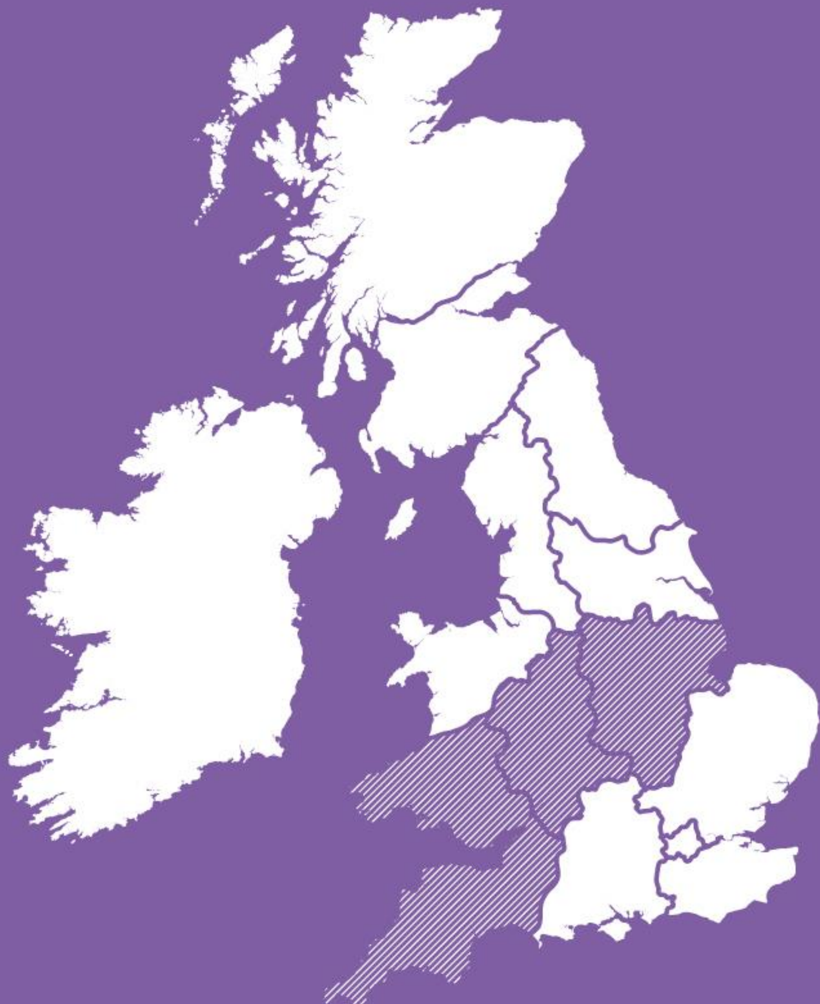
WESTERN POWER DISTRIBUTION

PROTEUS

AGILE TECHNOLOGY FOR FUTURE NETWORKS

Network Innovation Competition 2016

WPD NIC 003



RICARDO

RIIO NIC NETWORK INNOVATION COMPETITION

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RIIO NIC NETWORK INNOVATION COMPETITION

