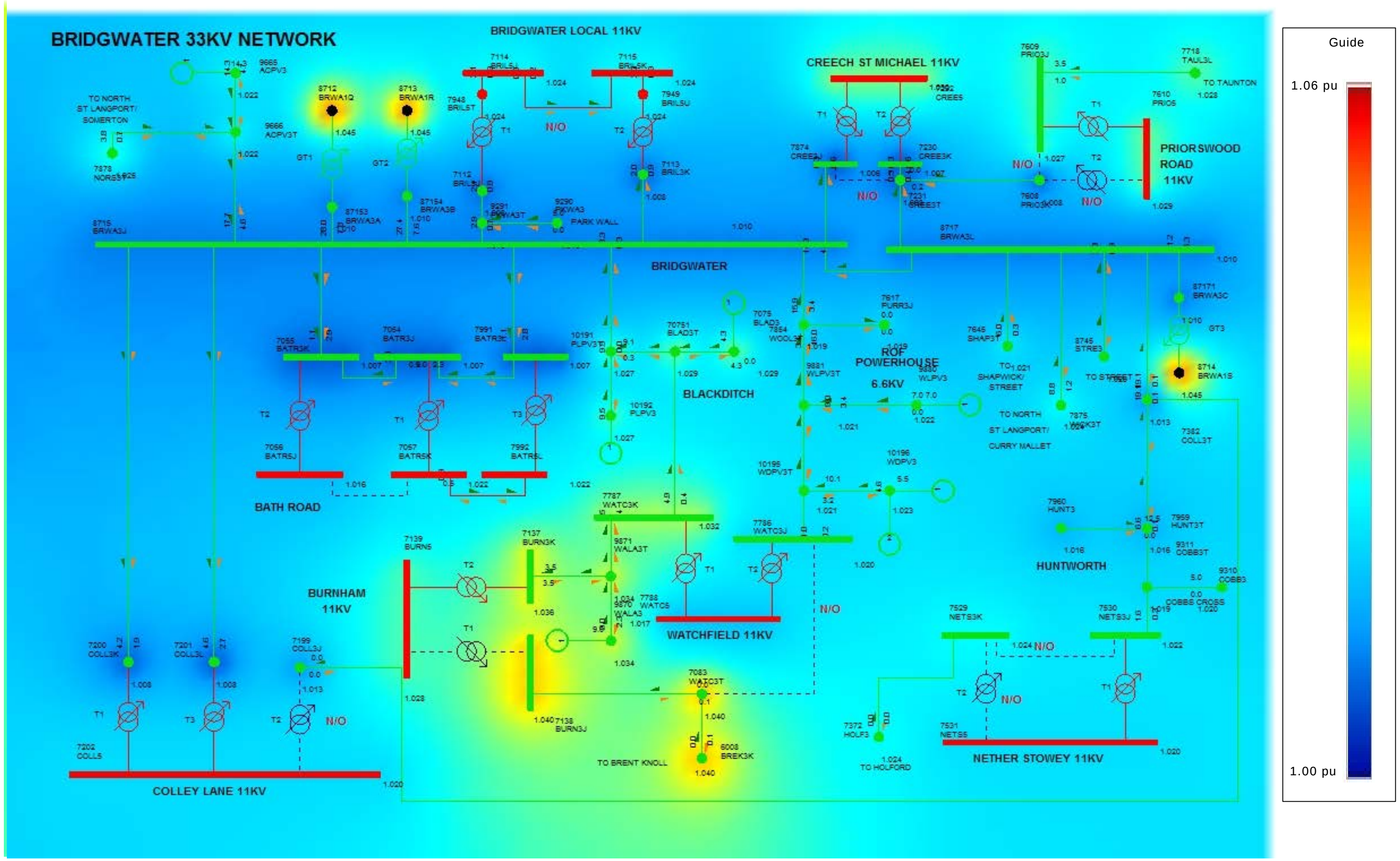
C1 – Constraint Map



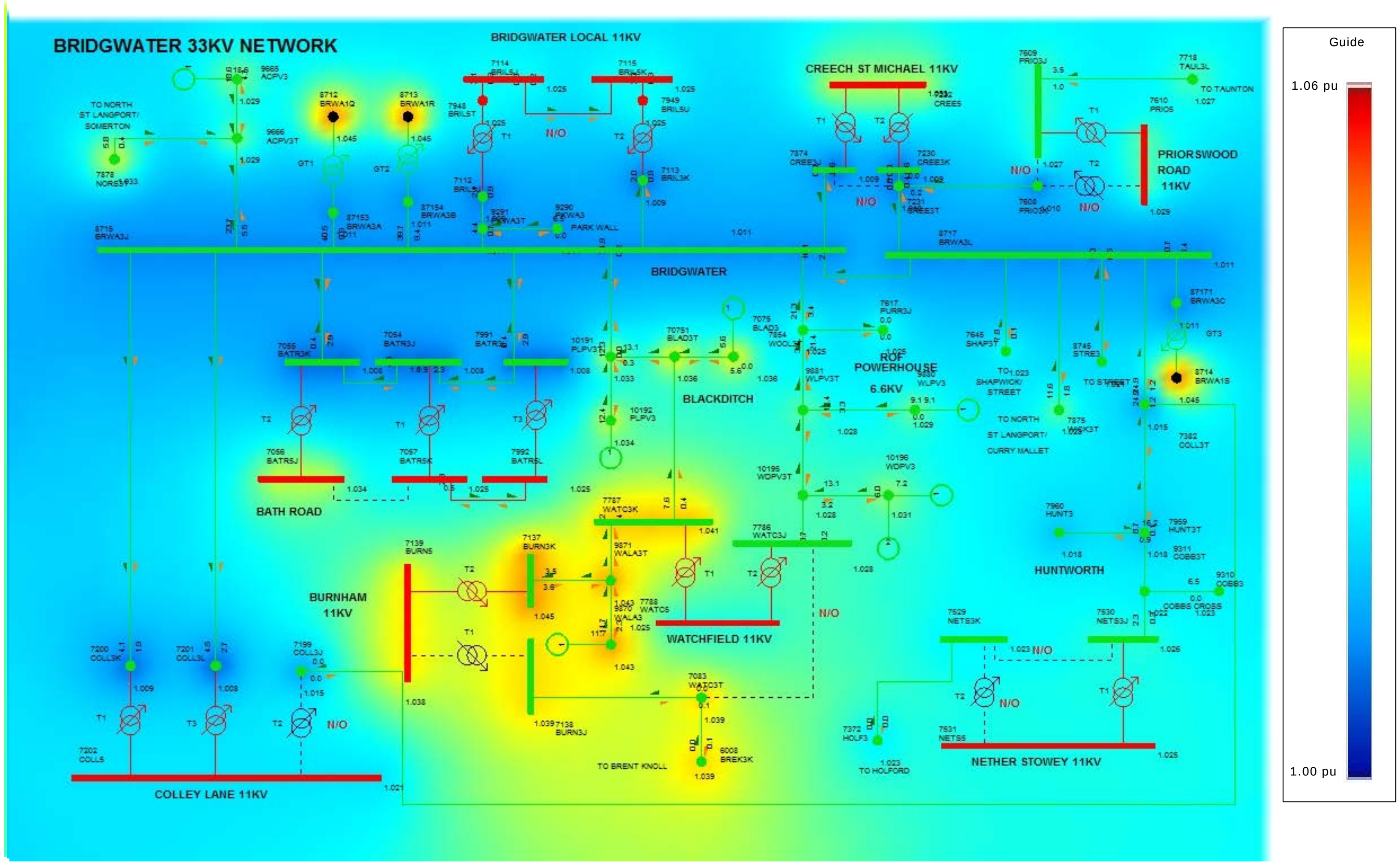
C2 – Existing Sample Network Voltage Heat Map



C3 – Proposed SVO Control Sample Network Voltage Heat Map



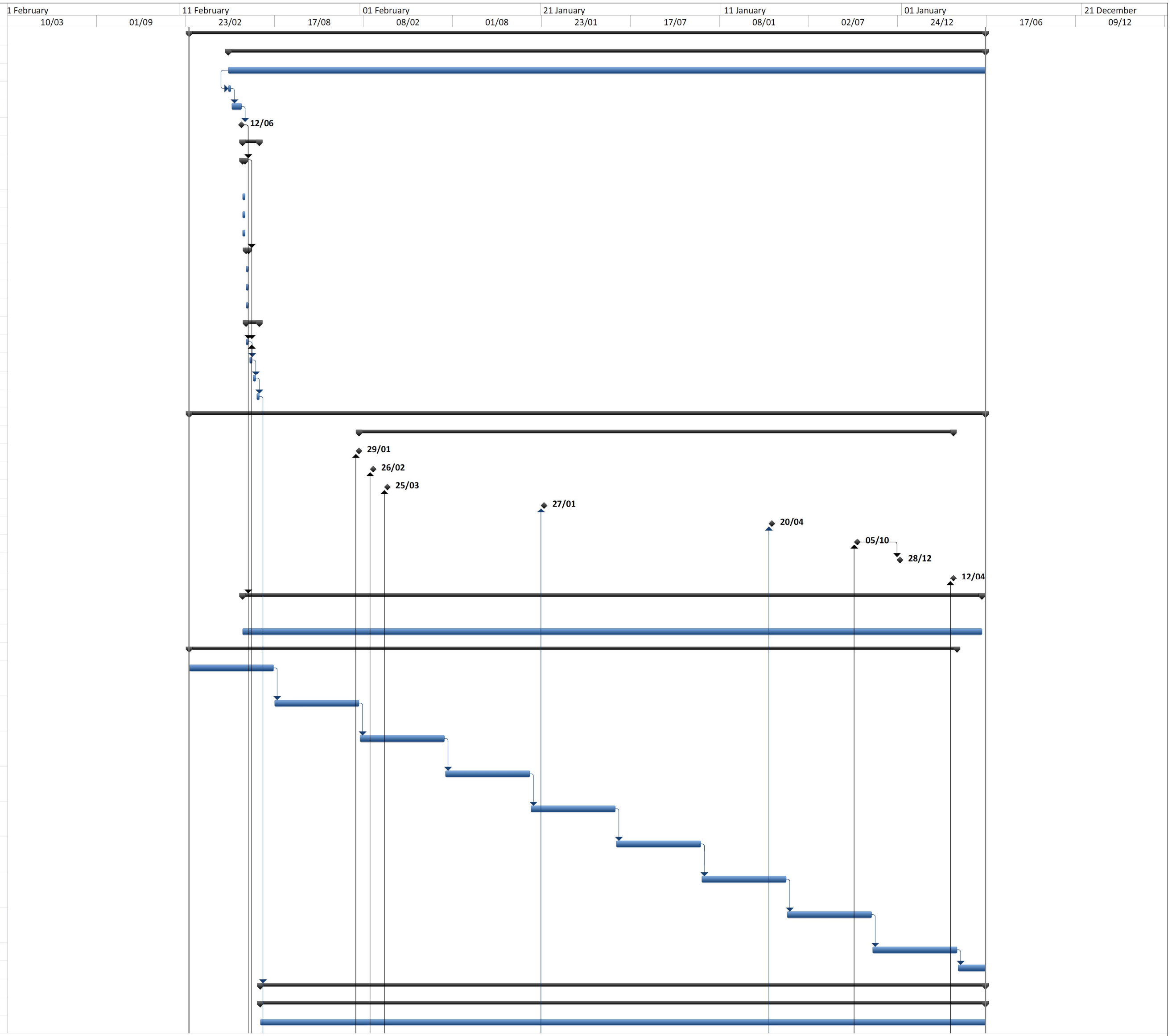
C4 – Proposed SVO Control with 30% additional Generation Sample Network Voltage Heat Map



Appendix D – Project Plan

D – Project Plan

ID		Task Name	Duration	Start	Finish
1		**Equilibrium**	**1120 days**	**Mon 02/03/15**	**Fri 14/06/19**
2		**Project Management**	**1065 days**	**Mon 18/05/15**	**Fri 14/06/19**
3		Manage Project	1065 days	Mon 18/05/15	Fri 14/06/19
4		Produce PID	5 days	Mon 18/05/15	Fri 22/05/15
5		PID Review	15 days	Mon 25/05/15	Fri 12/06/15
6		PID Approved	0 days	Fri 12/06/15	Fri 12/06/15
7		**Project Initiation**	**25 days**	**Mon 15/06/15**	**Fri 17/07/15**
8		**Consolidation in to existing governance structure**	**5 days**	**Mon 15/06/15**	**Fri 19/06/15**
9		Establish Project Governance Requirements	5 days	Mon 15/06/15	Fri 19/06/15
10		Establish Project Tolerances	5 days	Mon 15/06/15	Fri 19/06/15
11		Confirm Escalation Process	5 days	Mon 15/06/15	Fri 19/06/15
12		**Bid Review**	**5 days**	**Mon 22/06/15**	**Fri 26/06/15**
13		Review Aims	5 days	Mon 22/06/15	Fri 26/06/15
14		Review Objectives	5 days	Mon 22/06/15	Fri 26/06/15
15		Review Deliverables	5 days	Mon 22/06/15	Fri 26/06/15
16		**Mobilisation**	**20 days**	**Mon 22/06/15**	**Fri 17/07/15**
17		Project Team Kick-off Meeting	5 days	Mon 22/06/15	Fri 26/06/15
18		Update RAID Log	5 days	Mon 29/06/15	Fri 03/07/15
19		Set up Bank Account	5 days	Mon 06/07/15	Fri 10/07/15
20		Mobilisation to Design Gateway Review	5 days	Mon 13/07/15	Fri 17/07/15
21		**Reporting**	**1120 days**	**Mon 02/03/15**	**Fri 14/06/19**
22		**SDRCs**	**835 days**	**Fri 29/01/16**	**Fri 12/04/19**
23		SDRC-1	0 days	Fri 29/01/16	Fri 29/01/16
24		SDRC-2	0 days	Fri 26/02/16	Fri 26/02/16
25		SDRC-3	0 days	Fri 25/03/16	Fri 25/03/16
26		SDRC-4	0 days	Fri 27/01/17	Fri 27/01/17
27		SDRC-5	0 days	Fri 20/04/18	Fri 20/04/18
28		SDRC-6	0 days	Fri 05/10/18	Fri 05/10/18
29		SDRC-7	0 days	Fri 28/12/18	Fri 28/12/18
30		SDRC-8	0 days	Fri 12/04/19	Fri 12/04/19
31		**Create Status Report for Snr Management**	**1040 days**	**Mon 15/06/15**	**Fri 07/06/19**
32		Monthly Updates	1040 days	Mon 15/06/15	Fri 07/06/19
33		**Ofgem Progress Reports**	**1080 days**	**Mon 02/03/15**	**Fri 19/04/19**
34		1 - six monthly progress report	6 mons	Mon 02/03/15	Fri 14/08/15
35		2 - six monthly progress report	6 mons	Mon 17/08/15	Fri 29/01/16
36		3 - six monthly progress report	6 mons	Mon 01/02/16	Fri 15/07/16
37		4 - six monthly progress report	6 mons	Mon 18/07/16	Fri 30/12/16
38		5 - six monthly progress report	6 mons	Mon 02/01/17	Fri 16/06/17
39		6 - six monthly progress report	6 mons	Mon 19/06/17	Fri 01/12/17
40		7 - six monthly progress report	6 mons	Mon 04/12/17	Fri 18/05/18
41		8 - six monthly progress report	6 mons	Mon 21/05/18	Fri 02/11/18
42		9 - six monthly progress report	6 mons	Mon 05/11/18	Fri 19/04/19
43		CloseDown Report	2 mons	Mon 22/04/19	Fri 14/06/19
44		**Meetings**	**1020 days**	**Mon 20/07/15**	**Fri 14/06/19**
45		**Project Team**	**1020 days**	**Mon 20/07/15**	**Fri 14/06/19**
46		Monthly	1020 days	Mon 20/07/15	Fri 14/06/19

