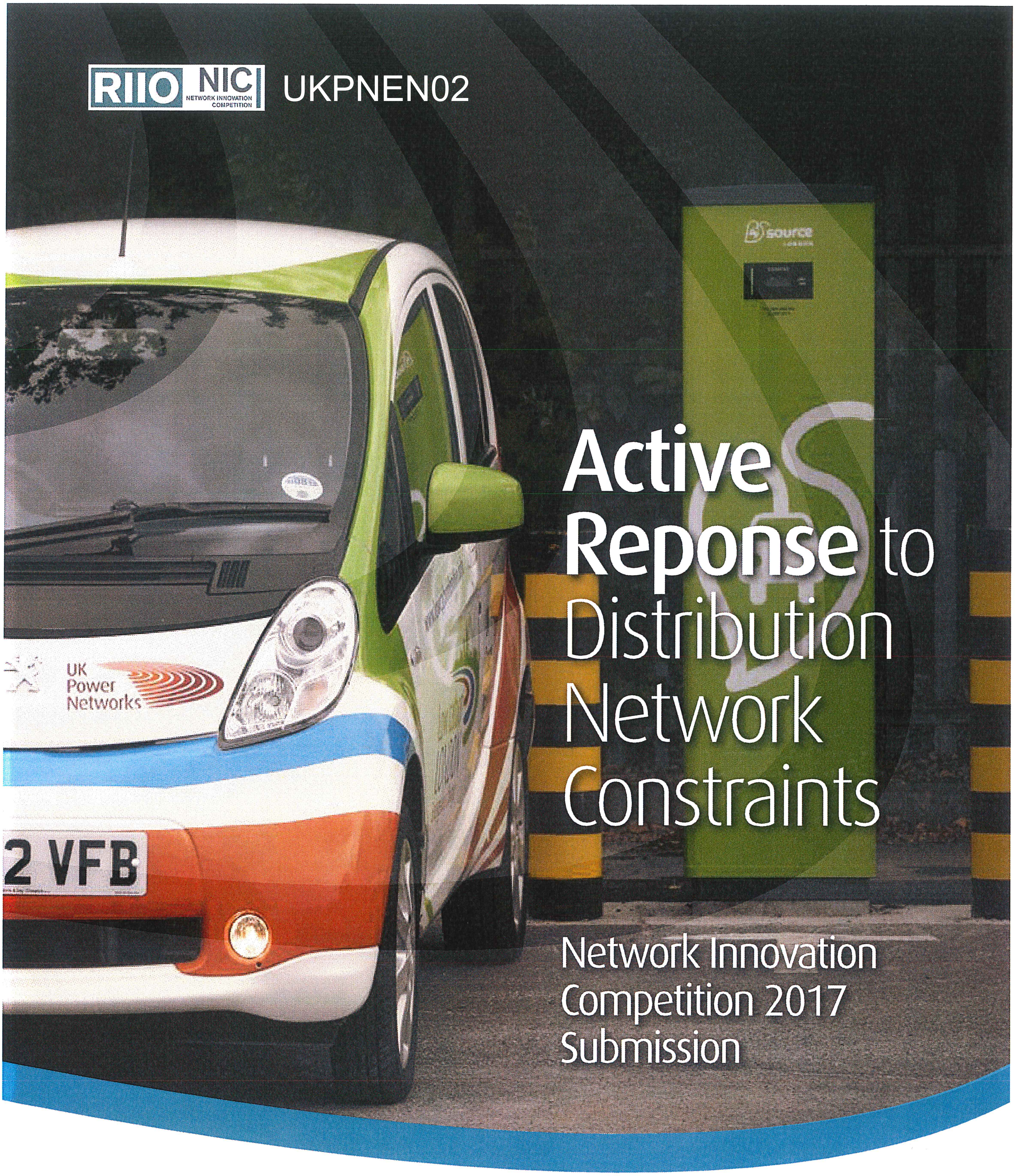
RIIO NIC NETWORK INNOVATION COMPETITION UKPNEN02



Active Reponse to Distribution Network Constraints

Network Innovation Competition 2017 Submission

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RIIO NIC NETWORK INNOVATION COMPETITION

1. Project Summary

1.1. Project Title	Active Response to Distribution Network Constraints (Active Response)
1.2. Project Explanation	Low Carbon Technologies (LCTs) could have a significant impact on peak electricity demand. The Project will demonstrate advanced automation to optimise network arrangements at LV and HV, and novel power electronics connecting adjacent networks to maximise capacity. This could save £271m across GB by 2030, equivalent to £9.16 per customer.
1.3. Funding licensee:	London Power Networks plc
1.4. Project description:	*1.4.1. The Problem(s) it is exploring* Distribution networks are experiencing a quicker than expected uptake in Low Carbon Technologies (LCTs). A significant uptake in Electric Vehicles (EVs) is expected in the early years of the next decade, as indicated by the actual EVs registered in our licence areas currently exceeding our RIIO-ED1 business planning forecasts by 15%. National Grid's Future Energy Scenarios 2017 expect this to materialise as 3.5GW additional peak demand across GB to 2030. This will require significant reinforcement with costs largely borne by customers. *1.4.2. The Method(s) that it will use to solve the Problem(s)* We are proposing to demonstrate two methods: 1. **Network Optimise** – Optimisation and Automatic reconfiguration of HV & LV networks in combination, using remote control switches and Soft Open Points (SOPs). 2. **Primary Connect** – Controlled transfers between primary substations using a Soft Power Bridge (SPB) to share loads and optimise capacity. *1.4.3. The Solution(s) it is looking to reach by applying the Method(s)* Active Response comprises three key novel technologies: • LV SOPs developed from TRL 6 to 8, allowing fully controlled power sharing between LV feeders with no fault level transfer; • HV Soft Power Bridges (SPBs), providing functionality similar to the LV SOP, but at HV using an innovative new design to significantly reduce cost and volume; and • Automation and optimisation software providing co-ordinated switching on both LV and HV networks to balance load, avoid constraints or reduce losses. *1.4.4. The Benefit(s) of the project* We estimate that **by 2030 Active Response solutions could save customers £271m in reinforcement costs**. This is equivalent to approximately £9.34 from every electricity customer's bill. The project methods also enable Carbon Savings of 448,255 tCO2 eq. and Capacity Benefits of 4.2GVA by 2030. Note: benefits derived from the FUN-LV project are not included in this project.

1.5. Funding

1.5.1 NIC Funding Request (£k)	£13,836	1.5.2 Network Licensee Compulsory Contribution (£k)	£3,068
1.5.3 Network Licensee Extra Contribution (£k)	£0	1.5.4 External Funding – excluding from NICs (£k):	£1,274
1.5.5. Total Project Costs (£k)	£18,298		

1.6. List of Project Partners, External Funders and Project Supporters (and value of contribution)	*Project Partners:* Scottish Power Energy Networks - £53k Ricardo Energy & Environment - £153k Turbo Power Systems - £808k CGI - £260k *External Funders*: n/a *Project Supporters*: Western Power Distribution Transport for London (TFL) Transport Research Laboratory (TRL)

1.7 Timescale

1.7.1. Project Start Date	2 January 2018	1.7.2. Project End Date	30 November 2021

1.8. Project Manager Contact Details

1.8.1. Contact Name & Job Title	Ian Cooper Innovation Lead – Opportunities and Bids	1.8.2. Email & Telephone Number	Ian.Cooper@ukpowernetworks.co.uk +44 (0)1293 657 641
1.8.3. Contact Address	UK Power Networks, Newington House, 237 Southwark Bridge Road, London, SE1 6NP		

1.9: Cross Sector Projects (only complete this section if your project is a Cross Sector Project, involves both the Gas and Electricity NICs).

1.9.1. Funding requested the from the [Gas/Electricity] NIC (£k, please state which other competition)	N/A
1.9.2. Please confirm whether or not this [Gas/Electricity] NIC Project could proceed in the absence of funding being awarded for the other Project.	N/A

1.10 Technology Readiness Level (TRL)

1.10.1. TRL at Project Start Date	6	1.10.2. TRL at Project End Date	8

THE GROWTH OF LOW CARBON TECHNOLOGIES WILL HAVE A SIGNIFICANT EFFECT ON ELECTRICITY DISTRIBUTION NETWORKS. THIS PROJECT WILL DEMONSTRATE ACTIVE RECONFIGURATION AND POWER ELECTRONICS TO MANAGE THESE EFFECTS.

2.1. Aims and objectives

At UK Power Networks we want to enable the uptake of Low Carbon Technologies (LCTs), at the lowest cost to customers. As such we are developing a smart solution toolbox to ensure we have the right solution for each challenge we face. Active Response delivers two physical asset smart solutions that can enable environmental benefits from released capacity where they are installed: the second-generation LV Soft Open Point (SOP) and a novel HV Soft Power Bridge (SPB). The project also delivers an advanced optimisation and automation platform; a software smart solution that can deliver benefits over a wide area, if the enabling technologies are in place.

Active Response will aim to select trial areas that allow re-use of existing smart controllable assets to reduce costs. We have chosen another trial to enable us to deliver a needed Load Index improvement, deferring a planned reinforcement project committed to in our ED1 business plan. If successful the project will deliver customer benefits within one year of completion, breaking even in year two if rolled out across our network, or GB. See Appendix 10.2: Project Business Case Modelling for more detail.

By partnering with Scottish Power Energy Networks (SPEN) we can ensure that the Methods, once proven, can be deployed in at least 5 of the 14 GB licence areas, and hence GB wide applicability is highly likely. SPEN have committed to a project deliverable determining where they can roll out these solutions. The software platform will work within or interface with the Network Management System used by 13 of the 14 GB licence areas. As such, if proven successful, it will be widely replicable.

The SOP and SPB power electronic devices are new designs using novel Silicon Carbide semi-conductors, unproven on distribution networks. This presents significant innovation risk that should be tried and tested before roll-out. Further the SPB is a new architecture that presents significant benefits over traditional inverter solutions. The integration of the software automation system, and network hardware, with the proven safe systems of work that govern how we operate our network is a challenge that we look forward to addressing.

The requirement for the Active Response methods is evident from data on uptake of LCTs, and regular reports in the media of the drive towards a low carbon economy, both described elsewhere in this document. This aligns with the timelines proposed in our Innovation Strategy, and the development of business plans for RIIO-ED2.

At UK Power Networks, we have a successful track record of delivering large innovation projects with Low Carbon London, Flexible Plug and Play, Smarter Network Storage and FUN – LV all being recognised for their successful delivery. We will build on the experience gained as we successfully deliver Active Response.

2.1.1 The Problem which needs to be resolved

The energy landscape of the UK is changing. Evidence shows that EV and solar photo-voltaic (PV) generation uptake has increased. Our expectation (see figure 4.3) is that they will continue to do so. At the end of Q1 2017 there were 92,414[1] plug-in-cars registered in the UK, with new registrations taking a record percentage of all new car registrations; 12,214 plug-in-cars were registered during Q1 2017 accounting for 1.46% of all new registrations (826,600 cars).

Government incentives and policy have an impact on the uptake and deployment of infrastructure. The UK government announced that £40 million of funding would be provided to drive the green car revolution across UK cities[2], and a ban on sales of new petrol and diesel cars from 2040[3]. London has ambitious plans to become zero carbon by 2050[4] and was awarded £13 million to create 'Neighbourhoods of the future'. This included allowing the charging of EVs from the street lights in Hackney, following other boroughs. The Queens Speech 2017[5] announced that the UK would aim to become a world leader for EVs, and pledged to increase the number of public EV charging points. These initiatives are expected to increase the popularity of EVs.

Subsidies in PV (since removed as they are now economic in their own right) caused dramatic growth by allowing the technology to become viable for many households. We anticipate a tipping point, where electric vehicles will become the normal choice for most consumers; electricity networks must be ready when this occurs.

> Green Alliance, a think-tank, says it could take as few as six "closely-located" vehicles charging simultaneously at a time when electricity is already in high demand — such as during the evening — for there to be possible shortages. The issue is not one of overall capacity but the possibility that electric vehicles will create additional demand during peak times.
>
> Stewart Reid, Head of Asset Management at SSEN, says: "The only solution we would traditionally have would be to replace the transformer or replace and upgrade the cables in the street."
>
> "Power networks navigate electric car challenge", Financial Times, 21st May 2017

The rapid growth in the numbers of EVs and PVs will have the most pronounced effect in distribution networks. Network solutions could be required as soon as 2020. EV load and PV generation will change the demand and voltage profiles at distribution and primary substations. PV is an intermittent source where local effects (e.g. passing cloud cover) could have a dramatic impact on the profile and capacity at the distribution substation. Fluctuations from PV and large numbers of EVs connecting to the network during the evening peak could see large and rapid changes in demands. Both technologies have the

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[1] Department for Transport – Vehicle Licensing Statistics: Quarter 1 (Jan – Mar) 2017
[2] Department for Transport and Office for Low Emission Vehicles, 25 January 2016
[3] https://goo.gl/KGYubf
[4] London Mayor Sadiq Khan, 2015
[5] https://goo.gl/msyjeN

capability to reduce the power quality, increase phase unbalance and present additional challenges to distribution networks.

For example, EV charging could increase substation peak load by 40%. If a typical primary substation feeds 7,700 homes (Eastern Power Networks, EPN, has approx. 465 Primary Substations, and 3.6m customers) and 10% of these plugged in their EV upon returning from work using a typical 7kW charger, peak demand would increase by 5.4MW. This would be a 40% increase on the 13.5MW 2016 average peak demand of the primary substations in our EPN license area, if no load diversity is available.

The traditional solution to this is reinforcement of the network, with additional or larger overhead lines, cables and transformers. However, these conventional solutions may no longer represent value for money for electricity customers. As such we already have smart solutions in our toolbox, such as incentivising customer usage behaviours (Demand Side Response (DSR)), which can reduce both the peak demand and reinforcement required. Several of these solutions are described in Appendix 10.4: Technical Appendix.

If distribution network operators do nothing…then by 2050, there will be an economic cost to customers of at least 2.2bn to traditionally reinforce networks.

("The Conversation", Network, April 2017, p10)

2.1.2 The Methods being trialled to solve the problem

To address the challenges described above Active Response is seeking to trial two methods:

Method 1: Network Optimise	Optimisation and Automatic Reconfiguration of HV & LV networks in combination, using remote control switches and SOPs.
Method 2: Primary Connect	Controlled transfers between primary substations using a SPB to share loads and optimise capacity.

These Methods are described below, with additional information included in Appendix 10.4: Technical Appendix.

2.1.2.1 Network Optimise

Electricity networks are currently configured with alternative feeding arrangements, so that in the event of an equipment failure, supplies can be restored. Networks may be designed:

- **With radial circuits**, with Normally Open Points (NOPs) that can be closed to allow alternative feeds; or
- **Meshed** so that loads are shared across multiple circuits, but with additional design complexity to ensure faulted equipment is correctly identified and isolated.

The running arrangement of a network will be determined by which of these designs is employed, and the loading, so that equipment ratings are not exceeded and voltages are kept within statutory limits. However, limited real-time information about loading conditions on HV and LV networks is currently available. Hence running arrangements are determined from an initial study and then only varied when conditions change significantly or when equipment is removed from service when damaged or for maintenance.

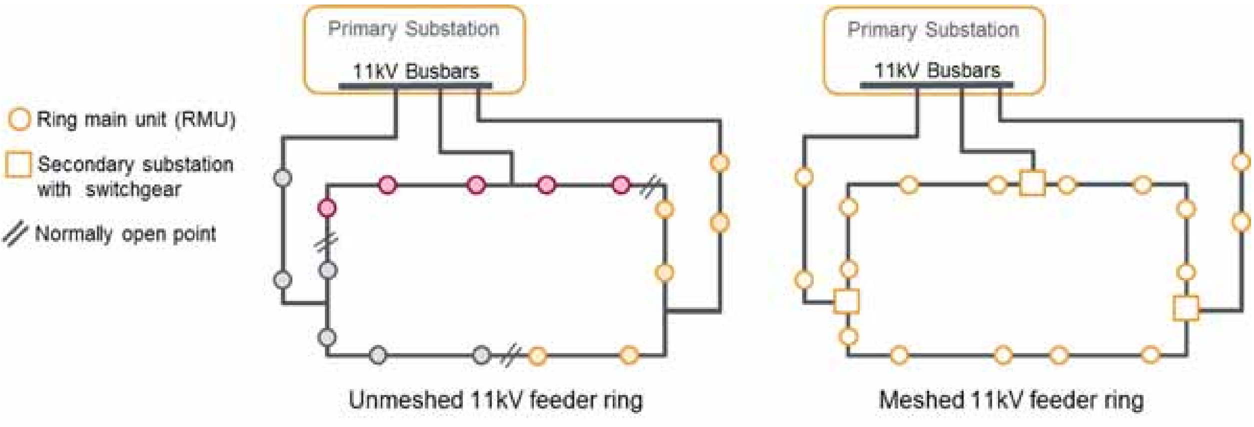

Figure 2.1 – Simplified arrangement of 11kV feeder ring (a) Radial & (b) Meshed

LCTs represent large demands or generation sources that can alter rapidly. Hence, with significant penetration of LCTs power flows around networks may alter considerably over the course of a season, a week or a day. The Network Optimise method will alter running arrangements in real time as conditions require, to provide the most effective use of the existing capacity. Network reinforcement works to provide additional capacity can therefore be deferred.

Network Optimisation techniques will be demonstrated based on modelling of the LV and HV networks to determine how automatic reconfiguration can increase the utilisation of assets to increase the amount of LCTs that can be connected. LV remote control circuit breakers and link box switches will provide the necessary control to implement the configuration determined by the optimisation tool in the LV network. Remote control of Ring Main Units (RMUs) in the HV networks will provide the necessary control to reconfigure the HV network. A description of the distinction between this Method and other optimisation trials is provided in Appendix 10.4: Technical Appendix.

The SOP will be used in Network Optimise, to enable connection of LV networks across electrical boundaries, and for the management of power flows and voltage. SOPs were developed to TRL 6 and trialled successfully in our FUN-LV project, demonstrating the equalisation of loads and release of latent capacity. However audible noise, efficiency and physical size currently prevent their use in BaU. Active Response will address these issues using Silicon Carbide technology to develop a product at TRL8 and ready for business as usual adoption. Further, Network Optimise has been developed to be complementary to the technology being developed in SPEN's "LV Engine" proposal, the Solid-State Transformer (SST). Further description of the SOP technology and the complementary nature of this method with SSTs is provided in Appendix 10.4: Technical Appendix.

2.1.2.2 Primary Connect

Interconnections between Primary substations are provided to allow for alternative supply arrangements under outage conditions and to allow the transfer of loads between them. This may be achieved via a directly interconnecting circuits between the substation bus bars, or through the downstream supply circuits.

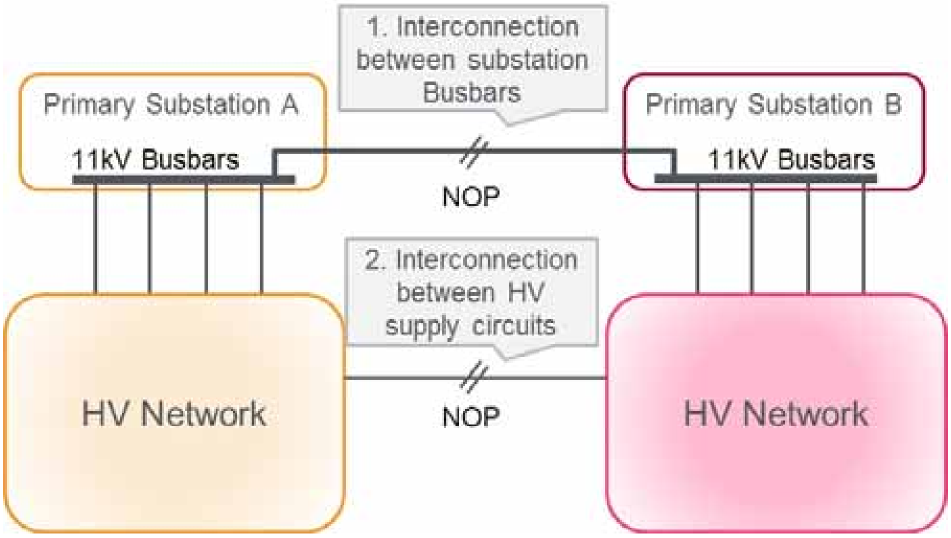

Figure 2.2 – Interconnection between 2 primary substations

It is often not possible to run the connection closed in normal conditions due to circulating currents between the two primary substations, excessive fault levels, protection coordination and in some cases phase differences.

However, interconnection between primary substations can offer benefits by enabling high demands at one substation to be partially met by the other. With increasing LCT penetration it is anticipated that load profiles at primary substations will become highly dynamic, with adjacent substations seeing peak demands at different times of day, depending on the type of customers they supply. Hence sharing of loads and generation between primaries can be used to reduce peak demands, thereby deferring the need to reinforce.

The Primary Connect method will trial the use of an SPB to enable bi-directional transfers between primary substations. The SPB applies the concept of the SOP[6] and the Flexible Power Link (FPL)[7] to the 11kV network, offering similar functionality but in a novel design and architecture. The device uses shunt connected partially rated power electronics, to reduce losses, noise, size and cost, as opposed to the previously trialled fully rated back-to-back convertors. See Appendix 10.4: Technical Appendix for more information.

2.1.3 The Solution which will be enabled by the Active Response Project

These two methods will be trialled individually and in combination. Upon project completion, the methods will become tools enabling effective use of network capacity. The project will adopt a proactive approach to transition the methods into Business as Usual, with inclusion of an associated project deliverable to ensure completion. The solution is anticipated to offer capacity, environmental and financial benefits as described

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[6] https://goo.gl/2PPFHV
[7] https://goo.gl/oNHgWu

in section 3, and will repay the project costs within two years of project completion at our estimated adoption rates.

Customer Benefits of the Solutions

Active Response is designed to manage the uncertainty which is being experienced due to the growth of LCTs. The solution will be able to respond quickly to the clustering of LCTs, particularly EVs, allowing more to connect without exceeding thermal and voltage limits. UK Power Networks ambition is to be a facilitator of the Low Carbon Economy. Reconfiguring networks and using power electronics to share capacity will allow LCT loads and generation to be managed. Managing power flows will reduce overloading and therefore Customer Interruptions (CI) and Customer Minutes Lost (CML).

A further benefit of the Active Response solution is in the reduced amount of customer disruption caused by street works, vehicle movements and temporary diesel generators required by reinforcement works, due to their deferral.

2.2. Technical description of Project

Active Response will allow optimal use of networks through **Advanced Automation** and **Power Electronic Devices**. We discuss each of these in turn in this section and how they complement each other. A more thorough description is provided in Appendix 10.4: Technical Appendix together with illustrative case studies.

2.2.1 Network Optimise

The **Advanced Automation** will enable active reconfiguration and network meshing. This will be achieved through a real-time network model which includes detailed information about the network and load profiles. An optimisation algorithm will determine the best arrangement of the LV and HV network, whilst ensuring safe operation and quick supply restoration in the event of a fault. Monitoring equipment installed in the LV and HV networks will provide visibility of the network and allow the monitoring of performance. In future, data from smart meters may be also be used.

A simplified arrangement of an 11kV radial feeder group is shown in Figure 2.3. The NOPs are selected to balance the loading of the three feeders and are implemented by opening HV switches on Ring Main Units (RMUs).

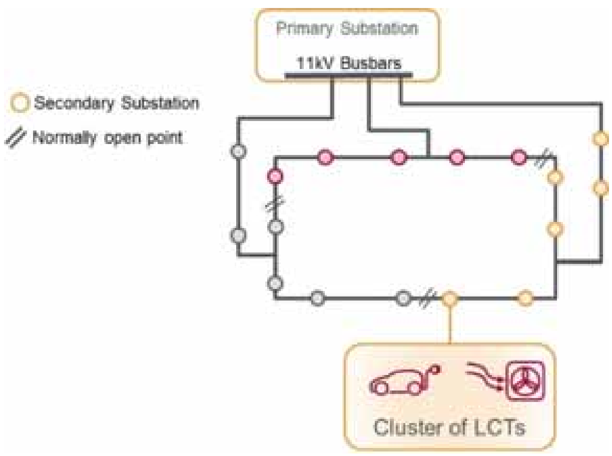

Figure 2.3 – Simplified arrangement of an 11kV feeder ring

If a cluster of LCTs are connected at one substation, the loading of that substation and the HV feeder supplying it will be altered. The **Active Response** solution will investigate the loadings around the network and using the optimisation algorithm will determine the NOP configuration that provides the best solution against predetermined criteria. These criteria, and the balance between them, will be determined during the project, but will include management of thermal and voltage limits, reduction of losses etc.

The **Advanced Automation** will then apply the optimal network configuration, monitor performance and periodically reassess conditions and requirements. **Power Electronic Devices** will be used around the network to cross LV network boundaries, manage fault levels and control power flows.

Optimal network configuration will release capacity to overcome constraints on the distribution network. However, in many locations it is not possible to apply meshing due to network complexity, voltage difference, uneven load sharing, phase shifts, circulating current or fault level. In these instances, **Power Electronic Devices** can be used.

The Power Electronic Devices trial will advance the technology readiness level from the position reached at the end of the FUN-LV project of 6, to level 8. The LV Soft-Open Points (SOPs, FUN-LV Methods 2 and 3) will be re-designed to trial Silicon Carbide technology which was not commercially available previously, resolving the key issues identified in FUN-LV.

The LV circuit breakers and link box switches (FUN-LV Method 1) will be improved to increase the operational life expectancy and increase the fault current break rating, allowing their benefits to be realised on more networks. This represents a significant challenge to overcome together with understanding the Methods impact on existing network equipment (for example the impact of increased switching frequency on RMUs). Please see Appendix 10.4: Technical Appendix for more information.

Active Response will install LV Network Visibility and Control equipment that will provide data for the **Advanced Automation** and LV SOPs. Having strategic visibility across the LV network will allow network planners to quickly identify constraints and determine if applying the Network Optimise Method can be used to solve them. The **Advanced Automation** software, operating holistically on both HV & LV networks is highly innovative, as described in Section 4.3.

2.2.2 Primary Connect

Active Response will also trial the use of an SPB providing a similar functionality to that of the LV SOPs. The SPB uses silicon carbide and a novel architecture that enables reduced losses, noise, size and cost as described in section 2.1.2.1. These were Business as Usual deployment barriers determined in the FUN-LV project.

Interconnection between primary substations is possible in two ways, as shown in figure 2.4, point-to-point between the primaries (1) or via the feeder groups (2).

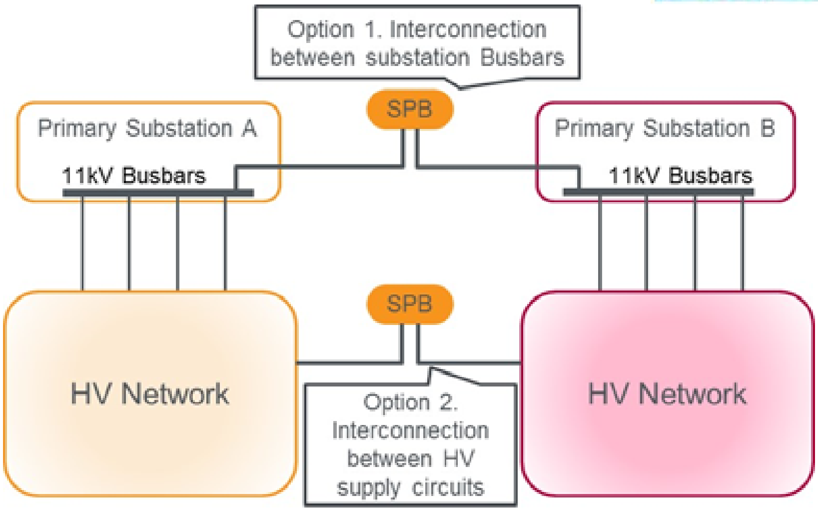

Figure 2.4 – Connection locations of an SBP between two primaries.

Interconnection between primary substations can offer benefits by enabling high demands at one substation to be partially met by the other. An example of this application is presented in a case study in Appendix 10.4: Technical Appendix, and an initial review indicates that additional locations within UKPN currently exist where the Method would be beneficial. With increasing LCT penetration it is anticipated that load profiles at primary substations will become more dynamic, with adjacent substations seeing peak demands at different times of day, depending on the type of customers they supply, and hence the solution will become increasingly applicable. Sharing of loads and generation between primaries can be used to reduce the peak demands, thereby deferring the need to reinforce.

2.2.3 Active Response – Network Optimise and Primary Connect

The two project methods have been developed to be complementary. They will be trialled independently at first, and then in unison to enable assessment of the combined benefits. Once the applications and associated benefits of each of the project methods are determined, they will be incorporated into our network planning process. The process will need to consider all suitable tools in order of cost effectiveness to assess the most appropriate response to a constraint.

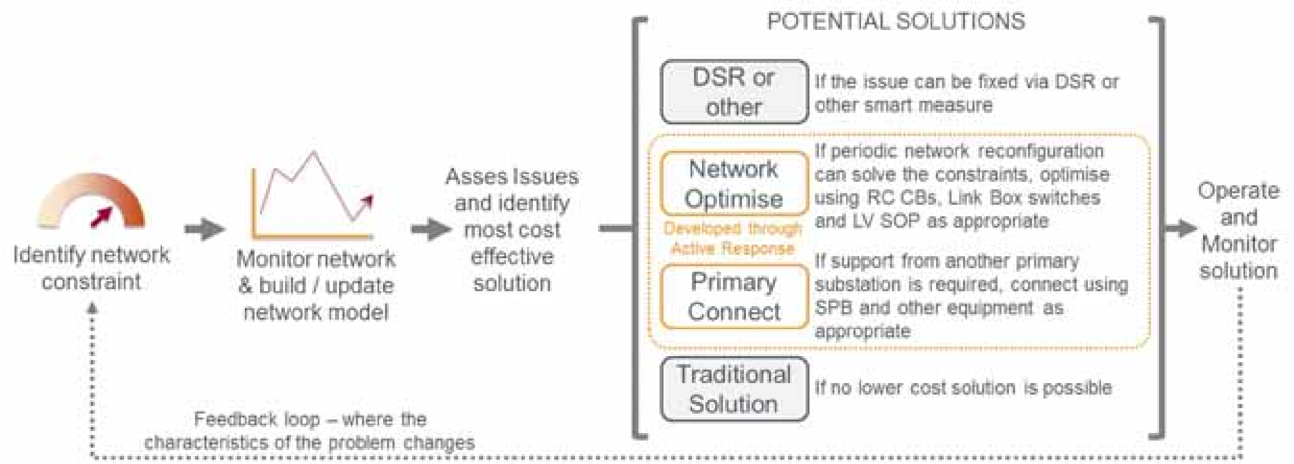

Figure 2.5 – Initial view of a network planning process

Research areas considered by the project

The project will consider four research streams to ensure that the developed solutions are fit for purpose, and appropriate for Business as Usual adoption by GB DNOs. See Section 5: Knowledge dissemination and Appendix 10.4: Technical Appendix for more information.

1. **Impact on conventional network equipment**: Advanced Automation will increase the number of switching operations and alter power flows. The project will investigate the impact of this through the field trials and laboratory tests on the various types and makes of equipment.
2. **Data gathering and processing techniques**: This element will consider the most effective way for implementing the software systems, such as the optimisation algorithm design, state estimation techniques, management of the large data volumes, consideration of equipment dynamic ratings etc.
3. **Power Electronics design and performance**: Examining the device architecture and control options, and any associated effect on safety or asset life.
4. **Application review**: This research stream will review the assumptions made in the development of the project. This will include a review following the trials of the project use cases and business case incorporating the results of further investigation into the scale and impact of LCT clustering and growth scenarios.

The findings from the trials and the research topics will be reviewed and validated by Scottish Power Energy Networks in their role on the project as Design Authority. Additional information on the learning objectives of the project is contained in Section 5.

2.3. Description of design of trials

The aim of the Active Response trials are to demonstrate the optimisation algorithms developed for the **Advanced Automation**, the correct operation of the **Power Electronics** hardware and to develop the hardware to TRL 8. The trials will demonstrate a range of the possible applications which the solution can be applied to and show the benefits which are provided both to the network and to customers.

Before the trials start, to ensure they are completed successfully, the following steps will be carried out:

- Detailed specifications, test criteria and designs will be developed, reviewed and approved by the project partners;
- The trial areas will be selected and design work for the trials carried out. This will ensure that maximum benefit can be obtained from the trials and all the necessary data is collected;
- The SOP and SPB will be tested at an appropriate facility witnessed by SPEN and UK Power Networks; and
- Software testing will be carried out on a test environment.

The trials will build in complexity over the course of the project to minimise risk to both customers and the network.

Trial	Trial Name	Description
1	Active HV	Active HV will demonstrate **Network Optimise** and the benefits of automated HV network optimisation only.
2	Network Optimise	**Advanced Automation** will be applied to the 11kV network and the new generation of LV hardware including SOPs. The trial will demonstrate the benefits of the active reconfiguration of networks, by releasing capacity for new connections.
3	Primary Connect	Primary Connect will trial a SPB and demonstrate direct connection between two primary substations. The trial will show the ability of the SBP to release network capacity by managing primary substation peak demands. It is intended that this trial will be carried out at South Stevenage substation to defer the reinforcement need at that site.
4	Active Response	Active Response will demonstrate both project methods in combination. This will enable the complete solution to be trialled to prove that the technologies operate in conjunction with each other to maximise the benefits.

We have included in our project costs for the following hardware volumes for use in the trials. As the trial areas will be confirmed in the first year of the project, it is possible that these volumes will change. The change control governance process will be followed, and any material change notified as per the NIC guidance document.

Hardware	Quantity
SPB	2
SOP	6 off two-port devices 4 off three-port devices
LV Circuit Breakers	200 (3 phase sets)
LV Link Box Switches	100 Link Box sets

2.4. Changes since Initial Screening Process (ISP)

Significant development of the project concept and technologies has taken place since submission of the ISP. The project intent has not altered. However, as a result of a more detailed understanding of the scope of supply and with actual cost estimates from suppliers and project partners, the overall project cost has increased by £2.9m. The NIC Funding Request has increased by £1.7m.