Project Code/Version Number:
WPD NIC 003

Section 1. Project Summary

1.1. Project Title	Proteus
1.2. Project Explanation	With the uptake of low carbon technologies, LV network capacity issues will become more frequent, complex, and difficult to solve. Proteus solutions provide temporary LV network capacity within hours of issues being discovered. They provide network diagnostics and buy time needed to optimise delivery of a permanent solution.
1.3. Funding Licensee:	Western Power Distribution (East Midlands)
1.4. Project Description:	1.4.1. The Problem it is exploring The increasing penetration of Low Carbon Technologies is expected to cause an increase in network capacity issues, and the nature of these issues to become more complex, resulting in traditional approaches to network reinforcement not being appropriate or possible at every location. 1.4.2. The Method that it will use to solve the Problem A mobile package that can be rapidly deployed onto LV networks that are encountering circuit or asset constraints. The package will contain a flexible toolkit of potential temporary solutions to constraints, which is able to autonomously determine and implement the most appropriate configuration, without the need for manual intervention. The diagnostics and network information will be available to support the optimisation of the permanent solution. 1.4.3. The Solution(s) it is looking to reach by applying the Method(s) The method will be capable of solving network capacity issues within hours of them being discovered. The network is then supported, mitigating risk of outage or issues for the customer, until a permanent solution is determined. The solution provides additional time and diagnostics information with which to determine and implement an optimal permanent solution to the constraint(s). 1.4.4. The Benefit(s) of the project The Proteus temporary solution will enable connection of low carbon technologies on a "connect and manage" basis. There is no equivalent solution in use today. This solution can be deployed quickly, operates autonomously once installed, and provides time and diagnostics information to support the optimisation of a permanent solution. The project learning will inform the industry on the use of the technologies and methods included in the solution. Recommendations will be produced to support new Business as Usual applications. This project will be led by Ricardo and is resultant from an open call for projects from WPD.

1.5. Funding			
1.5.1 NIC Funding Request (£k)	7,820.1	*1.5.2 Network Licensee Compulsory Contribution (£k)*	882.2
1.5.3 Network Licensee Extra Contribution (£k)	-	*1.5.4 External Funding – excluding from NICs (£k):*	566.9
1.5.5. Total Project Costs (£k)	9,389.3		
1.6. List of Project Partners, External Funders and Project Supporters (and value of contribution)	Project Partners: Western Power Distribution and Ricardo-AEA Ltd, with Ricardo-AEA Ltd subcontracting to Ricardo UK Ltd, Turbo Power Systems Ltd, Imperial College, and ASH Wireless Electronics Ltd. External Funders: Ricardo ([redacted]), Turbo Power Systems Ltd ([redacted]), Imperial College ([redacted]) Project Supporters:		
1.7 Timescale			
1.7.1. Project Start Date	January 2017	*1.7.2. Project End Date*	January 2021
1.8. Project Manager Contact Details			
1.8.1. Contact Name & Job Title	Simon Terry, Principal Consultant	*1.8.2. Email & Telephone Number*	Simon.terry@ricardo.com 01483 544943 07837 062009
1.8.3. Contact Address	1 Frederick Sanger Road, Surrey Research Park, Guildford, GU2 7YD.		
1.9: Cross Sector Projects (only complete this section if your project is a Cross Sector Project, i.e. involves both the Gas and Electricity NICs).			
1.9.1. Funding Requested 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		

Section 2: Project Description

2.1. Aims and Objectives

The Problem to be Solved by Proteus

The energy requirements of GB society are changing. With the emphasis on reducing impact on the environment, and the development of new technologies, it is anticipated that there will be a significant change in the way energy is used by customers. This includes the uptake of low carbon technologies (LCTs), such as electric vehicles, electric heat pumps, distributed renewable generation, and energy management technologies.

This change in energy use will result in a change in the requirements placed on the electricity distribution networks. The network operators will need tools to adapt and respond to ensure that supplies are maintained at a high quality and an affordable cost.

One of the impacts of the changing future energy demand will be a change in the occurrence and characteristics of network capacity issues, for example, where the system demand exceeds the equipment's designed power carrying capability, or where the network is operating outside of allowed voltage limits. These issues will become more numerous, and will become more dynamic with complex interactions.

Proteus will allow DNOs to adopt a practical "Connect and Manage" approach to connecting LCTs at LV, enabling the most appropriate reinforcements to be identified in terms of both form and location. This will ensure that investments are made in the correct location and timeframe to minimise the risk of stranded assets.

The changing network requirements will mean that the current methods for solving network capacity issues will become less suitable. Figure 2.1 below shows the current method that is used for managing these issues on the low voltage distribution network. It also notes the likely impact of the changing future energy demand on this process.