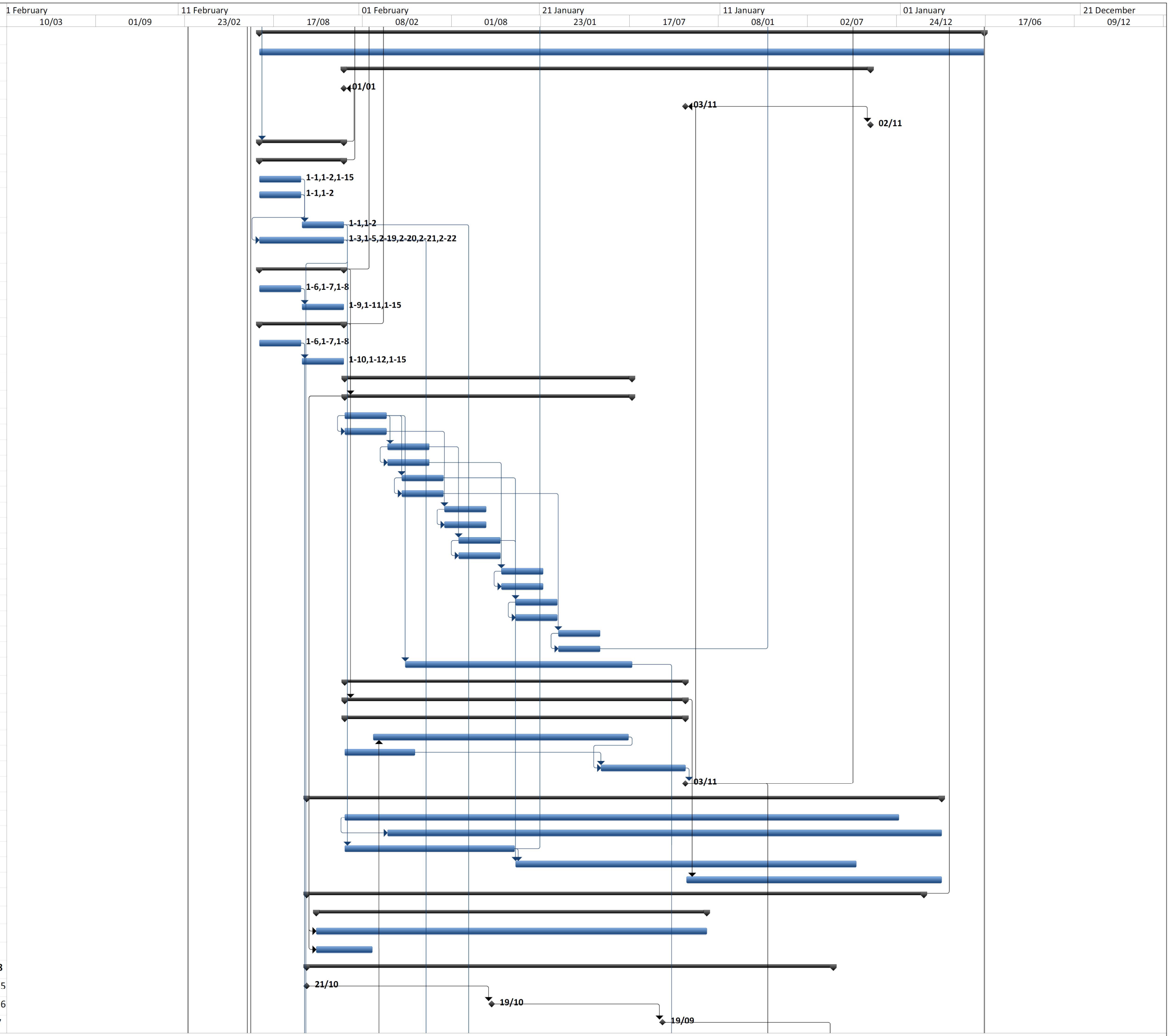


Project: EQBM - Project Plan - V0.
Date: Mon 06/10/14

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Deadline | Progress

Appendix D – Project Plan

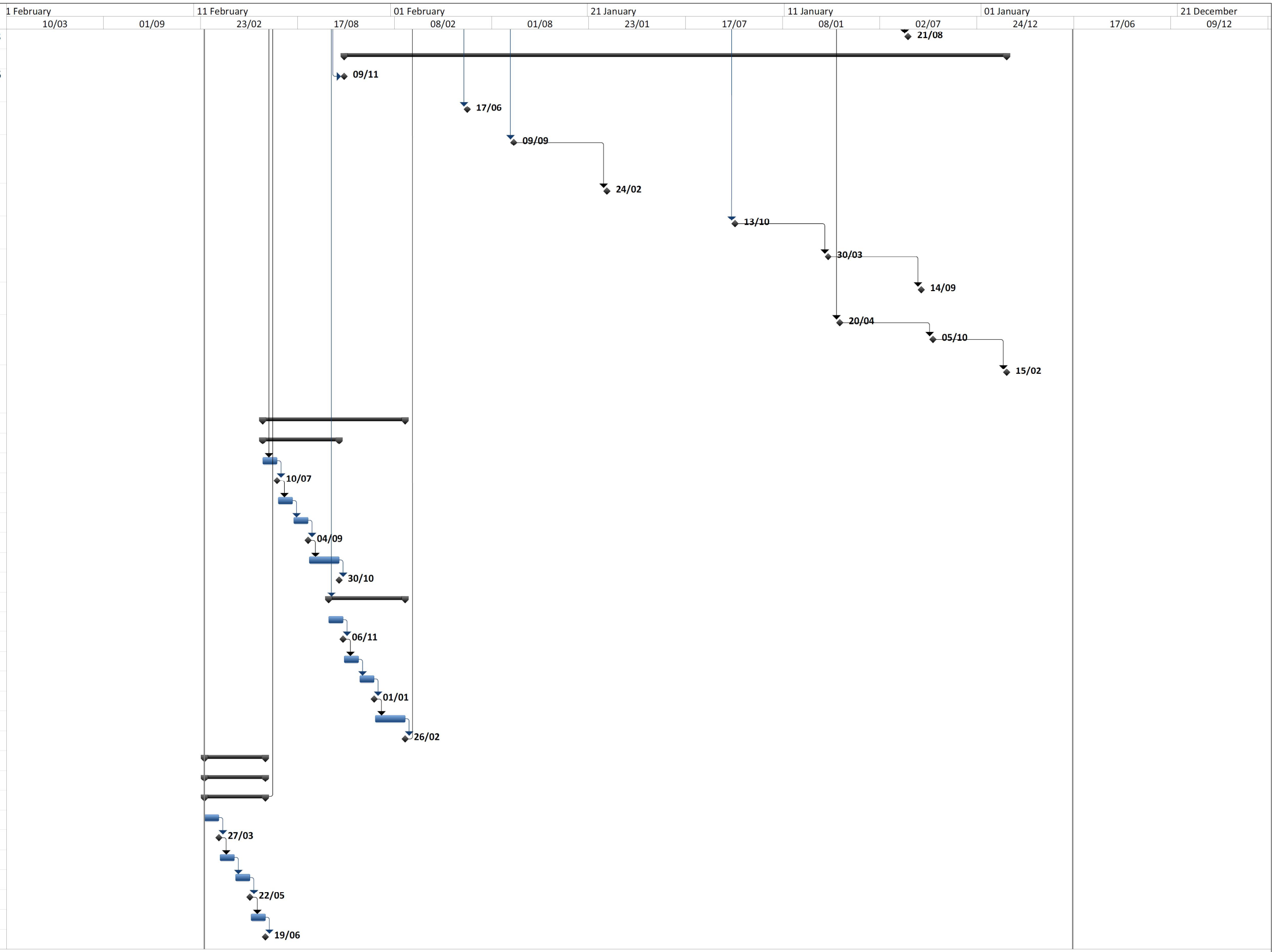
ID	Task Name	Duration	Start	Finish
47	**Steering Group**	**1020 days**	**Mon 20/07/15**	**Fri 14/06/19**
48	Quarterly	1020 days	Mon 20/07/15	Fri 14/06/19
49	**Gateway Reviews**	**740 days**	**Fri 01/01/16**	**Fri 02/11/18**
50	Design to Build	0 days	Fri 01/01/16	Fri 01/01/16
51	Build to Trials	0 days	Fri 03/11/17	Fri 03/11/17
52	Trials to Share	0 days	Fri 02/11/18	Fri 02/11/18
53	**Work Package A - Detailed Design**	**120 days**	**Mon 20/07/15**	**Fri 01/01/16**
54	**EVA**	**120 days**	**Mon 20/07/15**	**Fri 01/01/16**
55	Advanced Network Modelling and Data Recover	3 mons	Mon 20/07/15	Fri 09/10/15
56	Detailed Investigation of Substations - Method Feasibility	3 mons	Mon 20/07/15	Fri 09/10/15
57	Enhanced Modelling	3 mons	Mon 12/10/15	Fri 01/01/16
58	Detailed Assessment of Voltage Limits - EVA Specification Planning & Operational	6 mons	Mon 20/07/15	Fri 01/01/16
59	**SVO**	**120 days**	**Mon 20/07/15**	**Fri 01/01/16**
60	Site Selection	3 mons	Mon 20/07/15	Fri 09/10/15
61	Site Design	3 mons	Mon 12/10/15	Fri 01/01/16
62	**FPL**	**120 days**	**Mon 20/07/15**	**Fri 01/01/16**
63	Site Selection	3 mons	Mon 20/07/15	Fri 09/10/15
64	Site Design	3 mons	Mon 12/10/15	Fri 01/01/16
65	**Work Package B - SVO Build**	**405 days**	**Mon 04/01/16**	**Fri 21/07/17**
66	**SVO**	**405 days**	**Mon 04/01/16**	**Fri 21/07/17**
67	Site 1 - BSP (Delivery & Installation)	3 mons	Mon 04/01/16	Fri 25/03/16
68	Site 1 - Primary (Delivery & Installation)	3 mons	Mon 04/01/16	Fri 25/03/16
69	Site 2 - BSP (Delivery & Installation)	3 mons	Mon 28/03/16	Fri 17/06/16
70	Site 2 - Primary (Delivery & Installation)	3 mons	Mon 28/03/16	Fri 17/06/16
71	Site 3 - BSP (Delivery & Installation)	3 mons	Mon 25/04/16	Fri 15/07/16
72	Site 3 - Primary (Delivery & Installation)	3 mons	Mon 25/04/16	Fri 15/07/16
73	Site 4 - BSP (Delivery & Installation)	3 mons	Mon 18/07/16	Fri 07/10/16
74	Site 4 - Primary (Delivery & Installation)	3 mons	Mon 18/07/16	Fri 07/10/16
75	Site 5 - BSP (Delivery & Installation)	3 mons	Mon 15/08/16	Fri 04/11/16
76	Site 5 - Primary (Delivery & Installation)	3 mons	Mon 15/08/16	Fri 04/11/16
77	Site 6 - BSP (Delivery & Installation)	3 mons	Mon 07/11/16	Fri 27/01/17
78	Site 6 - Primary (Delivery & Installation)	3 mons	Mon 07/11/16	Fri 27/01/17
79	Site 7 - BSP (Delivery & Installation)	3 mons	Mon 05/12/16	Fri 24/02/17
80	Site 7 - Primary (Delivery & Installation)	3 mons	Mon 05/12/16	Fri 24/02/17
81	Site 8 - BSP (Delivery & Installation)	3 mons	Mon 27/02/17	Fri 19/05/17
82	Site 8 - Primary (Delivery & Installation)	3 mons	Mon 27/02/17	Fri 19/05/17
83	Implementation of the SVO solution	16 mons	Mon 02/05/16	Fri 21/07/17
84	**Work Package C - FPL Build**	**480 days**	**Mon 04/01/16**	**Fri 03/11/17**
85	**FPL**	**480 days**	**Mon 04/01/16**	**Fri 03/11/17**
86	**Site 2 - 33kV**	**480 days**	**Mon 04/01/16**	**Fri 03/11/17**
87	Procurement of FPL Technology (Build)	18 mons	Mon 29/02/16	Fri 14/07/17
88	Substation Equipment (Switchgear Delivery)	20 wks	Mon 04/01/16	Fri 20/05/16
89	Site works (Substation Installations)	6 mons	Mon 22/05/17	Fri 03/11/17
90	FPL Energisation	0 days	Fri 03/11/17	Fri 03/11/17
91	**Work Package D - Trial and Share**	**893 days**	**Wed 21/10/15**	**Fri 22/03/19**
92	Capture Monitoring Data	780 days	Mon 04/01/16	Fri 28/12/18
93	Analyse Monitoring Data	780 days	Mon 28/03/16	Fri 22/03/19
94	EVA Testing (Evaluation & Verify)	240 days	Mon 04/01/16	Fri 02/12/16
95	Evaluate, Verify & Analyse SVO	24 mons	Mon 05/12/16	Fri 05/10/18
96	Evaluate, Verify & Analyse FPL	18 mons	Mon 06/11/17	Fri 22/03/19
97	**Knowledge Transfer and Dissemination**	**868 days**	**Wed 21/10/15**	**Fri 15/02/19**
98	**Training**	**550 days**	**Mon 09/11/15**	**Fri 15/12/17**
99	Operational Staff	550 days	Mon 09/11/15	Fri 15/12/17
100	Design Staff	80 days	Mon 09/11/15	Fri 26/02/16
101	**Conferences**	**740 days**	**Wed 21/10/15**	**Tue 21/08/18**
102	LCNI 2015	0 days	Wed 21/10/15	Wed 21/10/15
103	NIA/C 2016	0 days	Wed 19/10/16	Wed 19/10/16
104	NIA/C 2017	0 days	Tue 19/09/17	Tue 19/09/17



Project: EQBM - Project Plan - V0. Date: Mon 06/10/14	Task		Summary		External Milestone		Inactive Summary		Manual Summary Rollup		Finish-only
	Split		Project Summary		Inactive Task		Manual Task		Manual Summary		Deadline
	Milestone		External Tasks		Inactive Milestone		Duration-only		Start-only		Progress

Appendix D – Project Plan

ID	Task Name	Duration	Start	Finish
105	NIA/C 2018	0 days	Tue 21/08/18	Tue 21/08/18
106	**Workshops**	**855 days**	**Mon 09/11/15**	**Fri 15/02/19**
107	Workshop 1 - Amending 11kV and 33kV voltage limits	0 days	Mon 09/11/15	Mon 09/11/15
108	Workshop 2 - Unlocking capacity using amended voltage limits	0 days	Fri 17/06/16	Fri 17/06/16
109	Workshop 3 - How to implement enhanced planning tools for planning & operational purposes	0 days	Fri 09/09/16	Fri 09/09/16
110	Workshop 4 - Unlocking capacity using enhanced planning tools	0 days	Fri 24/02/17	Fri 24/02/17
111	Workshop 5 - How to implement SVO at a system level	0 days	Fri 13/10/17	Fri 13/10/17
112	Workshop 6 - Maintaining customer connections using enhanced operations tools	0 days	Fri 30/03/18	Fri 30/03/18
113	Workshop 7 - Ability to unlock capacity using SVO	0 days	Fri 14/09/18	Fri 14/09/18
114	Workshop 8 - How to implement FPLs	0 days	Fri 20/04/18	Fri 20/04/18
115	Workshop 9 - Ability to unlock capacity using FPLs	0 days	Fri 05/10/18	Fri 05/10/18
116	Workshop 10 - Implementing and unlocking capacity (generation & demand) as a combined project	0 days	Fri 15/02/19	Fri 15/02/19
117	**Tender Process - Systems**	**185 days**	**Mon 15/06/15**	**Fri 26/02/16**
118	**Supplier 3 - SVO**	**100 days**	**Mon 15/06/15**	**Fri 30/10/15**
119	Produce ITT	20 days	Mon 15/06/15	Fri 10/07/15
120	Release Tender	0 days	Fri 10/07/15	Fri 10/07/15
121	Tender Completion	20 days	Mon 13/07/15	Fri 07/08/15
122	Tender Analysis	20 days	Mon 10/08/15	Fri 04/09/15
123	Tender Award	0 days	Fri 04/09/15	Fri 04/09/15
124	Form Contract	40 days	Mon 07/09/15	Fri 30/10/15
125	Sign Contract	0 days	Fri 30/10/15	Fri 30/10/15
126	**Supplier 4 - FPL**	**100 days**	**Mon 12/10/15**	**Fri 26/02/16**
127	Produce ITT	20 days	Mon 12/10/15	Fri 06/11/15
128	Release Tender	0 days	Fri 06/11/15	Fri 06/11/15
129	Tender Completion	20 days	Mon 09/11/15	Fri 04/12/15
130	Tender Analysis	20 days	Mon 07/12/15	Fri 01/01/16
131	Tender Award	0 days	Fri 01/01/16	Fri 01/01/16
132	Form Contract	40 days	Mon 04/01/16	Fri 26/02/16
133	Sign Contract	0 days	Fri 26/02/16	Fri 26/02/16
134	**Tender Process - Suppliers 1 & 2**	**80 days**	**Mon 02/03/15**	**Fri 19/06/15**
135	**Project Partner Selection**	**80 days**	**Mon 02/03/15**	**Fri 19/06/15**
136	**Overall Project Partner Tender**	**80 days**	**Mon 02/03/15**	**Fri 19/06/15**
137	Produce Tender	20 days	Mon 02/03/15	Fri 27/03/15
138	Release Tender	0 days	Fri 27/03/15	Fri 27/03/15
139	Tender Completion	20 days	Mon 30/03/15	Fri 24/04/15
140	Tender Analysis	20 days	Mon 27/04/15	Fri 22/05/15
141	Tender Award	0 days	Fri 22/05/15	Fri 22/05/15
142	Form Coll Agg	20 days	Mon 25/05/15	Fri 19/06/15
143	Sign Coll Agg	0 days	Fri 19/06/15	Fri 19/06/15