The software supplier's estimates and associated integration costs have been higher than we had anticipated, increasing the total cost by approx. £2m. The equipment and installation costs have also increased from our initial estimates and we had not made allowance for a third-party review of the project deliverables. The project cost breakdown is shown in Section 4: Benefits, timeliness, and partners and the accompanying Full Submission Spreadsheet.

ACTIVE RESPONSE OFFERS SIGNIFICANT BENEFITS, INCLUDING FINANCIAL, CAPACITY AND ENVIRONMENTAL BENEFITS, AND THE BENEFITS OF A MORE FLEXIBLE, AGILE, AND CONTROLLABLE NETWORK ENABLING REACTION TO FUTURE CHANGES.

3.1. Summary of Active Response benefits

At UK Power Networks, we are well aware of the challenges of decarbonising Britain. As a result, we have a co-ordinated strategy of innovation projects to address challenges at all levels of the network – from Power Potential (TDI 2.0) at the National Grid interface to FUN-LV which focuses on the LV distribution network. These link together with the common aim of delivering an electricity network that can keep the lights on at lowest cost to our customers.

Active Response will provide a further suite of smart solutions, which build on other projects such as our current NIC project "Power Potential", our previous LCNF project "FUN-LV", and those of other DNOs such as "FlexNet" and "Smart Street". It will add to the network toolbox such that we continually build a portfolio of new smart grid functions and capabilities that can be used to address constraints, reflecting the fact that each solution may not be applicable to all situations.

There are significant benefits to Active Response which will accrue to customers, as the approach is rolled out across the UKPN and GB electricity networks. These are highlighted below.

- **Significant financial, capacity, and carbon benefits associated with deferral / mitigation of network reinforcement** – The business case modelling has focussed on the deferment of reinforcement of the network to quantify financial, capacity, and carbon benefits:
    - **Over £700m** in direct financial benefits up to 2050 across GB
    - **Over 6,000MVA** capacity released up to 2050 across GB
    - **About 40,000 tCO_2e** saved directly by the methods up to 2050 across GB, as well as potential for **750,000 tCO_2eq.** 'indirect' savings through **supporting the connection of low carbon technologies (LCTs)** and the considerable carbon benefits of a green future society.
- **Faster and more cost-effective distributed generation connection offers** – enabled by the release of capacity associated with the Active Response methods. This enables LCTs to be accommodated as required. Frequently these require primary reinforcement, which can take several years to implement due to legal and outage constraints. The Active Response methods are quicker to implement, due to their small physical size, and release capacity from existing assets. This would enable DG to be connected more quickly, and may even prove cost effective as a temporary solution to enable a connection while primary reinforcement is being carried out.
- **Increased network flexibility** – the provision of quickly deployable and flexible methods, and the increased network visibility and control associated with the methods, enables future uncertainty and the impacts of LCTs to be managed more effectively. For example, further capacity could be released by the Network

Optimise method if it is used to form larger HV feeder groups while keeping the operation and emergency switching requirements to a manageable level.

- **Reduction in customer disruption** – Reduced disruption and logistical benefits associated with network reinforcement projects (including constructions works), and the potential reduction in LV fuse operations associated with overload (enabled by Network Optimise).
- **Network control benefits** – Additional network control benefits using power electronics, such as the ability to manage network Voltage, and Active/Reactive power flows, which can offer customers improved quality of supply.

3.2. Business case methodology

The quantified financial, capacity, and carbon benefits included above and in the benefits tables in the appendices have been calculated using our Active Response business case cost benefit analysis model. The detailed methodology and underlying assumptions for this model are described in Appendix 10.2. The key components of this modelling are listed below:

- **Forecast of the need for Active Response methods** – The Active Response methods both enable the network to support higher levels of loading. Our model forecasts load for each primary substation in the UKPN area, based on the 2016 loading, and the predicted number of LCTs that will be connected in each area up to 2050. There is significant uncertainty about the implications of LCTs on network demand, the impact of methods such as demand side response (DSR) to minimise this impact, and these aspects have been investigated in the sensitivity analysis detailed in Appendix 10.2. Moderate load impact and DSR assumptions have been selected for use to produce the key project benefits.
- **Forecast of the number of deployments for each method** – There are a set of criteria that need to be met for the installation of the methods. First is that the methods have been developed for network assets nearing their capacity and requiring reinforcement. As both of the methods are based on the sharing of loads across network assets, a key criterion is that there are nearby assets suitable for this, with a compatible load profile, geographic proximity, and suitable network configuration. Our model makes the necessary assumptions around the deployment criteria for each method to forecast the numbers of installations up until 2050 over UK Power Networks and GB.
- **Assess the benefits of a single installation of each method** – The benefits are assessed by comparing cost (capital and operational), carbon, and capacity implications of a single implementation of the method with a representative base case. The costs for the method case have been estimated based on quotes for any innovative equipment obtained for the project, or through validated assumptions, and no assumptions have been made about these costs decreasing with time or volume, giving a conservative figure. The base cases represent traditional reinforcement, based on representative case study projects across UKPN. As mentioned above, the impact of other innovative methods such as DSR or innovative tariffing has been considered through the load growth forecast. The carbon assessment is based on the carbon cost of materials and installation, and capacity released is based on the technical capability of the methods.
- **Assess the benefits of the roll out of each method** – The cost, capacity release, and carbon cases for each method are then assessed over a UKPN and GB-wide roll out. The costs are discounted to 2018 values, using a discount factor of 3.5% for the first 30 years, and 3% thereafter.

3.3. Active Response Financial Benefits

The graph below shows the forecasted financial benefits of Active Response:

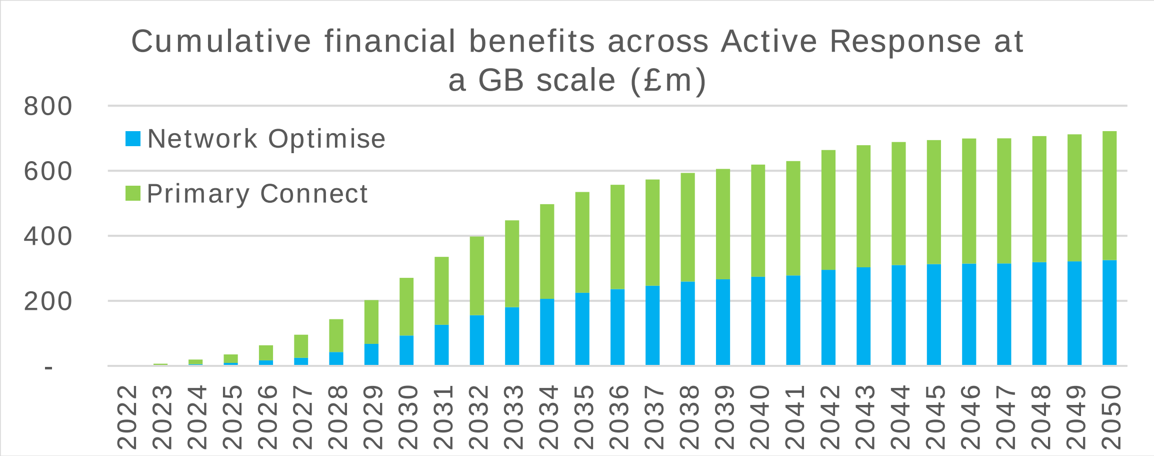

Figure 3.1 – Forecasted Financial Benefits in the central case at GB Scale

The graph illustrates that there is a considerable financial benefit of the Active Response methods up to 2050. The tables below show the financial benefits and the cumulative installations for each method for the central case scenario for 2030, 2040, and 2050:

Single Deployment			
Network Optimise (£k)	173		
Primary Connect (£k)	808		
Licensee Scale	2030	2040	2050
Network Optimise (£k) (cumulative installations)	20,128 (165 installations)	58,781 (555 installations)	69,700 (707 installations)
Primary Connect (£k) (cumulative installations)	39,462 (68 installations)	75,013 (144 installations)	85,774 (176 installations)
GB Scale	2030	2040	2050
Network Optimise (£k) (cumulative installations)	93,164 (765 installations)	273,928 (2589 installations)	325,069 (3301 installations)
Primary Connect (£k) (cumulative installations)	177,472 (308 installations)	344,938 (666 installations)	396,660 (820 installations)

The model ignores the impact that the methods would have on losses, as there is considerable uncertainty as to what these may be. The methods may decrease losses through more efficient running on the networks, but there are loss implications of the methods, particularly conversion losses in the SPB of Primary Connect. The balance of these loss implications is not known, and will be investigated within the project.

The model also only focuses on the benefits of Network Optimise associated with the HV network. The LV element of Network Optimise includes the use of LV Soft Open Points as developed within the FUN-LV project. The LV deferred reinforcement benefits determined by the FUN LV project are not included here to avoid double counting of these benefits.

3.4. Active Response Capacity Benefits

The core benefit of the Active Response solutions is the release of network capacity, quickly and where it is needed, and at a lower cost and carbon impact to traditional methods. This capacity will enable the connection of LCTs onto the network more quickly and cheaply by deferring or mitigating the need for costly reinforcement without negatively impacting its robustness. It is difficult to accurately predict when or where LCTs will connect, so quick response tools such as Active Response are key to meeting customer expectations.

The capacity release benefits are based on the ability to share load across the network, therefore releasing capacity of stranded assets and deferring or mitigating the need to reinforce overloaded assets. The amount of capacity released will depend on the application, and the shape of the load profiles of the nearby assets.

In order to quantify the capacity benefits in our model, we have used the following average capacity release for each method:

- **Network Optimise: 1.5MVA per installation** – This is based on initial modelling of the Network Optimise method in action. The method stays in place permanently, and therefore the capacity release is also permanent.
- **Primary Connect: 10MVA per installation** – The SPB used in the Primary Connect method has a capacity of 5MVA power transfer in either direction, so the total capacity release is potentially 10MVA. In most cases, substation reinforcement is deferred rather than prevented permanently (in the central case, the deferment is for an average of 13 years), and when reinforcement is installed, and the method removed. The capacity release model only accounts for capacity release while the method is in place.

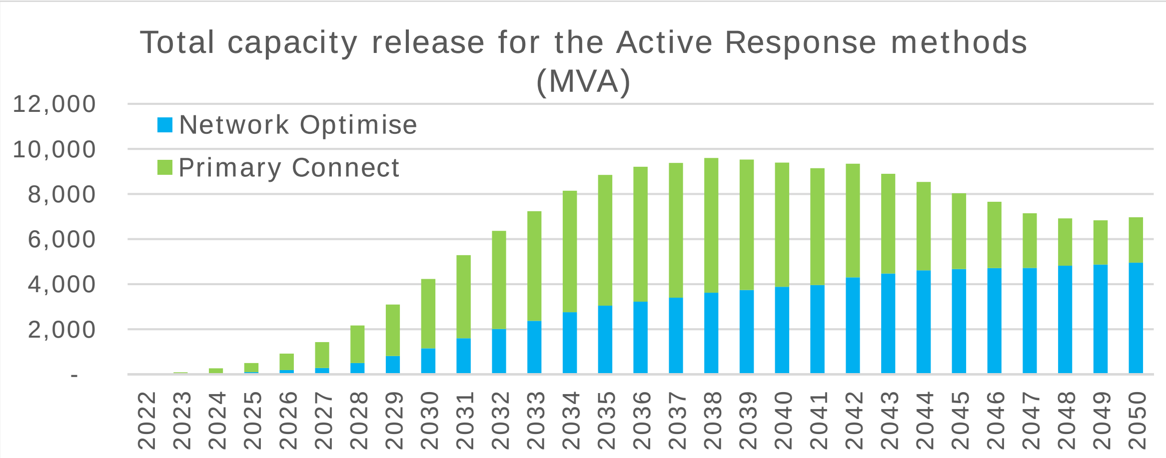

Figure 3.2 – Forecasted Capacity Release in the central case at GB Scale

The graph shows the capacity released for Network Optimise growing over time, as each additional deployment is being implemented. This is because Network Optimise remains in place permanently, and so the number of active solutions grows over time.

However, the capacity benefits of Primary Connect has a very different shape. As the SPB is removed when network reinforcement takes place, the capacity release benefits are only temporary. Hence the number of active installations, and their associated capacity release benefits, fluctuates with the shape of the roll out forecasts.

3.5. Active Response Environmental Benefits: Carbon Emission reductions

The environmental impact of the Active Response solution can be considered in two ways:

- **Direct Environmental Benefits**, which compares the carbon impact of the Base Case and the Active Response Case; and
- **Indirect Environmental Benefits**, from the wider impact of the solution.

Direct Benefits
The direct carbon benefits of Active Response are driven by the creation of capacity for a lower carbon cost than in the base case. To quantify the carbon benefits in our model, we developed the following assumptions:

- **Network Optimise** – The benefits are assumed to be the avoidance of the installation of an additional feeder cable of 1km, which is estimated at just over 10tCO_2e for each implementation of the method.
- **Primary Connect** – In most installations of Primary Connect, the need for reinforcement is only temporarily deferred (in the central case, the average deferment is 13 years), and the carbon impact of this work will be realised eventually. The carbon associated with that reinforcement is estimated as 40tCO_2e. There is also a carbon cost of the Primary Connect method itself, which will be incurred in all implementations of the method. This has been estimated as about 4tCO_2e.

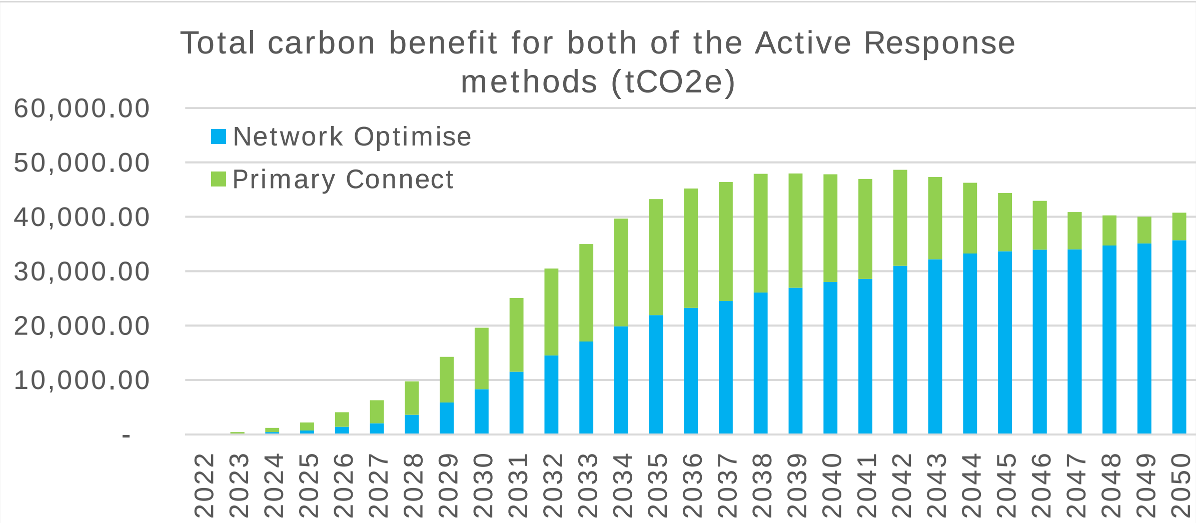

Figure 3.1 – Forecasted Carbon Benefits in the central case at GB Scale

This graph shows similar characteristics to the Capacity Release graph; the carbon benefits for Network Optimise grow over time as the number of active solutions also grows, and the carbon benefits of Primary Connect fluctuates as the solution is not permanent and the number of active solutions grows and reduces in line with the roll out profiles. It should be noted that the whole-life carbon case of Primary Connect actually increases direct carbon cost overall. However, it is a significant contributor to the indirect carbon benefits described in the section below.

Indirect Benefits
A key objective of Active Response is to enable the adoption of LCTs and behaviours, which combined has the potential to greatly reduce carbon emissions of the UK.

The Future Energy Scenarios (FES) identified by National Grid give a view on the carbon benefits of the adoption of such technologies, based on the four energy scenarios. The graph below shows the total carbon emissions for the UK in each of the four scenarios. (Note that these figures reflect the 2016 scenarios as the 2017 scenarios do not provide this information):

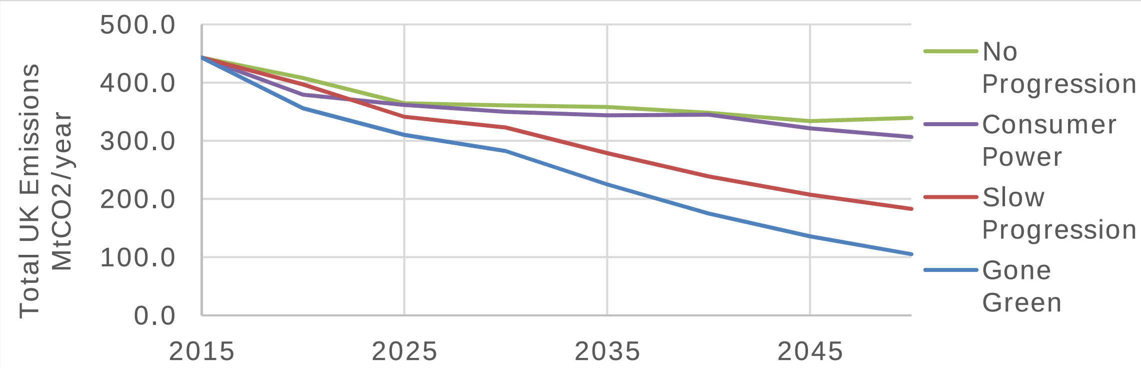

Figure 3.4 – Total UK Emissions forecasted up to 2050, from the FES (2016).

Based on the capacity released by the Active Response methods, and using the following assumptions, the following carbon benefits can be derived if all of that capacity is used to charge Electric Vehicles (EVs):

- 7kW Electric Vehicle Charging,
- an average EV produces 74g/km[8] against 130g/km from a typical conventional car in tax band D[9], and
- that average annual distance covered in vehicles is 12,714km per year[10], and that this figure is the same for both conventional and Electric vehicles:

Year	Capacity released (MVA)	Equivalent Number of Electric Vehicles	Potential Carbon Benefits (tCO_2e)
2030	4,228	604,000	428,663
2040	9,394	1,342,000	952,426
2050	6,962	994,571	705,853

Active Response supports and enables these carbon savings, by enabling the adoption of LCTs and behaviours. Without these or similar tools, the uptake of such technologies may be restricted, for example by restricting their affordable connection.

[8] Based on a 0.211kWh/km average EV energy usage (http://shrinkthatfootprint.com/wp-content/uploads/2013/02/Shades-of-Green-Full-Report.pdf) and a 2017 UK Grid Emission Factor of 351.56 gCO2e/kWh (https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2017).
[9] Note that EV carbon emissions per km will reduce with time assuming the UK generation mix continues to decarbonise, so the carbon benefits from EVs may be greater than stated here.
[10] http://www.bbc.co.uk/news/uk-england-28546589

ACTIVE RESPONSE BUILDS ON EXISTING INNOVATION TO DELIVER NOVEL, COST EFFECTIVE SOLUTIONS TO CONSTRAINTS THAT ARE NOW BEING ENCOUNTERED.

4.1 Evaluation Criteria (a) - Accelerates the development of a low carbon energy sector and/or delivers environmental benefits whilst having the potential to deliver net financial benefits to future and/or existing Customers

To demonstrate the benefits of Active Response we have focussed on three key areas:

- **Capacity benefit:** 4.2 GVA of capacity for LCT connections may be released by 2030 by deploying the Active Response Solutions across GB. The core benefit to the Active Response solutions is the release of additional network capacity, quickly and where it is needed, and at a lower cost and carbon impact to traditional methods. This capacity will enable the connection of LCTs onto the network without negatively impacting its robustness, whilst deferring or mitigating the need for costly reinforcement. It is difficult to accurately predict when or where LCTs will connect, so quick response tools are beneficial.
- **Financial benefit:** Rolling out the Active Response solutions would save customers a total of £271m by 2030 through deferring network reinforcement work. The project will also provide a direct benefit via a trial that will defer planned reinforcement work.
- **Environmental benefits:** An objective of Active Response is to enable the adoption of LCTs and behaviours, which combined has the potential to greatly reduce carbon emissions of the UK, potentially by 428,000 $tC0_2eq$. to 2030, and this offers a significant benefit of the project. A direct reduction in carbon emissions of 19,592 tCO_2eq. by 2030 is offered from the method costs having a lower carbon impact than in the base case.

Further details, including description of the benefit calculation methodologies and our assumptions, are included in Appendix 10.1: Benefits Tables & Appendix 10.2: Project Business Case .

4.2 Evaluation Criteria (b) - Provides value for money to electricity distribution/transmission Customers

Active Response will develop tools for a smart solutions toolbox that could deliver £59.6m in financial benefits rolled out across UK Power Networks licence areas by 2030; £271m rolled out across GB. A GB-wide rollout would provide 15 times the return on the £18.3m project cost in benefits to customers by 2030.

4.2.1 Potential direct impact on the network

The Active Response project will offer possible solutions for solving distribution network constraints. The technologies demonstrated fit within a network planning decision making process that will enable selection of the most cost effective way of mitigating constraints.

This process will include consideration of all applicable solutions to a constraint, and will build upon the work completed by other projects[11]. The solutions that can be applied will be developed in collaboration with our partner Scottish Power Energy Networks to maximise applicability, and will be kept under review to incorporate emerging technologies. An initial view of this process is shown in Figure 4.1. The solutions will provide direct impact on distribution networks, increasing the available capacity and enabling LCT connections in ED1, ED2 and beyond.

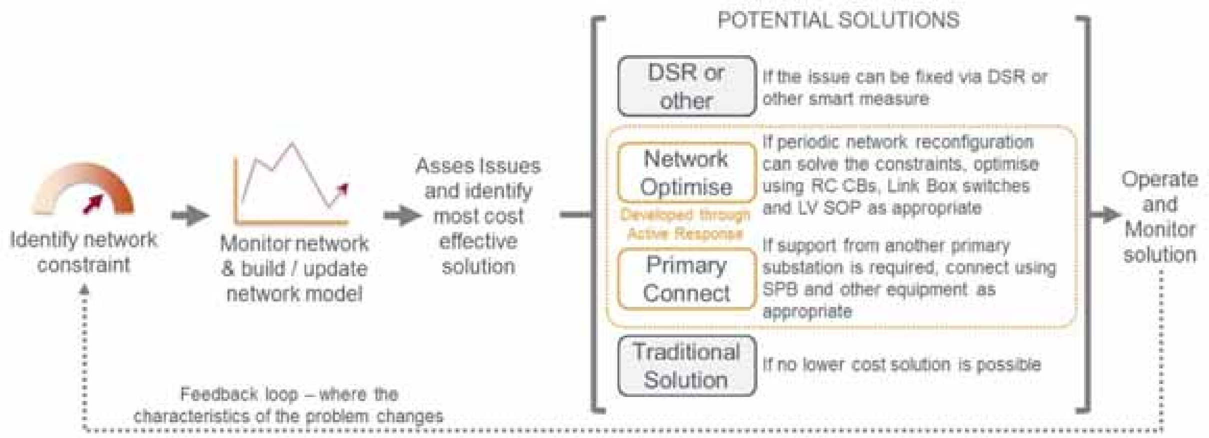

Figure 4.1 Example network planning decision hierarchy.

The project has been developed with assistance from Scottish Power Energy Networks, to ensure that it will deliver relevant learning to the wider DNO community. A robust dissemination plan has been developed to ensure that other DNOs can receive the learning from the project and replicate the solutions. Continuing collaboration with Scottish Power Energy Networks throughout the project is planned to ensure that the equipment and trials are widely relevant, ultimately producing a draft document on the use of “Power Electronics in Distribution Networks”, that will then be progressed with the ENA for industry wide use.

4.2.2 Project costs and contributions

To ensure this project is delivered at a competitive cost, values have been calculated with a bottom-up approach based on the project plan, across each of the project workstreams with inputs from UK Power Networks managers, Ricardo Energy & Environment, TPS, and CGI. The values have been reviewed by multiple levels of relevant internal stakeholders, including fellow innovation project managers, up through key directors as part of our innovation funding governance process.

Our costs estimates are based on:

- inputs from UK Power Networks’ experts for labour requirements, including procurement, legal and dissemination activities;
- inputs from UK Power Networks’ technical specialists including labour elements for technical specification documentation activity and equipment installation for the trials;
- quotations received from the partners and suppliers; and
- project management costs, considering previous experience of delivering similar

[11] For example, Scottish Power Energy Networks “FlexNet” https://goo.gl/29H7gM

projects, particularly other NIC & Low Carbon Network Fund tier 2 projects.

We will use a competitive procurement process to select suitably-qualified suppliers for those elements of the project where several potential suppliers are available. This includes the research streams, the remote-control LV hardware and the optimisation software. Where possible we will award this work in stages of fixed price and scope. This will allow us to manage any scope creep and avoid unexpected cost overruns.

UK Power Networks has a robust procurement process which endeavours to acquire the best value for money for customers. The process involves advertising an invitation to express interest (ITEI) across several forums, and our existing vendor list. Those who express an interest will receive subsequent invitations to tender (ITT). Bidders will be evaluated and reduced to a shortlist of suitable suppliers. The final selection will be based on a scored technical evaluation and a commercial evaluation.

This activity will be carried out in advance of the project start where possible to enable the supplier to start at project kick-off with the rest of the project team. This will be at UK Power Networks' risk and expense.

We believe that trialling multiple Methods for solving network constraints represents good value for money to customers, providing efficiency benefits in innovation overheads and increasing confidence in achieving the benefits in full.

UK Power Networks will on this project continue its track-record of investing in innovation beyond the minimum level contribution. In this case, we will be contributing 17% of the project cost, which – above the 10% minimum level – represents the direct benefits we would receive should the project methods be successful. This helps motivate us to deliver the project successfully, providing benefits to customers and our shareholders.

Additional partner contributions to the project are detailed in Section 4.4.

4.2.3 Summary Cost tables

The project costs for each workstream as a percentage of the total is summarised below:

Workstream	Name
1	Hardware development and deployment
2	Software development and deployment
3	Project planning, trials and analysis
4	Learning and Dissemination

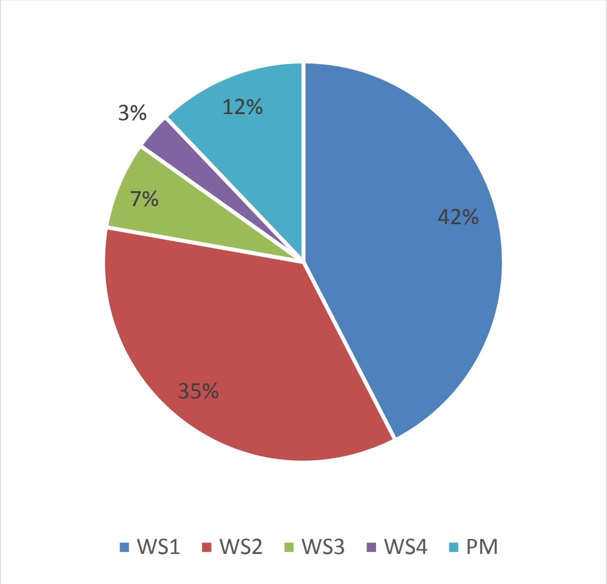

Figure 4.2 % Project costs per workstream

Costs by category are shown in the below table. This provides the break-down of the total project cost between Labour, Equipment, Consultants, IT suppliers, Travel & Subsidence, Contingency and "Other":

Cost Category	Cost (£k)	Percentage (%)
Labour	1,747.34	9.5
Equipment	7,144.47	39.0
Consultants	2,064.14	11.3
IT Suppliers and Integration	6,155.92	33.6
Travel & Subsidence	42.41	0.2
Contingency	750.00	4.1
Other	393.50	2.2
Total	18,297.78	100.0

Staffing costs for each Project stage, indicating the number of staff expected to be used (FTEs by stage), the number of days required, the cost per day and the total personnel cost are shown below:

Project Participant	Workstream	Total (£k)	FTEs	Person days	Cost (£) / Person Day
UK Power Networks	1	[redacted]	[redacted]	[redacted]	[redacted]
	2	[redacted]	[redacted]	[redacted]	[redacted]
	3	[redacted]	[redacted]	[redacted]	[redacted]
	4	[redacted]	[redacted]	[redacted]	[redacted]
	PM	[redacted]	[redacted]	[redacted]	[redacted]
SP Energy Networks	1	[redacted]	[redacted]	[redacted]	[redacted]
	2	[redacted]	[redacted]	[redacted]	[redacted]
	3	[redacted]	[redacted]	[redacted]	[redacted]
	4	[redacted]	[redacted]	[redacted]	[redacted]
	PM	[redacted]	[redacted]	[redacted]	[redacted]
Ricardo Energy & Environment[12]	1	[redacted]	[redacted]	[redacted]	[redacted]
	2	[redacted]	[redacted]	[redacted]	[redacted]
	3	[redacted]	[redacted]	[redacted]	[redacted]
	4	[redacted]	[redacted]	[redacted]	[redacted]
	PM	[redacted]	[redacted]	[redacted]	[redacted]
Total		3136		5509	

[12] Note Ricardo Energy & Environment day rates are reduced to £[redacted] via project contribution.

4.3 Evaluation Criteria (d) - Is innovative (ie not business as usual) and has an unproven business case where the innovation risk warrants a limited Development or Demonstration Project to demonstrate its effectiveness

Active Response is aligned with UK Power Networks' Innovation strategy and facilitates our recently published transition to DSO vision[13].

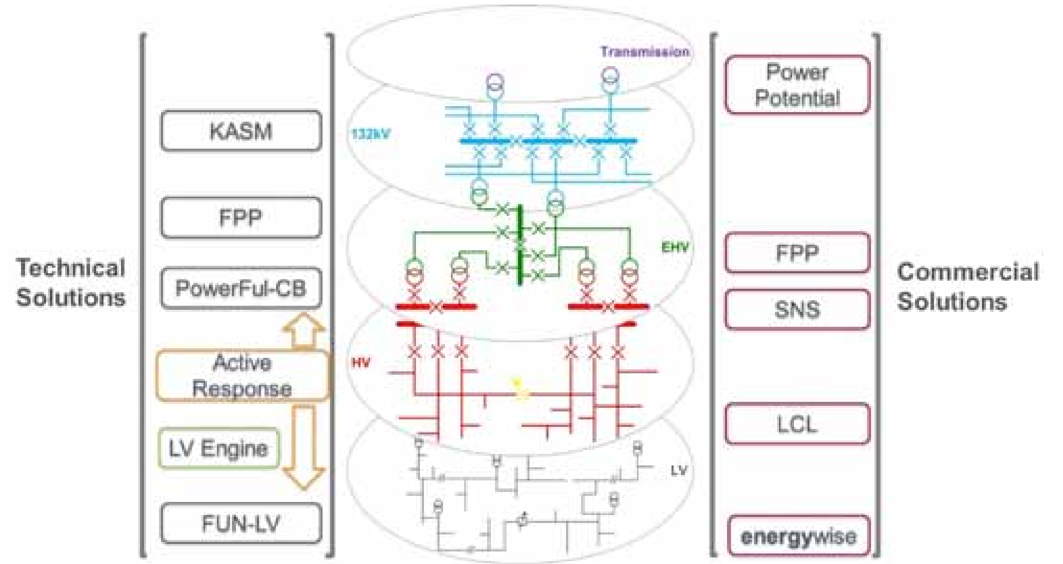

Figure 4.3 UK Power Networks Innovation strategy

Active Response contains two highly innovative and untested aspects.

Advanced Automation and Optimisation system (Technology 1)

This holds significant technical challenges, in particular with the prioritisation of automated control actions when using third party provided network services. This becomes a significant challenge when combined with the impact of regular automated network switching. Understanding the network configuration will be unpredictable, and therefore performing a switching schedule or operating a flexibility contract is complicated by the potentially unknown network arrangement. All this must be carried out while ensuring the safety of those working on or near the network.

In addition, the algorithms required to correctly forecast and optimise networks at both HV & LV in close to real time, are anticipated to be complex and require significant innovative thinking to successfully implement and trial. These technologies therefore represent a technical and operational risk to the project, and justify the use of NIC funding to trial.

These systems will build on the learning derived in other automation systems from both Business as Usual applications (such as the Automated Power Restoration System (APRS) used in our Distribution Management System) and other innovation projects, such as "Power Potential" and Electricity North West Ltds' "Smart Street" Project (which both use an optimisation system), and Scottish Power Energy Networks "FlexNet" (which

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[13] http://futuresmart.ukpowernetworks.co.uk/

demonstrated network automation). Whilst these demonstrated similar techniques to those proposed in Active Response, the solutions required are distinct and require additional challenging innovation. We will ensure that we incorporate the relevant findings from these previous projects and will seek to develop existing solutions where possible to match the specification of this project.

There are also significant challenges to overcome regarding the LV hardware and the Methods impact on existing network equipment. Please refer to Appendix 10.4: Technical Appendix for more information.

Power Electronics Devices (Technologies 2 and 3)

We believe that power electronics will play a big part in distribution networks of the future. They will enable the optimal use of existing assets, and form part of a toolbox of smart solutions as we transition to a low carbon future. Recent innovation projects and developments in power electronics have made dramatic improvements in the TRL of distribution network solutions.

Our findings from the recently completed FUN-LV project show that for LV power electronics to be widely adopted improvements in the technology are required. This necessitates the use of innovative new semiconductor technology, silicon carbide, which was previously not possible, due to its immaturity, and the disproportionately high cost of the components. 1.7kV, 300A silicon carbide Metal-Oxide-Semiconductor Field Effect Transistors (MOSFETs) and Diodes will be used, offering significant benefits over previously demonstration devices, including reduced audible noise levels (by increasing the switching frequency outside of audible range and reducing cooling system requirements) and increased efficiency, such that at the end of the project the devices will be at TRL level 8. However, the new design is significantly innovative such that their use does represent a technical and operational risk, which therefore justifies the use of NIC funding to trial their implementation.

The design for the SPB is also completely novel over that trialled previously including both the FUN-LV SOPs and the "Flexible Power Link" currently being installed in Western Power Distribution's (WPDs) "Equilibrium[14]" project. The architecture of the SPB is new, and offers substantial benefits in terms of cost and efficiency (Appendix 10.4: Technical Appendix). Estimates from the supplier indicate that the SPB would reduce the cost of the Flexible Power Link by 64%. This would allow the adoption of this solution to be cost effective in a wider range of applications, providing benefits to customers in excess of the £449m WPD are expecting from this technology. Jon Berry, Innovation and Low Carbon Engineer at WPD, said, "We are interested in the novel architecture you are proposing to trial with the Soft Power Bridge, and the potential cost reductions it could enable" (See Appendix 10.10: Letters of Support).