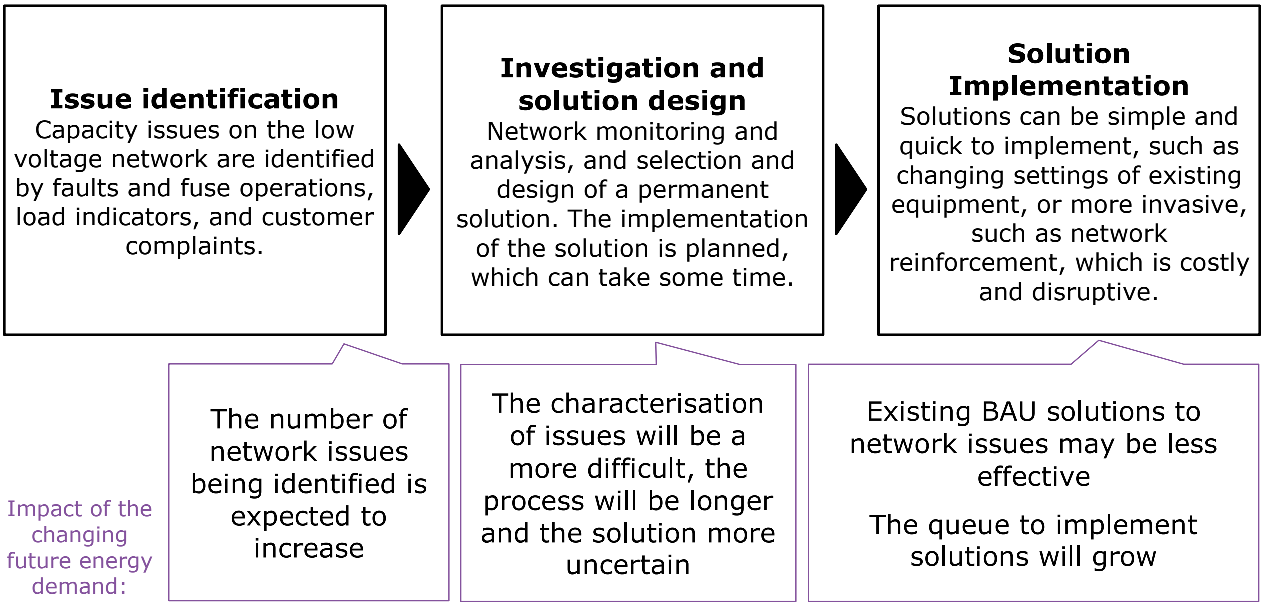

Figure 2.1: Generic method for managing network capacity issues, and the likely impact of the changing future energy demand.

In summary, the impact of the changing future energy demand is:

- **The number of network issues that are identified will increase,** due to changing demand profiles, behaviours, and clustering of LCTs. There will also be increased network visibility and awareness, as a result of smart metering, smart techniques, and active network management technologies.
- **Issue characterisation is a more difficult, and therefore longer, process,** as the characteristics of the capacity issues on the network will change, meaning that learning and experience developed to date will not always apply or be adequate. Identifying the most appropriate solution will be more difficult.
- **Existing Business as Usual (BAU) solutions to network issues may be less effective or relevant**. Solutions such as tap changing, reconfiguration, and reinforcement will not always be adequate to cope with future network issues, particularly where they are dynamic and widespread.
- **The queue to implement solutions will grow** as more problems are being found. This causes a further delay in implementing the solution.

It is anticipated that the combined effect of the factors listed above will be significant, and may emerge rapidly as the adoption of new technologies reaches a critical level. The impact of these will be that the issues are more common, and they take more time to be solved.

Additionally, it is possible that the solution which is then installed is not optimised to the network conditions, as the traditional solutions to these issues (such as reconfiguration or reinforcement) are static solutions which may not be suitable for the very dynamic conditions on the network. Reinforcement can also be costly and disruptive.