Project: EQBM - Project Plan - V0.
Date: Mon 06/10/14

Task	Summary	External Milestone	Inactive Summary	Manual Summary Rollup	Finish-only
Split	Project Summary	Inactive Task	Manual Task	Manual Summary	Deadline
Milestone	External Tasks	Inactive Milestone	Duration-only	Start-only	Progress

Appendix E – Risk Register

E – Risk Register

Risk Ref. No.	Risk Status	Risk Frequency	Owner	High Level Definition "There is a risk that..."	Impact	Probability	Proximity	Rating	Raised by	Raised on	Risk Start Date	Target Date	Last Updated	Review Date	Cause "...because of..."	Effect "...leading to..."	Mitigation Action Plan	Signs that the risk is about to occur or
Next No.	Dropdown list	1=Timebound/One-off 2=Ongoing/Recurring 3=Not started	Responsible for mgmnt	Details of the Risk	Score 1-5 (see guide)	Score 1-5 (see guide)	Score 1-5 (see guide)	Auto Calculated	Who raised the Risk?	when was it raised?	When does this risk become relevant (eg: installation risks will not occur until the after the procurement process)	Target Date for Resolution	Last date the risk was updated	Date risk rating should be reviewed	What will Trigger the Risk?	What will happen if it occurs?	How will this Risk be avoided?	
R001	Assigned	1	PB	Insufficient WPD resource is available for project delivery	4	1	3	12	JB	02/06/2014	30/03/2015	31/03/2015	06/10/2014	27/10/2014	High workload due to a combination of asset maintenance, ED1 schemes and DG connections	Strands 2 and 3 not deliverable	Engage with senior stakeholders and the project sponsor to ensure they are aware of the resourcing requirements to deliver the project	Notification from project stakeholders or delivery schedules being delayed
R002	Assigned	1	PB	Project cost of high cost items are significantly higher than expected	5	2	4	40	JB	02/06/2014	30/03/2015	11/12/2015	06/10/2014	20/10/2014	Procurement stage of the project results in higher costs than in the submission spreadsheet	Project contingency being used or issue created and escalated to project board	During bid process RFIs were issued to understand the cost of these items Use the lessons learnt from BAU and other LCNF projects where appropriate	Responses from ITTs are higher than expected
R003	Assigned	1	PB	No SVO available from the contracted supplier	5	2	4	40	JB	02/06/2014	30/03/2015	14/08/2015	06/10/2014	20/10/2014	No systems available due to requirements or technical constraints	Unable to deploy Strand 2	Issue a RFI to the industry to ensure multiple SVO solutions exist Engage with key experts to ensure the requirements are achievable	No suitable system proposals during the tender stage
R004	Assigned	1	PB	No FPL available from the contracted supplier	5	2	4	40	JB	02/06/2014	30/03/2015	11/12/2015	06/10/2014	20/10/2014	No devices available due to requirements or technical constraints	Unable to deploy Strand 3	Issue a RFI to the industry to ensure multiple FPL solutions exist Engage with key experts to ensure the requirements are achievable	No suitable device proposals during the tender stage
R005	Assigned	2	PB	The overall project scope and cost could creep	4	2	3	24	JB	02/06/2014	30/03/2015	31/03/2019	06/10/2014	03/11/2014	Poor control, underestimation of costs at bid stage, changes in technical scope, partner uncertain of scope	Increased cost, delays in project schedule, dissemination outputs are poor quality	Early planning, RfI process and project accountant role identified to manage project costs. A system architecture has been completed and shared with key business stakeholders to ensure that all parties are aware of what is in and out of scope.	Project costs slip
R006	Assigned	3	PB	A partner/supplier may withdraw from the project or have oversold their solution	4	2	2	16	JB	02/06/2014	30/03/2015	31/03/2019	06/10/2014	30/03/2015	Misunderstood technical requirements or misinterpretation of solution	Delay in schedule, inability to achieve SDRCs	Create a clear functional requirement for the procurement stage Consider if activity is critical, understand if the activity can be delivered by an existing partner/supplier or seek new resource Through the RFI process, ensure there is always more then one supplier for every activity.	Partner/supplier under delivers
R007	Assigned	1	PB	Project team does not have the knowledge required to deliver the project	5	3	3	45	JB	02/06/2014	30/03/2015	31/03/2019	06/10/2014	20/10/2014	Lack of continuity from bid to delivery	A gap in project delivery knowledge	Detailed documentation of technical solution, key members of bid team proceed to project team Through the RFI process - Identify where expert support can be used to support the project if required.	Project under delivers
R008	Assigned	2	PB	Technologies/Solutions do not deliver the anticipated network benefits by unlocking capacity	2	4	3	24	JB	02/06/2014	30/03/2015	31/03/2019	06/10/2014	03/11/2014	Technology/Solution not performing as expected and modelled	Project will deliver negative learning	Engage with manufacturers through a RFI process to understand their capabilities Ensure that the scope and specification of the technologies and solutions is clearly designed and tested prior to implementation If appropriate, select two different manufacturers to de risk the trial	Project under delivers
R009	Assigned	1	PB	Selected sites for technology installations become unavailable	3	3	3	27	JB	02/06/2014	30/03/2015	31/12/2017	06/10/2014	27/10/2014	Another business unit requires the site	Different site will be required	Redundant sites will be identified and designed so that technologies can be included in these if required	A business unit indicates that the site is no longer available
R010	Assigned	1	PB	Lack of business buy in / support for the project from key departments including planning, design, control, policy and telecomms	4	1	4	16	PB	25/06/2014	25/06/2014	18/07/2014	06/10/2014	27/10/2014	Any of the business sections refusing to support the project	Potential project termination, delays, high cost	Engagement with identified senior stakeholders starting wk commencing 30th June Identification of the most appropriate Project Sponsor Sharing the project goals and the importance of the learning to key WPD stakeholders	Lack of response or escalation of intent not to support
R011	Assigned	2	PB	Changes to Key Personnel	3	2	4	24	PB	25/06/2014	25/06/2014	31/03/2019	06/10/2014	03/11/2014	Move to another project	Loss of key project knowledge	Rigorous and robust documentation of work. Induction Package to aid new starters.	Projects/business restructures
R012	Assigned	1	PB	FPLs are larger than originally identified and are not suitable for installation	4	2	3	24	JB	01/09/2014	01/09/2014		06/10/2014	20/10/2014	Manufacturer has underestimated the size of the device	larger device with fewer suitable sites	Maximum dimensions provided by manufacturers has been used to select suitable sites	When the tender information is returned the size of the units have increased
R013	Assigned	1	PB	The build of the FPLs takes longer than manufacturers anticipate	3	3	3	27	JB	01/09/2014	01/09/2014		06/10/2014	27/10/2014	Manufacturer has underestimated the build requirements of the device	a slip in the project build schedule and potential effect on learning	Work closely with manufacturers to ensure that the build timescales are realistic and that they have the appropriate resource	the device is delayed or a delay is identified
R014	Assigned	1	PB	FPL manufacturers have underestimated the costs in the RFIs	4	2	3	24	JB	01/09/2014	01/09/2014		06/10/2014	20/10/2014	Manufacturer has not included all the costs involved in providing the device	An increase of cost on the project or the device not being suitable	A suitable cost for the devices is used in the bid, i.e. not the cheapest	Manufacturer requests a larger amount at the tender stage
R015	Assigned	2	PB	Manufacturers do not want to be involved in LCNF projects due to project publication	3	3	3	27	JB	01/09/2014	01/09/2014		06/10/2014	03/11/2014	Negative learning is often shared on LCNF projects	Minimal suitable suppliers available	Identify Network Equilibrium is a LCN Fund project at the RFI stage	Few tenders received

Appendix E – Risk Register

Risk Ref. No.	Risk Status	Risk Frequency	Owner	High Level Definition "There is a risk that…"	Impact	Probability	Proximity	Rating	Raised by	Raised on	Risk Start Date	Target Date	Last Updated	Review Date	Cause "…because of…"	Effect "…leading to…"	Mitigation Action Plan	Signs that the risk is about to occur or
Next No.	Dropdown list	1=Timebound/One-off 2=Ongoing/Recurring 3=Not started	Responsible for mgmnt	Details of the Risk	Score 1-5 (see guide)	Score 1-5 (see guide)	Score 1-5 (see guide)	Auto Calculated	Who raised the Risk?	when was it raised?	When does this risk become relevant (eg: installation risks will not occur until the after the procurement process)	Target Date for Resolution	Last date the risk was updated	Date risk rating should be reviewed	What will Trigger the Risk?	What will happen if it occurs?	How will this Risk be avoided?	
R016	Assigned	1	PB	Integration of SVO algorithm in to existing WPD systems is unachievable	4	2	3	24	JB	01/09/2014	01/09/2014		06/10/2014	20/10/2014	Incompatibility of systems	Unsuitable SVO system or additional cost to provide a suitable interface	Ensure that in the tender it is explicit that the SVO algorithm must interface to WPD's existing system	Integration is unsuccessful
R017	Assigned	2	PB	The amount of data to be transferred as part of SVO Method means an advancement in the communications system used is required	4	2	3	24	JB	01/09/2014	01/09/2014		06/10/2014	03/11/2014	data transfer is not fast or reliable enough	Additional cost and delay on project due to comms build	Work closely with WPD's comms team to ensure the existing can achieve what is required	data is missing/unavailable
R018	Assigned	1	PB	SVO algorithm is not properly tested prior to installation on live system	5	1	3	15	JB	01/09/2014	01/09/2014		06/10/2014	27/10/2014	Manufacturer not understanding testing requirements	Potentially a system that is unsuitable	Ensure that the tender is clear on the testing requirements of the system WPD to have early milestones to operate the SVO in the PowerON Test environment before going live, ironing out any bugs.	testing is not as required
R019	Assigned	1	PB	Existing data points for SVO use are not available	2	4	3	24	JB	01/09/2014	01/09/2014		06/10/2014	27/10/2014	Interfacing to the data points is not available due to mismatched systems	Additional cost and delay to install additional data points	During sites visits, review and record the data points, identifying if additional functionality is required.	Interfacing issues at installation stage
R020	Assigned	2	PB	Broadening voltage limits causes failure/under performance of customer equipment	5	2	2	20	JB	01/09/2014	01/09/2014		06/10/2014	03/11/2014	voltage being too high or too low for the equipment	Damage and/or unavailability of device to customer	Detailed modelling in the EVA method and extensive research on device performance at different voltage levels	customer complaint relating to a device
R021	Assigned	1	PB	PSS/E is unsuitable to run models using historic real-time data or is very slow	4	2	3	24	JB	01/09/2014	01/09/2014		06/10/2014	20/10/2014	PSS/E not being able to handle large sets of time-domain data	different system having to be used Simplified historic data used to reduce data requirements	Ensure that data is produced in a suitable format for PSS/E to process Place functional requirements in the ITT	Concerns raised at the ITT stage Data is in an unsuitable format and PSS/E fails
R022	Assigned	1	PB	PSS/E can not or is slow to converge due to large project network size	3	2	3	18	JB	01/09/2014	01/09/2014		06/10/2014	27/10/2014	PSS/E cannot manage the large amount of network nodes in the model	Splitting of model or running the studies in another system	Understand the maximum model size (number of nodes that PSS/E can converge) Engage with an expert PSS/E software engineer during the bid stage to discuss functional requirements	PSS/E doesn't converge
R023	Assigned	1	PB	PSS/E is unsuitable to model FPL devices	4	2	2	16	JB	01/09/2014	01/09/2014		06/10/2014	27/10/2014	PSS/E cannot model the dynamic nature of FPLs	Another modelling system being required	Ensure that the FPL model is produced in a format suitable for PSS/E Engage with an expert PSS/E software engineer during the bid stage to discuss functional requirements	FPL model cannot be integrated in to PSS/E
R024	Assigned	1	PB	PSS/E is unsuitable to model SVO performance	3	2	3	18	JB	01/09/2014	01/09/2014		06/10/2014	27/10/2014	PSS/E cannot model the dynamic nature of SVO	Another modelling system being required	Ensure that the SVO model is produced in a format suitable for PSS/E Engage with an expert PSS/E software engineer during the bid stage to discuss functional requirements	SVO cannot be integrated in to PSS/E
R025	Assigned	1	PB	Monitoring points cannot be accessed due to substation locations (i.e. on customer premises)	3	3	3	27	JB	01/09/2014	01/09/2014		06/10/2014	27/10/2014	specific locations of the equipment to be monitored	Other monitoring points / different network having to be used	Preparation and co-ordination with the customer to access their property/substations on their site Learn from other LCNF projects who have experienced the same issues	Site is unavailable to be accessed
R026	Assigned	2	PB	National Grid network arrangement means that an FPL cannot be installed at certain locations	3	2	3	18	JB	01/09/2014	01/09/2014		06/10/2014	03/11/2014	Perceived interconnection issues	Another installation location is required	Early engagement with NG to inform them of the technology and the aims of the project Multiple locations at different points in the trial area network	NG refuse a proposed interconnection
R027	Assigned	2	PB	Controlling the 33kV and/or 11kV network using SVO algorithm makes other voltages exceed maximum allowable tolerances	4	2	3	24	JB	01/09/2014	01/09/2014		06/10/2014	03/11/2014	cascade effect of voltage change	complaints / voltage limit excursions	Detailed modelling of the effect on voltage changes on the adjacent voltage levels Modest changes in Target voltage settings Extensive testing in the PowerON simulator	voltage becomes out of limits
R028	Assigned	1	PB	Terms and conditions cannot be agreed with suppliers	4	2	3	24	JB	01/09/2014	01/09/2014		06/10/2014	20/10/2014	Lack of understanding of the LCNF requirements or IPR requirements	Significant delays and/or re-tendering for supplier	Include standard WPD T&C's and IPR requirements in the pre bid RFI Ensure that the full T&Cs of the proposed contract are provided at tender stage	Cannot reach a contractual agreement with a supplier
R029	Assigned	2	PB	The Flexible power links do not meet the UK Harmonics limits	3	2	2	12	PB	02/09/2014	02/09/2014		06/10/2014	03/11/2014	The power electronics emitting high levels of harmonics or causing harmonic resonance	The device being disconnected until the issues are rectified	Harmonic limits included in FPL functional specification. Transient and harmonic studies on all FPL locations. Tested at the FAT.	Device failing the FAT High PQ readings
R030	Assigned	2	PB	The statutory limits for 33kV and 11kV networks can not be amended	3	2	3	18	PB	02/09/2014	02/09/2014		06/10/2014	03/11/2014	1) Technical or commercial barriers prevent the amending of voltage limits 2) Sufficient evidence is not sufficient to result in a change 3) There is not supported by the rest of the industry.	The benefits associated with the method are not achieved	Pre project investigation by the project team, into restrictions in Statutory limits at 11kV & 33kV	Technical limitations identified to the projects team
R031	Assigned	2	PB	FPL have reliability issues resulting in an unacceptable availability	4	2	3	24	PB	03/09/2014	03/09/2014		06/10/2014	03/11/2014	A lack of reliability in the technology or control system	The technique not being suitable for unlocking capacity	1. De risk the method by engaging with manufacturers through issuing a detailed RFI to manufacturers. 2. Select a established and proven Power Electronics technology 3. Include availability in the functional specification 4. Trial another FPL in a separately funded project, if required	If customers of PE devices or control systems highlight reliability issues Device failing the FAT Companies not agreeing to reliability figures in the functional specification.

F – Contingency Plan

A contingency plan has been written for the significant risks on the Risk Register. All risks will be continually monitored and appropriate risk will be referred to the project board. Below are details of how we will mitigate against significant risks becoming an issue and the contingency plans.

R002: Costs of high cost items are significantly higher than expected
Mitigation • During bid process RFIs were issued to understand the cost of these items Contingency • Re-evaluate the technology specification and requirements • Look to reduce the number of technology installations
R003: No SVO available from the contracted supplier
Mitigation • Through the RfI process the availability and lead time for delivery has been discussed and recorded for each system • SVO systems are to be chosen at as high a Technology Readiness Level (TRL) as possible • Substation site investigation has taken place to determine site suitability for SVO inclusion Contingency • Change the Trial location sites to provide locations suitable for the Technology installation • Source the system from an alternative vendor, in order to deliver the project's objectives
R004: No FPL available from the contracted supplier
Mitigation • Through the RfI process the availability and lead time for delivery has been discussed and recorded for each FPL device • Substation site investigation has taken place to determine site suitability for FPL device inclusion Contingency • Change the Trial location sites to provide locations suitable for FPL device • Source the devices from an alternative vendor, in order to deliver the project's objectives
R007: Project team does not have the knowledge required to deliver the project
Mitigation • Key members of the bid team to carry on through project mobilisation • Ensure that project partners and suppliers provide required skills and expertise Contingency • Consider third party resource that has the level of knowledge to support the delivery of the project
R009: Selected sites for technology installations become unavailable
Mitigation • Redundant sites have been identified and will have outline device/system designs carried out • Devices/systems designed to be transferable between sites Contingency • Change the project's area to a location with available sites for device/system installation

G – Roles and Responsibilities

In order to ensure that the best value is provided to the LCN Fund the involvement of each supplier, as part of Network Equilibrium, will be competitively tendered on award of the project.