The SPB design is highly innovative, and therefore carries with it significant cost and a level of technical and operational risk to develop justifying the use of NIC funding for demonstration. The Soft Power Bridge has both series and shunt elements, in a similar configuration to a Unified Power Flow Controller (UPFC).

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[14] https://www.westernpowerinnovation.co.uk/Projects/Network-Equilibrium.aspx

4.4 Evaluation Criteria (e) - Involvement of other partners and external funding

Active Response will use a collaborative approach amongst a carefully selected project team to develop the solutions described.

Details of the project Partners, their role within the project and why they have been selected are contained in Appendix 10.8: Project Team

Project Participant	Total Costs (£k)	Contribution (£k)	Contribution (%)	Outstanding funding required (£K)
UK Power Networks	[redacted]	[redacted]	33%	[redacted]
Turbo Power Systems	[redacted]	[redacted]	17%	[redacted]
CGI	[redacted]	[redacted]	12%	[redacted]
Ricardo Energy & Environment	[redacted]	[redacted]	10%	[redacted]
Scottish Power Energy Networks	[redacted]	[redacted]	68%	[redacted]
Total	18,298	4,341	24%	13,956

We have worked hard to gain support from a variety of external companies and organisations. Letters of support can be found in Appendix 10.10: Letters of Support.

4.5 Evaluation Criteria (f) – Relevance and timing

4.5.1 Enabling Low Carbon Technologies

There is now a key focus in policy towards decarbonisation. The UK Government's Carbon Plan highlights the importance of decarbonising key areas of energy consumption, such as transport, heat, and power generation to achieve the 2050 target of reducing greenhouse gas emissions by at least 80% relative to 1990 levels. Though progress has been achieved over the last few years, especially in the electric power sector, the Committee on Climate Change (CCC) highlighted in its 2016 Progress Report to Parliament the need for further support beyond 2020 from the Government, in areas such as transport and heat in buildings.

There are also key technological and commercial developments in the sector, such as a decrease in manufacturing costs and proliferation of market offerings. In the case of EVs, automotive manufacturers such as Ford, Toyota, VW, Audi, and BMW have committed to increase the number of plug-in vehicle models on the market over the next few years. Volvo have stated all new cars from 2019 will have an electric motor. Battery pack costs have been reducing rapidly, and are expected to continue declining in the coming decade (the cost of lithium-ion battery packs in 2010 was $1,200 per kWh, and by 2020 their cost will be lower than $200 per kWh[15]).

UK Power Networks' internal business planning forecast for the adoption of LCTs across our three licence areas indicates that, in the case of EVs, 1.9 million vehicles will be

[15] Battery Cost Plunge Seen Changing Automakers Most in 100 Years, Bloomberg, 11 October 2016

connecting to our network by the end of RIIO-ED2. Comparing these figures with our forecasts in 2014 when we were defining our investment plans for RIIO-ED1, we now expect that EVs will arrive quicker and in greater number than previously thought (our forecast for EVs at the end of RIIO-ED2 was 550,000; see Figure 4.4 below). This increase in the forecasted uptake of EVs can be attributed to revised policy support, rapid reduction in the costs of materials, and improved technological performance, which could not have been predicted in advance.

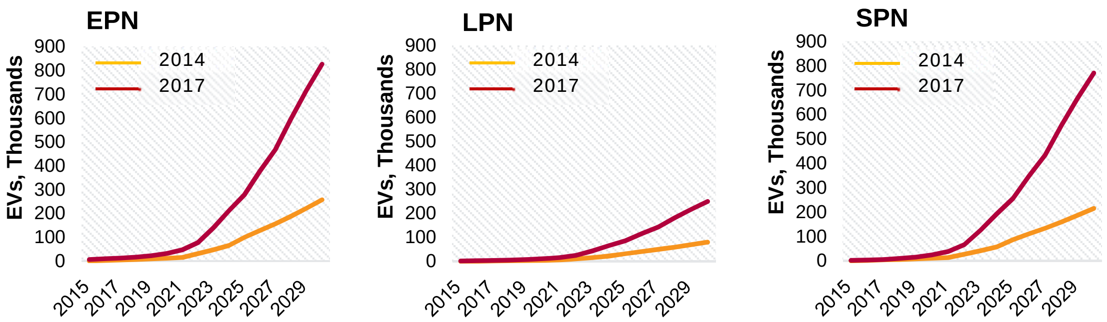

Figure 4.4: Connected EVs forecasts across UK Power Networks (2014 and 2017)

The issue will be particularly pronounced in the first half of RIIO-ED2, as we are now forecasting that by 2027, 330,000 more vehicles than we originally forecasted will be connected on our networks.

To have solutions ready to respond to EV growth early in the next decade we need to be developing and testing the solutions now. Active Response will deliver solutions that can deliver benefits to customers in 2021, ready for the anticipated increase in demand.

Electric vehicles are expected to be one of the major drivers behind transformation of the power system, thanks to the massive changes they will create in power consumption and demand – at least when rolled out at scale.

(Driving towards a Whole System Solution, Utility week, 30th June-6th July 2017, p10)

EVs are only one part of the challenge; other LCTs are also connecting to our networks at rates that are often dictated by rapidly changing policy decisions and new commercial offerings. For example, the Committee on Climate Change has emphasised in its reports to Parliament that decarbonising heat is essential to achieve the Government's ambitious carbon emission reduction targets. As a result, we expect renewed policy focus on heat pumps impacting electricity demand from the early parts of the next decade.

'We need to make sure we are flexible and that we facilitate the implementation of those [smart meters, EVs, renewables] technologies'.

(Basil Scarsella, Chief Executive UK Power Networks, Utility week, 30th June-6th July 2017, p11)

From a DNO perspective, the uptake in LCTs is currently an area of significant uncertainty and disruption – one for which we need a complete toolbox of smart solutions to keep the lights on at lowest cost to the customer. There have been significant developments recently, to name a few such as:

- The establishment of Electric Bus routes in London and the associated charging facilities at Waterloo Bus Garage;
- The UK Governments announcement to ban the sale of petrol and diesel fuelled cars from 2040 onwards (http://www.bbc.co.uk/news/uk-40723581); and
- Car Manufacturer Volvo's announcement that all new vehicles from 2019 onwards will have an Electric Motor.

The emergence of LCT clustering is also becoming apparent. Clustering is where the uptake of a technology occurs more rapidly in particular geographic regions than in others. This effect is significant as some networks will experience LCT related constraints far sooner than others, and it is difficult to anticipate where clusters will occur. The below figure illustrates the number of electric vehicles currently registered per post code in London, and highlights the significant variances between them.

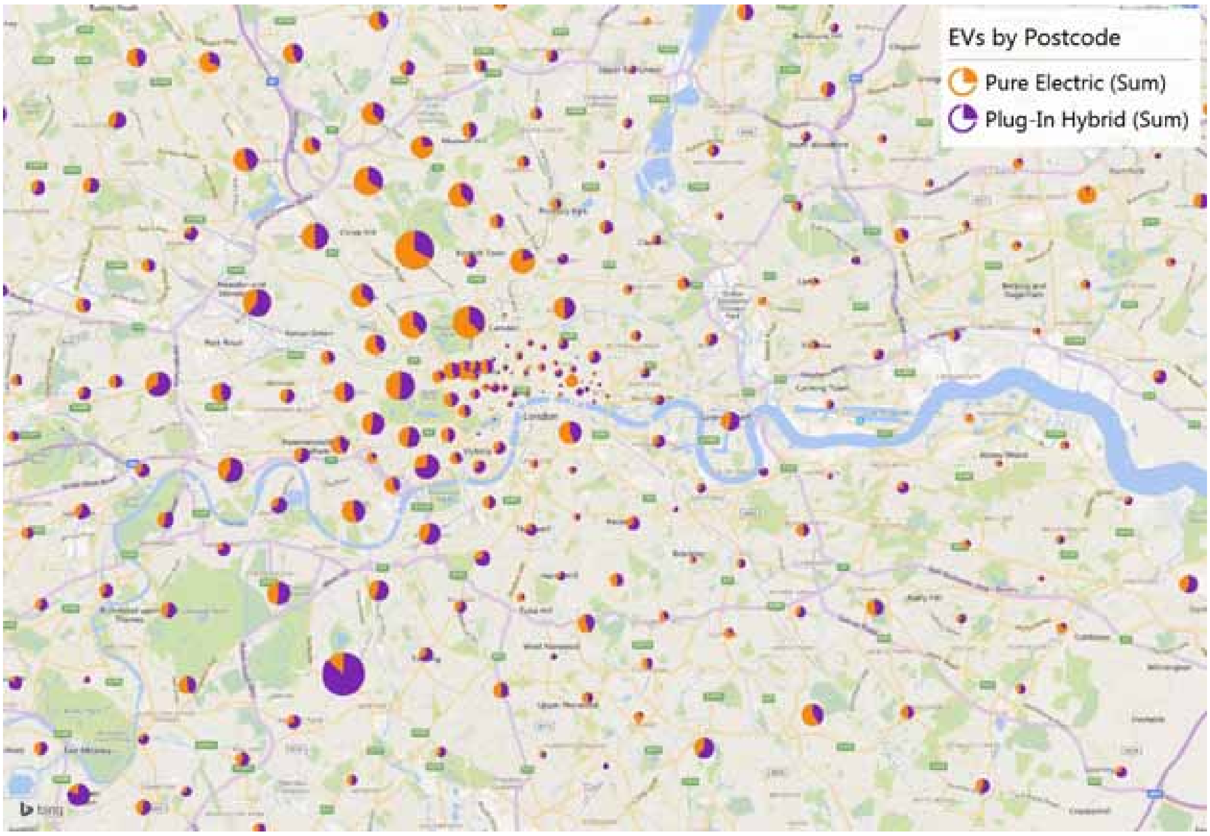

Figure 4.5 EV clustering around London by Postcode

We believe that now is the right time to incorporate the learning from several foundation projects to trial a system level solution. Our FUN-LV and SULVN projects successfully trialled the use of power electronics on LV networks. FlexNet and Smart Street trialled Optimisation and Automation technologies respectively. In Active Response we want to build on these innovative projects and develop the solutions to TRL 8 ready for roll out to business as usual.

UK POWER NETWORKS AND SCOTTISH POWER ENERGY NETWORKS ARE COMMITTED TO SHARE THE KNOWLEDGE GAINED IN ACTIVE RESPONSE, TO DELIVER BENEFITS TO ALL GB ELECTRICITY CUSTOMERS.

Active Response will conform to the Network Innovation Competition default IPR Arrangements.

Both UK Power Networks and Scottish Power Energy Networks are committed to sharing the learning generated within Active Response with the remaining network licence holders and beyond. This will enable all DNOs to roll out the solutions, if proved successful, to deliver benefits to customers.

The partnership with SPEN will ensure that the solutions will be applicable more widely than just within one DNO group. It will also help us understand how we can best help a "fast follower" DNO to adopt the solutions.

5.1. Learning generated

The Project's fundamental aim is to demonstrate and understand the benefits that can be realised by both power electronics, and the optimised automatic reconfiguration of networks in response to changing conditions. These benefits are relevant to the entire GB DNO community as we transition to Distribution System Operators (DSOs) to enable a low carbon future. It will build on the learning developed in previous innovation projects.

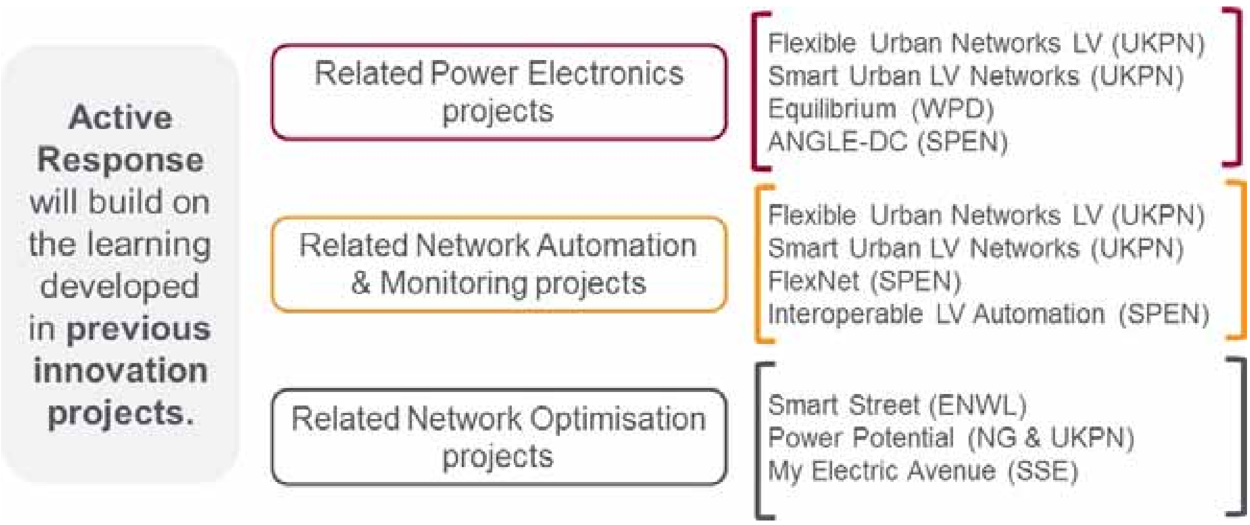

Figure 5.1 Innovation Projects considered to inform Active Response

Active Response will demonstrate two methods, Network Optimise and Primary Connect that will demonstrate significant new learning over that derived from FUN-LV.

Network Optimise will take a system view of both the HV and LV networks, and test the automated optimisation of both in a co-ordinated manner. This is new network learning. To demonstrate this will require the HV and LV networks to be controllable. At HV this is largely the case with existing ring main units, but to control the LV network will require LV CBs, link box switches and LV Soft Open Points (SOPs). In demonstrating this hardware there is some overlap in the network learning generated by FUN-LV. However, it is intended to use second generation SOPs that use Silicon Carbide semi-conductors to overcome the limitations of the first-generation FUN-LV SOPs. It is intended to investigate how the hardware can be co-ordinated where they overlap in area of network influence, something not considered in FUN-LV.

The Primary Connect method is expected to generate entirely new network learning, using a new device architecture and semiconductor material.

In achieving the project's fundamental aim, learning objectives have been identified and will be delivered and disseminated:

Work Package		Learning Objectives
1	**Hardware Development and Deployment**	Trial and review of SOP/SPB hardware designs so that the most appropriate architectures can be identified and developed for adoption.
		Consideration of the Methods impact on asset life, network operations, safety requirements and risk management.
2	**Software Development and Deployment**	Practical experience of hierarchical control systems.
		Review and demonstration of network optimisation algorithms and state estimation techniques.
		Knowledge of effective data analytics systems, in which large volumes of data are processed into useful, actionable information.
3	**Project Planning, Trials and Analysis**	Research into LCT growth and clustering assumptions.
		A review of the Active Response project business case and the use cases.
		An initial draft, in conjunction with Scottish Power Energy Networks, of a planning guide on the Use of power electronic solutions in Distribution Networks. This will outline to all DNOs the considerations for when power electronic solutions can offer benefits in network management. This will be developed fully via the ENA and industry consultation, incorporating the findings from all relevant innovation projects, as the deliverable of a subsequent project.
4	**Learning & Dissemination**	Effective Dissemination of the learning derived over the course of the project.

The quality of the learning is ensured by the combination of our experienced staff, our knowledgeable and respected project partners and our expert advisers and reviewers. The learning is directly applicable to other Licensees, as is confirmed by the positive feedback we have received from Scottish Power Energy Networks and Western Power Distribution who indicated a high level of interest in the project in letters of support.

Apart from DNOs, we believe that a spectrum of stakeholders can benefit from the learning generated:

- **Regulators and associated departments & bodies:** The trial can enable Ofgem to gain valuable information regarding the potential of alternatives to network reinforcement and their costs. Furthermore, the trial findings will enable the Department of Business, Energy and Industrial Strategy, to shape a more informed strategic view in regard to the potential deployment of network automation and power electronic solutions.
- **Industry groups & professional bodies:** These stakeholders can benefit from learning related to the hardware and software solutions developed. Specifically, technical forums such as the Electricity Network Association (ENA), Institution of Engineering and Technology (IET) and the power electronics Community can benefit from close engagement related to the impact on network design of automation and power electronic solutions.
- **Academic institutions:** This Project will accelerate the use of power electronics on distribution networks, which can revolutionise the way we design, build and operate networks. Electrical engineering departments and institutions will have access to trial data and project documentation to continue this work.
- **Other manufacturers:** Active Response will demonstrate the need, technical/commercial feasibility, and benefits of automation and power electronic commercial products, not just to the project participants and GB DNO community, but also to third parties who could bring competing technologies to market. The learning from this project will de-risk, remove technical and regulatory barriers, and stimulate further innovation across the market in the development of these technologies.
- **Local Authorities:** We intend to proactively collaborate with Transport For London and the local authorities for the trial zones, taking an active role in local events in which we will inform and update the audience on different aspects of the project. The aim is to facilitate discussion and explore ways to accommodate issues related to LCT connections and the benefits of the solutions trialled in the project. UK Power Networks is committed to working with local authorities to facilitate the uptake of LCTs.
- **Customers** will have the opportunity to understand the solutions being used and the impact on the network.

5.2. Learning dissemination

Facilitating knowledge transfer is key for project learning dissemination and ultimately for gaining maximum return of investment for the customer. Our Knowledge Dissemination Roadmap for this project is shown in Appendix 10.5: Knowledge Dissemination Roadmap.

The purpose of this Knowledge Dissemination Roadmap is to inform stakeholders what knowledge the project will share, how it will be shared, with whom and at what stages throughout the project.

Over the years we have gathered an extensive contact list of stakeholders, which we will use as an initial list. We will seek input from other DNOs who have run or are still running power electronics equipment or complex automation systems. In addition, as we have done in previous projects, we will conduct market research to identify stakeholders who would be interested and how they could benefit from this project.

For this project, we have engaged with Scottish Power Energy Networks to develop a joint dissemination strategy, so that the findings of both Active Response and LV Engine are delivered in a coherent and logical way.

A target group for this projects learning is the power electronics community. We aim to raise awareness and understanding of this potential new opportunity for power electronics solutions in Distribution networks, at HV and LV.

We will make our progress and findings transparent and easily accessible through a variety of dissemination channels which will give stakeholders the discretion to choose the way they would like to be informed. This will include direct engagement such as seminars and access through various online platforms. These are described in further detail in the table below.

Channel	Description	Outputs
Websites	Our innovation UK Power Networks microsite includes a diversity of information. (www.ukpowernetworks.co.uk/innovation) Alongside written documents, users can find videos, tutorials and online learning events. Relevant information will also be made available via the ENA Smarter Networks Portal.	Reports, tutorials, data, training material, news
Workshops and Seminars	Direct project dissemination to allow question time and engagement between the different stakeholders.	Face to face communication, video documentation, leaflets and printed material
Social Media	Regular updates through Twitter, Blogs and Linkedin.	Notifications, news, announcements
Press releases	Publications in industry magazines, websites, working groups and forums.	Notifications, news, announcements, articles
Other DNOs	We will collaborate to pool the learning from related projects to enable all DNOs and customers to understand the available solutions.	Share knowledge and lessons learned
Targeted communication	We aim to approach directly organisations involved in developing codes and standards, e.g. the ENA and the IET.	Collaboration in standards and codes development
Presentations at conferences and industry events	We will present Active Response in high profile industry events such as the annual LCNI conference. This will enable a wider audience such as STEM students, academics and policy makers to be exposed to the Active Response project.	Reach a wide audience and facilitate new opportunities for knowledge transfer and collaboration

Channel	Description	Outputs
Joint Presentations with Scottish Power Energy Networks	Scottish Power Energy Networks will have the design authority role in Active Response, as they are progressing the LV Engine project, also involving power electronics. power electronic solutions and their applications in the network are growing. In order to raise awareness within UK power electronics industry and create a competitive market we plan to arrange a joint dissemination event with SPEN with the audience from UK power electronics industry.	The opportunity to explore how UK industry can support DNOs to upskill their staff in operation and maintenance of power electronics technologies.

Availability of Trial Data

All data gathered during the trials will be stored in a UK Power Network owned database, and will be made available to interested parties at the end of the project in accordance with version 3 of the Network Innovation Competition Governance Documents. The UK Power Networks policy on this will be available on our innovation website.

5.3. IPR

Active Response will conform to the default IPR arrangements set out in the NIC Governance Document.

- All contracts with project partners/participants will include terms and conditions that reflect the default IPR arrangements.
- The project partners have reviewed the default IPR arrangements and confirmed that they will conform to them.
- Conformance with the default IPR arrangements will be an eligibility criterion for all project suppliers/partners yet to be appointed, e.g. the academic institutions.

5.3.1 Ensuring fair and reasonable terms for future use of commercial products

We recognise the need to ensure fair and reasonable terms for the future use of any Background IPR and Commercial Products needed for other Licensees to reproduce the Project outcomes (clause 5.53v of the NIC Governance Document).

To encourage fair and reasonable pricing of the Power Electronics and Advanced Automation commercial products we will enable and encourage academia and other manufacturers to develop competing solutions by sharing Relevant Foreground IPR with them. In many cases, there are manufacturers who we believe could develop these without access to the background IPR owned by our project partners.

We believe that this will enable the market to deliver commercial products at fair and reasonable prices for DNOs and their customers. We believe that funding this project via the NIC greatly increases opportunities to share knowledge and stimulate development of competing technologies.

UK POWER NETWORKS HAS DEVELOPED A ROBUST PLAN TO ENSURE THAT THE PROJECT STARTS, CONTINUES, AND DELIVERS IN A SUCCESFUL MANNER.

This project has been developed, and will be run in accordance with UK Power Networks Innovation procedure, SR 07 005i. This procedure has been developed so that all of our innovation ideas are subject to the appropriate level of review and governance via a stage gate review process, in accordance with Project Management best practice.

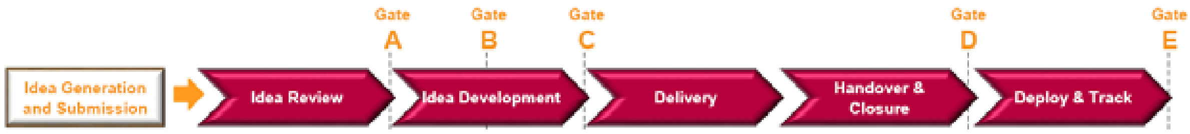

Figure 6.1 UK Power Networks stage gate process for innovation projects

Some innovation projects, across all sectors, have a reputation for taking longer than expected or not delivering according to budget. However, when the source of the funding is the customer, there must be certainty that the money is well spent from 'day one'. It is with that philosophy in mind that UK Power Networks have put together this bid and have produced the documents, plans, project governance and relationships to be ready to start on 'day one'.

This section will present:

- the evidence that we can start in a timely manner;
- the measures in place to minimise the risk of project overruns;
- confirmation of our information verification process;
- how we will ensure learning even when the uptake of low carbon technologies slows down; and
- how we manage change control.

6.1 Evidence that the project can start in a timely manner

As part of developing this bid, we have invested in a significant amount of preparatory work to enable the project to start in a timely manner. The outcomes of this work are:

- A clearly defined project management and governance structure;
- Engaged, committed, and qualified project team members, including the partners developing both the hardware and software systems;
- Strong support within UK Power Networks across multiple business units; and
- A robust project plan to enable the project to commence on 'day one'.

6.1.1 Project Management and governance structure is clearly defined

We will create a Project Execution Plan (PEP), based on project management best practice and learning gained from the Project Handbook we developed for Flexible Plug and Play (FPP) and all our subsequent large innovation projects, such as Smarter Network Storage (SNS) and FUN-LV. The Handbook earned its credentials through the

Low Carbon London (LCL) and FPP projects, both of which received Successful Delivery Reward recognition as being well run projects.

The PEP acts as a guide to the project as it moves from bid into the design and through delivery stages. It specifies the overall aims of the project and the key success criteria, the organisational structure of the project, the governance structure which will enable clear decision making, the key reporting and control processes that support that governance structure.

Each project develops a specific PEP that is used as a 'living document', which is updated as the project progresses.

The project team comprises stakeholders from multiple companies (i.e. UK Power Networks, Scottish Power Energy Networks, Turbo Power Systems, CGI, Ricardo Energy & Environment and others that will be appointed in the initial stages of the project). This approach will provide transparency, facilitate cohesion and collaboration amongst the stakeholders, and avoid duplication of work.

We have defined the project management and governance structure to enable the project to commence in a timely manner. The project will be delivered via four workstreams:

Workstream	Name
1	Hardware development and deployment
2	Software development and deployment
3	Project planning, trials and analysis
4	Learning and Dissemination

The key project roles and responsibilities are:

- **The Project Steering Group** comprises key stakeholders and decision makers within UK Power Networks, including the Project Sponsor Suleman Alli (Director of Safety, Strategy & Support Services) and chaired by Senior Responsible Owner Ian Cameron (Head of Innovation). This group is ultimately responsible for the project and will make decisions that have an overall impact on the benefits and outputs that the project will deliver.
- **The Project Manager** will be responsible for the day-to-day management of the project. This includes but is not limited to reviewing the project progress against plan, presenting the project progress report to the Project Steering Group, updating the project plan, monitoring project risks and project budget.
- **The Design Authority** reviews and approves all key project deliverables. However, ultimate responsibility for the delivery of the solutions rests with the project delivery team. On the Active Response project this role will be fulfilled by a partnership of key staff from SPEN and UK Power Networks.
- **Project Management Office** provides support to the Project Manager as required.
- **Project Support and Workstream Leads** assists the Project Manager to discharge their duties, particularly those associated with the delivery of key project deliverables.

6.1.2 Committed and Qualified team members

UK Power Networks and the project partners have the experience and capability to successfully deliver large complex technical projects to time, cost, and quality targets.

To advance the technologies used in the solutions, we have commitment from global technology providers participating in this project – TPS and CGI. The Project Partners recognise the potential of the solutions and the impact they could make on distribution networks, and have significant experience in the subject areas in which they will contribute. They are all keen to bring functioning and commercially viable products to market to benefit GB networks and ultimately GB customers. These committed and qualified project partners have been actively engaged in the development of our full submission to ensure that the project can commence in a timely manner.

For the UK Power Networks team, we have identified and appointed the appropriate people to fulfil the key project team roles to enable the project to start promptly. We have selected staff who had the right mix of seniority, technical skills and knowledge, with experience of delivering innovation projects. We will select the remainder of the team upon project award.

Full details of the project team can be found in Appendix 10.8: Project Team

6.1.3 Strong support from UK Power Networks internal staff and the business

The project was developed in conjunction with the business in order to gain their input and commitment. This includes support from:

- Key members of the **Executive Management team,** who have committed management time and ensured the availability of input and support from in-house specialists.
- **In-house specialists** who have provided input and committed to continued support. They are engaged through regular meetings in the development of the project plan with internal senior managers and other senior discipline leaders with expertise in a number of areas including power electronics and network management systems.

The project has progressed through UK Power Networks' internal Innovation and Project Governance and Control Governance processes (SR 07 005i) and the technical Design Review Board. This ensures that all the relevant internal stakeholders are fully engaged and formally committed to the project.

6.1.4 Robust Project Plan

The project plan has been drawn up using the experience from our innovation team managers and lessons learned from earlier large Low Carbon Network innovation projects such as LCL, FPP, FUN-LV and SNS to develop the project plan. The plan has been validated by our senior management team and our project partners' management for their inputs on the project scope and delivery phases. This combined input, feedback and guidance ensures that the resulting project plan is robust.

The detailed project plan is in Appendix 10.6: Project Plan. This robust project plan will enable the project to commence in January 2018.

6.1.5 Identification of key project risks

Our own internal project learning reviews and relevant close-down reports from previous Tier 1 and NIA/NIC projects from other DNOs were reviewed and the learning was used to identify project risks and appropriate mitigation. We have a high level of confidence that no insurmountable problems will be encountered, see Appendix 10.7: Risk Register and Contingency Plan.

The trials have been designed to build upon on another in a logical manner, and allow risks between the individual project elements to be decoupled.

6.2 Evidence of the measures a Network Licensee will employ to minimise the possibility of cost overruns or shortfalls in Direct Benefits

UK Power Networks has a strong track record for not only minimising project overruns, but delivering projects within budget. For example, the FPP project was able to deliver the same benefits at a lower cost, which delivered a 3% savings to customers. This was possible due to good project management practices, as outlined in our Handbook, which defines in detail the project control processes and provides effective mechanisms to manage and control the project scope, cost and schedule.

Our other recently completed Innovation projects, such as "Smarter Network Storage" and "Flexible Urban Networks – LV", have all been delivered on time and within budget, and have delivered the benefits stipulated at the outset.

We will implement the same five key control measures as used in previous projects. These defined processes and document controls will help the project board and steering committee to initially agree to the workstream initiation documents, plans and designs and then maintain control of the project to ensure the project delivers to its overall aims, as defined in the project proposal.

A summary of these processes is provided below:

1. **Review Process.** All formal outputs from the project must be put under formal review process (configuration management). Each output must go through the formal specialist or management product review. An output is not deemed completed until it has passed this review process. It is the responsibility of the workstream leads and project manager to ensure all outputs are placed under review.
2. **Approval Process.** This process will be implemented to ensure all deliverables are adequately approved before they are agreed as complete and released. The governance boards will check to ensure each deliverable is completed to the quality, cost and timescales as agreed in the initiation documents and detailed plans and designs for each workstream.
3. **Sign off Process.** The process of internal review and modification used to sign off all formal documents, ensuring accuracy and quality.
4. **Risk and Issue Management.** This process allows for the communication and escalation of key risks and issues within the project and defines where decisions will be made and how these will be communicated back to the workstream where the risk or issue has arisen.
5. **Change Management.** The purpose of this process is to control and agree any changes to the agreed baseline of the project, whether the change relates to

time, cost or quality. A key interaction in this process is between the design authority board and the project board to check and approve proposed quality changes. Approvals for changes will have to be within the board's delegated authority; otherwise the change will need to be escalated further up the governance structure.

We will adopt project monitoring and reporting procedures as follows:

- Monthly reporting to the Steering Group and to the UK Power Networks' Executive Management Team by the Project Sponsor to provide regular review points and allow full financial and project control;
- The project management team comprising the Project Manager, Workstream leads and Programme Management Officer, will meet fortnightly to monitor the project progress against its plans, project risks and project issues; and
- Workstreams will be managed in accordance with milestone plans supported by detailed project plans and a clearly defined list of deliverables for each workstream. These will be produced in consultation with our project partners to ensure a strong foundation for clarity of scope, objectives, approach; and deliverables.

In addition to the project monitoring and reporting procedures, we will embed risk management within project roles and responsibilities by:

- The Project Steering Group will assess change requests, review the impact on the project business case, and identify and review risks and issues associated with major change requests;
- The Project Board is responsible for the operational management of the project, focused on reviewing progress against plan, and resolving risks and issues. They will also approve change requests within a defined tolerance and prepare change requests for submission to the Steering Group for changes;
- Regular risk reviews undertaken by the Project Manager with results reported to the Project Sponsor and Project Steering Group;
- A Design Authority (a role undertaken on this project Scottish Power Energy Networks) who will review and approve all key project deliverables to ensure they are fit for purpose. Change requests may be initiated by the Design Authority directly or by the Workstreams. Change requests initiated by the Workstreams will be reviewed by the Design Authority prior to submission; and
- Quarterly project partner/supplier reviews will track and discuss progress and risks to project delivery.

We have produced a risk register and risk management process for the project that demonstrates how these roles interact. The risk register details the identified risks and mitigation strategies in Appendix 10.7: Risk Register and Contingency Plan.

6.3 Accuracy of information

UK Power Networks has endeavoured to ensure all of the information included within this full submission is accurate. Information included within the proposal has been gathered from within UK Power Networks, the project partners, suppliers and other subject matter experts. All of this information has been reviewed to confirm and refine understanding, whilst evaluating the validity and integrity of the information.

6.4 Managing Change and Contingencies

Through our strong track-record of delivering successful innovation projects, it is clear that the nature of innovation projects inherently includes the unexpected. It is essential, therefore, that there are effective mechanisms to manage change. The process used is one of the five project control processes described earlier in this section, and is illustrated in Figure 6.2 via an extract from our "Interactive Innovation Procedure (SR 07 005i)".

6.5 How the Project plan would still deliver learning in the event that the take up of low carbon technologies and renewable energy in the Trial area is lower than anticipated in the Full Submission

The Active Response project has been developed to enable DNOs to optimise the use of their existing assets, and enable GBs transition to a low carbon future.

However, the project has been designed to demonstrate the solutions and derive the learning irrespective of the level of uptake of LCTs in the projects selected trial zones. The trial zone site selection will be based on a number of criteria, of which suitable demand profiles will be an important consideration. Whether these profiles are caused by LCTs or not, the project methodology will still deliver important learning that is directly relevant to the management of LCTs in future. The project business case forecasts that even under a low LCT uptake scenario, significant benefits are delivered.

During the development of this proposal, we have identified a number of possible trial areas, with characteristics suitable for demonstrating the principles of the project (3 examples are provided as case studies in Appendix 10.4: Technical Appendix). Hence we have a high level of confidence in the availability of suitable trial zones, for each of the 4 trials.

6.6 The processes 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

As part of the UK Power Networks' internal governance, there are number of processes in place to identify, assess and manage any issues that may affect the project. These processes help to maintain the smooth running of the project, whilst also aiding identification of the most appropriate course of action at any point.

The internal UK Power Networks' Project Governance and Control process, based upon the APMP methodology, has a gate approval process which reviews the project at critical stages throughout its life-cycle. The project must meet the mandatory entry/exit criteria for any particular gate (which takes into account business case, risks, issues, benefits realisation and financial position), which the Project Manager will need to provide evidence. If the project does not meet the mandatory entry/exit criteria, the Project Steering Group has the authority to suspend the project where it is the most appropriate course of action, pending permission from Ofgem that the project can be halted.