A variety of other potential technical solutions to network constraints exist, some of which are used at different voltage levels, or have been developed and trialled as part of innovation projects. For example,

- Power electronics devices, such as Soft Open Points, Unified Power Flow Controllers (UPFC, able to act as a dynamic voltage restorer) and STATCOMs (able to act as phase balancer). Versions of these devices for use on Distribution networks are known as dUPFC and dSTATCOM;
- Energy Storage devices;
- Network meshing through remote controlled circuit breakers and switches at substations and link boxes; and
- Retrofit cooling systems.

However, each site and issue will require a tailored selection from within this range of potential solutions. This necessitates the need for detailed network monitoring, and a prolonged solution design process. This again delays solution implementation, increasing the time where the network and the quality of supply is at risk.

The Method being Enabled by Proteus

The diagram below shows the process which will be enabled by Proteus, and the advantages which will mitigate the challenges caused by the changing future energy demand:

Issue identification ▶ **Temporary Solution, Issue characterisation and solution design** ▶ **Solution Implementation**

Benefits bought by the Proteus solutions:

Benefits from the Temporary Solution include:
- Mitigation of the network issue early, decreasing the impact on customers
- Provision of improved network information for the characterisation of the issue
- Buys time to select, develop, and implement an optimised solution.

Solution selection from a mix of traditional and innovative solutions.

Figure 2.2: Method for managing network capacity issues which is enabled by Proteus, and its benefits.

The process enabled by the Proteus project includes the deployment of a temporary solution to the network issue. The Temporary Solution will be transportable and will be able to be easily retrofitted, which will allow it to be rapidly deployed into the network when a generation or demand issue is identified, even before it is fully understood. The Temporary Solution will be capable of assessing network conditions, and configuring itself to provide the most appropriate support.

The Temporary Solution will be based around a Flexible Capacity Unit (FCU), located at a substation, link box, or directly connected to cables or overhead lines, which is capable of managing local network power and voltage, connecting energy storage or generation capability, and providing retrofit cooling for substation assets. Additional equipment, Dispersed Capacity Units (DCU) may be connected to other points around the network, which will be capable of managing voltage and power flows. The combination of functions which will be needed for each site will vary, and the FCU/DCU will self-configure the suite of solutions to provide the requirements of that site and optimise operations within defined Asset Guarding constraints.

Figure 2.3: Conceptual view of a Proteus Flexible Capacity Unit

The aim will be to be able to install the Temporary Solution within a day of the network issue being identified. In this way, the network issue will be mitigated at an early stage, ensuring that the quality of supply to customers can be restored as early as possible. This will include preventing outages caused by overload, restoring voltages to statutory limits, and improving flicker and other power quality issues. The solution is equally applicable to generation and demand constraints, and provides a dynamic solution to situations where conditions change over the course of hours, days or weeks.

While the Temporary Solution is in place, it will collect detailed information, including power and temperature data from the assets, together with that regarding the performance and effectiveness of the Temporary Solution itself. This will provide the information needed to characterise any network issues, and to select an appropriate solution. The Proteus project will develop a Fast Response tool to be used in the future as part of a strategic approach to correctly targeting reinforcements towards constrained networks.

As the Temporary Solution supports the network while the permanent solution is being designed, this means that there will be time to carefully select and design the permanent solution. This, along with the increased detail of data that will be available, means that the permanent solution can be selected from a wider list of potential solutions, which will include traditional and more innovative options. This will enable the selection to be optimised for the network issue.

The Development and Demonstration Being Undertaken by Proteus

The Proteus project will be delivered in five work packages:

- **WS1: Technology Development and Deployment:** includes the tasks in which the technology is developed, including scoping, requirements, design, development, prototyping, and test. A first demonstration solution will be produced in order to carry out pre-deployment testing, and an initial deployment. The learning from these activities will be used to develop a second demonstration solution which optimises the equipment both from a technical and a physical layout perspective.
- **WS2: Logic and Control Development:** will develop the support and software elements of the overall solution, including the network monitoring, local autonomous logic and control capability, and the remote data management and control system.
- **WS3: Trials and Analysis:** includes the design and management of the field trials for the Proteus solution, and the analysis of the data to characterise and understand the operation of the equipment and its benefits to the network.
- **WS4: Project Reporting and Recommendations:** includes the development of regular reports for the project, as well as the management of the deliverables and SDRCs. It also includes the peer review process for the analysis and conclusions within the project, and the development of the recommendations for the business as usual implementation of the project learnings, including a proposed deployment and operations process.
- **WS5: Learning and Dissemination:** ensures that learning from the project is collected and communicated to be leveraged by all GB network licensees and other industry bodies. For this reason, there is a central set of tasks included under this work stream which will run for the duration of the project.

Proteus will deliver the following key outcomes:

- Development of integrated hardware and software for temporary flexible capacity solution;
- Learning in its deployment and operation, including a cost benefit analysis, and a comparison against the business case incorporating operational experience;
- Methodology for selecting an optimised permanent capacity solution to network issues, given data obtained from the flexible Temporary Solution;
- Recommendations for implementation of the Proteus learning to business as usual;
- Stakeholder dissemination highlighting technical advances as well as the existing and future problem we are looking to solve; and
- Produce a road map for development of full production model.

The Solution

The objective of the Proteus project is to:

- Engineer and demonstrate the concept solution in simulated and real world conditions
- Gather and disseminate measured temporal data on network operating parameters where excursions from statutory or asset guarding constraints as well as where transient fault conditions are known or suspected.
- Refine and confirm or refute the viability of the PROTEUS business case in light of project experience
- Determine the next steps after the project
- Detail the transition process for the solution into BaU

By 2050 we estimate that the Proteus solution will be expected to have delivered the following GB wide benefits:

Cumulative Financial Savings up to 2050	**£406.6m**
Capacity Released in the year 2050	**58,000 kVA**
Cumulative Reduction in Carbon Emissions up to 2050	**7,131 tCO2e**

These benefits are derived in Section 3 of this document.

2.2. Technical description of Project

This section provides a technical overview of the solution being developed by Proteus. A more detailed explanation can be found in Appendix D.

Proteus will develop a method of providing temporary, flexible, and deployable capacity solutions for the low voltage electricity network, which can be implemented more quickly than the solutions currently being used, and can adapt autonomously to the requirements of the network. Proteus will also propose a methodology for selected the most appropriate permanent solution, which can be optimised for cost and performance, from a range of possible traditional and innovative methods.

The Proteus Temporary Flexible Capacity Solution and Network Monitoring

The Proteus project will develop temporary flexible capacity solutions which are capable of meeting the following high level requirements:

- **Deployable** – the solution will be portable, and will be able to be easily transported to, secured at, and connected into the network at the required site.
- **Flexible** – the solution will be able to configure to the requirements of the site, including the following capabilities:
    - Control of real and reactive power flows of the substation feeders;
    - Control of voltage on substation feeders;
    - Connection of additional generation or storage;

  - Control of the loading of network assets;
  - Retrofit cooling of network assets; and
  - Additional benefits, including control of islanded networks, harmonics and mitigation of phase unbalance will also be possible with the equipment.
- **Linked** – Network and solution operational data will be communicated by a meshed wireless system and stored in a data management module, to enable performance to be analysed through post-processing. The data collection will include all data required to develop a tailored permanent solution to the network issue.
- **Autonomous, with remote management** – the solution will be autonomous, it will be able to configure and control its operation, to maximise benefits and maintain safety without requiring a complex installation procedure or manual intervention once installed. The operation of the units can be remotely monitored, and the settings, such as operating mode and set points will be remotely configurable.
- **Re-deployable** – Once the solution is no longer needed at a site, it can be easily disconnected and moved to another site, or stored for the next requirement.

The non-invasive network and asset monitoring systems will be capable of collecting the data required to understand the characteristics of the issue, including complex power flows, asset and ambient temperature measurements, accurate location and timing capabilities.

The configuration of the solution is illustrated in the diagram below.