Below is an overview of the roles and responsibilities of each of the suppliers identified in the bid along with a project Organogram.

Supplier 1 – Specialist Modelling & Design Engineering support

EVA Method

- Responsible for creating the Enhanced Voltage Assessment tool across 10 BSPs using PSS/E as the power system analysis model.
- Responsible for building and configuring the forecasting tool using historic generation and demand data.
- Support WPD with the creation of Policies for the Method.
- Create EVA training packs for 11kV, 33kV and 132kV network planners and control engineers running 6 training sessions with the support of WPD.
- Specifying and creation of power system analysis plugins for modelling smart solutions: SVO, FPL, Generation in voltage control mode and Statcoms.

SVO and FPL Method

- Design Engineering Support including:
    - Site selection;
    - Method feasibility;
    - Integration of System Voltage Optimisation, documentation and drawing modifications; and
    - Integration of Flexible Power Link (including civil designs, electrical designs and protection modifications).
- In conjunction with WPD, write the specification for the SVO method.
- In conjunction with WPD, write the specification for the FPL method.
- Support WPD with the creation of Policies for the Methods.

Project

- Update the original specification due to lessons learnt through Equilibrium.
- Data analysis of all three methods, optimising where appropriate.
- Simulation of future system utilisation and benefit.
- Cost Benefit Analysis of the three methods after implementation.
- Support WPD with knowledge dissemination for the project and all three methods.

Supplier 2 – Enhanced Voltage Assessment – Voltage limits

- Review existing ESQCR statutory voltage limits for 11kV and 33kV networks and the reasoning for their values.
- Review step change limits for 11kV and 33kV networks and the reasoning for their values.
- Evaluate new and existing equipment limitations and any impact of a change in statutory voltages, noting which customers and network assets are the limitations for further modifications.
- If appropriate, collate all evidence and support WPD in recommending amendments to statutory limits.
- Supporting WPD at knowledge capture and dissemination events.

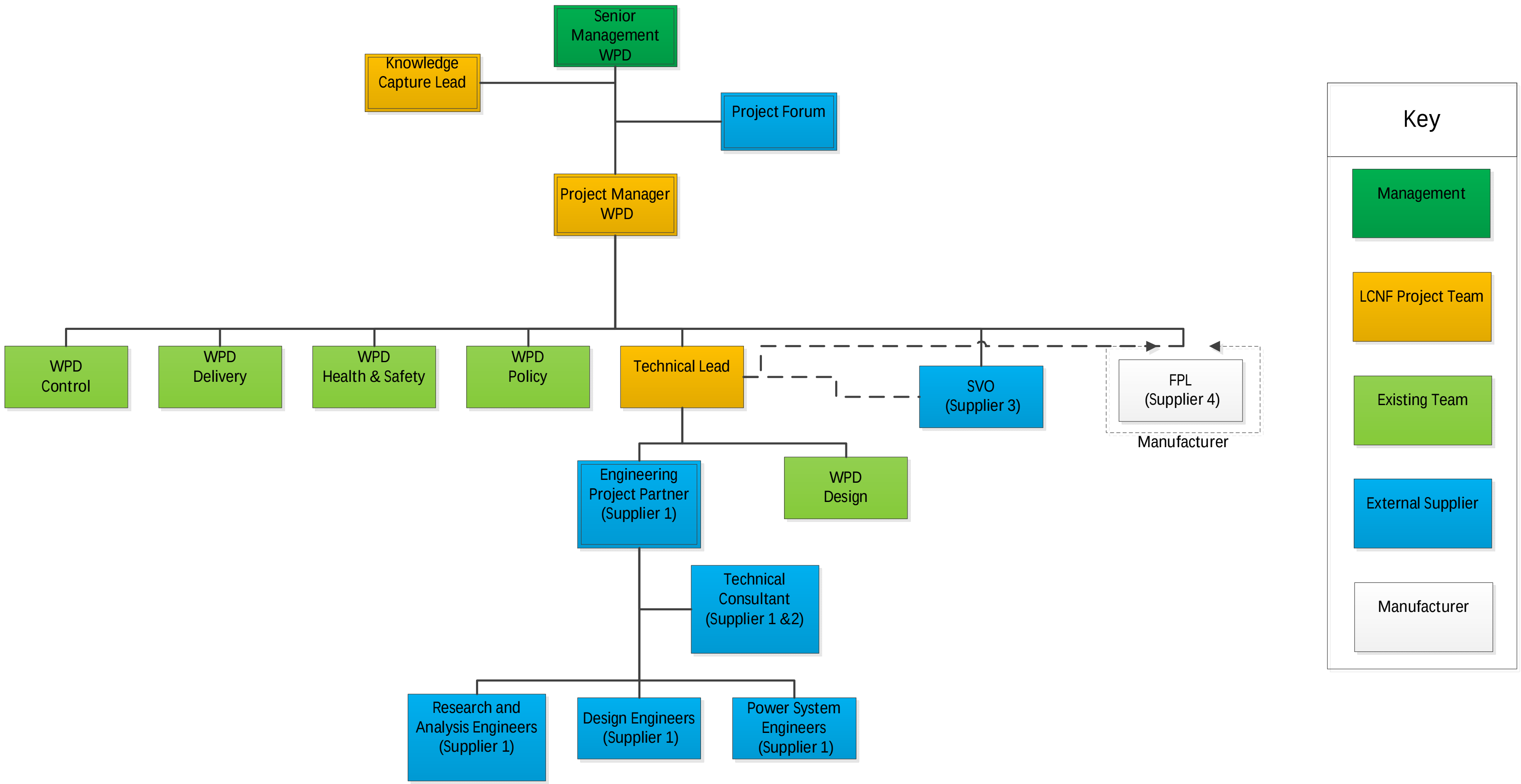
Supplier 3 – System Voltage Optimisation

- In conjunction with WPD, expand on the specification for the SVO method (central SVO system, algorithm, communications network, transducers, Grid and Primary substation equipment functionality).
- Detailed design of SVO architecture and supporting components, documenting how the method will be designed, installed, tested, operated and maintained.
- Script the SVO algorithm, test in PowerON simulator prior to a scaled roll out into PowerON incorporating 8 BSPs and 8 Primary Substations.
- Verify the SVO method, documenting the performance of the SVO, the optimum strategy for transducer location, the DG capacity unlocked under passive and alternative generation connections, the leg room created for increased demand connections.
- Detail the operation under both normal and abnormal operation.
- Support WPD with the creation of Policies for the Method.
- Create SVO training packs for network planners and control engineers running 6 training sessions with the support of WPD.
- Amend the original specification due to lessons learnt through Equilibrium.
- Support WPD with knowledge dissemination for the SVO methods.

Supplier 4 – Flexible Power Link Provider - 33kV

- In conjunction with WPD, expand on the method specification for the 33kV FPL.
- Work with WPD and Supplier 1 to create detailed civil and electrical installation designs for the 33kV FPL.
- Provide, install and cold commission a 33kV Flexible Power Link.
- Provide operational maintenance until June 2019 with an option for extended maintenance.
- Support WPD with the creation of Policies for the Method.
- Create FPL training packs for network planners, control engineers and field staff running 6 training sessions with the support of WPD.
- Amend the original specification due to lessons learnt through Equilibrium.
- Support WPD with knowledge dissemination for the FPL method.

Organogram



Senior Management WPD
Knowledge Capture Lead
Project Forum
Project Manager WPD
WPD Control
WPD Delivery
WPD Health & Safety
WPD Policy
Technical Lead
SVO (Supplier 3)
FPL (Supplier 4)
Manufacturer
Engineering Project Partner (Supplier 1)
WPD Design
Technical Consultant (Supplier 1 &2)
Research and Analysis Engineers (Supplier 1)
Design Engineers (Supplier 1)
Power System Engineers (Supplier 1)
Key
Management
LCNF Project Team
Existing Team
External Supplier
Manufacturer

H – Letters of Support

PARSONS BRINCKERHOFF

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Philip Bale
Innovation and Low Carbon Networks Engineer
Western Power Distribution
Herald Way
Pegasus Business Park
Castle Donington
DE74 2TU
pbale@westernpower.co.uk

4 July 2014

Dear Philip,

Western Power Distribution's 2014 LCN Fund Tier-2 Project: Network Equilibrium

Parsons Brinckerhoff fully supports Western Power Distribution's 2014 bid for project finance from Ofgem's LCN Fund, Tier-2.

Parsons Brinckerhoff is a global leader in electrical power distribution consultancy, providing independent technical advice and project management services to stakeholders across the energy sector. Our clients include regulators, utilities, government departments, project-financers and academic institutions. Parsons Brinckerhoff delivers excellence and innovation to our clients within the growing field of low carbon and sustainable electricity networks.

The project "Network Equilibrium" will demonstrate innovative voltage and power flow management solutions, which will enable greater levels of low carbon technologies to be integrated within electricity distribution networks in a timely and cost-effective way.

There are pertinent issues that Network Equilibrium will address, such as the demonstration of flexible power link technologies (which have not been used to couple distribution networks previously at 33kV and 11kV). This will deliver value to WPD's customers and other stakeholders within the electricity sector. Moreover, the project's aim to deal with power system, communication system and control system outages is highly topical for projects involving active network management.

If proven successful, the Equilibrium solution can be readily deployed across GB and the knowledge generated in this area will be relevant, applicable and transferrable to other GB DNOs.

Yours faithfully
Parsons Brinckerhoff

Séan McGoldrick
Director, Power Networks

Newcastle University

Faculty of Science, Agriculture & Engineering
Human Resources

Newcastle University
Devonshire Building
Newcastle upon Tyne
NE1 7RU United Kingdom

Philip Bale
Innovation and Low Carbon Networks Engineer
Western Power Distribution
Herald Way
Pegasus Business Park
Castle Donington
DE74 2TU

Ref: PT/la

Thursday, 10 July 2014

Dear Philip,

Re: Equilibrium Proposal

I read your Equilibrium proposal with great interest and I am fully supportive of the work described. The project is genuinely innovative and the ideas about the use of back to back converters to provide controllable interconnections at 11kV and 33kV are very exciting and could lead to significant breakthroughs in the flexibility and resilience of distribution networks.

The project is well placed to build on other LCNF projects such as the voltage control aspects of the Customer led Network Revolution project.

I am very encouraged to see that the project has concrete plans to make changes to planning standards, design guidelines and working practices as a result of the learning arising from the network trials. This is important to ensure that projects of this nature don't just become interesting one off initiatives but actually drive change in business as usual.

Another key aspect, which is nice to see in this project, is investigating ways to design systems which are safe and robust to failures in the communications networks. This is a real world practical issue that is often overlooked.

Yours faithfully,

P. Taylor

Phil Taylor
Director, Institute for Sustainability

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Geoff Murphy
SP EnergyNetworks
Prenton Way
Prenton
CH43 3ET

SP ENERGY NETWORKS

18th July 2014

Philip Bale
Innovation and Low Carbon Networks Engineer
Western Power Distribution
Herald Way
Pegasus Business Park
East Midlands Airport
Castle Donington
DE74 2TU

Dear Philip

Re: Network Equilibrium LCN Fund Tier 2 Bid

I am pleased to confirm our support for the Western Power Distribution (WPD) 'Network Equilibrium' LCN Fund Tier 2 bid.

As a Distribution Network Operator SP EnergyNetworks can see value in the research being undertaken by WPD under this proposal. In particular we can see value in the System Voltage Optimisation (SVO) and Flexible Power Link (FPL) methods WPD are looking to trial, particularly as we can see potential for a successful solutions application within our own network.

We would also welcome the opportunity to be involved in this project beyond attending any dissemination activities.

Yours sincerely

GMurphy

Geoff Murphy
Technology Development Manager, Future Networks

nationalgrid

National Grid House
Warwick Technology Park
Gallows Hill, Warwick CV34 6DA

To: Mr. Philip Bale
Western Power Distribution
Herald Way
Pegasus Business Park
East Midlands Airport
Castle Donington
DE74 2TU

16th July 2014

Dear Philip,

I would like to confirm the support in principle of National Grid for the LCNF T2 - Network Equilibrium by Western Power Distribution (WPD) for the Low Carbon Network Fund.

National Grid is the Electricity Transmission Owner of the England and Wales network, and the System Operator in Great Britain. We have number of grid supply points (GSP) with Western Power Distribution across our network and therefore are interested in Network Equilibrium from the technical prospective, and the value it can bring for the consumers.

The technical challenges that the Network Equilibrium is addressing are relevant to National Grid's business particularly the use of Power Electronics to transfer power at the distribution level, enabling careful evaluation of the impact of distributed generation on the Transmission Network. The proposed tool should also be a more economic and efficient measures to facilitate the connection of embedded generation, and provide the support to the network. We are also interested in the potential use of the Flexible Power Links to provide synthetic inertia and the benefits this could have to the transmission system. Additional system monitoring data, as per this proposal, would have augmented the analysis of network behaviour in more detail, and improvements to system reliability.

In conclusion, we are supportive of the proposal and recognise the benefits that will come from the methods which will be trialled and demonstrated as part of Network Equilibrium. We are looking forward to continue our engagement on this project in your knowledge dissemination events.

Kind regards,

Dr. Vandad Hamidi

SMARTer System Performance Manager

[By email]

I – Simple Project Overview

Equilibrium Project Overview

When a new wind turbine or solar panel farm is built, it has to connect to the electricity network to transport the power generated for homes and businesses to use. Due to the numbers that have been connected in recent years, a range of issues have emerged on the grid meaning in some circumstances there is no capacity to connect or that the connection may be very costly.

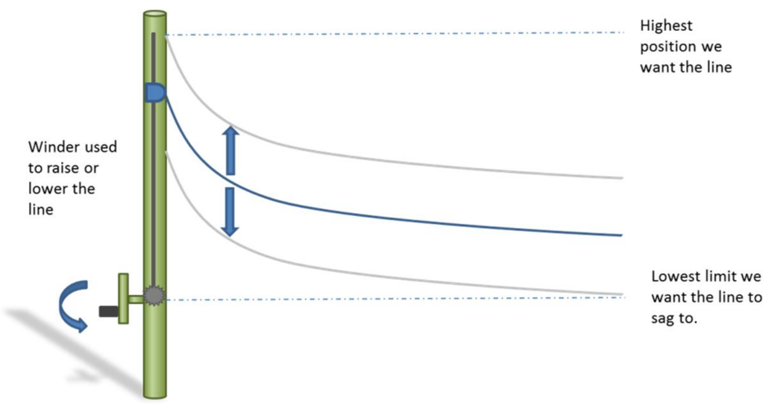
As the network operator, we have to assess and design these connections, primarily with tools not advanced enough to model some of the complex operations we are moving to. Secondly, once wind turbines and other generation are connected it can become more complex to manage the network. In some circumstances this means we cannot connect additional generators without the need for additional expensive network rebuilding. As a result, this can be so costly that projects are stopped.

The Equilibrium project has been designed to address these issues, to improve design and evaluation tools, assess new network operating practices and free up capacity for generators making it easier to connect. This includes the use of System Voltage Optimisation and Flexible Power Links, which are explained in the following pages.

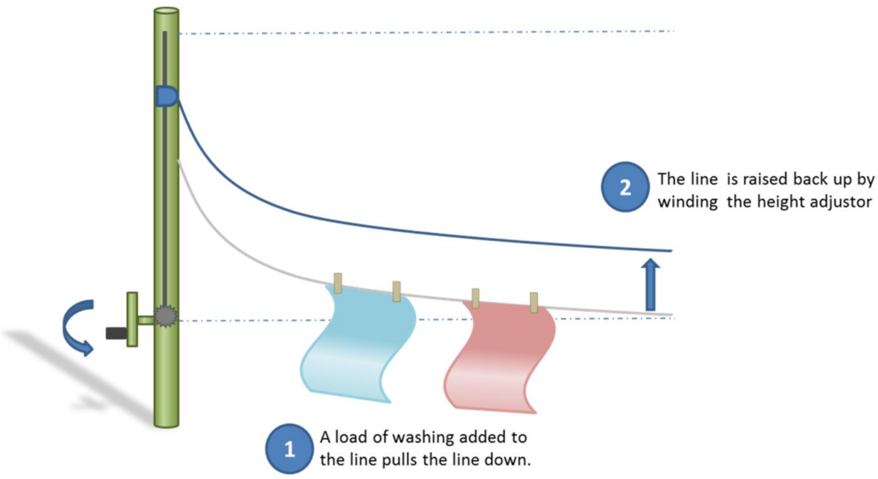
Understanding Network Voltage Control

One of the key issues we face is how to manage the voltage on our network with the presence of generators. If we let the voltage fall too low equipment in homes and businesses may not work properly, get it too high and devices may get damaged.

To help explain why managing voltage with generators is an issue consider the following example. Imagine we have a really long washing line and at one end we have a winder that allows us to raise or lower the line. Ideally we want to keep the line high enough so the washing does not drag on the floor, but not so high that the line can't be reached or it catches in the trees.