The Project Steering Group is also able to suspend the project outside the gate approval process if it is the most appropriate course of action. This could be triggered by an escalation from the Project Manager for a risk or issue that has exceeded the agreed tolerance.

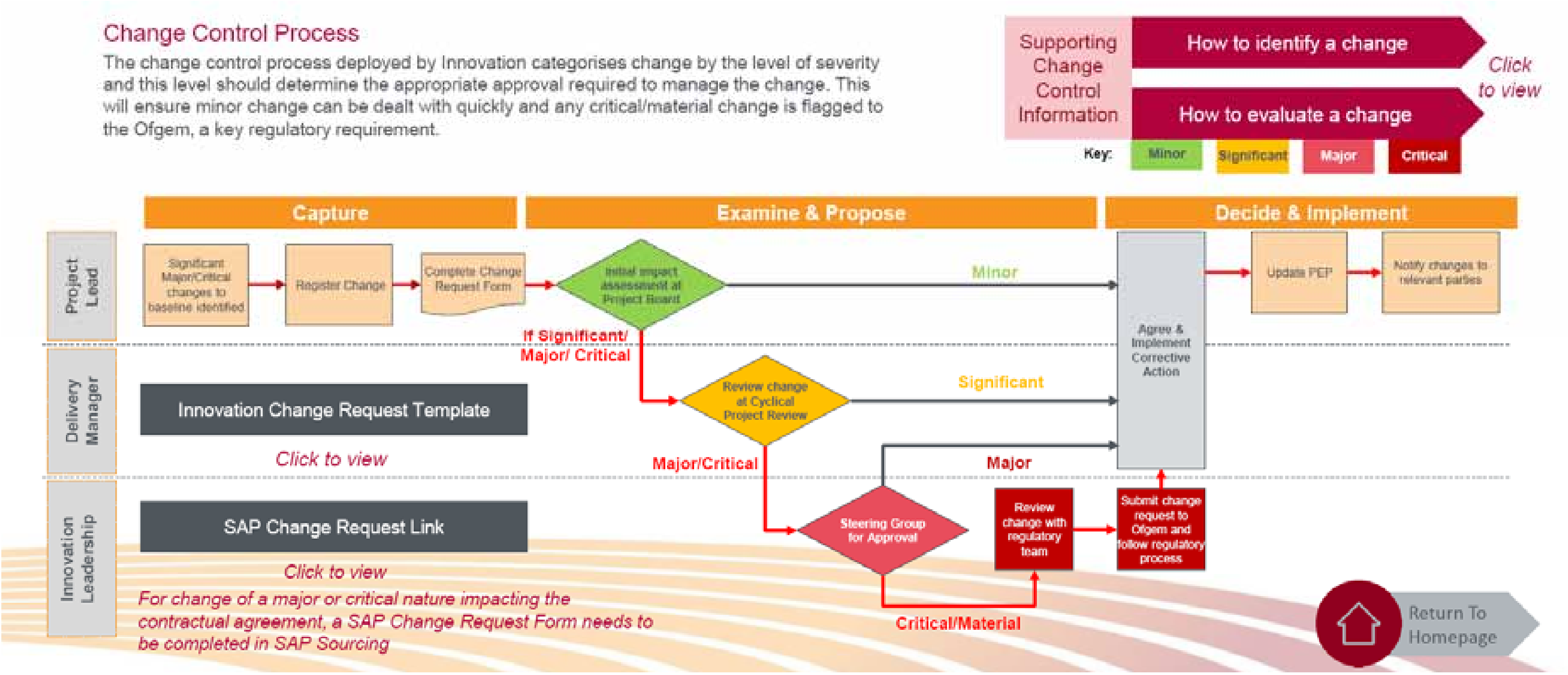

Figure 6.2. UK Power Networks change management process

Section 7: Regulatory issues

IT IS NOT EXPECTED THAT ACTIVE RESPONSE WILL REQUIRE A DEROGATION, LICENCE CONSENT, LICENCE EXEMPTION OR A CHANGE TO THE CURRENT REGULATORY ARRANGEMENTS IN ORDER TO IMPLEMENT THE PROJECT.

Section 8: Customer Impact

ACTIVE RESPONSE WILL BE DELIVERED WITH MINIMAL IMPACT ON CUSTOMERS.

The Active Response project has been developed to provide financial and environmental benefits to customers through the release of network capacity. The focus of this project will be on smarter operation of the existing network assets and we do not envisage that there will be any regular interaction with end customers.

It is not expected to have any direct customer impact for example through works at customer's premises, charging or contractual arrangements. However, it is noted that some of our substations are located within customer premises, and access to these will be arranged in accordance with our normal operational procedures.

As far as is possible during the project we will develop and approve safe methods of working for the installation of the project equipment on the 'live' LV system. Since the detailed product design and final trial locations are to be developed during the project, there remains a possibility that a method statement will require planned outages during the installation of some of the equipment. This will be delivered via normal operational procedures and in such a way as to minimise any disruption to affected customers.

As a result, we note that during the trials there is the potential for a number of short interruptions to some customers, but with the increased level of automation being installed this will yield a reduction in CIs/CMLs in the medium term, and hence will have a limited overall impact. All outages will be recorded in our IIS returns in accordance with requirements.

The installation of the SPB and LV SOPs will have some visual impact. This will be considered during the site selection process so that they are only installed in locations where this impact is acceptable, in common with our normal planning operations.

Section 9: Project Deliverables

The **Active Response** deliverables have been designed to demonstrate clear progress towards the project objectives and disseminate valuable learning.

Based on this approach, we propose the following deliverables and related evidence.

All learning reports will be published on the UK Power Networks' Innovation website, the Smarter Networks portal, and will also be sent directly to key stakeholders.

Prior to issue each deliverable will be peer reviewed by our collaborative partner on the project, Scottish Power Energy Networks. In addition, and in accordance with version 3 of the Network Innovation Competition Governance Documents, we will obtain "Independent Verification" that the project deliverables have been achieved.

Ref	Project Deliverable	Deadline	Evidence	% NIC funding requested
1	High Level Design Specification of Advanced Automation Solution	15 August 2018	Report outlining the requirements and options for the Active Response software solution (WS2)	1
2	Trial Site Selection Criteria and Process Outcome	31 January 2019	Description of possible site selection criteria, derivation of the selected methodology and details of the networks selected for the 4 project trials (WS3)	3
3	Learning from Hardware factory tests	15 August 2019	Details of the key learning from the hardware specification, design and testing process (WS1)	23
4	Learning from Commissioning and Operation of Active Response Software Solution tools	31 January 2020	Report outlining the key learning from the initial off-line trials of the project software tools (WS2)	35
5	Initial Learning from the Installation and Commissioning of Active Response Hardware	31 March 2020	Report outlining the key learning from the initial installation and commissioning of the project hardware (WS1)	23
6	Project technology handover, rollout and adoption into BaU plan	29 January 2021	Implementation Plan for the adoption of the project solutions into Business as Usual (WS4)	3
7	Review of the Active Response Methods applicability in Scottish Power Energy Network licence areas	30 June 2021	A report by Scottish Power Energy Networks detailing the number implementations in their license areas that the project methods provide benefits (WS3)	1

8	Presentation of findings from the project trials	31 August 2021	Analysis and findings from the 4 project trials, including key learning and recommendations (WS3)	7
9	Review of solution applications and project business case	30 November 2021	Comparison of the project technology following the trials against that envisaged at inception, and review of applications and benefits (WS3)	4
[Note this is a common Project Deliverable to be included by all Network Licensees as drafted below]				
N/A	Comply with knowledge transfer requirements of the Governance Document.	17 December 2021	1. Annual Project Progress Reports which comply with the requirements of the Governance Document. 2. Completed Close Down Report which complies with the requirements of the Governance Document. 3. Evidence of attendance and participation in the Annual Conference as described in the Governance Document.	N/A

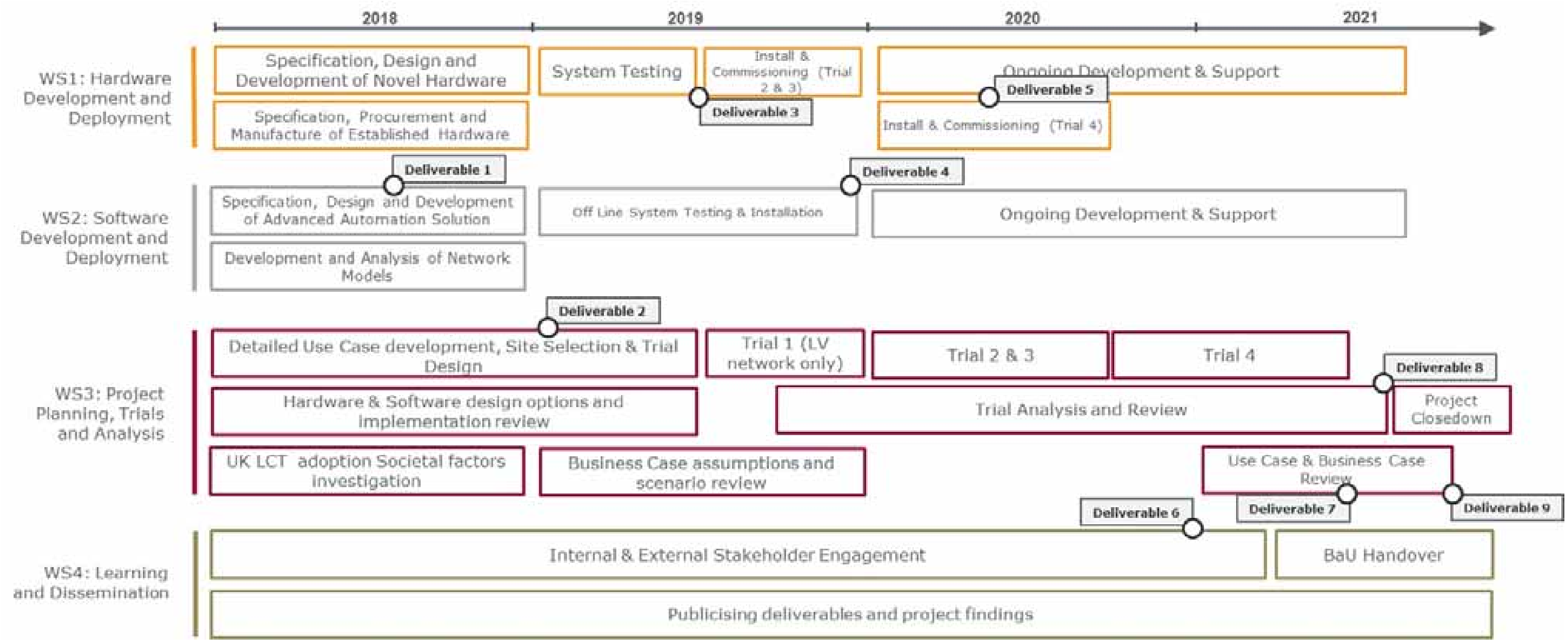

Figure 9.1. Active Response Project Deliverables programme

Section 10: List of Appendices

Appendix 10.1: Benefits Tables

Appendix 10.2: Project Business Case Modelling

Appendix 10.3 Detailed Business Case Assumptions

Appendix 10.4: Technical Appendix

Appendix 10.5: Knowledge Dissemination Roadmap

Appendix 10.6: Project Plan

Appendix 10.7: Risk Register and Contingency Plan

Appendix 10.8: Project Team

Appendix 10.9: Scottish Power Energy Networks Collaborative activities

Appendix 10.10: Letters of Support

Appendix 10.11: Glossary of Terms

ofgem RIIO NIC NETWORK INNOVATION COMPETITION

Appendix 10.1: Benefits Tables

Scale	Method	Method Cost	Base Case Cost	Forecasted Benefit 2030	Forecasted Benefit 2040	Forecasted Benefit 2050	Notes
Post-trial solution *(individual deployment)*	Network Optimise	£314,644	£141,362	£173,281	£173,281	£173,281	The values in this table are influenced by the assumptions described in Appendix 3. There is some uncertainty about these, but the assumptions used are considered conservative. For example, the method costs are not assumed to decrease with time or volume, and the modelling that produces these numbers does not include any benefits beyond deferment of reinforcement (though many such benefits are described in Section 3).
	Primary Connect	£4,116,347	£3,308,598	£807,749	£807,749	£807,749	
Licensee scale	Network Optimise	£314,644	£141,362	£20,127,733	£58,780,637	£69,700,111	The benefits at UKPN scale are calculated using the load growth forecasts and assumptions described in Appendix 10.2. Network Optimise is forecast to be rolled out into 707 sites over UKPN by 2050, and Primary Response will be rolled out in 176 sites. The load forecasts include assumptions of the impact of low carbon technologies on the network load, and the effectiveness of technologies such as Demand Side Response and innovative tariffs, of decreasing load peaks. The numbers in this table reflect our Central Case, which has moderate assumptions. We performed a sensitivity analysis on the benefits model, and even in the extreme low case, the benefits of the methods combined came to £18m by 2050 over UKPN, and in the extreme high case, the benefits came to £205m.
	Primary Connect	£4,116,347	£3,308,598	£39,461,796	£75,012,705	£85,773,697	
	Total benefit from both methods			**£59,589,529**	**£133,793,342**	**£155,473,808**	
GB rollout scale	Network Optimise	£314,644	£141,362	£93,164,317	£273,927,873	£325,068,976	The benefits at GB scale are calculated using the load growth forecasts and assumptions described in Appendix 10.2. Network Optimise is forecast to be rolled out into 3,301 sites over GB by 2050, and Primary Response will be rolled out in 820 sites. The load forecasts include assumptions of the impact of low carbon technologies on the network load, and the effectiveness of technologies such as Demand Side Response and innovative tariffs, of decreasing load peaks. The numbers in this table reflect our Central Case, which has moderate assumptions. We performed a sensitivity analysis on the benefits model, and even in the extreme low case, the benefits of the methods combined came to £86m by 2050 over GB, and in the extreme high case, the benefits came to £940m.
	Primary Connect	£4,116,347	£3,308,598	£177,471,873	£344,938,153	£396,660,215	
	Total benefit from both methods			**£270,636,190**	**£618,866,026**	**£721,729,191**	

Scale	Method	Forecasted Benefit (MVA) 2030	2040	2050	Notes
Post-trial solution *(individual deployment)*	Network Optimise	1.5	1.5	1.5	The values in this table are influenced by the assumptions described in Appendix 3. There is some uncertainty about these, but the assumptions used are considered conservative. For example, the method costs are not assumed to decrease with time or volume, and the modelling that produces these numbers does not include any benefits beyond deferment of reinforcement (though many such benefits are described in Section 3).
	Primary Connect	10	10	10	
Licensee scale	Network Optimise	248	833	1,061	The benefits at UKPN scale are calculated using the load growth forecasts and assumptions described in Appendix 10.2. Network Optimise is forecast to be rolled out into 707 sites over UKPN by 2050, and Primary Response will be rolled out in 176 sites. The load forecasts include assumptions of the impact of low carbon technologies on the network load, and the effectiveness of technologies such as Demand Side Response and innovative tariffs, of decreasing load peaks. The numbers in this table reflect our Central Case, which has moderate assumptions. We performed a sensitivity analysis on the benefits model, and even in the extreme low case, the benefits of the methods combined came to 263MVA by 2050 over UKPN, and in the extreme high case, the benefits came to 3,723MVA. Note that the Primary Connect method releases 10MVA of capacity only for the duration for which the traditional reinforcement is deferred, which means that the magnitude of capacity benefits is directly proportional to the number of active sites. While Network Optimise is assumed to remain in place permanently, most Primary Connect installations are assumed to defer rather than permanently prevent the need for reinforcement. The average deferral assumed for the central case is 13 years, after which the network is assumed to be reinforced, and the method removed, along with the capacity benefit.
	Primary Connect	680	1,170	420	
	Total benefit from both methods	**928**	**2,003**	**1,481**	
GB rollout scale	Network Optimise	1,148	3,884	4,952	The benefits at GB scale are calculated using the load growth forecasts and assumptions described in Appendix 10.2. Network Optimise is forecast to be rolled out into 3,301 sites over GB by 2050, and Primary Response will be rolled out in 820 sites. The load forecasts include assumptions of the impact of low carbon technologies on the network load, and the effectiveness of technologies such as Demand Side Response and innovative tariffs, of decreasing load peaks. The numbers in this table reflect our Central Case, which has moderate assumptions. We performed a sensitivity analysis on the benefits model, and even in the extreme low case, the benefits of the methods combined came to 1,270MVA by 2050 over GB, and in the extreme high case, the benefits came to 17,160MVA. Note that the Primary Connect method releases 10MVA of capacity only for the duration for which the traditional reinforcement is deferred, which means that the magnitude of capacity benefits is directly proportional to the number of active sites. While Network Optimise is assumed to remain in place permanently, most Primary Connect installations are assumed to defer rather than permanently prevent the need for reinforcement. The average deferral assumed for the central case is 13 years, after which the network is assumed to be reinforced, and the method removed, along with the capacity benefit.
	Primary Connect	3,080	5,510	2,010	
	Total benefit from both methods	**4,228**	**9,394**	**6,962**	

Scale	Method	Forecasted Benefit (Carbon, t CO2 Eq.)) 2030	2040	2050	Notes
Post-trial solution *(individual deployment)*	Network Optimise	10.81	10.81	10.81	The values in this table are influenced by the assumptions described in Appendix 3. There is some uncertainty about these, but the assumptions used are considered conservative. For example, the method costs are not assumed to decrease with time or volume, and the modelling that produces these numbers does not include any benefits beyond deferment of reinforcement (though many such benefits are described in Section 3). Note that the Primary Connect method is assumed to only defer the need for reinforcement, and so the carbon cost of the reinforcement will be felt eventually. As there is also a carbon cost to the method itself, it is assumed that each Primary Response method has a direct carbon cost.
	Primary Connect	-3.79	-3.79	-3.79	
Licensee scale	Network Optimise	1,784	6,000	7,643	The benefits at UKPN scale are calculated using the load growth forecasts and assumptions described in Appendix 10.2. Network Optimise is forecast to be rolled out into 707 sites over UKPN by 2050, and Primary Response will be rolled out in 176 sites. The load forecasts include assumptions of the impact of low carbon technologies on the network load, and the effectiveness of technologies such as Demand Side Response and innovative tariffs, of decreasing load peaks. The numbers in this table reflect our Central Case, which has moderate assumptions. We performed a sensitivity analysis on the benefits model, and even in the extreme low case, the benefits of the methods combined came to 5,607tCO_2e by 2050 over UKPN, and in the extreme high case, the benefits came to 243,347tCO_2e.
	Primary Connect	2,500	4,199	1,036	
	Total benefit from both methods	**4,284**	**10,199**	**8,679**	
GB rollout scale	Network Optimise	8,270	27,987	35,684	The benefits at GB scale are calculated using the load growth forecasts and assumptions described in Appendix 10.2. Network Optimise is forecast to be rolled out into 3,301 sites over GB by 2050, and Primary Response will be rolled out in 820 sites. The load forecasts include assumptions of the impact of low carbon technologies on the network load, and the effectiveness of technologies such as Demand Side Response and innovative tariffs, of decreasing load peaks. The numbers in this table reflect our Central Case, which has moderate assumptions. We performed a sensitivity analysis on the benefits model, and even in the extreme low case, the benefits of the methods combined came to 27,797tCO_2e by 2050 over GB, and in the extreme high case, the benefits came to 1,127,718tCO_2e.
	Primary Connect	11,322	19,819	5,043	
	Total benefit from both methods	**19,592**	**47,806**	**40,727**	
Other Environmental Benefits	Capacity Released (MVA)	4,228	9,394	6,962	The key objective of Active Response is to enable the adoption of LCTs and behaviours, which combined has the potential to greatly reduce carbon emissions of the UK. While this is not direct carbon saving due to the adoption of these methods, the benefits delivered through the wider roll out of low carbon technologies will be enabled, in part, by these methods. Using the calculated capacity release by both methods, at GB rollout scale, and using the following assumptions: • 7kW Electric Vehicle Charging; • an average EV produces 74g/km against 130g/km from a typical conventional car in tax band D; and • that average annual distance covered in vehicles is 12,714km per year, and that this figure is the same for both conventional and Electric vehicles; The detailed carbon benefits can be derived if all of that capacity is used to charge EVs.
	Eq. No of EVs	604	1,342	995	
	Indirect Carbon Benefits	**428,663**	**952,426**	**705,853**	
	Total Carbon Benefits	**448,255**	**1,000,232**	**746,580**	

Appendix 10.2: Project Business Case Modelling

1. Summary of Active Response benefits

At UK Power Networks, we are well aware of the challenges of decarbonising Britain. As a result, we have a co-ordinated strategy of innovation projects to address challenges at all levels of the network – from Power Potential (TDI 2.0) at the National Grid interface to FUN-LV which focuses on the distribution network. These link together with the common aim of delivering an electricity network that can keep the lights on at lowest cost to our customers.

Active Response will provide a further suite of smart solutions, which build on previous projects such as our LCNF project "FUN-LV", and those of others such as "FlexNet" and "Smart Street". It will add to the network toolbox and reflects the fact that each solution may not be applicable to all situations.

There are significant benefits to Active Response which will accrue to customers, as the approach is rolled out across the UKPN and GB electricity networks. These are highlighted below.

- **Significant financial, capacity, and carbon benefits associated with deferral / mitigation of network reinforcement** – The business case modelling has focussed on the deferment of reinforcement of the network to quantify financial, capacity, and carbon benefits:
    - **Over £700m** in direct financial benefits up to 2050 across GB
    - **Over 6,000MVA** capacity released up to 2050 across GB
    - **About 40,000 tCO_2e** saved directly by the methods up to 2050 across GB, as well as potential for **700,000 tCO_2eq.** 'indirect' savings through **supporting the connection of low carbon technologies (LCTs)** and the considerable carbon benefits of a green future society.
- **Faster and more cost-effective distributed generation connection offers** – enabled by the release of capacity associated with the Active Response methods. This enables LCTs to be accommodated as required. Frequently these require primary reinforcement, which can take several years to implement due to legal and outage constraints. The Active Response methods are quicker to implement, due to their small physical size, and release capacity from existing assets. This would enable DG to be connected more quickly, and may even prove cost effective as a temporary solution to enable a connection while primary reinforcement is being carried out.
- **Increased network flexibility** – the provision of quickly deployable and flexible methods, and the increased network visibility and control associated with the methods, enables future uncertainty and the impacts of LCTs to be managed more effectively. For example, further capacity could be released by the Network Optimise method if it used to form larger HV feeder groups while keeping the operation and emergency switching requirements to a manageable level.
- **Reduction in customer disruption** – Reduced disruption and logistical benefits associated with network reinforcement projects (including constructions works), and the potential reduction in LV fuse operations associated with overload (enabled by Network Optimise).
- **Network control benefits** – Additional network control benefits using power electronics, such as the ability to manage network Voltage, and Active/Reactive power flows, which can offer customers improved quality of supply.

- **Potential reduction in losses** – the losses on the network may be reduced by either method – Primary Connect may enable the more efficient running of the network by reducing unbalance and associated losses, and Network Optimise will enable the assets to be operated to a lower utilisation allowing them to operate more efficiently. However, some assets may be operated closer to their design ratings, increasing their temperatures and their losses, and there will also be loss implications of the methods themselves. The balance of these loss implications is not known, and will be investigated within the project. The work undertaken by the project will be co-ordinated with our overall losses strategy

2. Business case methodology

In order to build up the business case model for the Active Response methods, the benefits of each of these methods need to be understood in detail. This includes understanding the costs, capacity release, and carbon impacts of implementation, and those of a representative base case. It is also necessary to forecast the need for these solutions in to the future, up to 2050. The approach and assumptions for these aspects are described in the sections below.

Both of the methods being trialled bring a set of financial, capacity, and carbon benefits. The table below describes the Active Response methods and the resulting benefits.

Method		Benefits
Network Optimise	HV/LV network optimisation using advanced software, network monitoring, remote switching, and LV Soft Open Points to share load across the network.	Financial, capacity, and carbon benefits associated with deferral / mitigation of HV reinforcement.
Primary Connect	Soft Power Bridges connecting Primary Substations to move load to where there is spare capacity.	Financial, capacity, and carbon benefits associated with deferral / mitigation of Primary Substation reinforcement.

As shown in the table above, the solutions being developed by the Active Response project provide opportunities to delay or avoid capital expenditure on the network and to ensure that customers' quality of supply is maintained. The benefits from the methods arise from release of capacity at the primary substation and HV network levels, and the consequential deferral of reinforcement. Forecasting the need for the Active Response methods

As mentioned earlier in this proposal the use of Low Carbon Technologies (LCTs), especially the increasing volume of EVs, the utilisation of electricity for heating, and introduction of embedded generation such as solar panels, will over time increase demand on the electricity network and put it under greater stress. The traditional response to this would be costly investments in the system with further lines, cables and plant being added. Several approaches are being developed to maximise the use of existing network capacity, including increased use of demand side response (DSR) to change the time at which electricity is consumed, as well as a range of techniques directly impacting the network. However, more needs to be done to progress improved methodologies and technologies.

For the business case modelling of Active Response, the forecast increase in demand up to 2050 is based on the 2016 demand for each Primary Substation in our three licence areas (which have been obtained from our Long Term Development Statement). It is assumed that load growth from these numbers will be dominated by the installation of LCTs, such as Electric Vehicles and Heat Pumps. This assumption is supported by the National Grid Future Energy Scenarios analysis, which concludes in the executive summary that "Electricity demand has the potential to increase significantly and the shape of demand will also change. This is due initially by electric vehicles and later on by heat demand."

The numbers of these LCTs that will be connected are forecasted for each primary substation (based on publicly available information on their likely rate of growth), and these figures can be used to forecast the load growth at a primary substation level. There are two key assumptions needed to produce this load growth from numbers of connected LCTs:

- **Impact of low carbon technologies on demand (ADMD):** There is continuing uncertainty about the likely demands that LCTs will place on electricity networks, as the use of the technologies will vary significantly from user to user. An After Diversity, Maximum Demand (ADMD) figure can be used to account for the diversity between the times that customers choose to charge their electric vehicles, heat their homes using heat pumps, or generate from PV.
- **Impact of techniques to minimise the impact of low carbon networks on the network (DSR):** It is important to consider the impact of the various incentives and techniques that can be used to encourage energy consumption at times other than at the time of peak, i.e. the extent to which the need to reinforce the system can be deferred or be no longer required by demand side response (DSR) and other techniques. In this model, DSR, DG and other solutions are assumed to reduce the impact of electric vehicle loads.

There is significant uncertainty about the future values of both of these factors. Therefore, the cost benefit analysis has explored in detail the impact of a range of these values in order to understand the range of sensitivity which is present. This analysis is described in the Financial Benefits section below.

The scenario chosen as the central case scenario, from which the numbers in the benefits tables are based, assumes that there is some engagement in Demand Side Response, and there is a moderate demand due to LCTs.

The load growth is forecasted for over 800 substations. The graph below shows the total load growth at 813 Primary substations in the UK Power Networks licence areas as a percentage of the total installed firm capacity in 2016 for the central case scenario.

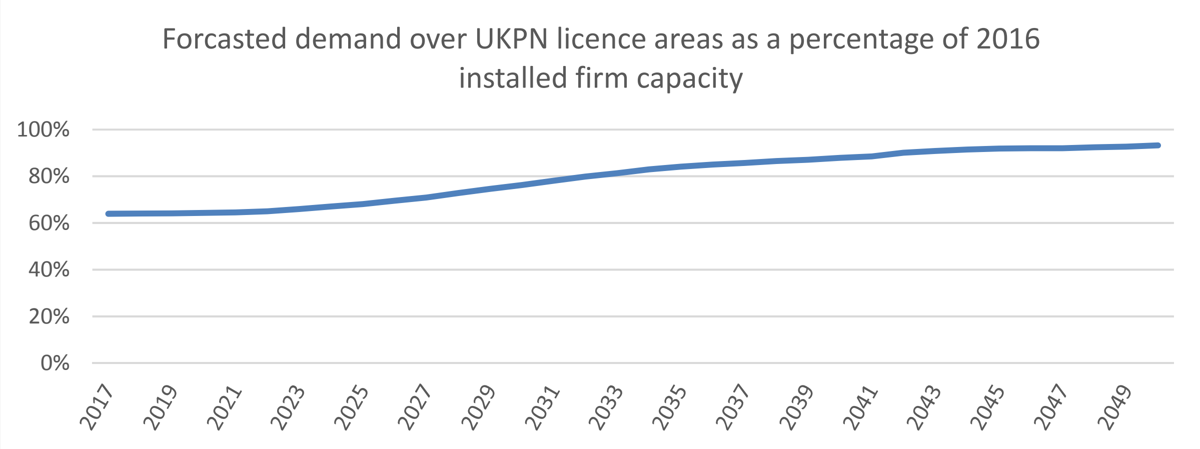

Figure 10.2.1.

For these assumptions, there is enough capacity in the UK Power Networks licence area at primary level to support the demand without the requirement for increasing the total firm capacity in the networks. However, the clustering of LCTs means that the load is not spread evenly throughout the networks, and the necessary capacity will not always be available where it is needed. 398 of the 813 (49 %) of the primary substations in the UKPN area are forecast to have a demand which is greater than their firm capacity up to 2050. The graph below shows the ten Primaries with the highest forecasted load as a percentage of their firm capacity. Please note that there may be other sites for which load growth exceeds firm capacity by a greater amount, but due to a higher firm capacity the relative difference is lower.

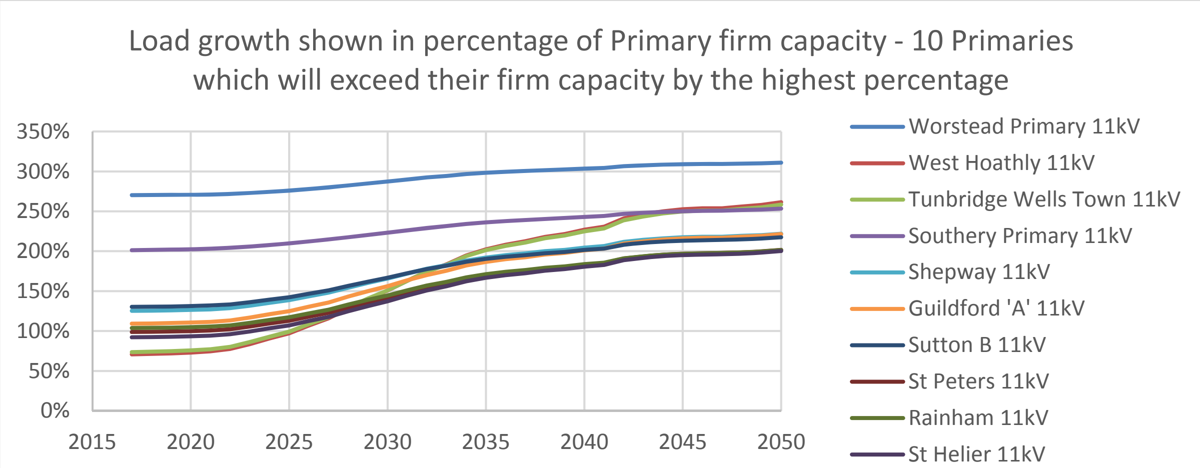

Figure 10.2.2.

In order to translate this forecast into the number of sites where the Active Response methods are needed, the criteria for each method must be understood. These are summarised in the table below:

Method	BAU trigger points	Active Response Business Case model trigger points.
Network Optimise	Network Optimise is implemented on HV networks when an HV	The load growth forecasts available for the Active Response business case modelling disaggregates data down to primary substation level, and therefore there

	feeder is nearing its capacity, and when there are compatible adjacent feeders with which load can be shared. The method stays in place permanently, even when load growth exceeds the capacity releasing capability of the method and more extensive reinforcement is needed. The methods may be triggered on more than one feeder group fed by the same primary substation.	is no visibility of the load growth of individual HV feeders. Therefore, proxy assumptions were made. Two trigger points were used (so the solution is triggered if EITHER one of these apply): • Load growth from the 2016 peak is significant (greater than 20% of the firm capacity for EPN and SPN, and 10% for LPN, to account for the larger firm capacity and density of feeders in LPN's area), • The primary substation load is greater than the firm capacity. It is assumed that the other criteria (such as the need for compatible adjacent substations) are met in about 50% of cases, reducing the roll-out figures. Installations in other feeder groups fed by the same primary are assumed to take place when the primary substation load grows another 3MVA over the above figures, based on a proportion of that growth clustering on individual feeders. This is an average assumption, and, in practice, some cases will be higher and others will be lower. The total number of Network Optimise methods that can be installed for each Primary Substation is 4.
Primary Connect	Primary connect is installed when primary substations are nearing their rating, and where there are compatible adjacent substations to share load with (including criteria such as compatible load profiles, and suitable connections between them). The method stays in place until the loads at the connected substations are such that additional capacity is required beyond that which can be released by the solution.	The load forecast for primary substations is used. In the model, Primary response is triggered if all of the following criteria are met: • The maximum demand exceeds the substation capacity by up to 5 MW; • The method would defer the need to reinforce by more than 5 years before further reinforcement is needed; and • There is available spare capacity and a complementary profile at a nearby primary substation, and suitable locations to place the equipment. It has been assumed that up to 50% of the cases will not meet these criteria, which is considered to be a conservative estimate. The assets associated with Primary Connect have a capacity of 5MW. Therefore, once the load growth of a substation supported by Primary Connect exceeds 5MW over the substation capacity, then the substation will need to be reinforced and the method removed.

These assumptions enable us to establish a forecast of need for each of the two methods over UKPN's networks. The results from our three licence areas are then scaled up to account for all 14 licence areas in GB. This is achieved by simply finding the average need for a licence area, and multiplying that by the number of GB licence areas. UK Power Networks span densely populated urban areas to sparely populated rural areas and as such can be considered representative of GB. However, it is assumed that adoption is slower for other licensees than UKPN, as the experience is built to implement the solutions.