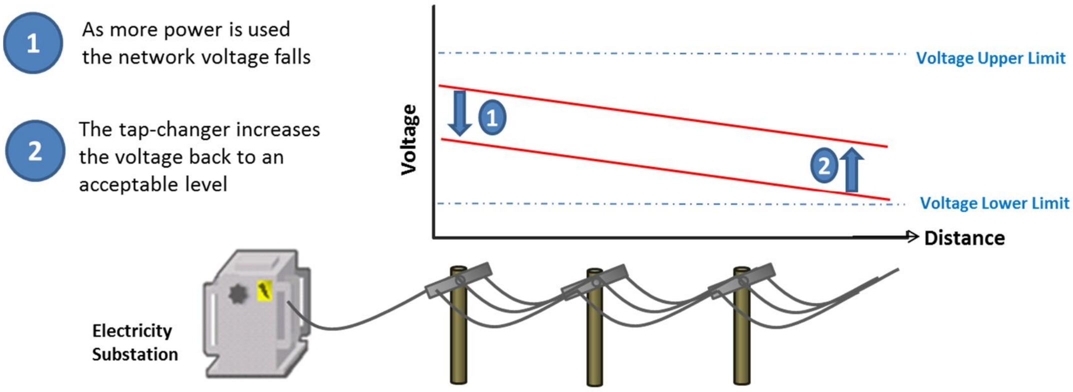


When a load of washing is hung on the line, the weight pulls the line down increasing the risk of the washing dragging on the floor. Winding up at the pole then allows the washing to be lifted.



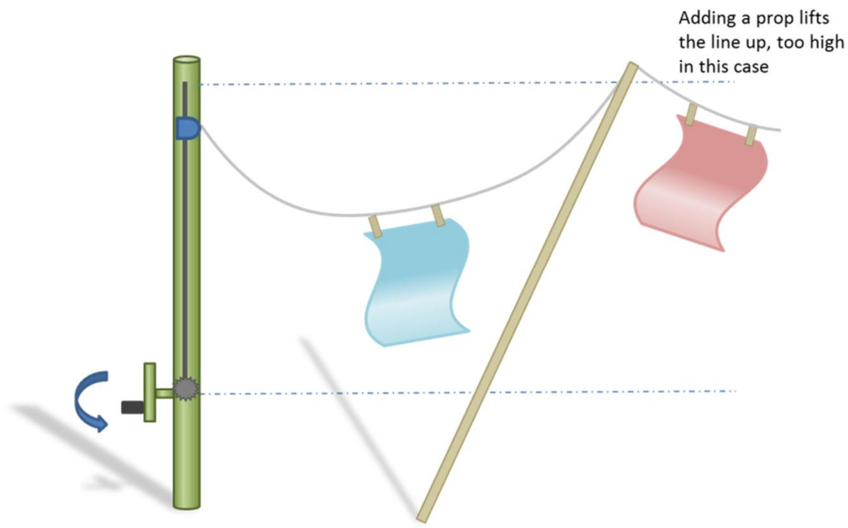
This is similar to how we currently control the voltage on our electricity network.

As electricity flows away from a substation down the cables and conductors, the voltage reduces the further away you get. This voltage falls further as more power is used by homes and business. So, like the winder on the clothes line, we have a device at substations called a tap changer which allows us to turn up or down the voltage to compensate for increasing load and voltage drop on the system. This way we can keep the voltage within the limits we have to work to.



The main challenge with this is to ensure that the voltage across the length of the line is neither too high or too low at all points. So imagine our washing line scenario again. It is relatively easy to control the height of the line if you can see it all. However, our washing line is so long that we can't see the whole length. In fact the only bit we can see is how high the line is at the pole. However based on a number of assumptions such as how stretchy the line is, and how much weight there is on the line we can calculate how much adjustment we need to make to keep the clothes off the floor. This approach is similar to how we model and calculate the settings for our voltage control systems. We can measure the load on the line, and know other factors such as how thick the wires are and how much power they can carry, allowing us to develop static settings for our tap changer controls. Whilst this voltage control technique is automated, it is a fairly passive approach to voltage control as it relies on factors affecting the static settings remaining the same.

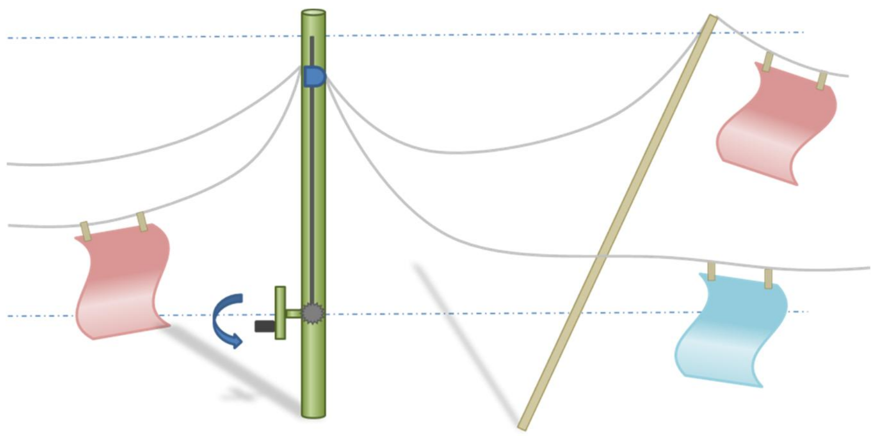
One other aspect we can use to manage the height of our washing line is by adding a prop in the line. This effectively lifts the line and changes its shape as well. However, if we were now to try and model this, the calculations become significantly more complex.



Now imagine the length of this prop can change of its own accord, or even be taken away. Trying to manage the height of the line from the winder alone without full visibility of the line becomes very complex. One solution to this would be to limit the size of the props on the line and cap how many can be used.

This is similar to the effect an embedded generator may have by feeding power into our network. Firstly it can increase the voltage on the network, and secondly it can mask some of the load. In some circumstances, if the load is reduced on the network to a sufficient level, this can result in an excessive rise in the voltage or power flowing back up the network. This can affect the validity of some of the static settings in the voltage control systems making the control less reliable.

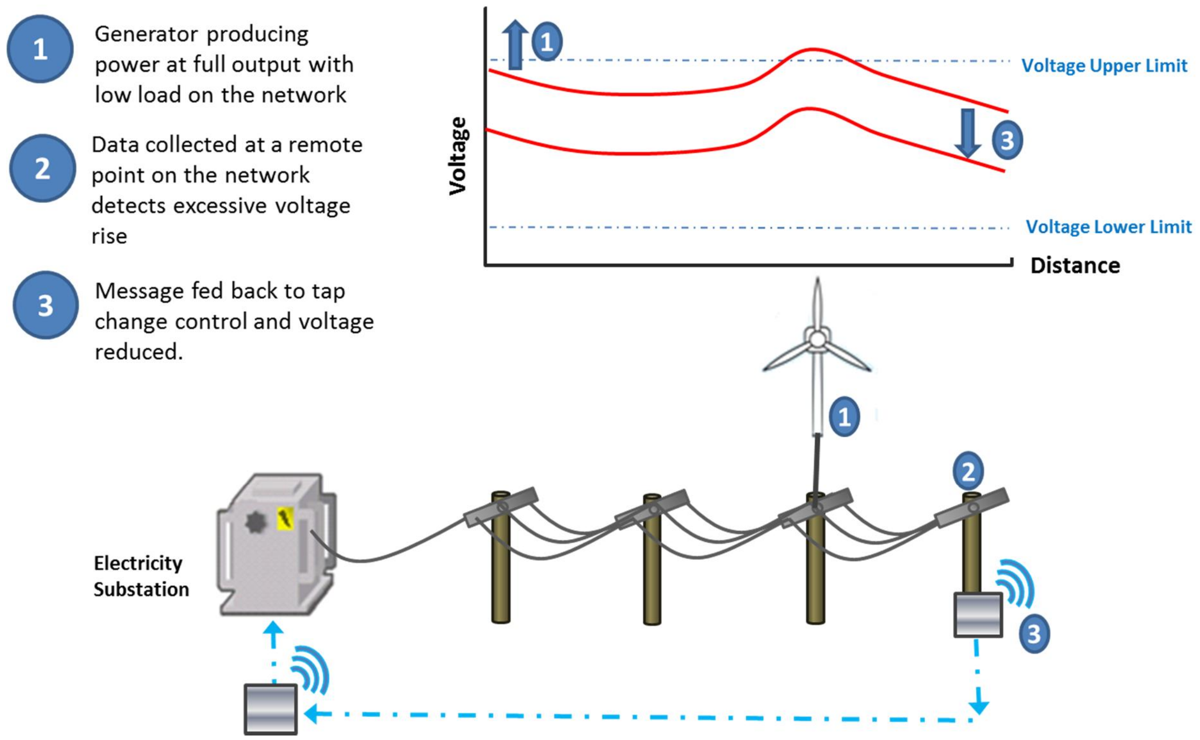
Not only do we have this mix of generation and load to manage, but the generation can be intermittent. As the weather changes, the output of solar or wind generation may vary greatly during short periods. Also, the controls we use to change the voltage does not just affect one bit of network. Going back to the washing line analogy, it is the same as several different washing lines being attached to the same pole with one control.



Therefore, any setting that is made at the pole to adjust the line height has to be appropriate for all the lines attached. Props may be added and removed, as with washing, which makes for a number of complex scenarios.

The solution to this is dynamic washing line control (bear with me on this one). If you can see the full line with props and washing then you can set the height at the pole in the optimum position for all of the lines. If you had someone watching the most critical parts of your washing lines, and reporting back to the pole if the line is too high or too low, you can then optimise the system.

So it is with system voltage control. Information on the voltage across a number of circuits can be collected and then fed back into the voltage control system to allow the optimum voltage to be set for all points of the network.



With Equilibrium, we are looking to deploy system voltage optimisation on a wide scale that will involve covering a network that supplies around 500,000 of our customers. This will create greater security on the network, whilst releasing capacity allowing numerous generators to connect. Additionally, we will develop improved computer modelling tools that will help us understand the complex scenarios on our network before equipment is installed, allowing us to make much more informed decisions, open up capacity on the network and minimise risk to electricity supplies.

Appendix I – Simple Project Overview

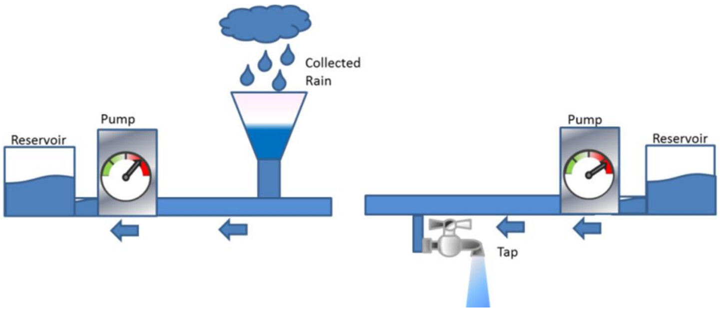
Flexible Power Links

Another area of technology we are going to trial is a Flexible Power Link, a piece of equipment that will allow us to create additional flexibility on how we configure the grid. Our network is made up of many electrical circuits constructed from a mix of underground cables and overhead lines. These circuits run in what is known as a radial design. This can look very similar to trees with sections of line branching off as in the example below. The red lines represent circuits at 11,000 volts, branching out from the main substation, represented by the big green dot.

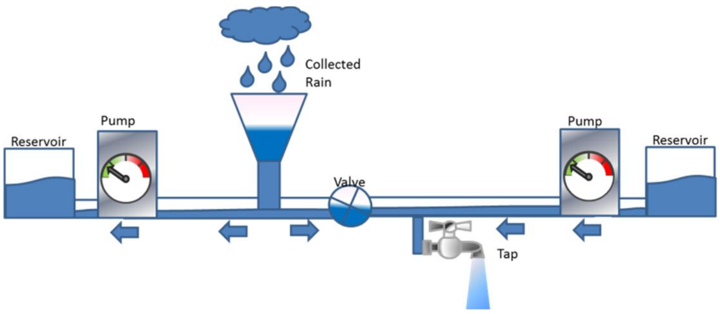
To ensure maximum flexibility in the network, some of the branching circuits connect with other circuits via some form of switch. Usually that switch is off (open) meaning no power can flow between the circuits. However in some circumstances such as faults on the network or maintenance, we may want to join circuits up to change the way power flows. This is done by turning switches on (closed) and connecting the circuits up.

To demonstrate this, and some of the challenges we face, we can consider the flow of electricity to be similar to water flowing in pipes. Imagine two unconnected water pipes. On one side we have a device collecting rain water; on the other side a tap using water. On the rain water side, there is so much water that the pipes are up to capacity and pumps are at full power to move the water away to a reservoir. Meanwhile on the side with the tap, water is being pumped in from another reservoir to meet demand.

Appendix I – Simple Project Overview

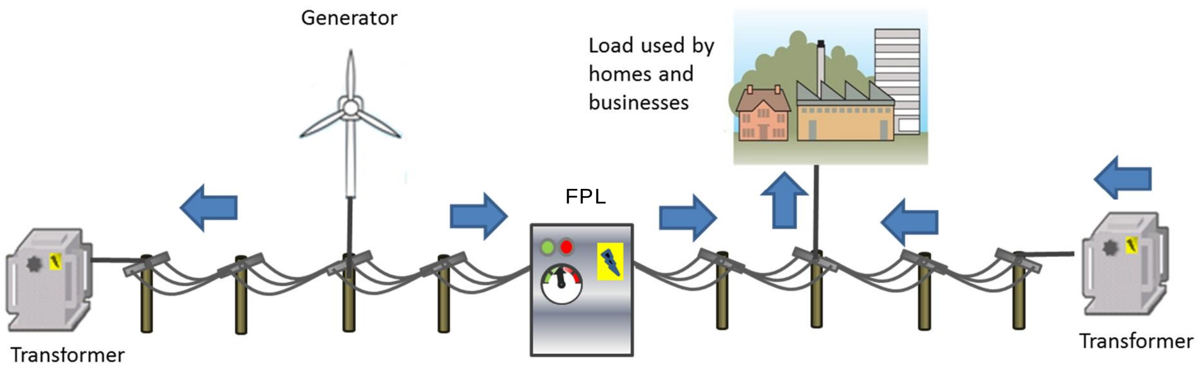


As the pipes are at capacity no additional rain water collectors can be added on the left, or taps on the right. To help alleviate these problems a pipe could be added between the two systems allowing water to be used nearer the reservoir, but having no control over this could cause additional problems. The solution is to add a valve that can facilitate this but limit the flow of water between the two pipes. Also, if there is a significant difference in pressure between the two systems, the valve helps to equalise the water pressure.



On some areas of our network, joining two circuits up can have a similar problem. Where two circuits meet the voltage on one side of the switch may be considerably higher than on the other. Closing the switch and joining the circuits can cause some instability in the network and in some causes result in network protection devices turning the power off for safety reasons.

The Flexible Power Link works in the same way as the water valve. It allows us to safely manage and transfer some load between circuits, while also managing any of the voltage difference between the two circuits. Many of the points where this occurs are down to historic network layout arrangements and are now becoming limiting factors in connecting additional generation. Adding the Flexible Power Link technology will allow more capacity to be added for generation by creating additional stability and flexibility on the network.



J – Project Methods

Background

The management of voltage is a growing concern with the integration of low carbon technologies, particularly distributed generation (DG), within electricity networks. The issue of voltage rise (during steady-state conditions) and voltage step change (during transient network conditions) were recently highlighted by the IET in their Power Network Joint Vision report “Electricity Networks – Handling a shock to the system”. There are increasing numbers of occurrences where a large amount of generation is connected to one distribution system and large amounts of demand occur on another, geographically close, distribution system. However, due to fault level issues and phase angle differences, the distribution systems cannot be coupled and power cannot be efficiently transferred from one system to the other.

Figure 1 shows a generic electricity network with generation connected along a circuit and load connected along another. At times of high generation and low load, the voltage could rise above statutory limits (in excess of 106%). At times of low generation and high load, the voltage could drop below statutory limits (lower than 94%).