The cumulative roll out of Active Response methods is shown in the graph below:

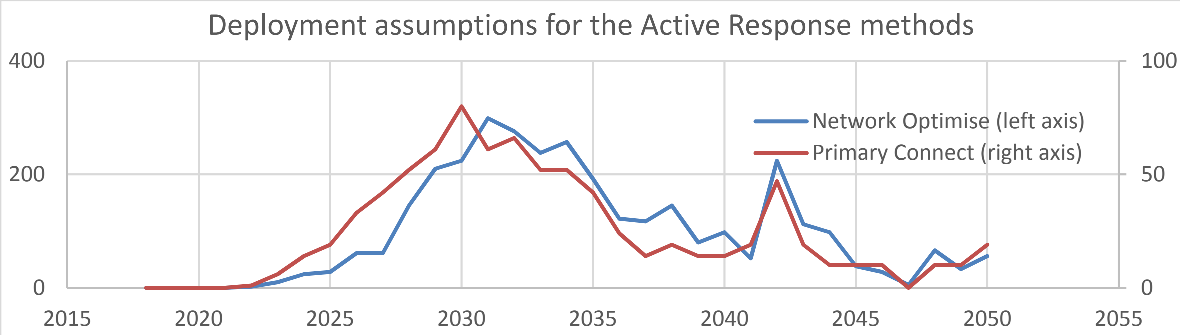

Figure 10.2.3.

The graph shows that the forecasted need for the Network Optimise method is higher than the Primary Connect method. This is because the Network Optimise method will be applied at the HV network and associated LV network level, of which there are far more cases than primary substations. Additionally, the impact of clustering of LCTs is likely to be greater at this network level, while the primary substation can experience more demand and DG diversity, and the impact of individual clusters is not as significant due to aggregation.

Network Optimise

The Network Optimise approach involves the utilisation of advanced software, LV SOPs and remote terminal units (which are used to facilitate remotely reconfiguring equipment and for monitoring the network) to optimise the network and to increase its capacity. For the business case, neither the costs of the LV SOP deployment or its benefits are considered as these have been taken account of in the FUN-LV project benefits.

The benefits of Network Optimise are based on the ability to share load across the network, therefore releasing capacity of stranded assets and deferring or mitigating the need to reinforce overloaded assets. Network Optimise achieves this by monitoring and actively reconfiguring the network by moving the open points in the HV feeder group. This allows the loads to be actively distributed across the feeder group ensuring that no one HV feeder is over the rating of the feeder.

The model includes the following assumptions for Network Optimise modelling, noting that these assumptions show a generic case for the delivery of the method and the corresponding base cases, and in practice, each individual situation will be different:

- **Base Case Costs:** A range of representative case studies have been identified for the traditional reinforcement solutions that are representative of those that would be used in these scenarios. They range from approximately £10k (in particularly simple cases), to over £800k (in rare, complex cases). The average figure calculated from these is about **£315k**.
- **Method case Costs:** This cost includes the required monitoring and automation equipment (for which standard budget figures are used), and a representative cost for a network operational model. The cost is estimated to be around **£100k**. It is assumed that there will be ongoing maintenance costs for the optimisation software, network models, and the monitoring and control equipment. Within the model, these ongoing costs are assumed to be 2% of the capital costs of the method every year, which comes to about **£2k per year for each installation**.

- **Method deferment:** It is assumed that once a Network Optimise scheme is in place, it will remain in place permanently.
- **Capacity release:** There are two mechanisms by which the Network Optimise solution releases capacity. The first mechanism is to join feeder groups together. For example, if we join two 2-feeder groups together to a 4-feeder group, each cable can carry more load such that the planning standard of n-1 is satisfied. The second mechanism is the capacity released from moving load by changing the position of the NOP in the 11kV network. These produce a combined average capacity release of **1.5MVA per active application of the method.** This is based on initial simulations of the Network Optimise method, where on average, the load of 3 transformers can be shared between feeders.
- **Direct Carbon Benefits:** The direct carbon benefits are calculated based on comparing the carbon cost of releasing the capacity described above through the Network Optimise method when compared with the base case. The base case describes the capacity being released through the installation of an additional feeder, and the carbon cost is estimated considering the carbon cost of cable materials as well as the installation, as 3 tCO_2 for a 1KM aluminium cable, including the construction works (in tCO2eq.). The carbon cost of the secondary equipment (protection, automation etc.) for the feeder is assumed to be equal to that of the method case. Therefore, the carbon benefit of the Network Optimise method is estimated to be just over **10 tCO_2eq. for each implementation of the method**.

The quantitative benefits resulting from the application of Network Optimise for 2030, 2040 and 2050 for both the UKPN and the networks are shown in Sections 3, 4, and 5 of this appendix below.

Primary Connect

The Primary Connect approach involves the installation of a SPB between primary substations. This enables load to be shared between these primary substations, releasing capacity of stranded assets and deferring or mitigating the need to reinforce overloaded assets.

The model includes the following assumptions for Primary Connect modelling, noting that these assumptions show a generic case for the delivery of the method and the corresponding base cases, and in practice, each individual situation will be different:

- **Base Case Costs:** The base case for Primary Connect is the reinforcement of primary substation, e.g. replacement of a primary transformer and switchgear, and associated civil works. Alternative solutions such as DSR have been considered as part of the load growth forecast. In order to find a representative cost for these works, more than 70 representative case studies have been identified and analysed. The costs of these case studies range from approximately £500k (in particularly simple cases), to over £15m (in rare, complex cases). The average figure calculated from these is approximately **£4.1 million.**
- **Method case Costs:** This cost includes the equipment and installation costs of the Primary Connect equipment. The cost of each SPB device in the project is estimated at £295k. While it is accepted that this cost is likely to reduce in time and with volume production, this factor is not taken into account in the modelling, producing a conservative estimate. The installation is given a conservative estimate of £100k. Therefore, the method cost is assumed to be

about **£396k**. It is assumed that the SPB equipment has a lifetime of 10 years, after which it will need replacing unless the rating has been exceeded and it is removed anyway. It is likely that upgrades and maintenance will be possible to extend this lifetime, and so 10 years is seen as a conservative estimate.

- **Method deferment:** The benefit of the method is based on the deferment of traditional reinforcement, and so the eventual costs of this reinforcement must be included in the model. The number of years deferred depends on the assumptions made in the model, as it is driven by the rate of load growth, and therefore the amount of time before the capacity of the solution is reached. For the central case scenario used to produce the benefits table, the deferment is **13 years.** In practice, it is likely to be more beneficial to install an additional SPB to operate in parallel to the existing project, rather than reinforce the primary substation, and this would result in a higher estimated value of the project, but this aspect is not included in the model.
- **Capacity release:** The rating of the SPBs used in the Primary Connect method is **5MVA in either direction.** This gives a **maximum released capacity of 10MVA** for each active application of the method. Note that as the method is removed when a reinforcement is triggered by additional load growth beyond the capacity of the SPB, and these applications are therefore removed from the capacity release model.
- **Direct carbon benefits:** In most cases, the Primary Connect method will defer reinforcement for several years, rather than mitigate the need permanently. Therefore, the carbon associated with that reinforcement will be felt eventually, and cannot be thought of as being 'saved'. There is also an additional carbon cost of the SPB equipment for each installation.
    - Carbon cost of traditional reinforcement: The carbon cost of reinforcement is estimated based on the carbon cost of transformer materials (steel production at 2.3tCO_2 /t and oil at 0.7tCO_2 /t, and a transformer with a dry weight of 15t and oil weight of 8t, totalling 40.3 tCO_2) well as the transportation (based on 200 miles at 10mpg, totalling 0.25 tCO_2e), and is estimated as **40.5tCO_2eq**.
    - Carbon cost of the Primary Connect method: There is also a carbon cost of the Primary Connect itself, which will be incurred in all implementations of the method. This has been estimated based on the carbon cost of material (with approximately 5kg of silicon carbide at 3.2tCO_2/t, 24kg of copper at 2gCO_2/t, 1t of steel at 2.3tCO_2/t and 0.75t of aluminium at 1.5tCO_2/t), and transport (based on 200 miles at 10mpg, totalling 0.25 tCO_2eq.), as about **3.8tCO_2eq**.

The quantitative benefits resulting from the application of Primary Connect for 2030, 2040 and 2050 for both the UKPN and the networks are shown in Sections 3, 4 and 5 below.

3. Financial Benefits

Active Response Financial Benefits

The graph below shows the forecasted financial benefits of Active Response up to 2050 over all of GB.

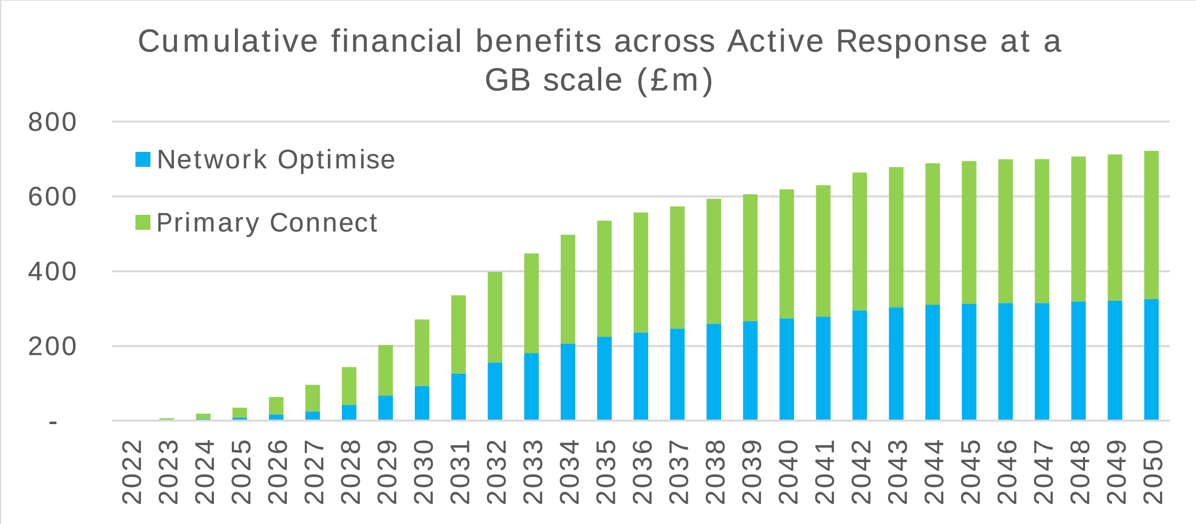

Figure 10.2.4.

This is based on the central case, which assumes some engagement in DSR (where 25% of all EV charging ADMD is moved away from the peak), and a moderate demand due to LCTs (ADMD of EVs is 2kW, and ADMD of HPs is 0.9kW). These are seen as credible moderate assumptions, which are explored further in the sensitivity analysis section below.

The graph illustrates that there is a considerable financial benefit of the Active Response methods up to 2050. The tables below show the financial benefits and the cumulative installations for each method for the central case for 2030, 2040, and 2050:

Single Deployment			
Network Optimise (£k)	173		
Primary Connect (£k)	808		
Licensee Scale	**2030**	**2040**	**2050**
Network Optimise (£k) **(cumulative installations)**	20,128 (165 installations)	58,781 (555 installations)	69,700 (707 installations)
Primary Connect (£k) **(cumulative installations)**	39,462 (68 installations)	75,013 (144 installations)	85,774 (176 installations)
GB Scale	**2030**	**2040**	**2050**
Network Optimise (£k) **(cumulative installations)**	93,164 (765 installations)	273,928 (2589 installations)	325,069 (3301 installations)
Primary Connect (£k) **(cumulative installations)**	177,472 (308 installations)	344,938 (666 installations)	396,660 (820 installations)
All figures are in 2018 value, using a discount factor of 3.5% for the first 30 years and 3% thereafter, in accordance with the submission guidance documents released on 07/06/2017			

The model ignores the impact that the methods would have on losses, as there is considerable uncertainty as to what these impacts may be. The methods may decrease losses through more efficient running on the networks, but there are loss implications of the methods, particularly conversion losses in the SPB of Primary Connect. The balance of these loss implications is not known, and will be investigated within the project.

The model also only focuses on the benefits of Network Optimise associated with the HV network. The LV element of Network Optimise includes the use of LV Soft Open Points as developed within the FUN-LV project. The LV deferred reinforcement benefits determined by the FUN LV project are included there and are therefore not included in Active Response to avoid double counting of these benefits.

Sensitivity Analysis

Sensitivity analysis has been undertaken to understand the impact that varying assumptions have on the results of the business case.

DSR

The impact of varying the DSR assumptions on the business case of each method is shown in the graphs below. In each, the same, moderate demand assumptions (ADMD of EVs is 2kW, and ADMD of HPs is 0.9kW) are made, and only the DSR assumption is varied.

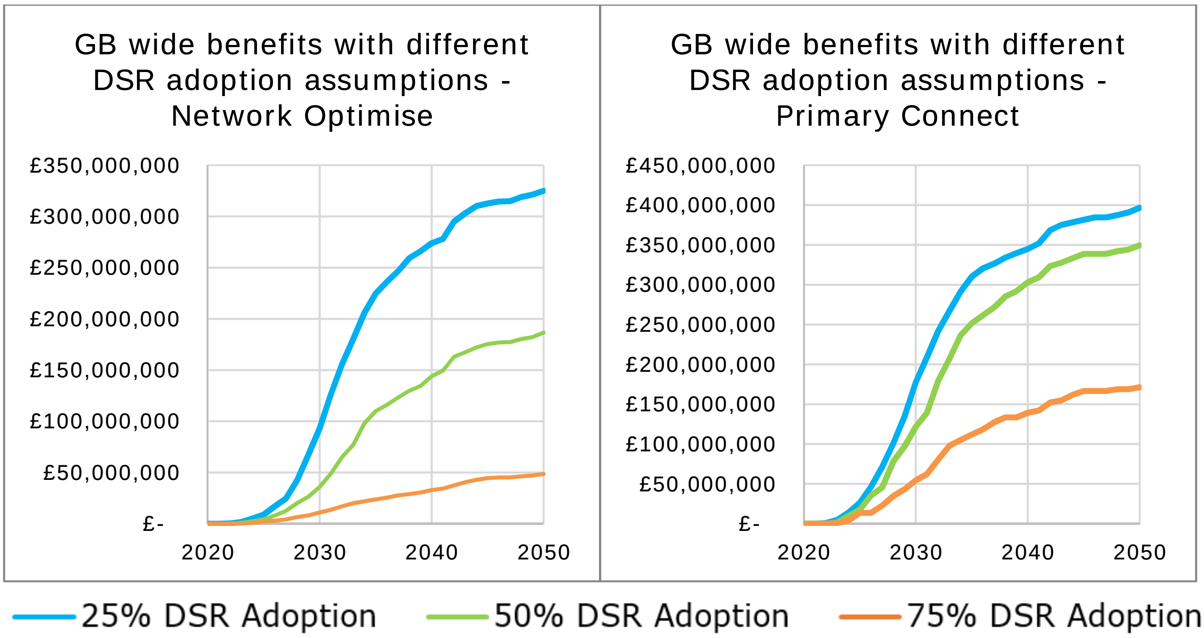

Figure 10.2.5.

The highest uptake of DSR adoption which has been investigated in this sensitivity analysis is 75% (which assumes that 75% of all EV charging load is moved away from the peak). This is considered to be towards the top end of the plausible assumptions, and it is considered highly unlikely that DSR will be 100% effective at moving demand from the peak, and so including higher DSR adoption would not be useful. It is also recognised at DSR adoption as high as 75%, it is probable that the peak has effectively been moved the load peak only to form another peak at another time. This has not been accounted for in the model for Active Response, and makes these results conservative.

The lowest uptake of DSR adoption included was 25%. It is also considered unlikely that DSR or similar tariff or incentive mechanisms will have no future impact, and so 25% has been used to understand the impact of a low level of DSR adoption.

As shown in the graphs above, the benefit of the Network Optimise method varies significantly with DSR adoption. The value is directly linked to the roll out of the solution, which is driven by the forecasted need over GB networks. Where DSR is more successful in moving load away from peak times, there are fewer instances of the network reaching rated capacity, and therefore less need for the solution. However, even with the highest DSR impact figure used in this analysis, 75%, the Network Optimise method has an NPV value of just under £49m by 2050, having been deployed at 538 sites across GB.

The benefit of Primary Connect method is also impacted by the DSR assumptions, but to a lesser extent. Again, the forecasted value of the method is linked to the roll out over GB networks, and this is driven by the forecasted load growth in primary substations. Where the DSR adoption is very high, this load growth is lower, and fewer substations become overloaded. Conversely, where DSR is much lower, the load growth is much higher, resulting in more primary substations being overloaded. However, the increase in value between the 50% DSR case and the 25% DSR case is reduced because in the 25% DSR case, the load growth is such that the capacity of the installed Primary Connect assets has been exceeded in a higher proportion of cases, and therefore the number of suitable sites becomes limited.

Demand Growth

The impact of varying the demand growth assumptions, and the effects of DG on apparent demand growth, on the business case of each method is shown in the graphs below. Here, a 50% DSR adoption assumption is used in all three cases, and only the demand assumption is varied.

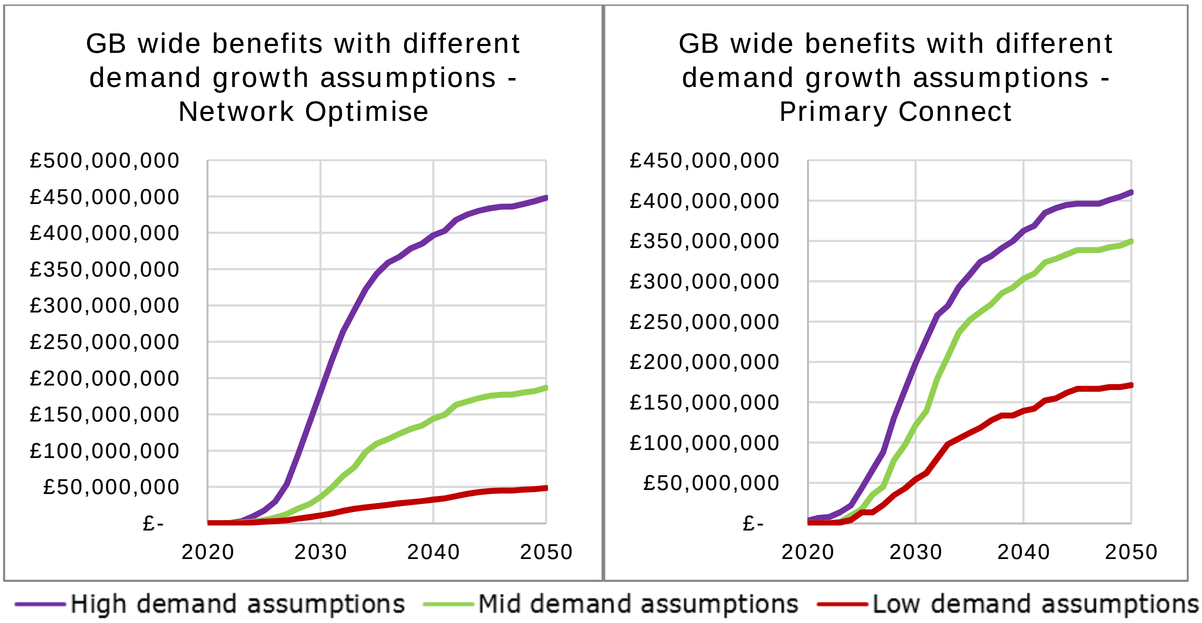

Figure 10.2.6.

The demand growth in the forecast is driven by an After Diversity Maximum Demand (ADMD) assumption for both electric vehicles and heat pumps. This figure represents the average maximum demand that the low carbon technologies will have on the system, taking into account the range of use patterns that the technologies will have. An ADMD figure can be used to take into account the diversity between the times that customers choose to charge their electric vehicles or heat their homes using heat pumps.

The ADMD range for electric vehicles and heat pumps that has been investigated is:

- **EV ADMD of 1kW** – taken from Low Carbon London and My Electric Avenue (a low carbon networks project led by Scottish and Southern Electricity Networks and EA Technology) as the low EV option.
- **EV ADMD of 2kW** – taken as a central assumption between My Electric Avenue and Customer Led Network Revolution.
- **EV ADMD of 4kW** – taken from the Customer Led Network Revolution (a low carbon networks project led by Northern Powergrid) and extrapolated from Low Carbon London as the high EV option.
- **HP ADMD of 0.9kW** – taken from Customer Network Led Revolution as the low HP case.
- **HP ADMD of 1.7kW** – taken from Northern Powergrid's policy for 100 customers.

In the graphs, the three scenarios are:

- **High demand Assumption** – EV ADMD of 4kW and HP ADMD of 1.7kW.
- **Mid demand assumptions** – EV ADMD of 2kW and HP ADMD of 0.9kW.
- **Low demand assumptions** – EV ADMD of 1kW and HP ADMD of 0.9kW.

As with the change in DSR assumptions, the benefit of the Network Optimise method varies significantly with demand growth assumptions, as a more dramatic load growth triggers more solutions to be used, and therefore more value to be drawn from its development. In this case, the range is even wider, with the high demand assumption resulting of an NPV of this solution of over £448m by 2050 (compared to approximately £320m for the DSR adoption of 25%). Again, even with the most extreme assumptions used in this analysis, (EV ADMD of 1kW and HP ADMD of 0.9kW), the Network Optimise method has an NPV of approximately £49m by 2050.

The impact of the demand growth assumptions on the value of the Primary Connect method is not as significant, with the 2050 NPV ranging from approximately £170m to £410m. A similar feature can be seen in this graph to the DSR analysis, where the high demand assumptions result in such a significant load growth that the rating of the solution in exceeded more quickly, and the overall number of active Primary Connect solutions is limited to only slightly above the levels shown for mid demand growth.

Boundary Analysis

The most extreme scenarios analysed as part of this sensitivity analysis were the extreme high case (the very high demand and low DSR adoption assumptions), and the extreme low case (the low demand and very high DSR adoption assumptions). The impact of these assumptions on the Active Response business case (both of the methods combined) is shown in the graph below.

The impact of these assumptions on the results of the business case is understandably significant. However, even in the most pessimistic case, the project benefits are approximately £85m, making back the customer funding and producing some additional benefit. In the highest benefit case, the project makes more than £946m.

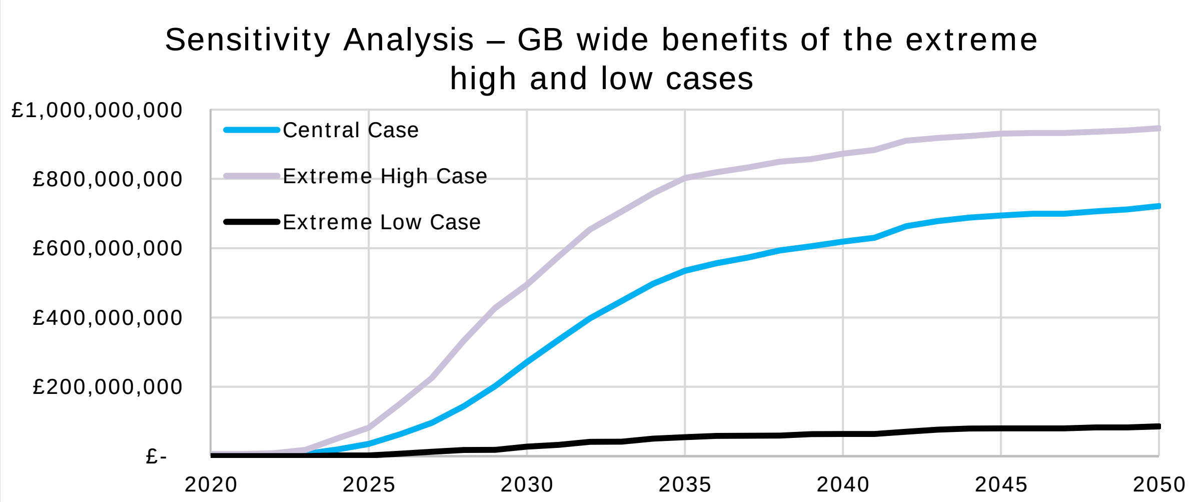

Figure 10.2.7

Breakeven Analysis

A breakeven analysis is based on the cash analysis of the project and ongoing benefits. This is based on the central case, and the rolled out over a GB scale as described above. The project breaks even in **2023** and recovers more cash that then customers' initial investment in 2024.

The cash breakeven analysis has a particularly fast breakeven as this include the cash flow benefits of avoiding reinforcement, even where this is only deferred a certain number of years. The long-term value of the project beyond the short-term payback can be seen in the graphs above. Each of the two methods successfully bring benefit on a per-project basis.

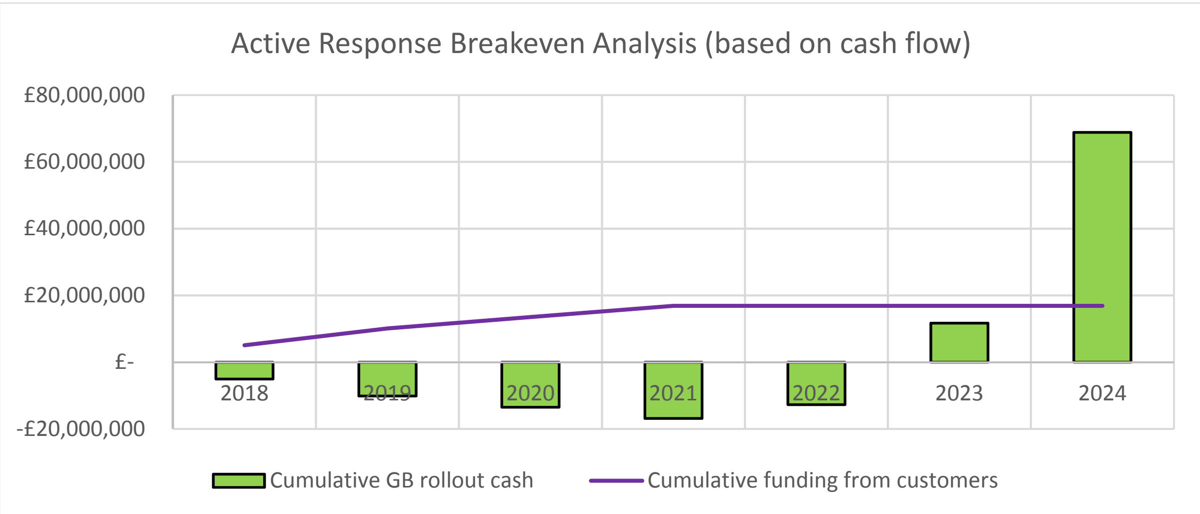

Figure 10.2.8

On an NPV basis, each of the two methods bring financial benefits per installation. To the extent that either one would make back the total customer investment with relatively few installations, when compared to the forecasted roll out (12 installations of Network Optimise, or 3 installations of Primary Connect would deliver the project investment costs of £18m, assuming a steady pace of installation between 2022 and 2050).

4. Capacity Benefits

The core benefit of the Active Response solutions is the release of additional network capacity, quickly and where it is needed, and at a lower cost and carbon impact to traditional methods. This capacity will enable the connection of LCTs onto the network more quickly and cheaply by deferring or mitigating the need for costly reinforcement without negatively impacting its robustness. It is difficult to accurately predict when or where LCTs will connect, so quick response tools such as Active Response are beneficial.

The capacity release is dependent on the number of installations of each method, and is therefore driven by the demand forecast of need for each of the methods. The graph and table below shows the capacity released in the central case, as described above.

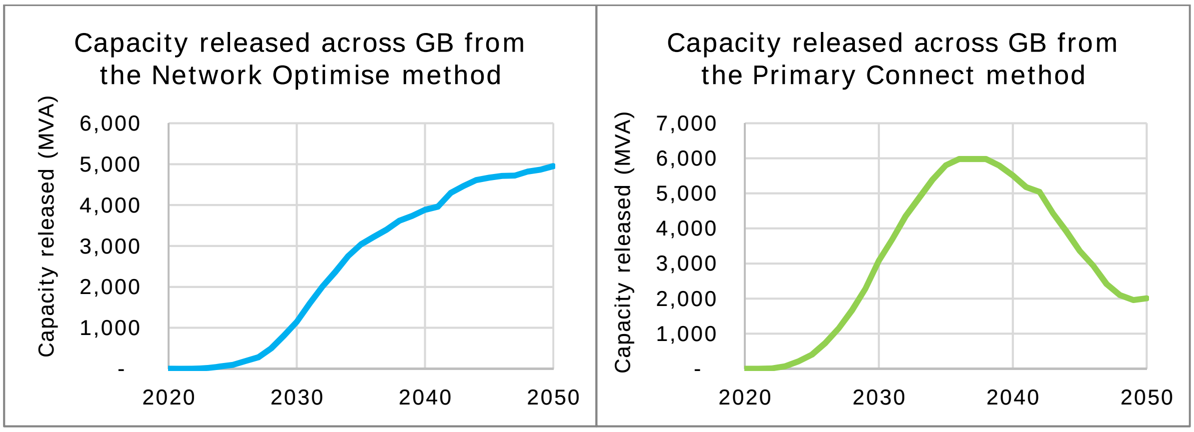

Figure 10.2.9

Single Deployment			
Network Optimise (MVA)	1.5		
Primary Connect (MVA)	10		
Licensee Scale	**2030**	**2040**	**2050**
Network Optimise (MVA)	248	833	1,061
Primary Connect (MVA)	680	1,170	420
GB Scale	**2030**	**2040**	**2050**
Network Optimise (MVA)	1,148	3,884	4,952
Primary Connect (MVA)	3,080	5,510	2,010

As described in the sections above, the Network Optimise methods is capable of releasing an average of 1.5MVA of capacity for each application, and when the method has been installed it remains in place permanently. Therefore, the capacity released is also permanent.

However, the Primary Connect method releases 5MVA of capacity only for the duration for which the traditional reinforcement is deferred. While there will be cases that the reinforcement is permanently deferred, and therefore the capacity release will be ongoing, most cases show a time limited deferral. The average deferral assumed for the central case is 13 years. For this reason, the collective capacity release for this method is less dramatic than that of Network Optimise.

As the roll-out of Primary Connect in the central case shows a steep increase in installations between 2025 and 2030, with a plateau thereafter, the shape of the capacity released for Primary Connect also increases steeply, but then decreases as Primary Connect methods are replaced with reinforcement, before settling to a plateau.

5. Environmental Benefits: Carbon Emission reductions

The environmental impact of the Active Response solution can be considered in two ways:

- **Direct Environmental Benefits**, which compares the carbon impact of the Base Case and the Active Response Case; and
- **Indirect Environmental Benefits**, which considers the wider impact of the solution.

Direct Benefits

The direct carbon benefits of Active Response are driven by the creation of capacity for a lower carbon cost than the base case. The assumptions made within the carbon savings model, including the carbon cost of each method and its associated base case are described in the sections above.

The direct carbon benefit is dependent on the number of installations of each method, and is therefore driven by the demand forecast of need for each of the methods. The graph and table below shows the carbon benefit in the central case.

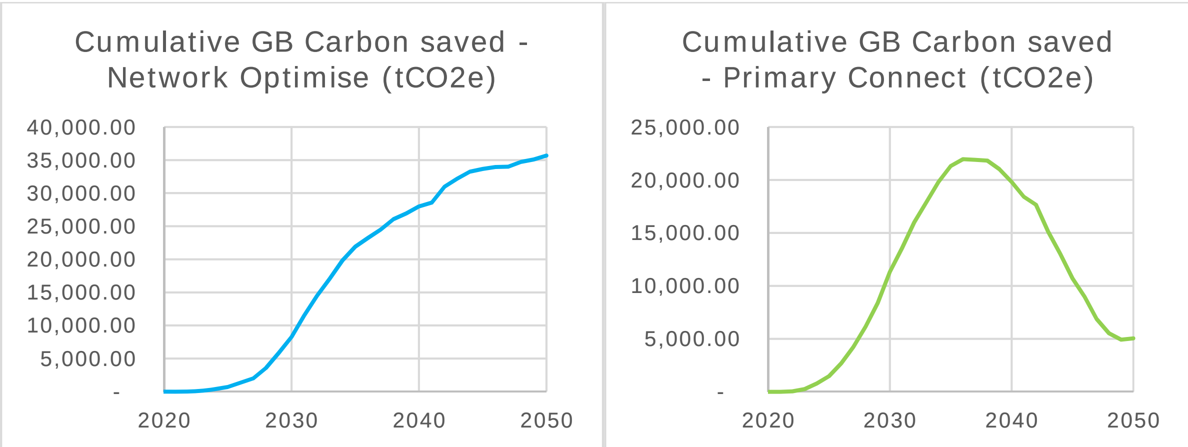

Figure 10.2.10

Single Deployment			
Network Optimise (tCO_2 eq.)	10.81		
Primary Connect (tCO_2 eq.)	-3.79		
Licensee Scale (tCO_2 eq.)	**2030**	**2040**	**2050**
Network Optimise (tCO_2 eq.)	1,784	6,000	7,643
Primary Connect (tCO_2 eq.)	2,500	4,199	1,036
GB Scale	**2030**	**2040**	**2050**
Network Optimise (tCO_2 eq.)	8,270	27,987	35,684
Primary Connect (tCO_2 eq.)	11,322	19,819	5,043

The carbon benefit for Network Optimise grows over time with the roll out of the solution, providing significant carbon benefit over time.

The carbon benefit of the Primary Connect solution is more complex, as there is an initial carbon benefit where the need for reinforcement is deferred, and only the carbon cost of the method is felt. This explains the initial steep increase in carbon benefits. However, as the deferral of reinforcement is only temporary, the carbon cost of that reinforcement will be felt eventually, and therefore the carbon benefits start to decrease. As the model assumes that all Primary Connect installations only defer the reinforcement, then there is a whole-life direct carbon cost for the installations. This is a conservative view as it is probable that a proportion of the installations will result in a permanent mitigation of the need for reinforcement, which would result in a carbon benefit.

Indirect Benefits

The modelling of direct carbon benefits is only part of the carbon picture. A key aim of the Active Response methods is the fast and flexible enablement of low carbon load growth, which itself has the potential of delivering significant carbon benefits across society.

The key objective of Active Response is to enable the adoption of LCTs and behaviours, which combined has the potential to greatly reduce carbon emissions of the UK.

The future energy scenarios (FES) identified by National Grid have developed a view on the carbon benefits of the adoption of such technologies, based on the four energy scenarios which represent the range of activity and attitudes in the future. The graph below shows the total carbon emissions for the UK in each of the four scenarios (Note that these figures reflect the 2016 scenarios as the 2017 scenarios do not provide this information).

Active Response supports and enables these carbon savings, by enabling the adoption of LCTs and behaviours. Without these or similar tools, the uptake of such technologies may be restricted, for example by restricting their affordable connection.

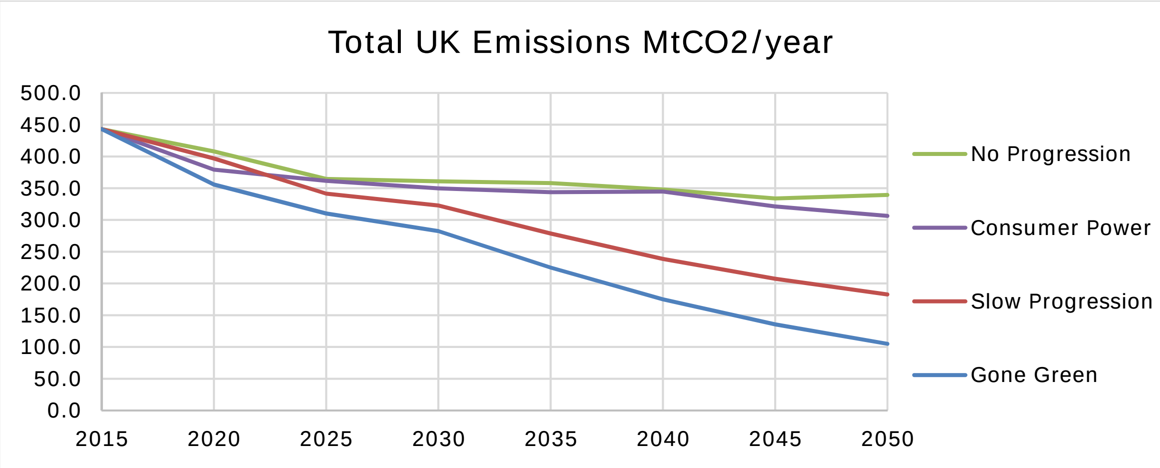

Figure 10.2.11 - Total UK Emissions forecasted up to 2050, from the Future Energy Scenarios (2016).

Based on the capacity released by the Active Response methods, and using the following assumptions, the following carbon benefits can be derived if all of that capacity is used to charge Electric Vehicles (EVs):

- 7kW Electric Vehicle Charging,

- an average EV produces 74g/km[16] against 130g/km from a typical conventional car in tax band D[17], and
- that average annual distance covered in vehicles is 12,714km per year[18], and that this figure is the same for both conventional and Electric vehicles:

Year	Capacity released (MVA)	Equivalent Number of Electric Vehicles	Potential Carbon Benefits ($tCO_2eq.$)
2030	4,228	604,000	428,663
2040	9,394	1,342,000	952,426
2050	6,962	994,571	705,853

[16] Based on a 0.211kWh/km average EV energy usage (http://shrinkthatfootprint.com/wp-content/uploads/2013/02/Shades-of-Green-Full-Report.pdf) and a 2017 UK Grid Emission Factor of 351.56 gCO2eq./kWh (https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2017).
[17] Note that EV carbon emissions per km will reduce with time assuming the UK generation mix continues to decarbonise, so the carbon benefits from EVs may be greater than stated here.
[18] http://www.bbc.co.uk/news/uk-england-28546589

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Appendix 10.3 Detailed Business Case Assumptions

The detailed business case assumptions enable the business case findings to be replicated by others. For a full explanation of methods, context and reasoning, see Appendix 10.2: Project Business Case Modelling.

Network Optimise Cost-Benefit Modelling Assumptions

Assumption	Value	Notes
Base Case Cost	£314,644	Taken from the average of case study projects using traditional methods to reinforce HV networks, e.g. adding a feeder to support a group.
Method Case Capital Cost	£102,169	Estimated from the cost of hardware (RTUs, RMU upgrades) and software (network models)
Method case operational cost	£2,043	Estimated as 2% of the capital cost per year, maintain hardware and software components.
Single implementation NPV	£173,281	Based on a 32-year project cashflow discounted back to year 0 of the project. Discount factor is 3.5% for 30 years and 3% thereafter.
Capacity Release	1.5MVA	Capacity release associated with sharing load between assets
Carbon Benefit	10.81 tCO_2eq.	Based on avoided need for installation of 1km of HV cable. The carbon cost of the associated equipment is assumed to be equal to that of the method case.

For NPV of roll out (UKPN and GB scale), the single implementation NPV is assumed to be accrued at the project year. This prevents over-estimation of value due to the early saving in cost which will be incurred later. The costs are then discounted back to 2018 prices. Discount factor is 3.5% for 30 years and 3% thereafter. The modelling ends at 2050. The roll out installation forecast volume is shown in the table below.

Year	UKPN roll out	GB roll out	Year	UKPN roll out	GB roll out	Year	UKPN roll out	GB roll out
2022	1	2	**2032**	59	276	**2042**	48	224
2023	3	10	**2033**	51	238	**2043**	24	112
2024	5	24	**2034**	55	257	**2044**	21	98
2025	6	28	**2035**	41	192	**2045**	8	38
2026	13	61	**2036**	26	122	**2046**	6	28
2027	13	61	**2037**	25	117	**2047**	1	5
2028	31	145	**2038**	31	145	**2048**	14	66
2029	45	210	**2039**	17	80	**2049**	7	33
2030	48	224	**2040**	21	98	**2050**	12	56
2031	64	299	**2041**	11	52			

Assumption	Value	Notes
Base Case Cost	£4,116,347	Taken from the average of case study projects
Method Case Capital Cost	£395,916	Taken from the cost of the SPB and its installation within the project.
Lifetime of equipment	10 years	Therefore, where an installation is forecasted to remain in place for more than 10 years, the project incurs the full method case again.
Deferment of reinforcement	13 years	This is the average deferment, driven by the load growth forecasts
Single implementation NPV	£807,749	Based on cashflow discounted back to year 0 of the project. Discount factor is 3.5% for 30 years and 3% thereafter.
Capacity Release	10MVA	Based on the capacity of the SPB
Reinforcement Carbon Cost	40.55 tCO_2eq.	Based on the carbon cost of the material (including oil) of a primary transformer, and its transport.
Method carbon cost	3.79 tCO_2eq.	Based on the carbon cost of the SPB.

For NPV of roll out (UKPN and GB scale), the single implementation NPV is assumed to be accrued at the project year. This prevents over-estimation of value due to the early saving in cost which will be incurred later. The costs are then discounted back to 2018 prices. Discount factor is 3.5% for 30 years and 3% thereafter. The modelling ends at 2050. The roll out installation forecast is shown in the table below, including those forecasted as permanent mitigation of reinforcement, used for carbon benefit calculation.

Year	UKPN roll out	GB roll out	Year	UKPN roll out	GB roll out	Year	UKPN roll out	GB roll out
2022	1	1	**2032**	14	66	**2042**	10	47
2023	3	6	**2033**	11	52	**2043**	4	19
2024	3	14	**2034**	11	52	**2044**	2	10
2025	4	19	**2035**	9	42	**2045**	2	10
2026	7	33	**2036**	5	24	**2046**	2	10
2027	9	42	**2037**	3	14	**2047**	0	0
2028	11	52	**2038**	4	19	**2048**	2	10
2029	13	61	**2039**	3	14	**2049**	2	10
2030	17	80	**2040**	3	14	**2050**	4	19
2031	13	61	**2041**	4	19			

Appendix 10.4: Technical Appendix

10.4.1 Introduction to Distribution networks

Distribution networks are fed from the transmission network through Grid Supply Points (GSPs), with each GSP feeding the local area through a number of Bulk Supply Points (BSPs). Each BSP will be fed via a number of supply circuits that in normal circumstances are only partially loaded, so that in the event of a fault the remaining circuits can carry all of the required load. Redundancy ensures that outages, for faults and maintenance, can be taken without affecting customers' supplies, and is a requirement of network planning standards (Engineering Recommendation P2/6).

Each BSP will supply a number of Primary Substations (also known as Main Substations – MSS). Each Primary Substation may supply between 7,700 and 10,000 customers via approximately 10 to 20 feeders (or up to 40 feeders in central London) at 11kV or 6.6kV, referred to in this document as HV. These feeders are configured to provide alternative supply arrangements should a fault occur.

The 11kV network connects distribution substations through Ring Main Units (RMUs). RMUs typically have two HV network connections and one output to a distribution transformer to feed customers at 415 V (LV). RMUs allow the network to be easily reconfigured, allowing load to be moved from one circuit to another to:

- Balance the network loadings;
- Restore supplies following a fault; and
- Perform maintenance.

Remote Terminal Units (RTUs) can be installed to allow remote controlled operation of the RMU switches, from a network control centre. RTUs allow the communication of network measurements back to the control centre.

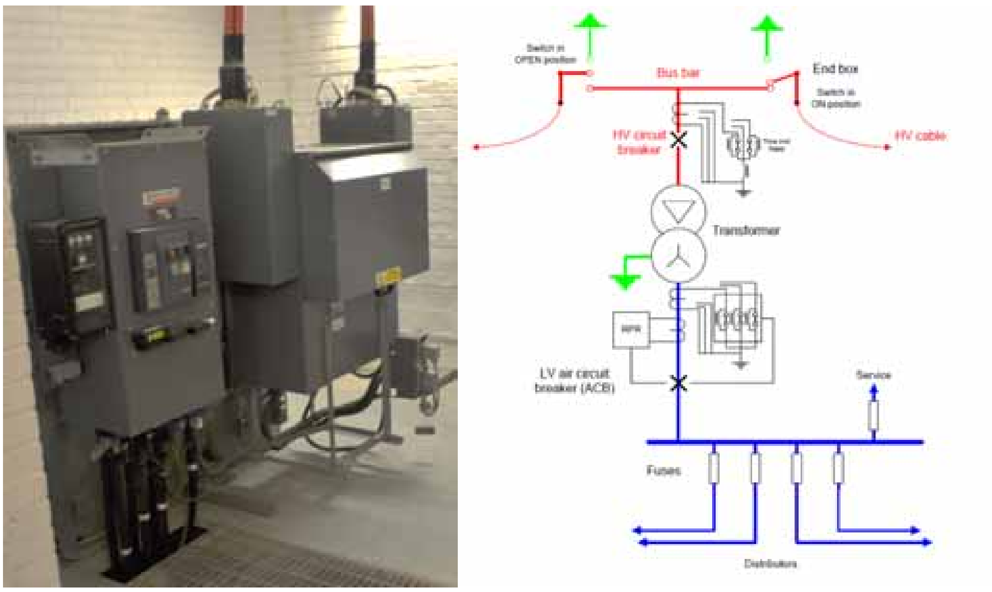


Figure 10.4.1. A Ring Main Unit showing an air circuit breaker which is typical for the central London network (photo and diagram)

HV networks are often run radially. However, in central London and some other locations, some of they may be operated in a meshed configuration. Meshed networks enable greater utilisation of assets as multiple feeders and transformers can share load. Meshed networks require additional protection systems to ensure that faults are correctly detected and isolated, without unnecessarily disconnecting healthy equipment.

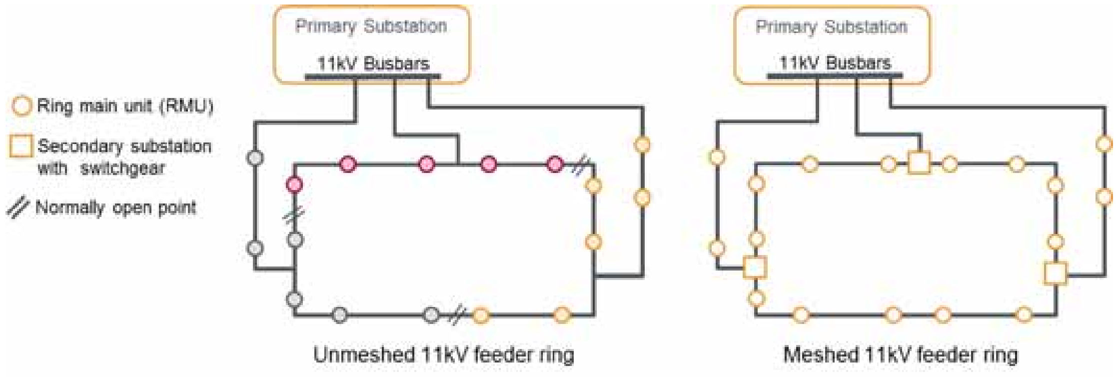


Figure 10.4.2. Radial and Meshed 11kV Circuit configurations

Primary Substations are not normally interconnected through the HV network as doing so may cause high losses caused by unnecessary circulating currents and excessive fault levels. There may also be a voltage magnitude and/or phase difference between sites, which would cause equipment damage if connected.

However, there may be interconnection between substations which is normally run open. This enables load to be transferred between adjacent primaries under outage conditions or for planned maintenance.

Like HV networks, LV networks are typically radial, however in some locations they may be meshed. Meshed LV networks are supplied from the same 11kV feeder group, again to prevent circulating currents, excessive fault levels and to prevent connections between circuits at different voltage magnitude or phases. This requirement to keep networks separated from each other creates electrical boundaries (e.g. at the 11kV feeder boundary, the Primary Substation boundary, the BSP boundary etc.) that must be coordinated and managed to ensure safe and efficient operation.

Network Reinforcement and Reconfiguration

UK Distribution Networks are designed to ensure that the peak demand of a group of customers can be supplied. Engineering Recommendation P2/6 specifies the degree of redundancy that must be available, and the timescales under which supplies must be restored for demand groups of various sizes. If the peak demand of a group rises such that it no longer satisfies the requirements of P2/6, the network feeding that group must be reinforced through the installation of additional equipment. The demand that can be met by a network under the outage conditions stipulated in P2/6 is known as the “Firm Capacity”.

Given the dynamic nature of demand profiles, which will get more variable as penetration of LCTs increases, there is existing capacity available on HV & LV networks that could be used if effective reconfiguration and sharing between networks can be achieved. If suitable configurations are available, then capacity from one substation could be used to add extra capacity to an adjacent substation.

Distribution networks are designed assuming that the connected loads have diversity. For example, a set of customers may each have a peak load of 10 kW. However they will not all consume 10 kW at the same time, and an average figure for each customers' continuous demand derived. UK Distribution networks are designed assuming that the average customer After Diversity Maximum Dement (ADMD) is 1 kW.

At present, network reconfiguration is undertaken as part of a post-fault recovery solution or pre-planned works. For example, the Automated Power Restoration System (APRS) is used to reconfigure networks following a fault event in order to restore supplies to as many customers as possible. Also load transfers between demand groups are performed periodically to balance networks loads, and reduce overloading. This is manual intervention via the control engineer. However, automated and regular network reconfiguration to optimise network performance is not currently undertaken.

10.4.2 Smart Solutions

LCNF and NIC projects have investigated smart solutions, in the following categories:

Category for innovation initiative	Brief description
Ancillary service	Frequency response
Asset Rating	Real time thermal rating – Overhead line, cables, transformers
DG Connection	Active network management
FACTS	Flexible AC transmission systems
Fault Level management	Management of fault levels
Flexible Demand	Industrial, commercial, residential time of use tariffs and controlled demand (electric vehicle charging)
Large scale storage	Large battery demonstration
Network configuration	Interconnected actively managed networks
Small scale storage	LV battery demonstration
Visibility	Enhanced monitoring, as an enabler to other solutions, demand profiling
Voltage Control	Primary and secondary network voltage control

These projects have delivered substantive learning around these areas, and their use in the operation and management of Electricity networks could offer substantial benefits. This project has considered the impact of the adoption of these solutions, by reducing the number of instances where the Active Response solution would be the most effective.

A brief description of three of these categories is provided below, as an aid to understanding of the descriptions provided.

Demand Side Response

Demand Side Response (DSR) curtails the load when the network is constrained or generation is not available. It is already being implemented by some commercial premises as a service to National Grid to balance demand and generation. By applying DSR to the load caused by the charging of EVs, DNOs will be able to manage EV charging to keep the voltage of the 415 V network above minimum levels and to ensure that the LV distribution transformer does not operate above 100 % of firm capacity. However, if many distribution transformers are operating at 100 % capacity, then unless DSR further curtails the load, the 11kV network may still require significant reinforcement. If only a few distribution transformers are nearing capacity, sharing between distribution substations, in complement to DSR, will allow more load to be connected to the LV and HV distribution networks without the need for reinforcement.

SSENs LCNF project “My Electric Avenue” concluded that EV charging can be managed, but additional loading of existing assets is inevitable. When between 40 % and 70 % of households have electric vehicles using a 3.5 kW (16 A) charger is expected that at least 32 % of these networks (312,000 circuits) across Britain will require intervention (My Electric Avenue 2016). My Electric Avenue demonstrated that an additional 10 % of customers could be connected through DSR.

Our Low Carbon London (LCL) report into opportunities for smart optimisation of new heat and transport loads concluded that both behavioural and technical interventions will be necessary and there is no single mitigating action against the impact on the network from EV charging and HP loads. The LCL time of use EV trial showed that 70% of domestic EV users modified their charging behaviours to predominately charge their vehicle at off-peak times, despite the monetary incentive being small. There is some suggestion that this may have been down to users being monitored by the project, but the consistent manner in which participants charged off-peak indicates that the time of use tariff acted as a useful mechanism to shift load from time of peak demand. The LCL project also noted that the Smart Meter Auxiliary Load Control Switches would be a suitable future option to control residential EV charging. (Low Carbon London Report B5 2014).

Network Monitoring

However, it is difficult to determine which networks will be affected and when, particularly if significant clustering occurs. The LCNF project Distribution Network Visibility developed equipment to allow monitoring of the LV network. This allows network planners to identify the substations which are experiencing rapid load growth.

Meshing

Meshing 11kV and 415 V networks enables sharing between feeders and substations. Meshing has been found to be effective in reducing or removing the need for network reinforcement. The example case study of two Primaries in Gravesend demonstrates how equalisation by network meshing is able to add capacity to the network.

The modelling of HV and LV networks has historically only considered the peak demand at the substation. Information about the profiles of the load have not been available. Effective sharing options between substations with complementary profiles has been difficult to assess. The limited measurements and automatic control available on these networks means that it is difficult to implement effective sharing and assess the performance of the reconfigured network.

Meshing does not allow connections to be made across many network boundaries, and in some instances, due to the network architecture, may not allow effective load sharing. When using the Method 1 devices in FUN-LV, there were some instances where meshing the network removed the load from the lightly loaded substation and increased the load on the heavily loaded substation. Simple meshing also increases the fault current which in urban area may exceed equipment ratings. The sharing requirements may be daily due to PV during the day and EV during the evening and night. Or seasonal, for example more load in the winter months may require a different meshing solution to when there is more PV generation in the summer months.

UK Power Networks has extensive experience of Meshed networks, and these methods will form a template of possible network management tools for use in Meshed networks for other DNOs adopt their use. This will be tested and proved through the involvement of SPEN in the project.

10.4.3 Active Response Technologies

The Active Response project will demonstrate innovative technologies, which are described in the following sections.

Software system

The software systems developed will actively optimise and manage HV and LV networks. Each of the projects' four trial networks will demonstrate the ability to automatically and in real time reconfigure the network in response to changes in network. Reconfiguration is required due to changing demand and generation patterns on the networks, and may be seasonal, daily or hourly as both EV charging and PV generation are highly dynamic.

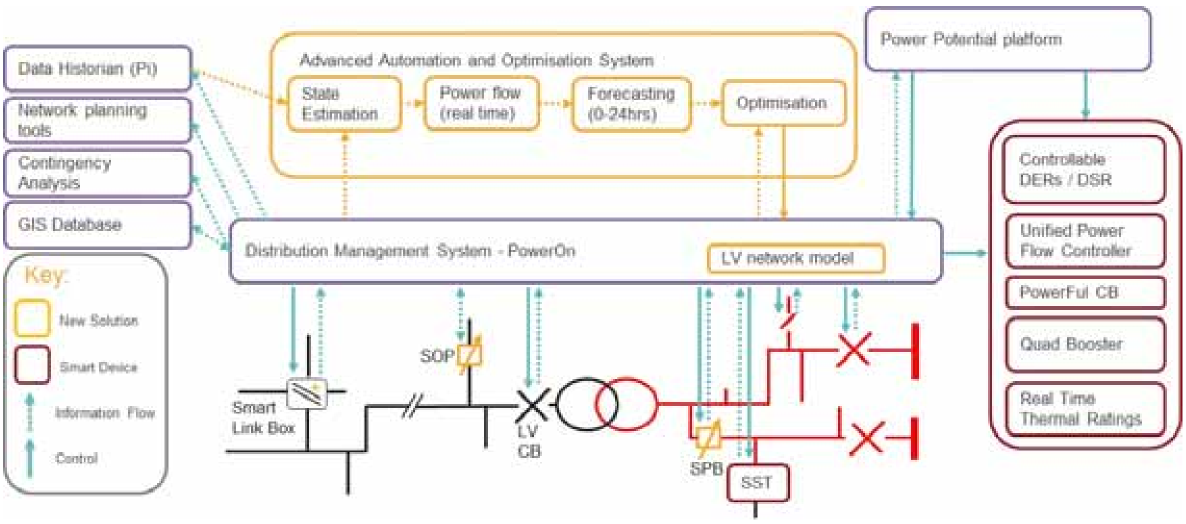


Figure 10.4.3. High-level design of the optimisation software

The system will interface to several UK Power Networks existing operational software systems, to obtain the required input data and implement the outputs.

Network data will be provided via existing measurement systems and from new locations required to give the level of detail required to perform the optimisation. We anticipate that this data will include:

- Electrical quantities such as voltage, current and phase information, and also possibly include additional quantities such as levels of harmonic content,
- Indications of switch positions and the number of operations,
- Any other data identified during the specification, design and development phases of Work Streams 1 and 2 of the project.

In future smart meter data may also be used.

We believe much of this information can be provided by existing instrumentation systems such as are used by our operational control system, as provided by Remote Terminal Units (RTUs) at our secondary substation sites.

The Optimisation module will utilise this data, and also that provided through State Estimation and Forecasting functions. These use measurements to predict states and replicate the Optimisation module outputs for future periods.

State Estimation is becoming a core function within Advanced Distribution Management Systems and is a requirement for detailed load flow analysis. The need for it was demonstrated within Low Carbon London and an early implementation was demonstrated within the Customer Led Network Revolution project. In order to carry out optimisations it is required to understand the flow of power throughout the system but it is not practical or possible to measure this at all points and all times. As such there is a need to estimate the system state where these data points are not available. This has to be done by the three phases separately as the network, specifically at LV, is unbalanced.

The load forecasting function is a core part of the intended Active Response solution. It is the basis to enable look-ahead operations (24 hours, in this case), which is essential to provide our network operators with an anticipated view of potential issues, and let them tune and optimise the corrective actions with the help of the system. Weather forecast data will also be incorporated. Look-ahead capability enables a wide range of control levers available to us, both as a DNO, and potentially, in a way that can be coordinated with other stakeholders as a DSO.

The Optimisation Module will process the data and, via the use of a Load Flow Engine, will determine the most effective configuration of the network and SOP or SBP transfers. In determining what the optimal configuration is, it is necessary to specify what quantity the module is seeking to maximise or minimise. For example, it may be desirable to:

- Reduce power flows in each network component to the minimum level against ratings that is possible;
- Ensure that voltages are kept as close to a certain set point as possible; or
- Minimise network losses.

It is also possible that a balance of each of these outcomes is required, and the relative importance of each must be determined via weighting factors.

A further element to be considered in performing the optimisation, is the requirement to enable rapid restoration of supplies following a fault on any network component. Hence network states that require many switching operations to restore supplies must be avoided.

Providing a coordinated response across the network voltage levels will provide significant technical challenge to ensure that:

- All developed technology must work together and not perform conflicting operations;
- There is not a large amount of reconfiguration for small benefits to the network. Frequent switching will reduce the operational lifetime of the RMUs and LV switches, as both have a limited number of switching operations before replacement or maintenance is required. Therefore, switching should only be completed when significant improvements in network performance will be achieved;
- Safe operation of the network is provided at all times. The reconfiguration must consider network boundaries and not allow meshing to cross these boundaries; and
- Protection systems must operate correctly in all configurations. All connected loads must have a connection to a transformer and not only be connected to the SOP or SPB, to ensure that the fault level is high enough to operate the protection systems.

The developed solution must not preclude the use of other technologies or systems that may be required in future. For example, Solid-State Transformers could be used to manage power flows, voltage and fault levels in future networks. The Active Response solution should there not preclude the integration of this functionality in its design.

Our aim within Active Response is to develop and demonstrate a solution that is applicable as widely as possible, for different devices and topologies and we will seek to develop existing solutions where possible to match the specification of this project.

Hardware systems

Active Response will both build on the expertise gained in the SULVN and FUN-LV projects to improve devices previously demonstrated, whilst expanding the approach to Medium Voltage through development of new hardware, the SPB. All hardware will be developed to TRL 8 and be ready for BaU deployment at the end of the project. These technologies combined with the measurement systems UK Power Networks have applied for under the Innovation Rollout Mechanism will provide a more complete solution for network planners when managing networks.

LV Circuit Breakers and Link Box Switches

To provide automated reconfiguration of LV networks, Remote Controlled switches must be deployed at key points. Both the FUN-LV and SULVN projects have utilised devices that allow this to demonstrate the potential benefits of network meshing. However, both projects determined that the devices available at the time had technical limitations that reduced the applicability.

Specifically, these limitations were:

- A Fault current break capability of 6kA; Fault currents above this level being cleared by an in-line fuse. This has the effect that in many locations fault clearance would be achieved by fuse operation, requiring a replacement to be installed via a site visit. This limits the benefits provided as a result of network automation.
- A limit on the operational life of the devices in terms of the number of operations. For the devices used previously this limit was 1000 load switching operations. If frequent network reconfiguration is to be achieved this will be a limiting factor before the equipment must be replaced.

Active Response aims to deliver solutions to TRL 8, and therefore both of these limits must be improved such that widespread adoption is achievable, without a resulting detrimental impact on network performance.

In improving the performance of the devices, it is necessary to ensure that the safety implications of using the new equipment is considered, so that additional risks are not introduced into network operation.

LV SOPs

The FUN-LV project successfully demonstrated the benefits available through the use of Soft Open Points on LV networks, in order to achieve a viable solution that managed power flows, fault levels and network voltages concurrently. However, due to the limitation of semiconductor technology available at the time of development, the devices used in this project had a number of limitations such as efficiency, cost, audible noise level, and weight, which preclude their use as a BaU solution.

Active Response aims to deliver solutions to TRL 8, so overcoming these challenges using the latest available semiconductor technology is necessary to achieve a new generation of LV SOPs. Highly efficient, high power (1.7kV, 300A) Silicon-Carbide Metal-Oxide-Semiconductor Field Effect Transistors (MOSFETs) and Diodes are now commercially available and will therefore be used as the semi-conductor technology, enabling significant benefits over the Silicon devices previously used, including:

- Elimination of audible noise through increase in switching frequency beyond the human audible range;
- Improved efficiency through reduction in both conduction losses of the devices themselves, and heat rejected from the large filter components;
- Reduction in size and weight, due to smaller filter inductors made possible through the use of a higher switching frequency;
- Simplified servicing requirements through improvement of cooling arrangements, as a result of the more efficient design; and
- Higher current carrying capability, requiring less devices in parallel to be used for a given current rating.

Hence the devices that will be developed and trialled in Active Response will overcome the limitations found in the FUN-LV devices and enable their use as a BaU solution.

Silicon-Carbide MOSFETs are much more challenging to produce than the Silicon equivalent, and have only recently become commercially feasible at higher powers. The new SOPs will be the first demonstrable use of Silicon-Carbide MOSFETs in a distribution network solution, and hence their use represents a technical and operational risk. However, in mitigation to this risk, Turbo Power Systems have developed, and now manufacture, power supplies for the rail industry, demanding long life and high reliability in a harsh environment application, that have successfully deployed Silicon Carbide switching technology.

Soft Power Bridge

The SPB has been designed to offer similar functionality to the LV SOPs, but will use a novel architecture to offer benefits in terms of size, cost and efficiency necessary for deployment at 11 kV and above.

The LV SOPs demonstrated in FUN-LV, and the 33kV "Flexible Power Link" (FPL) currently being trialled in the Western Power Distributions "Equilibrium" project both use a back-to-back convertor design. In this architecture, the convertors must process all of the power that is being transferred. The design for the SPB uses a partially rated convertor connected in shunt with the network, so that less power is processed, meaning that fewer power electronic devices are required to achieve a more competitive solution with significantly lower cost per kVA. The Soft Power Bridge has both series and shunt elements, in a similar configuration to a Unified Power Flow Controller (UPFC).

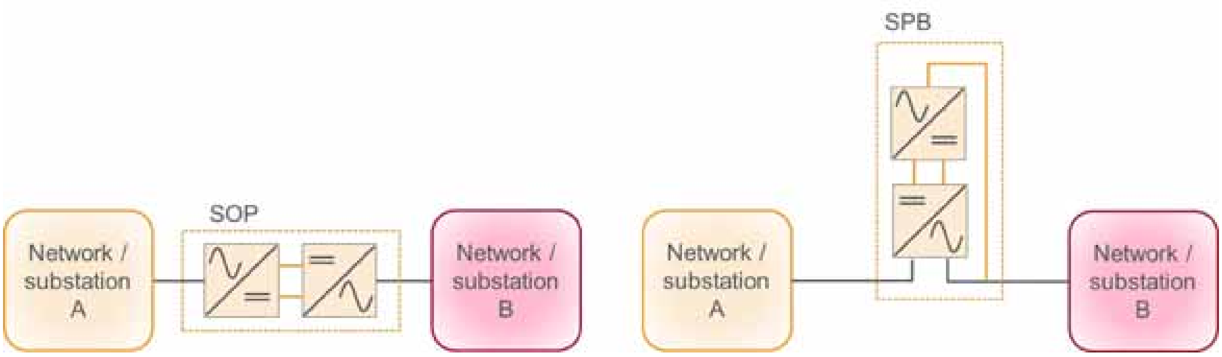


Figure 10.4.4. Comparison between the design of the SOP and the SPB

The SPB will be able to:

- Control real and reactive power transfer between the connected networks;
- Provide voltage support;
- Provide harmonic reduction and phase power balancing;
- Allow connection without increasing fault levels; and
- Connect between different networks at different voltage levels and phase via the use of an interposing transformer.

The SPB will also use 1.7kV, 300A Silicon Carbide MOSFETs and Diodes, as per the LV SOPs, and hence allows the benefits of this technology to be realised.

The design of the SPB will allow the benefits of the SOPs and FPL to be realised cost effectively in a wider range of applications. However, once again its design is highly innovative, and therefore carries with it a level of technical and operation risk that justifies the use of NIC funding for demonstration. The power electronics hardware will be able to be located at the Primary Substations as per the WPD NIC project Equilibrium or alternatively within the HV networks as a secondary substation sized solution.

Research areas

To ensure that Active Response delivers effective solutions suitable for BaU rollout, three research streams have been included in Workstream 3 of the project. These will critically review key project elements, enabling optimal development of solutions. The research streams are:

1. Software Solutions	
Task	**Activity**
Network Optimisation techniques	Options Review & Implementation Review
State Estimation techniques	Options & Implementation Review
Intelligent data analytics	Demonstration System & Implementation Review
Profile compression/coding	Demonstration System & Implementation Review
Loading to dynamic ratings	Options & Implementation Review
Single phase connection apportioning	Demonstration System & Implementation Review

2. Hardware Solutions	
Task	**Activity**
SOP algorithms	Design, coding & Implementation Review
SOP hierarchical control	Specification & Implementation Review
PE electronics design / performance/ test	Design Review
Hardware safety/risks/asset life	Review of Solution impact on network equipment (e.g. increased Switching frequency of RMUs)

3. Project applicability	
Task	**Activity**
LCT Clustering & UK growth	Desktop report of assumptions and evidence
Business cases/assumption/scenarios	Desktop study report and Review
Use cases/ benefits and replicability	Desktop study & report

10.4.4. Project Orientation

Differences from other projects

Active Response differs from other proposals and NIC projects by first considering the use of Advanced Automation. This is a more cost-effective solution than using power electronics or network reinforcement as only monitoring equipment and switchgear is required for the hardware. However, not all constraints will be able to be solved by

Advanced Automation and for these constraints, power electronic solutions will be deployed.

As previously described the new SPB architecture and semi-conductor technology offers benefits over the back-to-back convertor devices demonstrated in FUN-LV and Equilibrium.

SPENs FlexNet demonstrated the benefits of network automation when releasing capacity but their solution required significant manual intervention and only considered the 11kV network. Advanced Automation will reduce the manual intervention and operate across both the 11kV network and the 400V network.

Power Potential & Smart Street are both concerned with optimising networks, but both are concerned with optimising for network voltage, and not, as here, to manage thermal, and voltage constraints.

Links to LV Engine

Active Response has been developed in collaboration SPEN, who are submitting the LV Engine proposal. LV Engine is proposing a solid-state transformer (SST) which is able to control power flow through the substation and the bus-bar voltage. Both projects use Power Electronics solutions to manage network constraints, and offer customer benefits by allowing the connection of LCTs without the requirement for expensive network reinforcement.

The two solutions are complementary as:

- It is envisaged that Active Response optimisation will be able to control other smart-grid hardware including SSTs;
- Increase the learning about power electronics in the distribution network. SSTs replace the LV transformer, SOPs connect multiple LV feeders and SPBs connect multiple Primaries; and
- Power electronics is fault constrained and these projects will increase the understanding of protection implications.

Neither project is reliant on the award of the other project.

10.4.5 Primary Connect Case Studies

The following three case studies use actual demand data from UK Power Networks primary substations to demonstrate that the Primary Connect method can offer benefits by transferring demand, and reducing peak loading.

These sites were identified by examining a small sample of loading data from sites near each other. A further more detailed search will be conducted as part of the site selection process in the project.

Case Study 1: Gravesend South and Gravesend West

The profile for "Gravesend South" and "Gravesend West" primary substations are shown in the figure below.