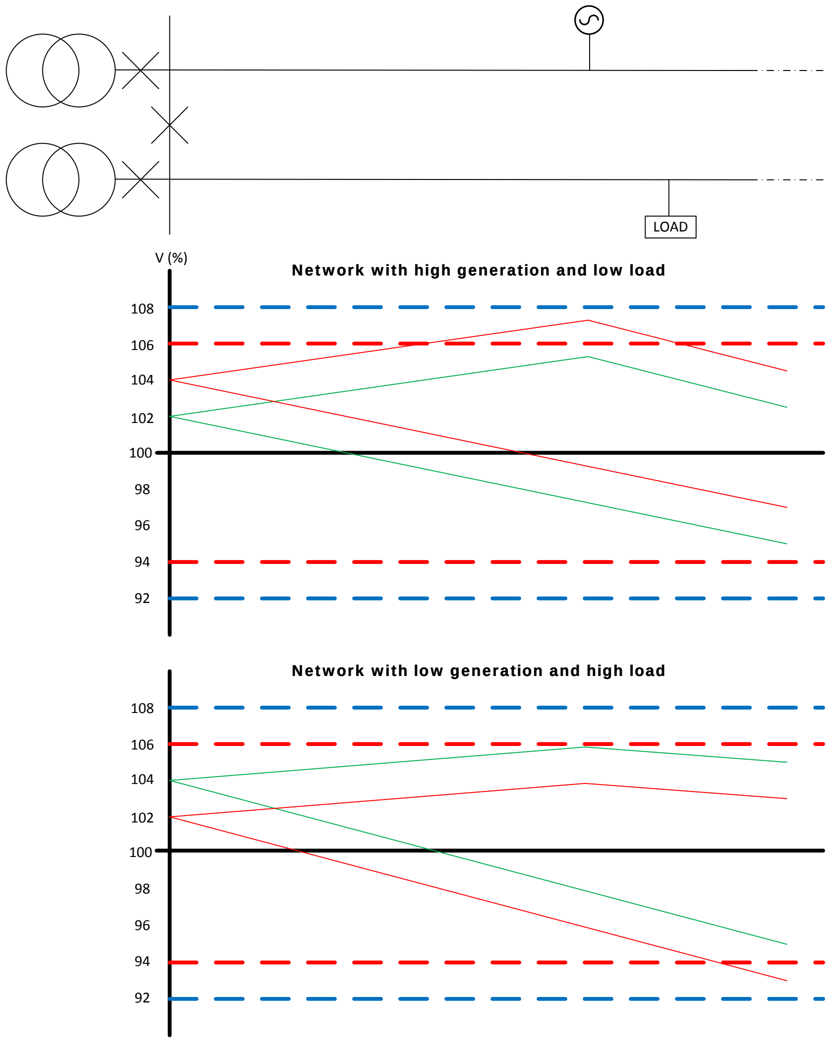


Figure 1 - Graphs of voltage along a line

J1 – Enhanced Voltage Assessment (EVA)

The Problem

At present, DNOs complete a one-off set of connection studies when a new generator applies to connect to the electricity network. The data used in these studies represents the most onerous operating conditions. The connection studies are single "snapshots" of network operating conditions (for example maximum demand coincident with minimum generation). Once the studies are completed and customers are connected to the network, they are not revisited as passive operation is assumed during normal running conditions. This can lead to underutilisation of the present network capacity, particularly for new DG connections.

Planned outages require complex studies to assess risk and decide whether or not generation customers can remain connected. As a result, abnormal (or unexpected) operation often results in existing customers being switched off until normal operation is resumed.

Current planning tools cannot represent how the system actually operates, in terms of actual power flows, due to this limitation it is extremely challenging to unlock capacity using new innovative techniques.

EVA Method

The statutory voltage limits for operating 33kV and 11kV electricity networks within ± 6% of nominal voltage were incorporated into GB's Electricity Supply Regulations in 1937. This was based on the passive operation of the electricity network, allowing an appropriate range of voltage supplies to low voltage customers. The statutory limits also assumed that 33kV and 11kV electricity networks had no systems in place to control voltages. As seen in Figure 2, the allowable range of operation is much tighter in 33kV and 11kV electricity networks when compared to the other voltage levels.

The EVA Method will demonstrate the automation and adaption of a PSS/E model (a commercially available and common power system nodal analysis software for EHV and HV networks). It will deliver the tools to enable DNO planners to design and commission a new generation of voltage control technologies and will also establish new operating procedures. This Method will support the other two Methods, System Voltage Optimisation and Flexible Power Links, by creating PSS/E software tools for each, making them useable by WPD planning engineers.

The model will accurately calculate the effects that the System Voltage Optimisation Method and the Flexible Power Link Method will have on the distribution system under normal and abnormal network operations, at all times of the year and under all operating conditions. The Enhanced Voltage Assessment Method will also develop a forecasting and configuration tool to assist with load and generation planning, including network reconfiguration considerations. This will enable the two Methods to consider all system operating conditions, i.e. under outage and reconfiguration, rather than as previous projects have done only consider the normal operating conditions.

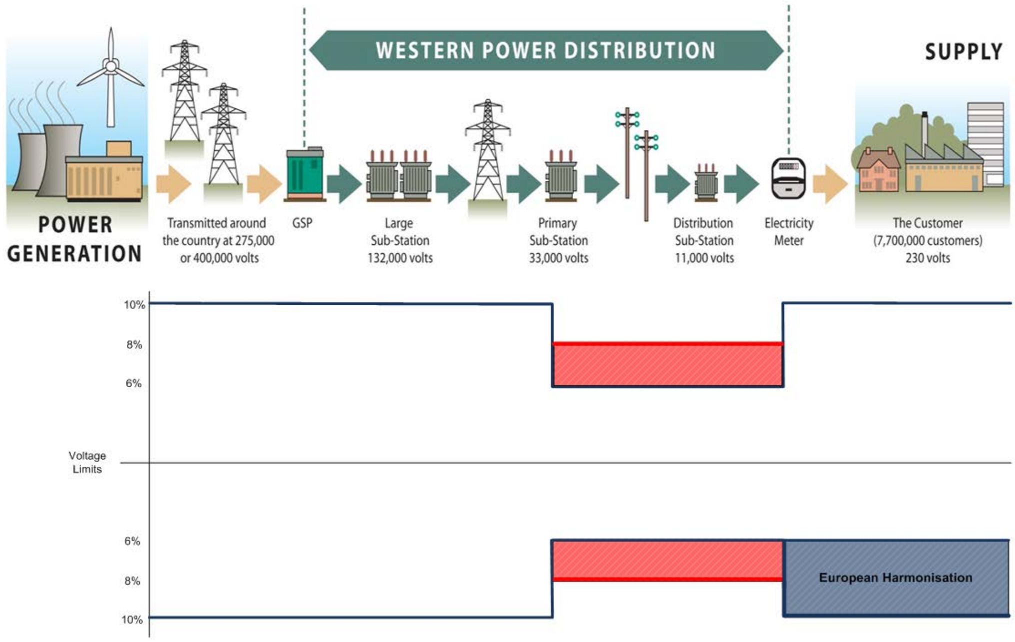


Figure 2 - Statutory voltage limits for operating GB's electricity networks

This Method will also explore and challenge the assumptions that underpin the existing voltage standards, such as percentage limits above and below nominal conditions (defined in ESQCR, P28 and P29, and DNO internal policies). This will be done to ensure they are still relevant, assessing whether modification could increase the ability to connect further generation and demand connections. A key aim is to facilitate the connection of more customers without compromising the safety of our employees and the public. Findings will be shared with DNOs and appropriate standards bodies for review and appropriate policy/standards updates.

Up to 10% connection capacity could be released through this Method. This is because current processes require the network to be studied in the most onerous condition, assuming that maximum generation output will be coincident with minimum demand and minimum generation output will be coincident with maximum demand, which will in turn result in the extreme voltage conditions being used. Actual operating conditions of the electricity network often lie well within these extremities and this can lead to conservative connection assessments for customers. By providing an enhanced model with access to additional information and data, meaning that currently essential safety margins can be reduced, this Method will establish a new operating procedure for GB distribution networks.

This Method will allow system planners to configure and operate complex distribution systems with new innovative voltage control techniques more effectively and safely.

J2 – System Voltage Optimisation (SVO)

The Problem

The voltage on a 11kV and 33kV network is currently controlled using an Automatic Voltage Control (AVC) scheme. This is where a fixed set point is determined, traditionally through the study of a network in relation to the amount of load connected, at the busbars of the substation. A system that is controlled in this manner is then limited in terms of what can be connected, downstream of the busbar controlled by the AVC, by the statutory limits imposed (±6%).

An example of the constraint is identified in Figure 1 where the voltage at the busbar, controlled by the AVC, is set at 104% of nominal voltage (either 11kV or 33kV), which means that the voltage can only increase by 2%. If the AVC scheme had the voltage set at 102% then the available voltage increase would be 4% and so on.

As generation increases the voltage on the system also increases due to the power exported at its connection point; there is a direct correlation between the available voltage headroom (the amount of voltage rise that can occur) and the size of a generator that can connect. Similarly for the connection of load, the available leg room (the amount of voltage drop that can occur) is often the limiting factor for the connection of demand.

SVO Method

The SVO Method will overcome the problem of fixed voltage points at bulk supply points and primary substation busbars through the use of a closed-loop, dynamically controlled voltage control system. This will involve monitoring key network points that will include the remote ends of network feeders and generation points connected to the substation.

In order to unlock latent capacity of the system a robust and controllable system to manage the network voltage is required. Previous innovation projects have demonstrated how monitoring key power flows and voltages across a network can be used to dynamically control the target voltage at a substation. These projects have shown that the source voltages can be configured to improve the voltage profile across multiple feeders, ensuring they're kept within the statutory voltage limits whilst reducing the impact of DG on voltage profiles. However, previous demonstrations have not permanently unlocked conventional generation capacity as this technique needs to:

- Take account of both normal and abnormal network conditions;
- Successfully operate when there is a loss of network communications from monitoring points;
- Produce models for nodal analysis that can be rolled out to network planners to facilitate future generation and demand connections; and
- Facilitate advanced controls using existing hardware.

This project will demonstrate a complete solution and provide guidelines that can easily be rolled out at scale across a complete licence area. The learning and processes will be clearly documented on how the scheme can be applied to other DNOs licence areas.

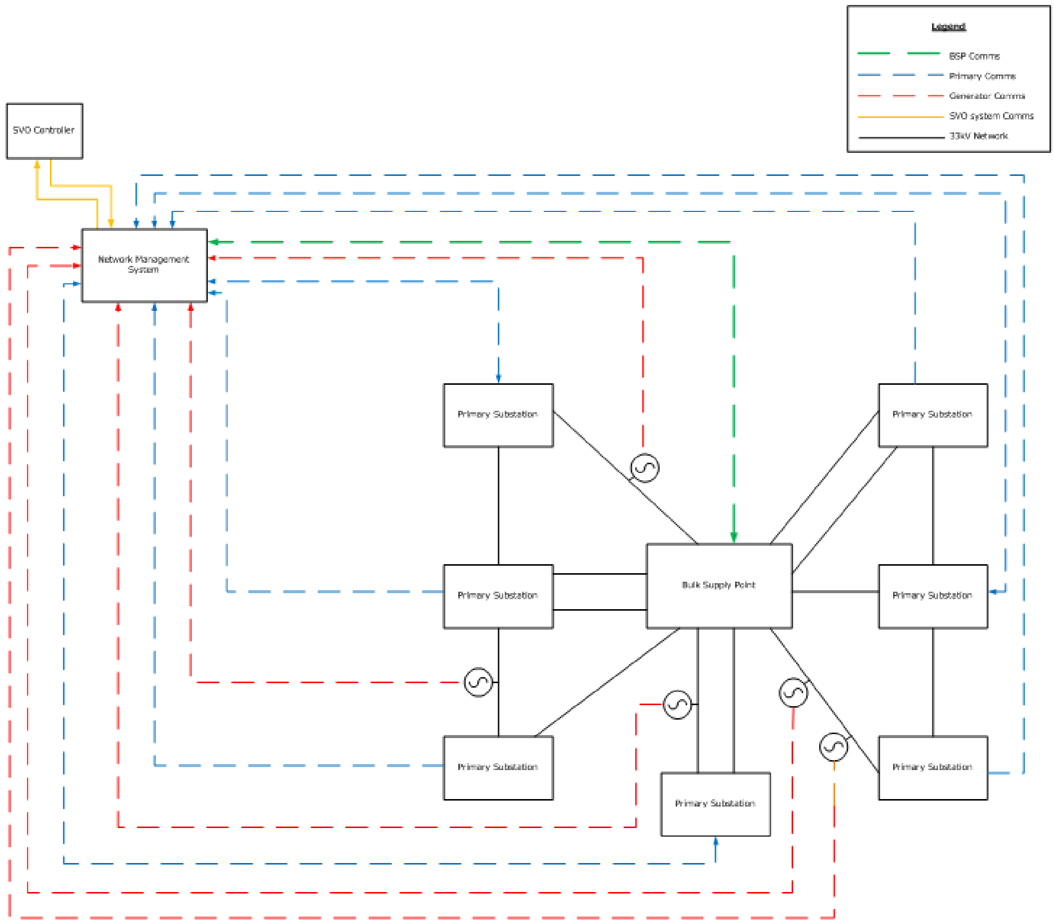


Figure 3 - System Voltage Optimisation Schematic

Figure 3 shows, schematically, the voltage and power data point requirements of a generic network architecture. This data will be communicated in to WPD's existing Network Management System (NMS) and through the use of an "SVO Controller" appropriate control signals will be generated to ensure that, under all operating conditions, the voltage profile of the system will be optimised.

The intelligence developed in the "SVO Controller" using historic data and state estimation techniques will be used to allow optimal voltage settings at the eight selected Bulk Supply Points (BSPs) and primary substations to be applied, based on real-time power flows.

This Method builds significantly on the learning generated from earlier LCNF projects, such as UKPN's Flexible Plug and Play and ENW's CLASS Tier-2 projects, and will overcome the current limitations preventing the wide scale adoption in to Business as Usual (BAU).

J3 – Flexible Power Links (FPL)

The Problem

Predominantly in the UK the areas that are most suitable for the connection of Distributed Generation (DG) are in rural locations, where there are often fewer people and at times insufficient demand locally to absorb the generation. This means that the power provided by DG on the system travels a much greater distance than in dense urban environments and due to the traditional design of rural networks (long overhead networks with a lot of inductance) the greater the distance the power must travel then the greater the voltage rise on the system will be. Also in these areas reverse power flow can occur, which is where power provided by the DG on the system is exported up the network, often through the 33kV network to the 132kV system, where it can then uncontrollably flow between DNO grid groups using the 132kV and transmission network.

Due to the levels of DG that are connecting to the existing system and the issue of reverse power flow, parts of this upstream system are now becoming the limiting factor on the connection of DG. Where, traditionally, there has been a low level of demand in an area with appropriately sized distribution networks to cater for this, an abundance of DG connections has meant that this, demand centred, network is not large enough to cope with the DG power flow requirements.

FPL Method

This Method will utilise new devices, to the distribution network, to facilitate the connection of sections of network that have previously, for issues such as fault level and phase angle, not been able to be connected. The device, a Flexible Power Link (FPL) is two back-to-back Voltage Source Converters (VSC) with a DC link connected between them, indicated in Figure 4. The VSCs facilitate the controllable transfer of both real and reactive power flows, on a dynamic basis, between previously unconnected networks. The DC link, between the two four-quadrant VSCs, removes the phase angle and fault level issues that have previously prevented these connections.

Often different substations and substation groups have significantly different demand and/or generation profiles. This is due to the varying types of load and generation connected at specific points. Often sections of network with a high demand could be physically close to a section of network with high levels of generation connected but due to engineering constraints cannot be connected. Through the use of FPLs a connection can be made that can now dynamically control the real and reactive power flow between these two previously unconnected systems.

The connection provided by the inclusion of an FPL on to the system means that DG power flows that previously travelled long electrical distances through multiple voltage levels can now be efficiently and controllably transferred to a network that is more heavily loaded. The advantage of this connection, along with the reduction of losses (through reduced power flow lengths) and the increased power flow capability by using it more effectively, locally, is the effect on voltage. Due to the reduced distances, provided by the FPL connection, between load and generation the voltage rise issue can effectively be minimised, meaning that the same network can now support the integration of additional generation. This level of integration can also be further optimised by the use of the FPL's reactive power support functionality, where reactive power can be absorbed from or provided to the system.

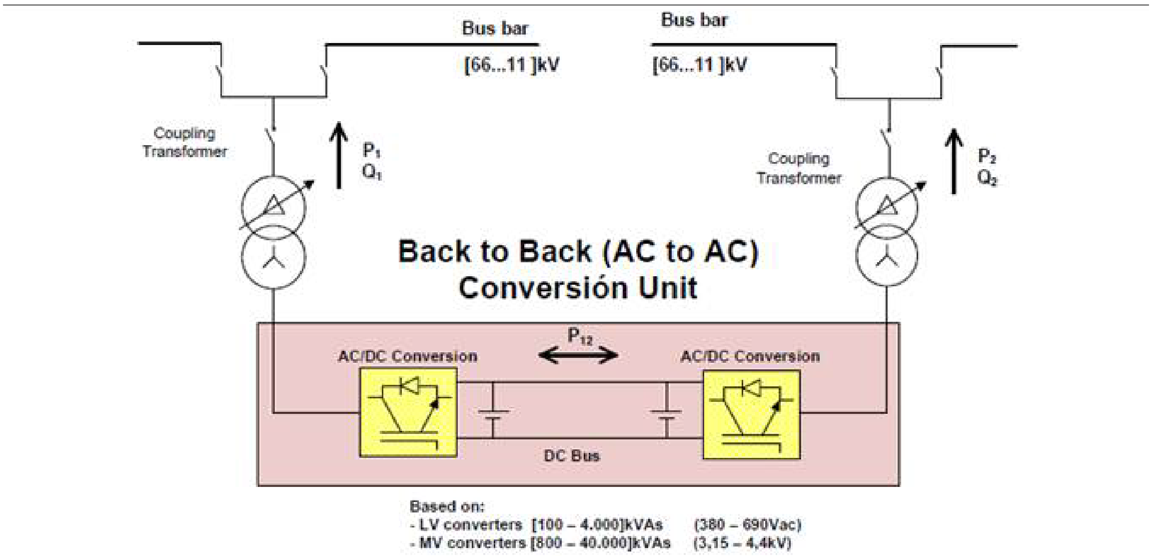


Figure 4 - Flexible Power Link Schematic (Indicative)

Along with the voltage control functionality of the FPL, a key benefit is the real power transfer capabilities of the device. This means that newly coupled networks can have their power flow more effectively controlled to ensure that, where required, excess load on one network can be transferred to a network with excess generation. This is carried out by the FPL essentially acting as a load on one side and a generator on the other. The level of load transfer from one system to the other can be controlled in order to maximise the level of additional generation and load that can permanently be connected to the system. As discussed in the Problem, networks are increasingly becoming “full” to their capacity, due to either load or generation connections. The FPL device, through the active transfer of power, allows the existing infrastructure to be optimised to accept additional load and generation.

Additional benefits, beyond that of voltage and real power control, are increased security of supply and intra and inter DNO connections. By connecting two previously separate networks an additional point of supply has been provided. This means that, much like the installation of an additional transformer at a substation, the reliability of supply to a customer is increased. This can have significant benefits in terms of CI and CML savings. Also, typically different DNO licence areas have operated and managed their systems in ways that make it very difficult for them to be connected. Through the use of an FPL device, the problem of two different systems being connected is overcome, meaning that significant advantages can be achieved through the connection of different DNOs systems, such as black-start capability and increased security of supply.

Future benefits, out of the immediate scope of Network Equilibrium, of FPLs are also active harmonic filtering and synthetic system inertia. Active harmonic filtering is used to provide control of the harmonic content on the system, often made more severe through the introduction of new demand and generation connections on to the system. ER G5/4 describes the allowable limits of harmonic content on the system and through the use of the FPL’s power electronic system harmonic content can be absorbed or supported, as required. Synthetic system inertia is the provision of system frequency support (50Hz ±1% in the UK). Traditionally large rotating plant, such as large synchronous generators at centralised power stations has provided the frequency stability required. As DG is connected to the system, often through power electronic inverters, this level of system inertia is decreased and therefore reduces the stability of the frequency. The power electronic nature of the FPL means that it can become a pseudo-rotating machine and provide a level of frequency support to ensure the stability of the system is maintained.

K - FPL Technology Overview

As part of the project's bid preparation a request for information (RfI) relating to the supply of Flexible Power Links (FPLs) was released. The RfI focussed on manufacturers providing information relating to the performance, dimensions and cost of the following permutations of device:

- 10MVA @ 33kV; and
- 20MVA @ 33kV.

Five manufacturers provided full and complete information, which has been used to support Appendix L – Substations & Suitability for Technology Inclusion. Below is the range of dimensions for the 33kV FPL.

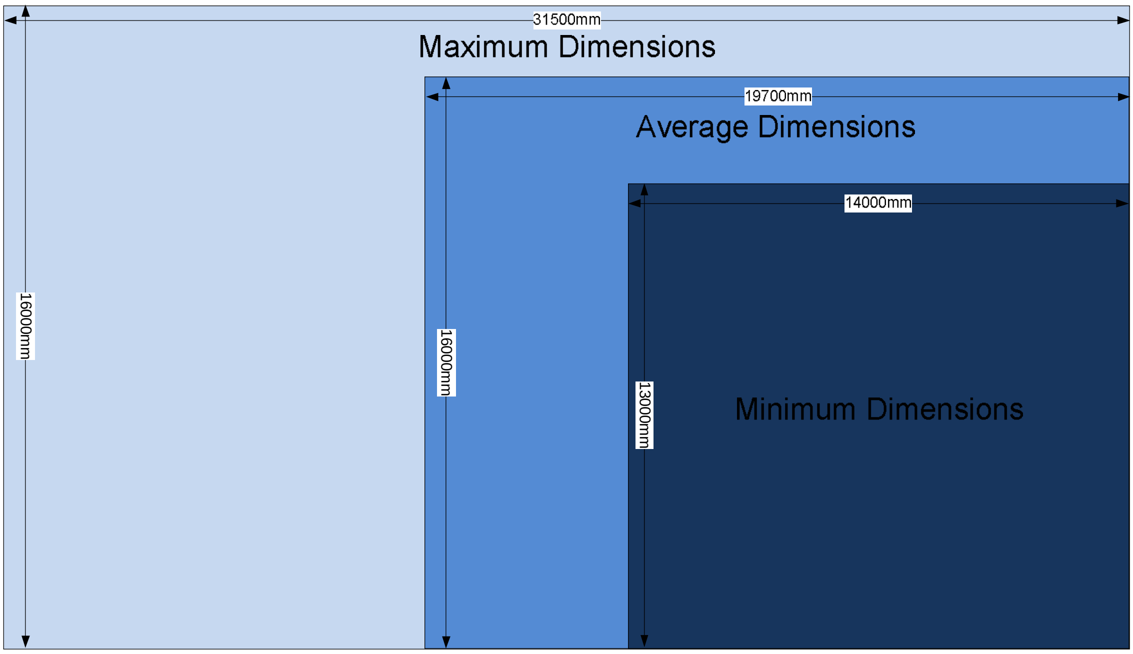


Figure 1 - 33kV FPL Dimensions

The cost of the device, based on the initial RfI data, used in the project Costs Spreadsheet is [redacted].

The system configurations of the FPLs from the five manufacturers were all based on the same configuration of two AC–to-DC converters with transformers connected at either end to step the voltage up to the required network voltage of 33kV. An indicative schematic is provided below.

Figure 2 - Indicative FPL Schematic

Appendix K - FPL Technology Overview

Technology Differentiators

As part of another LCNF project LV FPLs are being demonstrated. There are key differences between LV devices and EHV devices. These include:

- Insulation;
- Protection;
- Control; and
- Operation.

As with other devices that are used at both LV and EHV there are significant technical differences between the voltage levels. A comparison is the use of transformers; at LV these devices are protected by a simple fuse, have no active controls or indications back to a DNO's control system and have minimum ancillary components. Whereas an EHV transformer has a complex protection system to ensure it only operates as required, can actively control its voltage output and has a number of real-time information data provided to a central control system.

These differences between LV and EHV FPLs will, through Network Equilibrium, be considered and robustly designed in order to share the learning generated, meaning that a proven methodology for FPL integration is established for all voltages. This knowledge will be transferred to all GB DNOs.

Value for money

A FPL is the only smart solution that we have identified that can provide both voltage and thermal management to networks at normal open points between different grid groups. We haven't identified another solution which can be installed whilst avoiding either high levels of circulating currents when installed across national grid groups, or de-coupled networks preventing the additional fault level issues.

Why a FPL requires LCN funding

A Flexible Power Link at 33kV is a new innovative piece of power electronics technology currently estimated at TRL 6. The technology has been installed for industrial and rail applications in Indonesia and Germany. The power electronics components are continually evolving, with increasing reliability and reducing costs.

Appropriate mitigation action plans have been formulated against FPL risks; they are detailed in Appendix E – Risk Register.

L - Overview of Substations and Suitability for Technology Inclusion

Substation Selection Procedure

Ten 132/33kV substations and 33kV switching stations in the South West region were assessed for the deployment of Flexible Power Links (FPLs). The assessment was based on the following criteria:

- Connecting network having reached its capacity for generation and/or load connection availability with the existing network;
- Adjacent network having a significant amount of load connected to the system;
- Likely request for the connection of additional distributed generation;
- Presence of suitable 33kV switchgear;
- Available space for Flexible Power Link installation;
- Available space for additional 33kV switchgear associated with the installation of Flexible Power links; and
- Any consequential benefits arising from controllable power transfer.

Following this assessment, four substations were selected as suitable for the installation of a Flexible Power Link.

Network limitations

Power system analysis studies were undertaken on each of the chosen substations, or pair of substations, to assess the load flow conditions under existing operating conditions and after the addition of incremental amounts of Distributed Generation (DG) and load on to the system. Sites were identified where currently adjoining substations cannot be connected easily for the following reasons:

- Connected to different National Grid Groups;
- Varying phase angles;
- Voltage stability issues; and
- Imbalance of load to generation.

The use of FPLs is designed to optimise the existing network that would, using traditional solutions such as larger transformers and overhead lines and cables, be very complex and expensive to reinforce. Traditional solutions also do not have the capability to mitigate many of the problems to be solved through the installation of FPLs. This means that the base case, or business-as-usual scenario, against which each of the FPL installations is to be compared is the complete reinforcement of two isolated networks.

Appendix L – Overview of Substations and Suitability for Technology Inclusion

Flexible Power Link Initial Evaluation Procedure

In readiness for the Tier-2 project, Request for Information (RfI) enquiries were sent to several manufacturers, six usable responses (from five manufacturers) were obtained. These RfI responses will form the basis of the Tier-2 project Flexible Power Link assessments as part of a detailed procurement process.

All the technology responses provided by the five manufacturers are based on the use of two back-to-back AC to DC converters, connected through a transformer at each end to the correct system operating voltage of 33kV.

From the RfI responses, the potential Power Link capabilities to control power flows and manage voltage stability were assessed. Also, the space and weight requirements were compiled and compared to available space in each of the 33kV substations.

Summary

The initial substation selection process has identified four suitable 33kV sites in the defined project area. Substations have been selected on their ability to accommodate a range of manufacturers FPLs and because they are expected to be involved in DG or load schemes in the near future.

Further detailed analysis will be undertaken during the Tier-2 project to select the appropriate Flexible Power Link and the preferred installation substation based on the criteria set out in this document.

M - Learning from previous LCNF Projects

Projects involving Voltage Optimisation

There are several UK projects involving the trialling and demonstration of systems to manage network voltage. Specifically there are five LCNF Tier-2 projects that are trialling voltage optimisation techniques as part of the LCNF programme of projects.

- ### ENWL – Customer Load Active System Services

This project involves installing smarter voltage controls at Primary Substations to raise or lower tap changer positions. The aim of the project is to develop, trial and understand the relationship between voltage and power to take advantage of fixed resistance loads, where reducing the voltage will have a proportional reduction in power. The output of this project is to reduce the voltage on the system to reduce the power consumed by existing loads on the network. In the project, ENW expected to release, at peak demand, up to 11.8 MVA (the equivalent of a half of a new Primary substation) of network capacity across all the (60) Primary substations, with a 1.5% voltage decrement (provided through a single tap). The key learning is summarised below:

- Materials should be simple and informative but communicate the key issues;
- Customers are concerned about data protection;
- Integration of old and new plant presents unique challenges: During the installation it was found to be very challenging when trying to integrate new Microtapp relays with existing equipment that could be 50/60 years old. Furthermore, it was found that the existing equipment had probably been modified in some form during its life span which made every site solution bespoke.
- ASC Input / output channels are limited: Due to the size of the housing, the ASC was limited to 16 inputs and 16 outputs. Increasing this size would have required an additional box. This resulted in using a toggle system for the alarms and limiting the alarms to and from the ASC. The preferred number of inputs and outputs for a business as usual situation would be 32 to enable a more robust and complete set of alarms.
- Standardised ASC/ Software is required: The ASC device is currently tailored to each site type and on occasion the incorrect ASC was fitted at a site. When moving to a business as usual scenario, the ASC should be standardised so all functions are available at a site if required. Furthermore, the software loaded on the ASC is site specific, and this currently needs to be set-up offsite. The preferred option would be for the software to be standard with options that enable the ASC to be configured on-site.
- Business as usual approach: The building and installation of the Microtapp relays have pre-existing business as usual (BAU) processes. Consideration should have been given for Project installation activities to follow the BAU process, in other words fabricated by our framework panel supplier and installed by our Operation business. The benefit of this is that the process is well defined and issues encountered by the Project team are likely to have been already encountered and resolved.

- ### ENWL – Smart Street

This project involves the control and management of HV and LV voltage on 5 Primary substations and 40 Distribution substations. Through the use of switched capacitors and other systems, the project aims to provide a constant voltage along a complete feeder. The objective is to reduce the instantaneous demand of customers who are currently receiving higher voltages. The Smart Street Method provides clear benefit compared with traditional reinforcement where there is a clustered take up of LCTs, and a high penetration of electric vehicles (EVs), solar photovoltaics (PVs), and heat pumps (HPs). In the Project, Electricity North West could release 9.16MW of network capacity across the 160 LV circuits by application of the solution to address LCT clusters, assuming equal demand and generation led reinforcements. The key learning is summarised below:

- ENW have published a 'rule-based' design methodology for Smart Street on the project website: http://www.enwl.co.uk/smartstreet. This report describes the methodology that will be utilised for designing the Smart Street Trial circuits in relation to:
  - Suitability of circuits for the trials;
  - Positioning and sizing of the LV capacitors banks;
  - Positioning and sizing of the HV capacitors banks;
  - Meshing of the LV networks.
- Agreement of detailed software requirements pre-contract to de-risk delivery. Early contact with Partners is essential to maximise timescales available to review systems and processes pre-contract. This reduces the risk of misunderstanding or technical issues materialising later in the project causing an adverse effect on project delivery.
- Importance of Project start up meeting involving all internal and external stakeholders. Early interaction between all stakeholders is essential in order to give clear understanding to all parties of each stakeholder roles and accountabilities. This is particularly critical in ensuring that early SDRCs are understood and delivered.

The project is still at an early stage and there is limited learning, on which to build, in relation to the 'conservation voltage reduction' algorithm and its application.

- ### UKPN – Flexible Plug and Play

This project involves the installation of an updated Automatic Voltage Control (AVC) system at one Primary substation. A local Active Network Management (ANM) scheme is deployed that uses the available network information to optimise the voltage to maximise the generation connection capability. The proposed infrastructure and smart devices to be deployed by the FPP project will enable connection of up to an additional 188 MW of new wind generation with significantly reduced need for network reinforcement. The project will also address constraints already experienced by an existing biomass combined cycle gas turbine (CCGT) power station which will enable 41 MW of additional capacity to be deployed. Furthermore, the project will allow continued grid access to two other wind farms of 28 MW capacity currently disconnected under single circuit 132 kV outage conditions.

A number of learning reports are available of the FPP website:
http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Flexible-Plug-and-Play-(FPP)/.

In particular, the "Technical Solution Learning Report", Section 5.3, describes the scope of the AVC trial:
FPP has installed a set of SuperTAPP n+ relays at both March Grid and March Primary substations. The existing AVC schemes at March Grid and March Primary substations are equipped with SuperTAPP and MVGC01 relays

respectively. These have been replaced with Supertapp N+ which will provide more accurate voltage control at substation level and will also interface with the ANM system via the IEC 61850 protocol.

Appendix 6 of the "Technical Solution Learning Report" lists documents that are available to GB DNOs. Specifically, there is a "Performance Spec for Enhanced AVC scheme" and "FPP Functional and Non-Functional Requirements Specification V1.0".

The AVC commissioning reports (Appendix 5) may also be a useful reference for Equilibrium.

- ### NPG – Customer Led Network Revolution

This project involves the installation of an Enhanced Automatic Voltage Control solution, which utilises two voltage regulators and a switched capacitor. The aim of this system is to provide a stable voltage setting between two existing primary substations. Limited information is available in the public domain on the capacity released by the Enhanced AVC method for new generation or demand customer connections.

The voltage control aspects of CLNR are being demonstrated on a 'brownfield site' by fitting new devices and controllers on old devices. NPG are finding that the new devices, "a new application of well-proven technology" are behaving as expected. The control of the trial is cited by NPG as being the novel aspect of the project. Adding a wide-area controller such as the "Grand Unified Scheme" (GUS) allows the network to run closer to the limit, which is facilitating the connection of customers' solar PV.

Two papers have been published by the project, relating to EAVC and coordinated voltage control:
1. Hollingworth, D. et al: "Demonstrating enhanced automatic voltage control for today's Low Carbon Network" (CIRED 2012) http://www.networkrevolution.co.uk/wp-content/uploads/2014/02/CIRED-2012-EAVC.pdf
2. Liang, D. et al: "Coordinated voltage and power flow control in Distribution Networks" (CIRED 2013) http://www.networkrevolution.co.uk/wp-content/uploads/2014/02/CIRED2013_0711_COORDINATED-VOLTAGE-AND-POWER-FLOW-CONTROL-IN-DISTRIBUTION-NETWORK.pdf

- ### WPD – Lincolnshire Low Carbon Hub

This project involves the deployment of a 33kV voltage control system. This system is designed to utilise pre-set operating conditions provided to the control system to optimise the network's performance.