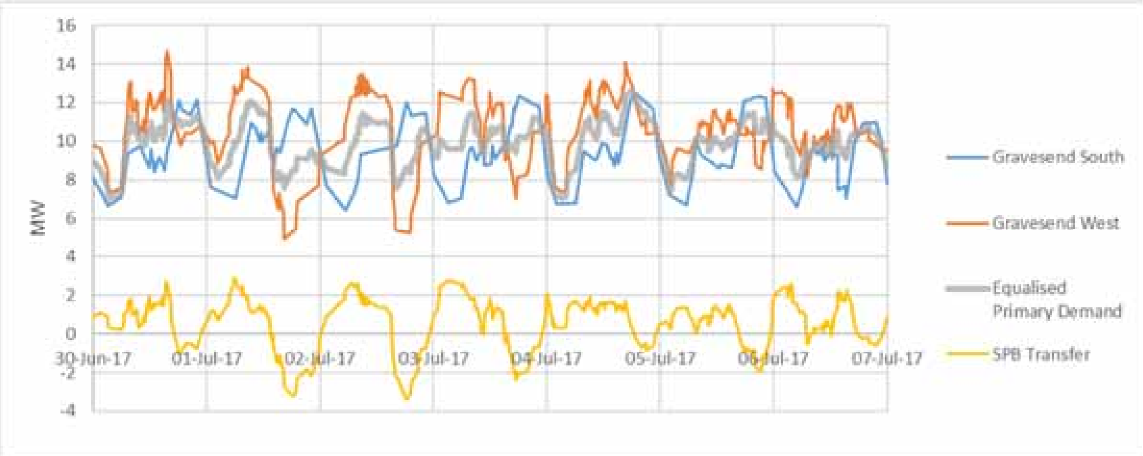


Figure 10.4.5. Demand at Gravesend South and Gravesend West Primaries during July 2017 and the estimated profile if an SPB were installed

The two primaries have complementary profiles where they their peaks do not coincide. The SPB can be used to share the demand between the two primaries.

The Equalised Primary Demand shows the new demand of the two Primaries if a SPB were to follow the transfer as shown. The SPB is able to release capacity of 3.4 MW from Gravesend South and 2.9 MW from Gravesend West by reducing the peak demand.

Case Study 2: Stevenage

The demand profile for the primary substations in and around Stevenage during July 2016 are shown in the figure below.

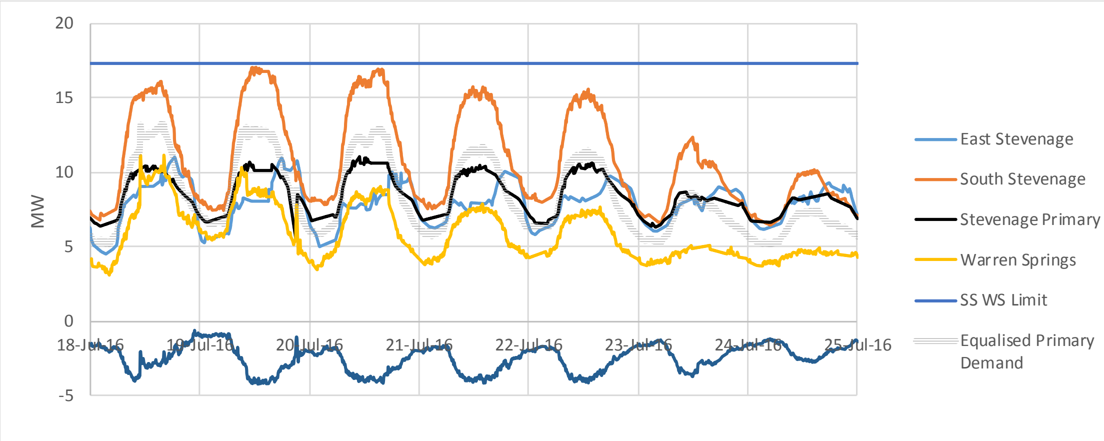


Figure 10.4.6. Demand at Stevenage Primary during July 2016 and the estimated profile if an SPB were installed

South Stevenage primary is scheduled for a £3m reinforcement project due to the peak loading approaching its firm capacity.

The adjacent substations have available capacity and East Stevenage has a complementary profile. Reduction of the peak loading at South Stevenage by 5 MVA using a Soft Power Bridge would defer the need for this reinforcement.

Our analysis indicates that the SPB could defer the project indefinitely at this site.

Case Study 3: Bloomfield Place

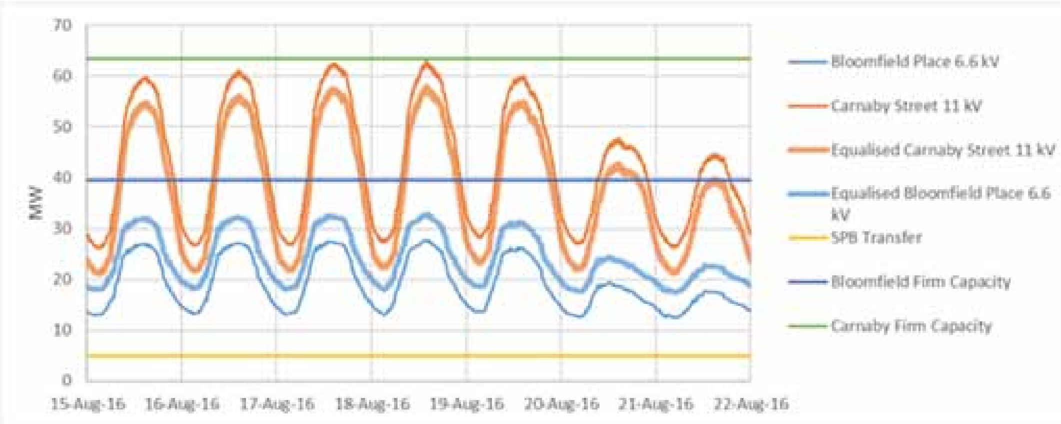


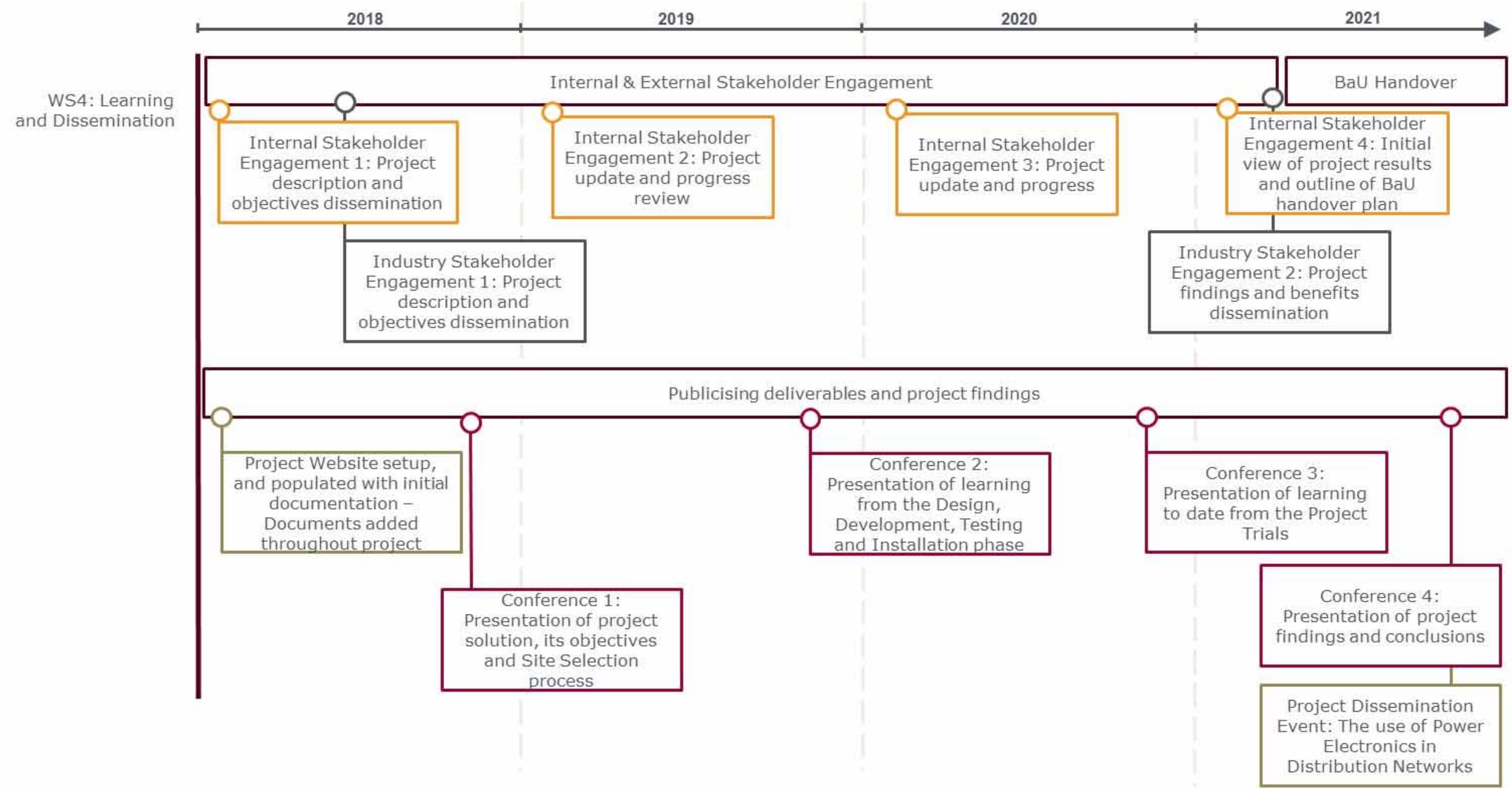
Figure 10.6.7 Demand and Firm Capacity at Bloomfield Place and Carnaby St in August 2016 and the impact the estimated Profiles if an SPB were installed

Bloomfield Place feeds a 6.6kV network in central London. Its demand in August 2016, together with the sites firm capacity is shown in blue on the chart above. Shown in orange is Carnaby St 11kV network, which is adjacent to Bloomfield place. Connection through conventional means does not allow useful support due to the networks' characteristics.

During August 2016, the demand at Carnaby St exceeds its firm capacity. Should a fault occur during this period, the network would have to be reconfigured to ensure supplies were secured.

It can also be seen that Bloomfield Place has available capacity, which could be used at Carnaby St, deferring the need for reinforcement. This is particularly important as Primary Substation reinforcement projects in Central London are extremely costly (>£15m) and cause large amounts of disruption over a long duration. The SPB could be used in conjunction with other connection equipment to support the Carnaby St Network during reinforcement works, ensuring security of supply.

Appendix 10.5: Knowledge Dissemination Roadmap



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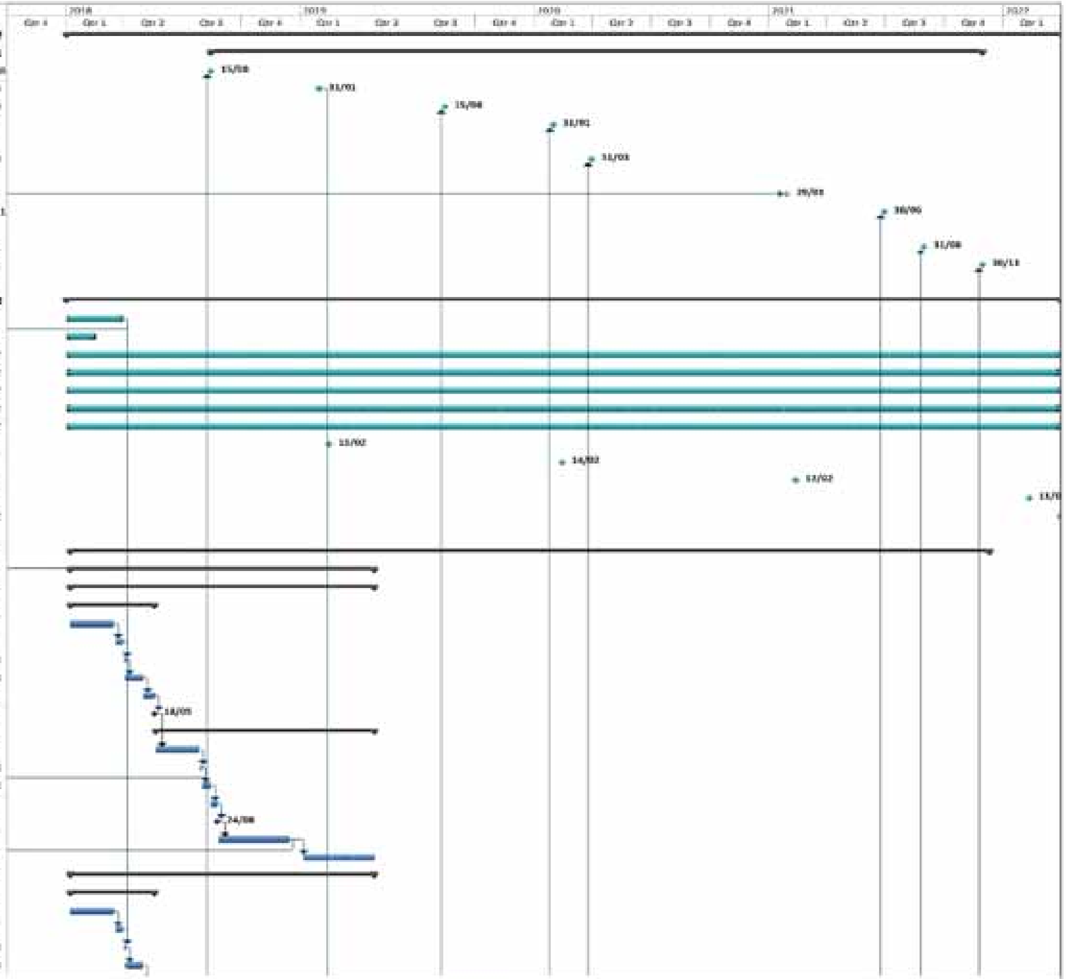
Appendix 10.6: Project Plan

ID	Task Name	Duration	Start	Finish
1	**Active Response Project Plan**	**1108 days**	**Tue 02/01/18**	**Thu 31/03/22**
2	**Project Milestones**	**859 days**	**Wed 15/08/18**	**Tue 30/11/21**
3	Deliverable 1. High Level Design Specification of Advanced Automation Solution	0 days	Wed 15/08/18	Wed 15/08/18
4	Deliverable 2. Trial Site Selection Criteria and Process Outcome	0 days	Thu 31/01/19	Thu 31/01/19
5	Deliverable 3. Learning from Hardware factory tests	0 days	Thu 15/08/19	Thu 15/08/19
6	Deliverable 4. Learning from Commissioning and Operation of Active Response Software Solution tools	0 days	Fri 31/01/20	Fri 31/01/20
7	Deliverable 5. Initial Learning from the Installation and Commissioning of Active Response Hardware	0 days	Tue 31/03/20	Tue 31/03/20
8	Deliverable 6. Project technology handover, rollout and adoption into BaU plan	0 days	Fri 29/01/21	Fri 29/01/21
9	Deliverable 7. Review of the Active Response Methods applicability in Scottish Power Energy Network's licence areas	0 days	Wed 30/06/21	Wed 30/06/21
10	Deliverable 8. Presentation of findings from the project trials	0 days	Tue 31/08/21	Tue 31/08/21
11	Deliverable 9. Review of solution applications and project business case	0 days	Tue 30/11/21	Tue 30/11/21
12				
13	**Project Management**	**1108 days**	**Tue 02/01/18**	**Thu 31/03/22**
14	Contract Negotiation	64 days	Tue 02/01/18	Fri 30/03/18
15	Mobilisation	34 days	Tue 02/01/18	Fri 16/02/18
16	UKPN Project Management	1108 days	Tue 02/01/18	Thu 31/03/22
17	WS1 Lead (TPS)	1108 days	Tue 02/01/18	Thu 31/03/22
18	WS2 Lead (UKPN)	1108 days	Tue 02/01/18	Thu 31/03/22
19	WS3 Lead (Ricardo)	1108 days	Tue 02/01/18	Thu 31/03/22
20	WS4 Lead (Ricardo)	1108 days	Tue 02/01/18	Thu 31/03/22
21	2018 Annual Progress Report	0 days	Fri 15/02/19	Fri 15/02/19
22	2019 Annual Progress Report	0 days	Fri 14/02/20	Fri 14/02/20
23	2020 Annual Progress Report	0 days	Fri 12/02/21	Fri 12/02/21
24	2021 Annual Progress Report	0 days	Fri 11/02/22	Fri 11/02/22
25	Closedown Report	0 days	Thu 31/03/22	Thu 31/03/22
26				
27	**Workstream 1: Hardware Development and Deployment**	**1025 days**	**Mon 08/01/18**	**Fri 10/12/21**
28	**Specification, Design and Development of Novel hardware**	**340 days**	**Mon 08/01/18**	**Fri 26/04/19**
29	**Soft Power Bridge**	**340 days**	**Mon 08/01/18**	**Fri 26/04/19**
30	**Specification**	**95 days**	**Mon 08/01/18**	**Fri 18/05/18**
31	Develop initial requirements	10 wks	Mon 08/01/18	Fri 16/03/18
32	Internal Review	2 wks	Mon 19/03/18	Fri 30/03/18
33	Specification workshop	2 days	Mon 02/04/18	Tue 03/04/18
34	Draft specification production	4 wks	Wed 04/04/18	Tue 01/05/18
35	Review	13 days	Wed 02/05/18	Fri 18/05/18
36	Finalised Specification	0 days	Fri 18/05/18	Fri 18/05/18
37	**Design and Development**	**245 days**	**Mon 21/05/18**	**Fri 26/04/19**
38	Initial Design	10 wks	Mon 21/05/18	Fri 27/07/18
39	Design Review workshop	2 days	Mon 30/07/18	Tue 31/07/18
40	Updates to Design	2 wks	Wed 01/08/18	Tue 14/08/18
41	Review	8 days	Wed 15/08/18	Fri 24/08/18
42	Finalised Design	0 days	Fri 24/08/18	Fri 24/08/18
43	Manufacture (Trial 3 Unit)	16 wks	Mon 27/08/18	Fri 14/12/18
44	Manufacture (Trial 4 Unit)	16 wks	Mon 07/01/19	Fri 26/04/19
45	**Soft Open Point - 2 Terminal & 3 Terminal**	**340 days**	**Mon 08/01/18**	**Fri 26/04/19**
46	**Specification**	**95 days**	**Mon 08/01/18**	**Fri 18/05/18**
47	Develop initial requirements	10 wks	Mon 08/01/18	Fri 16/03/18
48	Internal Review	2 wks	Mon 19/03/18	Fri 30/03/18
49	Specification workshop	2 days	Mon 02/04/18	Tue 03/04/18
50	Draft specification production	4 wks	Wed 04/04/18	Tue 01/05/18



Project: Active Response Project P
Date: Mon 07/08/17

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

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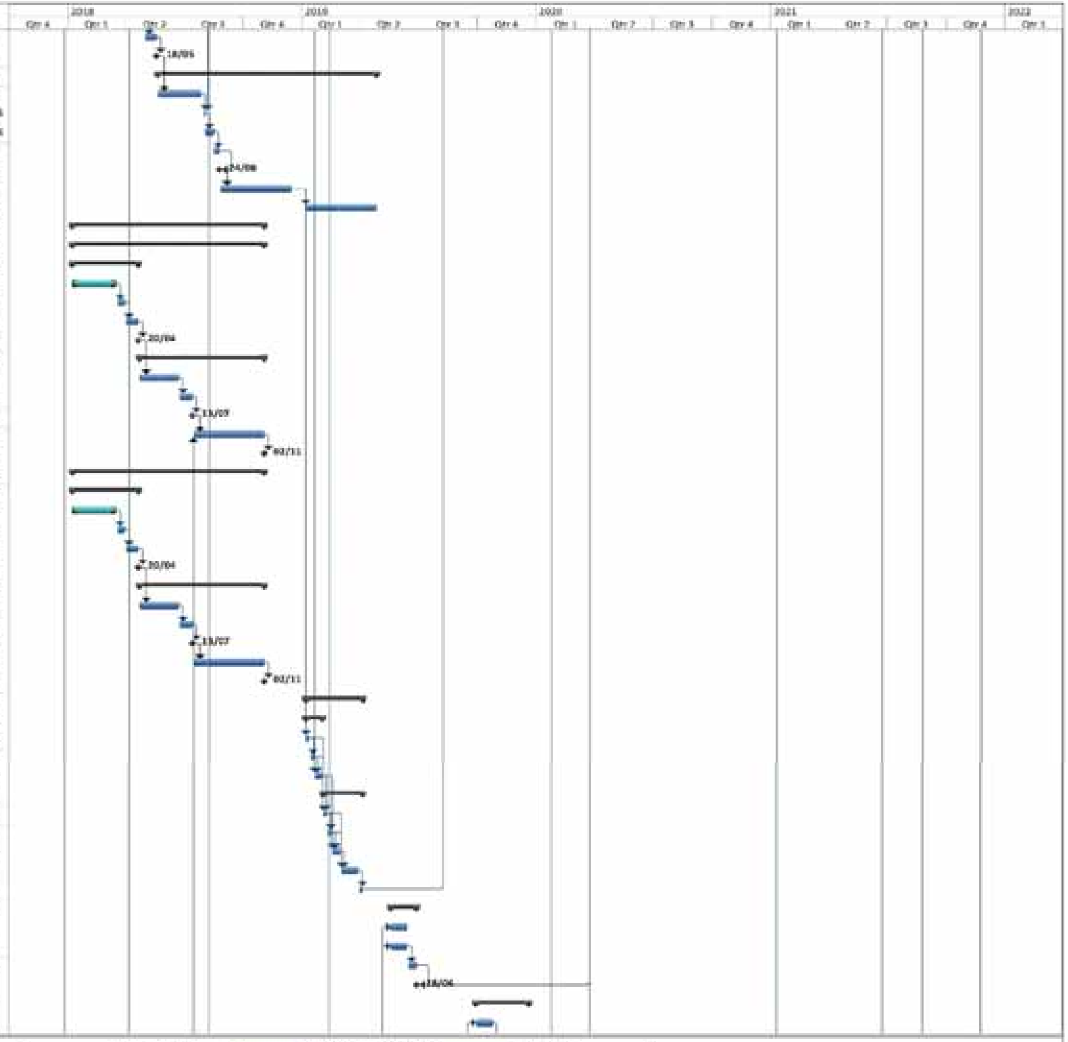
ID	Task Name	Duration	Start	Finish
51	Review	13 days	Wed 02/05/18	Fri 18/05/18
52	Finalised Specification	0 days	Fri 18/05/18	Fri 18/05/18
53	**Design and Development**	**245 days**	**Mon 21/05/18**	**Fri 26/04/19**
54	Initial Design	10 wks	Mon 21/05/18	Fri 27/07/18
55	Design Review workshop	2 days	Wed 01/08/18	Thu 02/08/18
56	Updates to Design	2 wks	Fri 03/08/18	Thu 16/08/18
57	Review	6 days	Fri 17/08/18	Fri 24/08/18
58	Finalised Design	0 days	Fri 24/08/18	Fri 24/08/18
59	Manufacture (Trial 2 Units)	16 wks	Mon 27/08/18	Fri 14/12/18
60	Manufacture (Trial 4 units)	16 wks	Mon 07/01/19	Fri 26/04/19
61	**Specification, Procurement and Manufacture of Established hardware**	**215 days**	**Mon 08/01/18**	**Fri 02/11/18**
62	**Remote Control Circuit Breakers and Link Box Switches**	**215 days**	**Mon 08/01/18**	**Fri 02/11/18**
63	**Specification**	**75 days**	**Mon 08/01/18**	**Fri 20/04/18**
64	Develop initial requirements and system design	50 days	Mon 08/01/18	Fri 16/03/18
65	Internal Review	10 days	Mon 19/03/18	Fri 30/03/18
66	Updates to Specification	15 days	Mon 02/04/18	Fri 20/04/18
67	Finalised Specification	0 days	Fri 20/04/18	Fri 20/04/18
68	**Procurement, Manufacture and Delivery**	**140 days**	**Mon 23/04/18**	**Fri 02/11/18**
69	Tender issue and response period	45 days	Mon 23/04/18	Fri 22/06/18
70	Tender Review	15 days	Mon 25/06/18	Fri 13/07/18
71	Contract award	0 days	Fri 13/07/18	Fri 13/07/18
72	Manufacture	16 wks	Mon 16/07/18	Fri 02/11/18
73	Equipment Delivery	0 days	Fri 02/11/18	Fri 02/11/18
74	**Ring Main Units & Remote Terminal Units**	**215 days**	**Mon 08/01/18**	**Fri 02/11/18**
75	**Specification**	**75 days**	**Mon 08/01/18**	**Fri 20/04/18**
76	Develop initial requirements and system design	50 days	Mon 08/01/18	Fri 16/03/18
77	Internal Review	10 days	Mon 19/03/18	Fri 30/03/18
78	Updates to Specification	15 days	Mon 02/04/18	Fri 20/04/18
79	Finalised Specification	0 days	Fri 20/04/18	Fri 20/04/18
80	**Procurement, Manufacture and Delivery**	**140 days**	**Mon 23/04/18**	**Fri 02/11/18**
81	Tender issue	45 days	Mon 23/04/18	Fri 22/06/18
82	Tender Review	15 days	Mon 25/06/18	Fri 13/07/18
83	Contract award	0 days	Fri 13/07/18	Fri 13/07/18
84	Manufacture	16 wks	Mon 16/07/18	Fri 02/11/18
85	Equipment Delivery	0 days	Fri 02/11/18	Fri 02/11/18
86	**System Testing**	**65 days**	**Mon 07/01/19**	**Fri 05/04/19**
87	**Factory Testing**	**20 days**	**Mon 07/01/19**	**Fri 01/02/19**
88	2 Terminal SOP	1 wk	Mon 07/01/19	Fri 11/01/19
89	3 Terminal SOP	1 wk	Mon 14/01/19	Fri 18/01/19
90	Soft Power Bridge	2 wks	Mon 21/01/19	Fri 01/02/19
91	**Functional Testing**	**45 days**	**Mon 04/02/19**	**Fri 05/04/19**
92	2 Terminal SOP	1 wk	Mon 04/02/19	Fri 08/02/19
93	3 Terminal SOP	1 wk	Mon 11/02/19	Fri 15/02/19
94	Soft Power Bridge	2 wks	Mon 18/02/19	Fri 01/03/19
95	Modifications following testing	4 wks	Mon 04/03/19	Fri 29/03/19
96	Repeat Functional Testing	1 wk	Mon 01/04/19	Fri 05/04/19
97	**Installation & Commissioning (Trial 1: Active LV)**	**30 days**	**Mon 20/05/19**	**Fri 28/06/19**
98	Installation of LV Link Boxes	4 wks	Mon 20/05/19	Fri 14/06/19
99	Installation of LV Circuit Breakers	4 wks	Mon 20/05/19	Fri 14/06/19
100	Configuration of Communications Network and Data Historian	2 wks	Mon 17/06/19	Fri 28/06/19
101	Completion of Commissioning	0 days	Fri 28/06/19	Fri 28/06/19
102	**Installation & Commissioning (Trial 2: Network Optimise)**	**60 days**	**Mon 30/09/19**	**Fri 20/12/19**
103	Installation of RMUs not already installed from IRM	4 wks	Mon 30/09/19	Fri 25/10/19



Project: Active Response Project P
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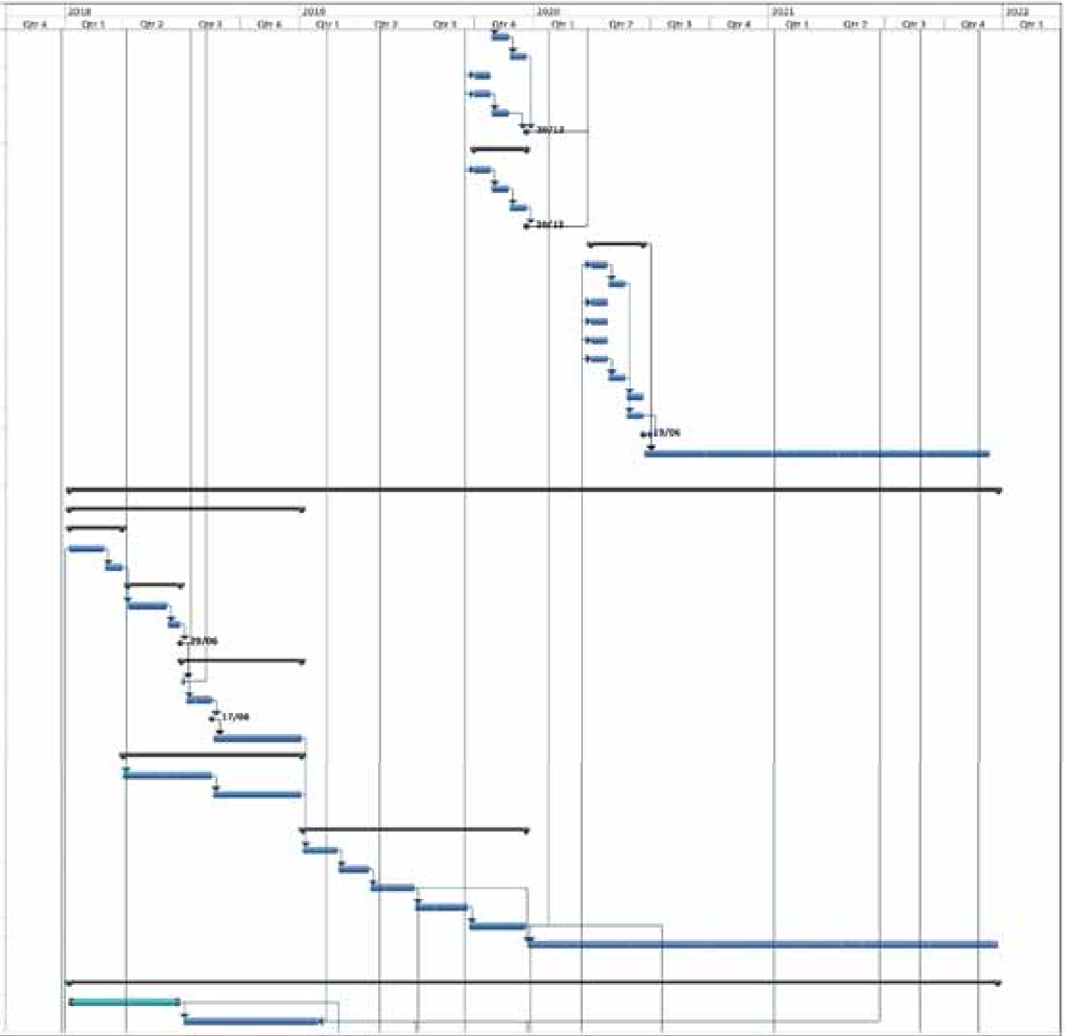
ID	Task Name	Duration	Start	Finish
104	Installation of three 2 Terminal SOPs	4 wks	Mon 28/10/19	Fri 22/11/19
105	Installation of two 3 Terminal SOPs	4 wks	Mon 25/11/19	Fri 20/12/19
106	Installation of LV Link Boxes	4 wks	Mon 30/09/19	Fri 25/10/19
107	Installation of LV Circuit Breakers	4 wks	Mon 30/09/19	Fri 25/10/19
108	Configuration of Communications Network and Data Historian	4 wks	Mon 28/10/19	Fri 22/11/19
109	Completion of Commissioning	0 days	Fri 20/12/19	Fri 20/12/19
110	**Installation & Commissioning (Trial 3: Primary Connect)**	**60 days**	**Mon 30/09/19**	**Fri 20/12/19**
111	Installation of SBP	4 wks	Mon 30/09/19	Fri 25/10/19
112	Connection of SPB to Communication Network and Data Historian	4 wks	Mon 28/10/19	Fri 22/11/19
113	Demonstration of Power Transfer	4 wks	Mon 25/11/19	Fri 20/12/19
114	Completion of Commissioning	0 days	Fri 20/12/19	Fri 20/12/19
115	**Installation & Commissioning (Trial 4: Active Response)**	**60 days**	**Mon 30/03/20**	**Fri 19/06/20**
116	Installation of three 2 Terminal SOPs in new Trial area	4 wks	Mon 30/03/20	Fri 24/04/20
117	Installation of two 3 Terminal SOPs in new Trail area	4 wks	Mon 27/04/20	Fri 22/05/20
118	Installation of RMUs not already installed from IRM	4 wks	Mon 30/03/20	Fri 24/04/20
119	Installation of LV Link Boxes	4 wks	Mon 30/03/20	Fri 24/04/20
120	Installation of LV Circuit Breakers	4 wks	Mon 30/03/20	Fri 24/04/20
121	Installation of SBP	4 wks	Mon 30/03/20	Fri 24/04/20
122	Connection Communication Network and Data Historian	4 wks	Mon 27/04/20	Fri 22/05/20
123	Demonstration of Power Transfer	4 wks	Mon 25/05/20	Fri 19/06/20
124	Demonstration of equipment operating correctly	4 wks	Mon 25/05/20	Fri 19/06/20
125	Completion of Commissioning	0 days	Fri 19/06/20	Fri 19/06/20
126	Ongoing Development and Support	77 wks	Mon 22/06/20	Fri 10/12/21
127				
128	**Workstream 2: Software Development and Deployment**	**1035 days**	**Mon 08/01/18**	**Fri 24/12/21**
129	**Advanced Automation solution**	**260 days**	**Mon 08/01/18**	**Fri 04/01/19**
130	**Initial Specification**	**60 days**	**Mon 08/01/18**	**Fri 30/03/18**
131	Develop initial requirements and system design	8 wks	Mon 08/01/18	Fri 02/03/18
132	Internal Review	4 wks	Mon 05/03/18	Fri 30/03/18
133	**Advanced Automation solution tendering**	**60 days**	**Mon 09/04/18**	**Fri 29/06/18**
134	Tender issue and response period	45 days	Mon 09/04/18	Fri 08/06/18
135	Tender Review	15 days	Mon 11/06/18	Fri 29/06/18
136	Contract award	0 days	Fri 29/06/18	Fri 29/06/18
137	**Detailed Specification and Development of Advanced Automation Solution**	**135 days**	**Mon 02/07/18**	**Fri 04/01/19**
138	Specification workshop	5 days	Mon 02/07/18	Fri 06/07/18
139	Updates to Specification	6 wks	Mon 09/07/18	Fri 17/08/18
140	Finalised Specification	0 days	Fri 17/08/18	Fri 17/08/18
141	Design and Development of Advanced Automation Solution	20 wks	Mon 20/08/18	Fri 04/01/19
142	**Development and Analysis of Network models**	**200 days**	**Mon 02/04/18**	**Fri 04/01/19**
143	Transcribe existing network models to Advanced Automation Solution	20 wks	Mon 02/04/18	Fri 17/08/18
144	Identify optimal network arrangements from previous measurement data for validation purposes	20 wks	Mon 20/08/18	Fri 04/01/19
145	**Off Line System Testing & Installation**	**250 days**	**Mon 07/01/19**	**Fri 20/12/19**
146	Install test system	8 wks	Mon 07/01/19	Fri 01/03/19
147	Verify test system operates to specification (Phase 1, LV Only)	7 wks	Mon 04/03/19	Fri 19/04/19
148	Performance and user acceptance testing (Phase 1, LV Only)	10 wks	Mon 22/04/19	Fri 28/06/19
149	Verify test system operates to specification (Phase 2, HV&LV)	12 wks	Mon 01/07/19	Fri 20/09/19
150	Performance and user acceptance testing (Phase 2, HV&LV)	13 wks	Mon 23/09/19	Fri 20/12/19
151	Ongoing Development and Support	105 wks	Mon 23/12/19	Fri 24/12/21
152				
153	**Workstream 3 : Project Planning, Trials and Analysis**	**1035 days**	**Mon 08/01/18**	**Fri 24/12/21**
154	Detailed Use Case development	25 wks	Mon 08/01/18	Fri 29/06/18
155	Site Selection & Trial Design	30 wks	Thu 05/07/18	Thu 31/01/19