The projects described above are predominantly focussed on the control of 11kV and LV voltages. The other projects trialling voltage control systems on the 33kV network are utilising local, isolated, control methodologies to successfully manage the network voltage. The significant learning provided through these projects and other IFI and LCNF Tier-1 projects will be transferred to Equilibrium. This will be done through WPD's robust methodology for capturing other DNOs' learning.

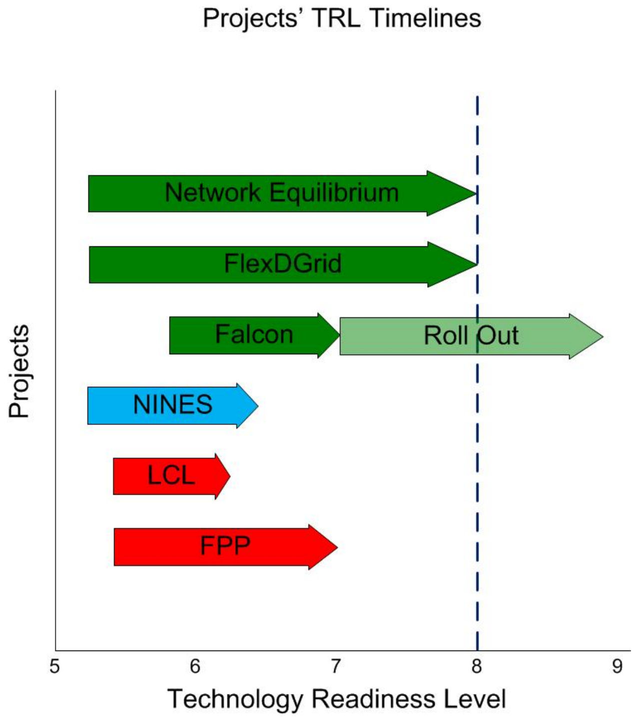
N – Differentiators from Previous Projects

WPD's aim with all innovation projects is to develop the trialled solution through to a technology readiness level (TRL) that allows for replication of the project within other WPD areas and also other DNOs' licence areas, i.e. TRL 8 and 9. Existing WPD projects including FALCON and FlexDGrid facilitate solutions that transition the TRL from 5 to 8/9. Other DNOs have chosen to focus on projects that deliver a lower TRL level, as demonstrated below.

As part of the bid preparation, WPD analysed existing projects using information available in the public domain. This included project websites, bid documents and project directions, six monthly reports, SDRCs and other relevant materials, which lead to a detailed qualitative assessment of existing LCN Fund projects. In summary:

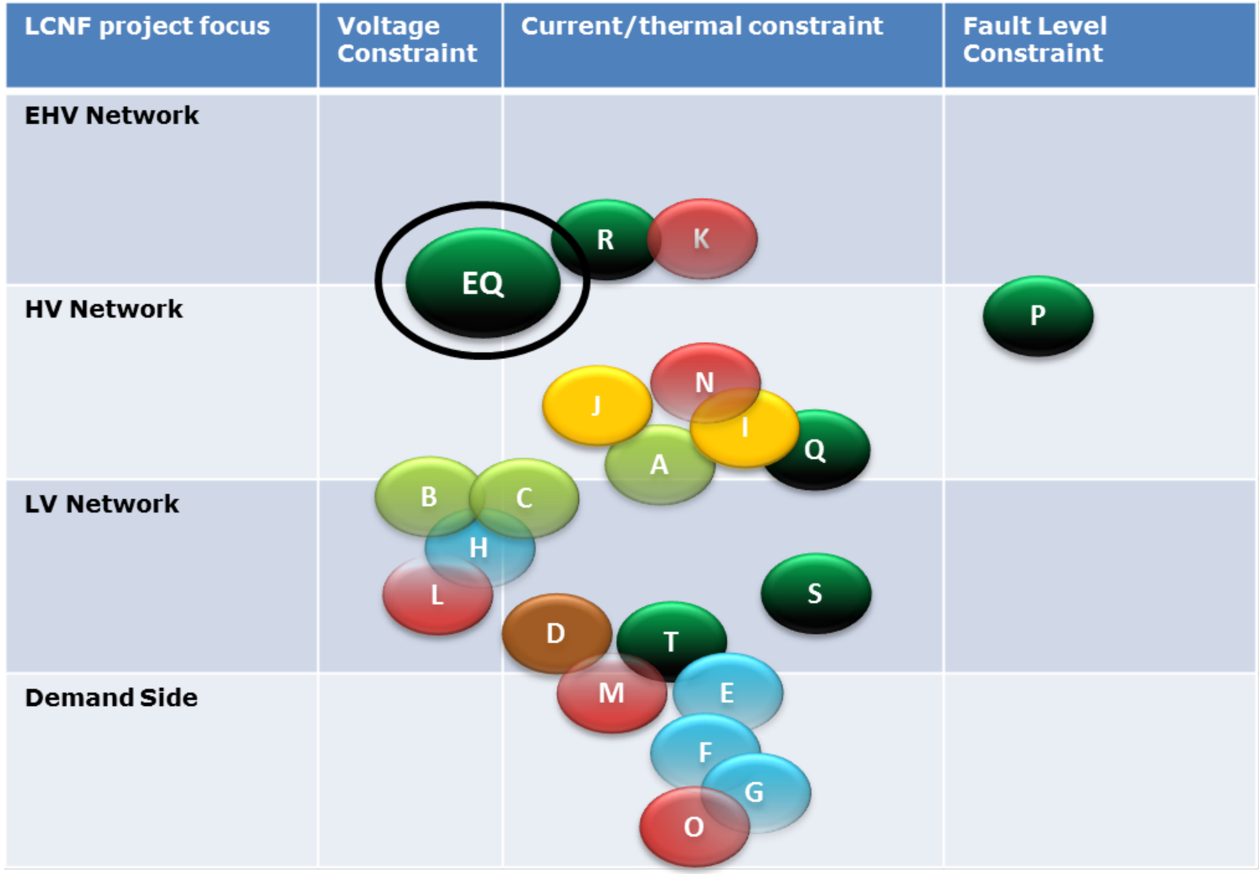
- UKPN's Flexible Plug and Play project is taking voltage control technology to TRL 7. The voltage automatic voltage control of transformer tap changers at a single location (March Grid substation) demonstrates the technology in a working environment but not at full scale across the network. The Quadrature booster element of the project has been classified as TRL 7; it is demonstrated in a single location with modest performance data.
- SSE's NINES project has demonstrated discrete components (1 MW battery for energy storage, domestic demand side response, 130MWh thermal water store and 4MW electrical boiler) in a working environment – TRL 5. When this is controlled through an active network management system, the technology will be at TRL 6.
- UKPN's Low Carbon London project is a system level project. The uptake from heat pumps and EV's have been monitored and modelled to statistically derive the cumulative impact on networks, the models are between TRL 6 and 7. The DSM trials are at TRL 7 (a full scale trial across 36 different sites across London). When fully integrated with the control and billing system the method will be at TRL 8.

Network Equilibrium, like other WPD innovation projects, will deliver a solution that is at TRL 8/9 at project completion, as indicated in the figure below.



Appendix O – Differentiators from previous LCNF Tier-2 Projects

O – Differentiator Table



KEY:	
EQ	**EQUILIBRIUM**
A	Capacity to Customers
B	CLASS
C	Smart Street (eta)
D	Customer-Led Network Revolution
E	My Electric Avenue
F	Northern Isles New Energy Solutions
G	Solent Achieving Value from Efficiency
H	Thames Valley Vision
I	Accelerating Renewable Connections
J	Flexible Networks for a Low Carbon Future
K	Flexible Plug and Play Low Carbon Networks
L	Flexible Urban Networks - Low Voltage
M	Low Carbon London
N	Smarter Network Storage (SNS)
O	Vulnerable Customers and Energy Efficiency
P	FLEXDGRID
Q	FALCON
R	Low Carbon Hub
S	LV Network Templates
T	SoLa Bristol

NB: Indicative only

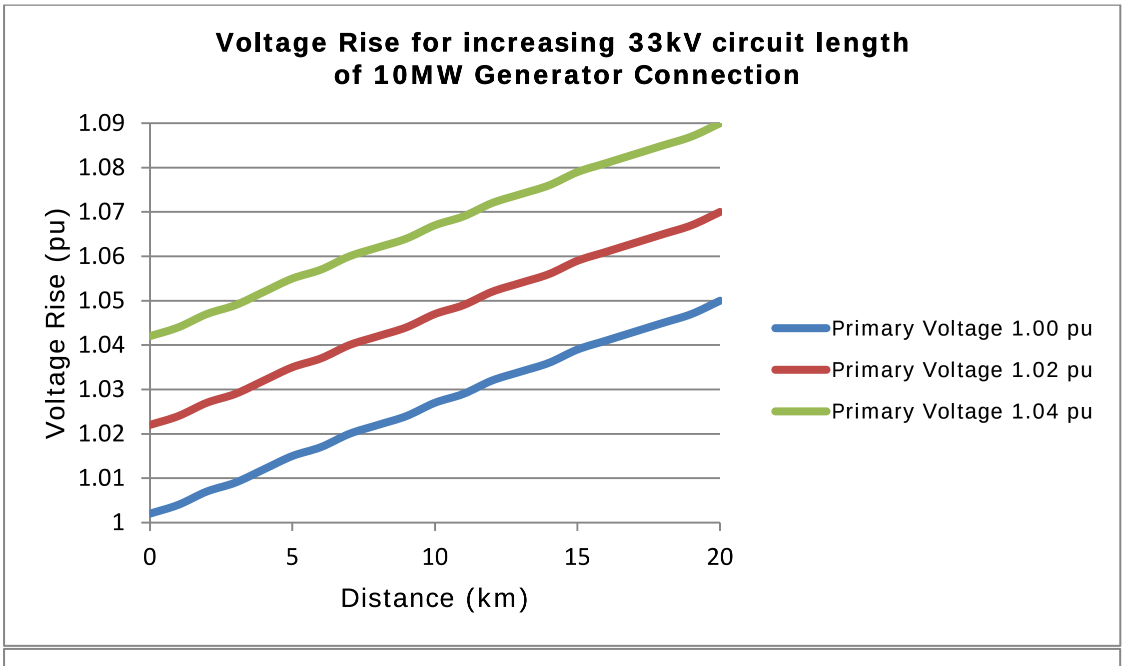
P - Generation Effect on Voltage

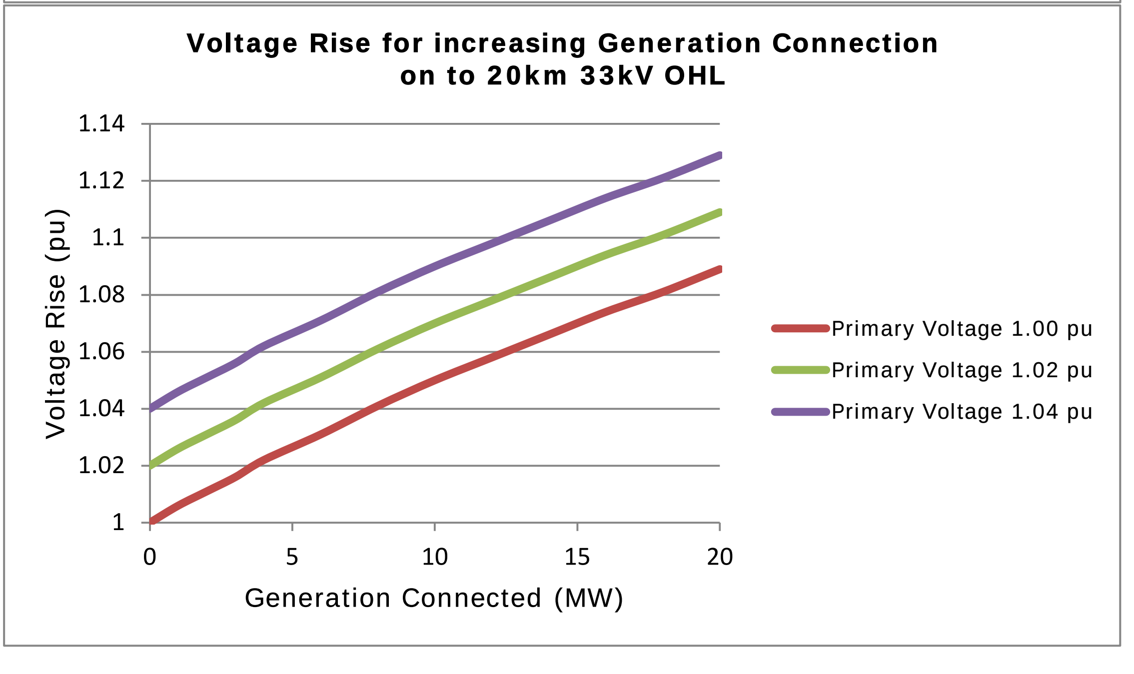
Preliminary studies have been conducted in a power system modelling tool to investigate the impact of proposed generation connections, within the 33kV network, on the system voltage profile. Example studies have been carried out on a 20km 33kV overhead network. The per unit increase in voltage (where the limit is +/-6% [0.94pu to 1.06pu]) is shown for two different conditions:

a) A 10MW generator connected to the 33kV OHL at incremental distances from the primary substation between 0km and 20km; and

b) A generator at incremental MW values from 1MW to 20MW at a distance of 20km on the 33kV OHL.

Three scenarios are provided for each condition, which is to have the primary voltage set point to be at 1.00pu, 1.02pu; and 1.04pu.





Q – Glossary of Terms

Asset Replacement	Replacement of distribution network assets (e.g. transformers and circuit breakers).
AVC	Automatic Voltage Control.
BAU	Business as usual.
Bulk Supply Point (BSP)	A point on the network where voltage transformation between 33kV and 132kV occurs (also: a 33kV/132kV Substation).
Capital Expenditure	Expense to acquire or upgrade network assets.
CHP	Combined Heat and Power.
Circuit Breaker	Protection device that interrupts the flow of current in an electric circuit in the event of a fault.
Connection Assessment Process	A series of technical and commercial steps by which the impact of a demand or generation connection to the electricity network is quantified.
Demand Side Management (DSM)	Actions undertaken by distribution network operators to influence customers to change their electricity use, in terms of quantity and/or time of use.
Distributed Generation (DG)	Generation connected directly into the distribution network, as opposed to the transmission network. This generation typically supplies local demand.
Distribution Network Operator (DNO)	The owner and/or operator of an electricity distribution system and associated assets.
Extra High Voltage (EHV)	33kV and above for a distribution network.
Electric Vehicle (EV)	A vehicle which uses one or more electric motors or traction motors for propulsion.
ENA	Energy Networks Association.
Enhanced Voltage Assessment (EVA)	Assessment of existing voltage standards and development of a forecasting and configuration tool in order to optimise system voltages.
ESQCR	Electricity Safety, Quality and Continuity Regulations.
Fault Level	Measure of electrical stress when faults occur within electricity networks.
Flexible Power Link (FPL)	A DC connection between different parts of AC networks by using a back-to-back voltage source converter.
Grid Supply Point (GSP)	A point on the network where voltage transformation between 132kV and 275kV or 400kV occurs.

Heat Pump (HP)	A device that provides heat energy from a source of heat to a selected destination, by moving thermal energy opposite to the direction of spontaneous heat flow.
High Voltage (HV)	6.6kV and 11kV on a distribution network.
IET	The Institution of Engineering and Technology.
Innovation Funding Incentive (IFI)	Ofgem incentive mechanism to encourage DNO innovation.
Long Term Development Statement (LTDS)	Statement published annually by DNOs to make network information available to the public domain. This enables anyone interested in connecting generation or load to the network to identify opportunities or constraints on the network.
Low Carbon Technology (LCT)	A type of technology implemented for the production of power with substantially lower amounts of carbon dioxide than is emitted from conventional fossil fuel power generation, typically utilising natural energy sources such as wind, solar, hydro etc.
Normally Open Point (NOP)	An interconnection point between two different parts of a network or feeder, divided by a circuit breaker, which is at an open (disconnected) state under normal operating conditions.
OHL	Overhead Line.
Primary Substation	A point on the network where voltage transformation between 11kV and 33kV occurs (also: a 33kV/11kV Substation).
RAID	Risk, Assumptions, Issues and Dependencies.
RfI	Request for Information.
Short Circuit Current	Current which flows during a fault.
Substation	A point on the network where voltage transformation occurs.
Switchgear	Device for opening and closing electrical circuits (including circuit breakers).
System Voltage Optimisation (SVO)	A method of monitoring and controlling voltage profiles centrally and in real time, by utilising monitoring equipment installed across the distribution network.
Technology Readiness Level (TRL)	Method of assessing and defining maturity of technology.
Transformer	Device that changes the voltage of an a.c. current, without changing the frequency.
Voltage Source Converter (VSC)	Converter which uses transistors, usually the Insulated-Gate Bipolar Transistor (IGBT), to convert electric power from alternating current (AC) to direct current (DC), or vice-versa.