Project: Active Response Project P
Date: Mon 07/08/17

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	

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RIIO NIC NETWORK INNOVATION COMPETITION

ID	Task Name	Duration	Start	Finish
156	Trial 1: Active LV	76 wks	Mon 01/07/19	Fri 27/12/19
157	Trial 2: Network Optimise	30 wks	Mon 23/12/19	Fri 17/07/20
158	Trial 3: Primary Connect	30 wks	Mon 23/12/19	Fri 17/07/20
159	Trial 4: Active Response	48 wks	Mon 20/07/20	Fri 18/06/21
160	Hardware & Software design options and implementation review	65 wks	Mon 02/04/18	Fri 28/06/19
161	UK LCT adoption societal factors investigation	48 wks	Mon 02/04/18	Fri 01/03/19
162	Business Case assumptions and scenario review	50 wks	Mon 04/03/19	Fri 14/02/20
163	Trial Analysis and Review	80 wks	Mon 27/01/20	Fri 06/08/21
164	Use Case & Business Case Review	16 wks	Mon 19/04/21	Fri 06/08/21
165	Project Closedown	20 wks	Mon 09/08/21	Fri 24/12/21
166				
167	**Workstream 4: Learning & Dissemination**	**1040 days**	**Mon 08/01/18**	**Fri 31/12/21**
168	Internal Stakeholder Engagement	207 wks	Mon 08/01/18	Fri 24/12/21
169	**External Stakeholder Engagement**	**786 days**	**Wed 03/10/18**	**Wed 06/10/21**
170	**Events**	**786 days**	**Wed 03/10/18**	**Wed 06/10/21**
171	Engagement Event 1: Project Description and Objectives Dissemination	1 day	Wed 03/10/18	Wed 03/10/18
172	Engagement Event 2: Project Findings and Benefits Dissemination	1 day	Wed 06/10/21	Wed 06/10/21
173	**Publicising deliverables and project findings**	**959 days**	**Tue 01/05/18**	**Fri 31/12/21**
174	Project Dissemination Event: The use of Power Electronics in Distribution Networks	1 day	Wed 08/12/21	Wed 08/12/21
175	Website and Social Media activities	959 days	Tue 01/05/18	Fri 31/12/21
176	Targeted Communications	959 days	Tue 01/05/18	Fri 31/12/21
177	**LCNI Conferences**	**839 days**	**Mon 01/10/18**	**Thu 16/12/21**
178	**LCNI Conference 2018**	**60 days**	**Mon 01/10/18**	**Fri 21/12/18**
179	Prepare Material	2 wks	Mon 01/10/18	Fri 12/10/18
180	Attendance and Presentation	3 days	Tue 20/11/18	Thu 22/11/18
181	Follow up actions and engagement	4 wks	Mon 26/11/18	Fri 21/12/18
182	**LCNI Conference 2019**	**60 days**	**Mon 30/09/19**	**Fri 20/12/19**
183	Prepare Material	2 wks	Mon 30/09/19	Fri 11/10/19
184	Attendance and Presentation	3 days	Tue 19/11/19	Thu 21/11/19
185	Follow up actions and engagement	4 wks	Mon 25/11/19	Fri 20/12/19
186	**LCNI Conference 2020**	**59 days**	**Mon 28/09/20**	**Thu 17/12/20**
187	Prepare Material	2 wks	Mon 28/09/20	Fri 09/10/20
188	Attendance and Presentation	3 days	Tue 17/11/20	Thu 19/11/20
189	Follow up actions and engagement	4 wks	Fri 20/11/20	Thu 17/12/20
190	**LCNI Conference 2021**	**54 days**	**Mon 04/10/21**	**Thu 16/12/21**
191	Prepare Material	2 wks	Mon 04/10/21	Fri 15/10/21
192	Attendance and Presentation	3 days	Tue 16/11/21	Thu 18/11/21
193	Follow up actions and engagement	4 wks	Fri 19/11/21	Thu 16/12/21
194	**Business as Usual Handover**	**205 days**	**Mon 08/03/21**	**Fri 17/12/21**
195	Stakeholder engagement	8 wks	Mon 08/03/21	Fri 30/04/21
196	Process design	8 wks	Mon 03/05/21	Fri 25/06/21
197	Procedure and Specification production	8 wks	Mon 28/06/21	Fri 20/08/21
198	Review period	8 wks	Mon 23/08/21	Fri 15/10/21
199	Updates	4 wks	Mon 18/10/21	Fri 12/11/21
200	Handover	5 wks	Mon 15/11/21	Fri 17/12/21

Project: Active Response Project F
Date: Mon 07/08/17

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 10.7: Risk Register and Contingency Plan

RISK & ISSUE LOG

ID	Risk / Issue	Status	Description	Impact	Risk Probability	Risk Impact	Risk Score	Mitigation / Planned Actions	Mitigated Probability	Mitigated Impact	Mitigated Score	Owner	Last updated	Date Closed
R1	Risk	Open	Project costs for high value items are significantly higher than expected	Project overspend requiring additional partner contribution or request to Ofgem for additional funds.	3	5	15	Realistic costs with contingency based on experience in FSP. Effective tendering/RFI process. Review of costs at the end of each project phase and revision of cost forecast and scope as appropriate.	2	4	8	PM	11/10/2017	
R2	Risk	Open	Some aspects of the technical solutions are not achievable to the desired specification within the project budget.	The project will not be able to investigate all of the intended techniques	3	4	12	Project scope is based upon an integration and evolution of existing techniques. Effective tendering/RFI process. Review of costs at the end of each project phase and revision of cost forecast and scope as appropriate.	1	4	4	Design authority	11/10/2017	
R3	Risk	Open	Equipment development is more complex than initially assumed	Potential overspend on device development, or scope reduction	3	4	12	Reasonable levels of contingency in included in project costs and timescales in FSP Review of costs at the end of each project phase and revision of cost forecast and scope as appropriate.	1	4	4	PM	11/10/2017	
R4	Risk	Open	Methods do not deliver anticipated benefits	Lower than anticipated value delivered	3	4	12	Some trialled techniques have already demonstrated benefits. The funding mechanism is for innovation projects where the outcome is uncertain, and is structured accordingly.	2	3	6	PM	11/10/2017	
R5	Risk	Open	Partner/Supplier performance is not adequate	Outputs delayed, potential overspends	2	4	8	Robust procurement process. Suitable incentivisation of suppliers where required. Shared responsibility for deliverables	1	4	4	PM	11/10/2017	
R6	Risk	Open	External perception of poor performance may impact future innovation project awards	Obtaining funding for future innovation projects is difficult	2	5	10	Effective management of project and external stakeholders.	1	4	4	All parties	11/10/2017	
R7	Risk	Open	Suitable equipment suppliers cannot be found	Project must be delayed or rescoped	2	5	10	Realistic requirements specified at FSP. Consultations with suppliers taken place to ensure that some equipment is available to meet all basic requirements.	1	3	3	PM	11/10/2017	
R8	Risk	Open	It is not possible to test equipment adequately in order to allow network trials	Project must be rescoped	2	5	10	Good understanding of supply chain capability. Realistic requirements specified. Potential test locations identified	1	3	3	PM	11/10/2017	
R9	Risk	Open	The project business case is not justifiable	Project will not receive Ofgem approval to proceed	3	5	15	Early investigation of Business Case and thorough presentation of evidence	1	5	5	PM	11/10/2017	
R10	Risk	Open	Failure to agree project contracts between UKPN and other partners	Project cannot proceed	2	5	10	Early discussion of contractual arrangements between partners.	1	5	5	PM	11/10/2017	
R11	Risk	Open	A partner/supplier may withdraw from the project	Partner/Supplier must be replaced	3	4	12	Robust procurement/due diligence process. Suitable incentivisation of suppliers where required.	1	4	4	All parties	11/10/2017	
R12	Risk	Open	Suitable sites for demonstration of solution are not available	Trials cannot proceed	2	5	10	Site requirements are developed in accordance with Design process and typical site conditions. Possible trial areas have been indicated.	1	5	5	WS3	11/10/2017	
R13	Risk	Open	Lack of business support for the project from key departments	Project suffers delays or cannot proceed	2	4	8	Stakeholder engagement plan to be enacted during early stages of project, including members of SMT and identification of project sponsor	1	3	3	Sponsor	11/10/2017	
R14	Risk	Open	Changes to key personnel	Possible delays during handover period	3	4	12	Comprehensive project documentation is maintained, although staff changes cannot be stopped it is possible to reduct the impact of the staff change. Induction pack produced for new resources	3	3	9	PM	11/10/2017	
R15	Risk	Open	The size of the equipment once developed is too large and not suitable for installation	Trials cannot proceed	2	5	10	Design process includes consideration from the site selection process in terms of available space	1	5	5	WS1	11/10/2017	

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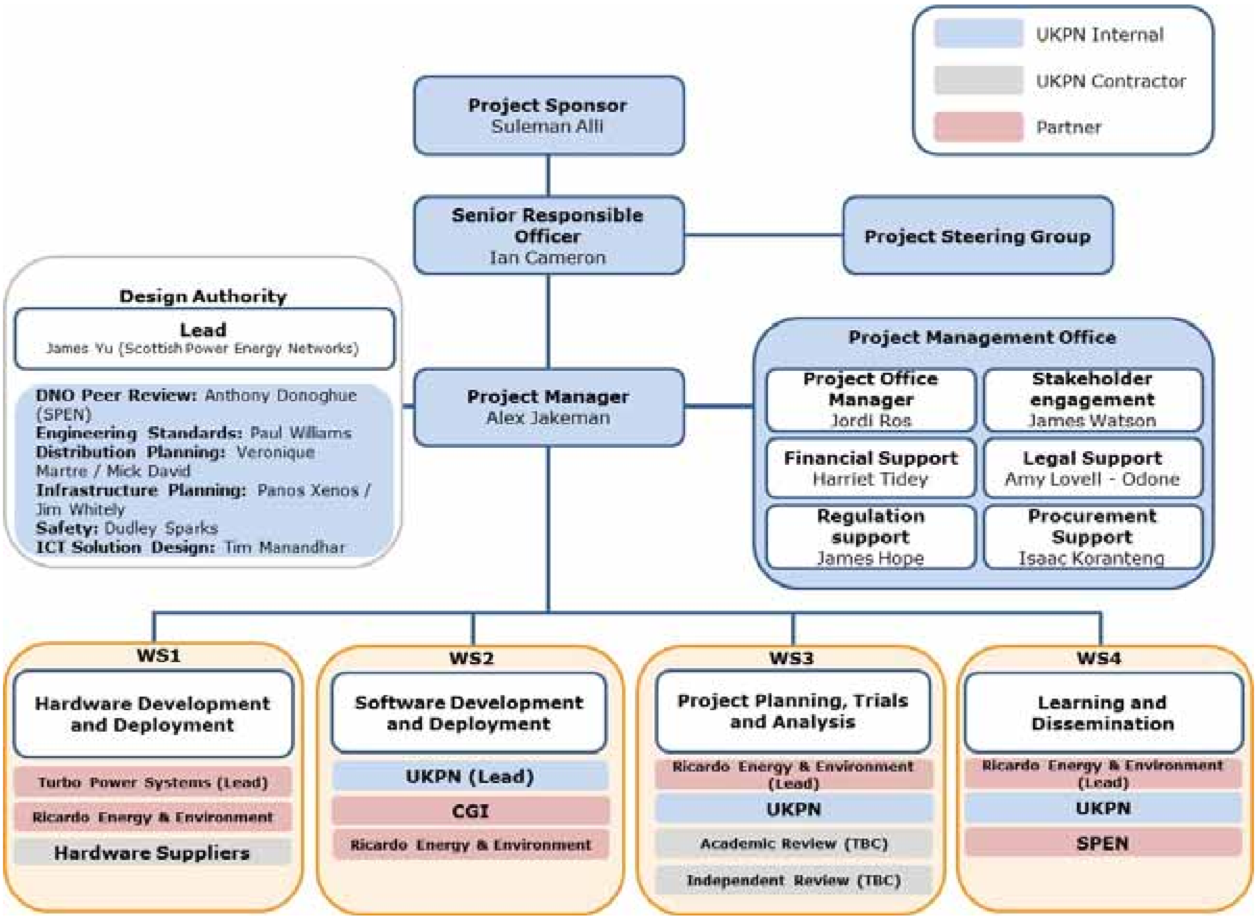
RIIO NIC NETWORK INNOVATION COMPETITION

RISK & ISSUE LOG

ID	Risk / Issue	Status	Description	Impact	Risk Probability	Risk Impact	Risk Score	Mitigation / Planned Actions	Mitigated Probability	Mitigated Impact	Mitigated Score	Owner	Last updated	Date Closed
R16	Risk	Open	The specification and build of equipment takes longer than anticipated	Project suffers delays	2	4	8	Realistic assessment of timescales included in project plan. Inclusion of contingency time. Review of costs and task durations at the end of each project phase and revision of cost forecast and scope as appropriate.	1	3	3	WS1	11/10/2017	
R17	Risk	Open	Equipment/supplier costs are underestimated in RFIs	Project costs rise outside of tolerances	2	4	8	Rigorous RFI process. Contingency allowances included in project budget. Review of costs and task durations at the end of each project phase and revision of cost forecast and scope as appropriate.	1	3	3	PM	11/10/2017	
R18	Risk	Open	IPR requirements deter some suppliers from involvement	Partner/Supplier must be replaced	3	4	12	Early discussion of IPR requirements with Key project suppliers/partners. Alternative suppliers identified.	2	4	8	PM	11/10/2017	
R19	Risk	Open	Integration of equipment and systems is not achievable, or is more difficult/takes longer than anticipated	Project suffers delays or cannot proceed	2	4	8	Collaborative design process enacted during inception phase with all key project partners	1	4	4	PM, WS1, WS2	11/10/2017	
R20	Risk	Open	The communications system is not adequate for the transfer of the required volumes of data	Project suffers delays or cannot proceed	2	5	10	Collaborative design process enacted during inception phase with all key project partners	2	4	8	WS1	11/10/2017	
R21	Risk	Open	Control system/algorithms etc. are not properly tested prior to installation on live system	Equipment does not perform as expected	2	4	8	Units are tested in factory and test environment. Sufficient time included in project plan to ensure sufficient testing occurs	1	3	3	WS2	11/10/2017	
R22	Risk	Open	Solution has unintended impact on the network causing network failure, under performance/failure of customer equipment etc.	Loss of supply, damage to customers equipment/lost production time etc.	2	5	10	Units are tested in factory and test environment. Sufficient time included in project plan to ensure sufficient testing occurs	1	5	5	UKPN	11/10/2017	
R23	Risk	Open	Solution does not meet UK standards (CE marking, G59, Harmonic limits etc.)	Equipment cannot be installed	2	5	10	Early discussion of relevant standards during inception phase. Time and budget included to ensure suitable testing is completed.	1	5	5	WS1	11/10/2017	
R24	Risk	Open	Catastrophic failure of equipment damages network equipment or causes injury	network equipment is damaged or an individual is injured	1	5	5	Failure Mode Analysis completed early in project and recommendations incorporated in the design process	1	5	5	PM	11/10/2017	
R25	Risk	Open	Failure to design a method to clear LV faults if Power Electronics switches fail in the closed position	Uncleared LV faults, leading to damage to network equipment and/or death/injury to humans	3	3	9	Initial options considered at project outset. Project descoped to remove the trialling of new design LV switches.	2	3	6	WS1	11/10/2017	
R26	Risk	Open	The Primary Connect Method does not offer a solution to enable the realisation of direct benefits at South Stevenage Trial site	Direct benefits are not realised and network reinforcement is needed at the site.	3	4	12	Robust Site selection process and design of method technology to ensure that the benefits can be realised.	1	4	4	PM	11/10/2017	

Appendix 10.8: Project Team

10.8.1 Organogram



10.8.2 Key UK Power Networks Staff

Alex Jakeman – Innovation Project Lead. Alex has worked in the utilities industry across electricity and water networks for 6 years. Over the past 4 years has worked on two of UK Power Networks' flagship Innovation projects called Low Carbon London and Kent Active System Management (KASM). In his current role as Project Lead for KASM, he is responsible for delivering vital modelling and analytics software that will allow DNOs to transition to DSOs.

Ian Cameron – Head of Innovation, will act as the Project's Senior Responsible Officer monitoring progress and providing initial point of escalation for project matters.

Jordi Ros – Portfolio Office Manager, will act as the Project Management Officer as a key part of UK Power Networks innovation portfolio. He brings to the project over 10 years of experience in project management and the project office function: creating robust project management solutions across private and public sector organisations and delivering benefits while increasing project performance and efficiency.

10.8.3 About Ricardo Energy and Environment

Ricardo is a global strategic, technical and environmental consultancy, and a specialist niche manufacturer of high performance products. The company employs over 2,000 professional engineers, consultants and scientists who are committed to delivering outstanding projects focused on class-leading innovation.

Ricardo will have several key roles within the project consisting of both technical and project management across all work streams. Ricardo will act as project support assisting UK Power Networks manage the project. Ricardo will also lead two of the four work streams, WS3 Project Planning, Trials and Analysis and WS4 Learning and Dissemination.

Ricardo will participate in the following technical activities:

- Site Selection
- Trial design and management
- Technical analysis
- Development of recommendations
- Dissemination of learning and results.

Ricardo has significant experience of working on NIC projects, including leading work streams, and it has relevant skills in each of the key project roles being provided summarised in the table below:

Area	Summary of expertise
Project leadership	Ricardo has developed and led a wide variety of projects and programmes in the energy sector. These include: Directional Earth Fault Passage Indicators, Smart Urban LV Networks, FUN-LV, Distribution Network Visibility (DNV), and Online Condition Monitoring System (PD project). Examples of Ricardo providing active partner and lead roles in previous NIC and LCNF Tear 2 projects include: • FUN-LV project scoping and Work stream 3 lead • DNV project scoping and technical lead and programme management of final phase (BaU)
Technical concept development through to product delivery	Ricardo has designed, developed and installed non-invasive Directional Earth-Fault Passage Indicators (DEFPI) used to indicate the direction of an earth-fault current in meshed and radial 11kV networks. DEFPI is enable to integrate with both legacy and new ring main units (RMU). Ricardo has helped UKPN to review, test, enhance an On-line Partial Discharge (PD) system used to detect and locate PDs in cables, switchgear and accessories.
Technical trials and demonstrations	Experience in designing and managing technical trials on GB electricity networks includes: • FUN-LV – Ricardo led the site selection and trial design process, and provides ongoing support to the project trials and data validation. • DNV - Ricardo led the technical trials of advanced and non-invasive monitoring systems on LV-33kVsystems • Celsius – Ricardo has scoped the technical programme, designed the site selection process, validated the selection, and is leading the development of trial designs, and installation methodologies and training.

Area	Summary of expertise
Data collection, management and analysis	Expertise in the collection, management and visualisation of data includes: • The collection, maintenance, and visualisation of the air quality data, in the UK and in other locations over the world. This is a significant repository of data, subject to strict rules about accuracy and reliability. • Celsius project, which will roll out a significant amount of monitoring into 520 distribution substations. This data will be collected, validated, processed, and visualised. Experience in using detailed data, such as network monitoring data, and developing this into usable, actionable information includes: • DNV 10,000+ sites • FUN-LV 36 schemes involving 100+ sites
Development of business as usual recommendations	Experience in developing input and recommendations into business as usual practices and processes include: • DNV: Ricardo provided business process, technology advice and training in order to integrate the visibility tool as business as usual. • Modification of UK Technical Codes to incorporate EU legislation

Key Personnel

Professor Cliff Walton, is an acknowledged international expert in the management of power network assets, particularly in the optimisation of performance of ageing network assets. Previously Head of Strategic Development for EDF Energy Networks, he has extensive experience in engineering, innovation, commercial, financial, business process and technology change activities.

Simon Terry, MEng, CEng, is a Chartered Electrical Engineer with 18 years of industry experience within both Utilities and Consultancy. He has led and worked within teams responsible for a broad range of Electricity projects, from identification of the need case and establishing viability to the detailed design and commissioning phases.

Dr Nathaniel Bottrell, MEng, PhD recently joined Ricardo and previously worked on innovation projects with UK Power Networks while as a post-doctoral researcher at Imperial College London. Nathaniel has been involved with the Smart Urban Low Voltage (SULVN) and FUN-LV projects. His competences are in power electronics hardware and their controllers, modelling and analysis of power electronics, modelling and analysis of microgrids, integration of power electronics into the distribution network and technical analysis for distribution projects.

10.8.4 About Turbo Power Systems Ltd

TPS design and manufacture world class power conversion systems using cutting edge technology. They have relevant experience in the delivery of power converters for use on public LV distribution networks through their role on the UKPN's FUN-LV project. Furthermore, they have experience of developing and manufacturing High Voltage products in the form of power supplies for laser cutting with operating voltage ranges of

35 to 50kV. TPS will provide the power convertors and associated electrical equipment for use on Active Response.

Key Personnel

Dr Fainan Hassan, MEng, PhD is the Engineering Manager for Smart Grid & Energy and will act as engineering program leader

Ian McDonald, MEng, CEng, is the Chief Systems Engineer and will act as technical design expert

Dr Tomas Hornik, MEng, PhD is the Senior Control Engineer responsible for deriving and optimising system control

David Gurwicz, B.Sc. C.Eng MIEEE FIET, is the Power Electronics Consultant and conceptualist of the Soft Power Bridge

Steve Mitchell, BEng is the Embedded Systems Engineer for Smart Grid

10.8.5 About CGI IT UK Limited

CGI has been selected as the main technical partner for Active Response to fully leverage and build upon experience gained through their role on the FUN-LV project, and a number of other energy industry innovation projects. CGI has the necessary expertise, industry-wide visibility and strategic alignment to act as ICT system architect. It is therefore cost beneficial and in the interest of customers to appoint CGI as project partner.

Key Personnel

CGI will draw on key personnel from a pool of expertise leveraging its industry experience and proven IT systems integrator capabilities.

[redacted] is our principal information architect with 35 years' experience of implementing complex business solutions. He is increasingly regarded as a leading Data Quality expert, having been responsible for the data architecture, modelling, migration, quality and cleansing aspects of many projects.

[redacted] is our principal business consultant and a chartered electrical engineer, having served the electricity industry for 30 years. His market and engineering expertise enables him to consider the technical, commercial and operational issues when advising on solutions.

[redacted] is our principal solution architect and geospatial / GIS specialist with over fifteen years in energy, utilities and telecoms, and eighteen years in IT architecture, design and delivery.

[redacted] is an experienced programme manager and business consultant and with proven ability to deliver innovative, customer-focussed technical and business solutions across a number of industry sectors.

Appendix 10.9: SP Energy Networks Collaborative activities

Deliverable	Work stream	Activity	Timescale
FSP	N/A	Bid Support, Business Case review and Expert Panel Interview support	Q3 & 4 2017
N/A	4	Production of linked Dissemination plan for Power Electronics in Distribution Networks	Q1 2018
2	3	Review and input to Site Selection methodology	Q3 2018
1	2	Peer Review of Deliverable (High Level Design Specification of Advanced Automation Solution)	Q2 2018
2	3	Peer Review of Deliverable (Trial Site Selection Criteria and Process Outcome)	Q4 2018
N/A	All	Year 1 Project Managers report review	Q4 2018
N/A	1 & 2	Review and Challenge of developed hardware and software specifications	Q1 2019
N/A	1 & 2	Confirmation of appropriateness of developed solutions for use in SPEN networks	Q2 2019
3	1	Peer Review of Deliverable (Initial Learning from Hardware factory tests)	Q2 2019
4	2	Peer Review of Deliverable (Initial Learning from Commissioning and Operation of Active Response Software Solution tools)	Q4 2019
N/A	All	Year 2 Project Managers report review	Q4 2019
5	1	Peer Review of Deliverable (Initial Learning from the Installation and Commissioning of Active Response Hardware)	Q1 2020
6	4	Review and input to Deliverable (Project technology handover, rollout and adoption into BaU plan)	Q4 2020
7	3	Scottish Power Energy Networks Deliverable: Review of the Active Response Methods applicability in Scottish Power Energy Network licence areas	Q1 & 2 2021
N/A	All	Year 3 Project Managers report review	Q4 2020
N/A	4	Joint Development of Power Electronics Distribution Networks policy document	Q3 2021
8	3	Peer Review of Deliverable (Presentation of findings from the project trials)	Q3 & 4 2021
9	3	Peer Review of Deliverable (Review of solution applications and project business case)	Q3 & 4 2021
8, 9	3	Review and Challenge of trial results and project business case	Q3 & 4 2021
N/A	4	Joint Dissemination event on the use of Power Electronics in Distribution Networks	Q4 2021
N/A	All	Year 4 Project Managers report review	Q4 2021

Transport for London

Ian Cameron, Head of Innovation
UK Power Networks
Newington House
237 Southwark Bridge Road
London
SE1 6NP

Transport for London
Strategy and Planning

Palestra
197 Blackfriars Road
London
SE1 8NJ

Phone 020 3054 1582

tfl.gov.uk

3 August 2017

Dear Ofgem

Letter of Support for Active Response, Network Innovation Competition bid 2017

This letter is written in support of UK Power Networks' (UKPN) Active Response bid into the Network Innovation Competition.

The Mayor's aim is that London's public transport fleet should produce zero exhaust emissions. The Mayor, through TfL and the boroughs, will work with Government and stakeholders across London to ensure that sufficient and appropriate charging infrastructure is put in place to support the transition from diesel and petrol-powered vehicles to Ultra Low Emission Vehicles.

It is vital that London's grid infrastructure is able to respond to these demands, helping to facilitate our transition to a low/ zero carbon city. Our own experience in working with UKPN to power charging infrastructure at a number of bus garages, shows that the grid serving London could be a constraint to the Mayor's plans. We are at the early stage of transition; by 2020 all 300 single deck buses serving central London will be zero-emission – the aim is for the whole TfL bus fleet of over 9,000 vehicles to emit zero exhaust emissions by 2037 at the latest.

At Transport for London we understand how innovation plays a vital role to ensure UK electricity distribution networks can deliver cost effective solutions to network constraints at the lowest cost and impact to all customers. As such we are supportive of UKPN's proposals to develop smart solutions such as Network Optimise and Primary Connect, which could be readily deployed to better utilise the existing grid infrastructure and facilitate additional capacity in a proactive and cost effective way for London's residents and businesses.

We believe more active demand management such as that proposed by UKPN is a key element in helping to solve the grid constraints London faces, helping to free up capacity for low carbon technology, electric vehicle charging and reducing grid reinforcement costs.

We would be delighted to support UKPN's Active Response project, should their bid prove successful.

Yours sincerely

Rhona Munck
Senior Strategy & Planning Manager
Email: RhonaMunck@tfl.gov.uk

MAYOR OF LONDON

VAT number 756 2769 90

31 July 2017

Ian Cameron
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Direct Tel: +44 (0)1344 770689
Fax: +44 (0)1344 770356
Email: dnaberezhnykh@trl.co.uk

Dear Ian,

Reference: UKPN Active Response 210 Network Innovation Competition Bid

I am pleased to provide this of letter of support for the Active Response proposal being submitted by UKPN in response to the Network Innovation Competition. TRL believes that developing and deploying innovative and flexible mechanisms for intelligently managing the network capacity between the High Voltage and Low Voltage levels would benefit transport users and operators, if it reduces barriers and delays to the deployment of charging infrastructure, while minimising impact on customer energy bills.

TRL agrees that anticipated acceleration in the electrification of transport will likely put considerable additional strain on the UK grid, and in particular on the distribution network in urban areas, in the coming years. Demand for charging from varying modes of transport and vehicle types will require rapid deployment of charging infrastructure and a flexible approach to increasing network capacity. Traditional reinforcement alone is unlikely to be sufficiently cost effective and could generate barriers and delays for electrification of transport at the pace the UK government and industry is hoping to achieve. Therefore, TRL supports this proposal and believes that, if successfully implemented then Active Response could enable faster electrification and decarbonisation of the transport sector.

In order to maximise the value and impact of the proposed Active Response solution it is essential that it is deployed across the network in an intelligent way. Targeting locations where it is most likely to enable electrification and defer the need for network reinforcement and upgrade. Furthermore, use of such Active Response should be carefully considered alongside demand-side management for charging. TRL is looking forward to working with UKPN to help it identify such locations and develop an implementation strategy that reflects latest developments in transport electrification and anticipated future developments.

Yours sincerely,

Denis Naberezhnykh

Head of ULEV and Energy

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RIIO NIC
NETWORK INNOVATION COMPETITION

WESTERN POWER DISTRIBUTION

Serving the Midlands, South West and Wales

Ian Cooper
Innovation Lead – Opportunities and Bids
UK Power Networks
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Toll End Road
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Tipton
West Midlands
DY4 0HH

Direct Dial: 0121 6239459
Email: jberry@westernpower.co.uk

Our ref	*Your ref*	*Date*
	Project Code UKPNEN02	26 July 2017

Dear Ian,

Letter of support for Active Response project

I am writing in response to the information you have provided about your NIC bid for 2017 – Active Response to Distribution Network Constraints.

At Western Power Distribution we have seen that the update of Low Carbon Technologies is creating a strain on our networks, and that passive networks will not deliver value for money for our customers in a low carbon energy system. To that end we are also very interested in the benefits that power electronics devices can bring to DNOs and to our customers.

As part of our Network Equilibrium project we are demonstrating a Flexible Power Link (FPL): a power electronics device which can control 33kV voltage profiles and allow power to be transferred between two, previously distinct, distribution systems. Once proven and rolled out across GB our FPL method could deliver £449m benefits to customers. We are interested in the novel architecture you are proposing to trial with the Soft Power Bridge and the potential technology cost reductions it could enable. Reducing the FPL method cost would further increase deployment opportunities and deliver even greater savings to customers across GB.

We are also interested in working with you to better understand the deployment opportunities of these technologies at other voltages. As such we will be keen to work through your deliverables looking at trial site selection and roll-out plan to business as usual. This will enable us to adopt successful Active Response products more quickly, to deliver greater benefits to our customers.

We therefore have great interest in Active Response and look forward to working collaboratively with you at UK Power Networks to share learning should your bid be successful.

Yours sincerely,

Jonathan Berry MEng (Hons) MIET
Innovation and Low Carbon Networks Engineer

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RIIO NIC NETWORK INNOVATION COMPETITION

SP ENERGY NETWORKS

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Innovation Lead – Opportunities and Bids
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19th July 2017

Ref: Partnership on Active Response project

Dear Ian,

It has been our pleasure to work with you over the last few months to support the preparation of your NIC bid for 2017 – Active Response to Distribution Network Constraints.

Like UK Power Networks we are committed to finding smart solutions to increase capacity on our network at lowest cost to our customers. Our LV-Engine project, [sourced from a 3rd party call], is focused on a similar area to Active Response by developing power electronic equipment for use on the distribution network. We have seen that the update of Low Carbon Technologies is creating a strain on our networks, and that passive networks will not deliver value for money for our customers in a low carbon energy system.

At SP Energy Networks we believe that the advanced automation and optimisation software and power electronic devices proposed in Active Response would complement the Solid State Transformer technology we are proposing. By being directly involved in the project we can ensure that these products developed during the project are suitable for application within our network. It will also allow us to roll out the Active Response methods more quickly into our business as usual practices, to deliver greater benefits to customers.

To demonstrate our commitment to the project we are pleased to contribute £38,660 in kind and £38,660 of chargeable support as per our agreed collaboration tracker, in support of Active Response which amounts to 100% of our costs associated with this project. We are committed to continue working with you as a project partner on Active Response should the bid be successful.

Yours sincerely

JAMES YU

James Yu,
Future Networks Manager

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Appendix 10.11: Glossary of Terms

Term	Description
ADMD	After Diversity, Maximum Demand
APMP	Association of Project Management Professionals
APRS	Automated Power Restoration System
BaU	Business as Usual
BSP	Bulk Supply Point
CI	Customer Interruptions
CML	Customer Minutes Lost
DNO	Distribution Network Operator
DSO	Distribution System Operator
DSR	Demand Side Response
DG	Distributed Generation
ENA	Electricity Networks Association
FES	Future Energy Scenarios
FPP	Flexible Plug and Play
FPL	Flexible Power Link
GSP	Grid Supply Point
HV	High Voltage (>1000V)
LCL	Low Carbon London
LCNF	Low Carbon Network Fund
LV	Low Voltage (<1000V)
MOSFET	Metal-Oxide-Semiconductor Field Effect Transistor
NIC	Network Innovation Competition
NOP	Normally Open Point
PEP	Project Execution Plan
RCCB	Remote Control Circuit Breaker
RMU	Ring Main Unit
RTU	Remote Terminal Unit
SNS	Smarter Network Storage
SOP	Soft Open Point
SPB	Soft Power Bridge
SPEN	Scottish Power Energy Networks
SSEN	Scottish & Southern Energy Networks
SULVN	Smart Urban LV Networks
WPD	Western Power Distribution