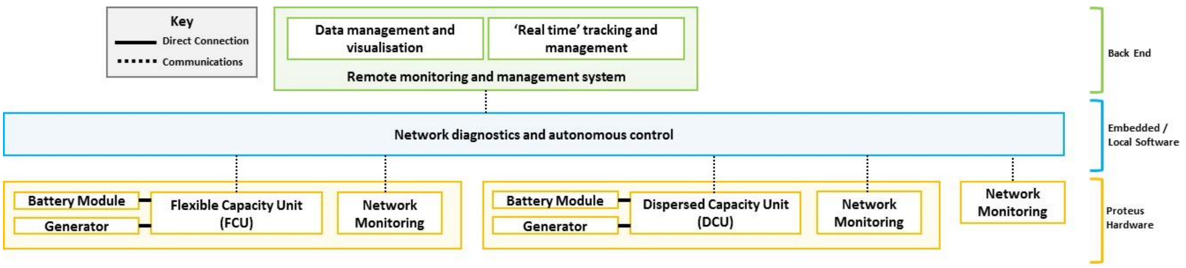

Figure 2.4: The Proteus temporary solution and its associated modules.

This solution is based on a central piece of equipment – the Flexible Capacity Unit (FCU). This unit is capable of carrying out the following functions:

- Control of the loading of network assets;
- Complementary use of generation or storage;
- Retrofit cooling of network assets;
- Equalisation of network loading with nearby connected substations; and
- Control of power quality characteristics, including harmonics, phase unbalance, and voltage.

These functions can be used individually, or in combination with each other, and this capability can be configured on installation, remotely, or autonomously. This provides a high level of flexibility in the solution, allowing it to autonomously adapt to the network characteristics as needed. The FCU will work in combination with network diagnostic equipment and/or a DCU to provide an optimal solution.

The Permanent Network Capacity Solution

The project will develop a methodology by which a permanent solution to network issues can be selected. This selection will be based on an optimisation of the costs and benefits, given a detailed understanding of the network requirements, and can include conventional and innovative options.

There has already been significant work into the development of innovative network capacity methods carried out as part of innovation projects. This includes:

- **Soft Open Points and flexible interconnection of networks** – this is explored in the Flexible Urban Network – LV project, which is led by UK Power Networks. Ricardo has a significant technical and task lead role in this project, and Turbo Power Systems provided much of the technology equipment.
- **Battery storage** – this has been explored through a number of recent projects, including FALCON, which was led by WPD.
- **Retrofit cooling of assets** – this is being explored by Celsius, led by Electricity North West. Ricardo has a significant technical and task lead role in this project.

Proteus aims to build on this understanding, and develop a methodology for assessing and selecting the most suitable solution for a given network issue. In developing the selection methodology, Proteus may uncover areas where there is inadequate information about a particular solution. Cases where these cannot be solved within the Proteus project will be identified, and potential solutions described.

Proteus will not implement any permanent solutions within the project. However, where constraints are identified, WPD may use the learnings from Proteus to develop and implement permanent solutions.

2.3. Description of Design of Trials

Technology Development and Deployment

The Proteus project activities are designed in such a way to enable the solution to be developed and improved throughout the project. The initial step of the project is an Inception phase to undertake the detailed design, where each component within the integrated solution is specified and this is shared between project partners to ensure that the designed solution is suitable and holistic. Where equipment is not being supplied by a project partner, a tendering exercise will be undertaken to ensure value for money is obtained.

Once the inception phase is complete, the project will produce a first demonstration solution in order to carry out pre-deployment testing, and an initial deployment. Learning from the production, testing, deployment and trial of this first solution will be used to develop a second demonstration solution.

The most appropriate UK test facility (e.g. NAREC, Ricardo's Shoreham Technical Centre, a WPD test location) will be selected to enable component testing as the solution is being developed, and testing of the complete solution. This will demonstrate:

- That the system is safe to install onto the live network;
- That the system functions as expected, including the local and remote control, data collection and autonomous systems are functioning correctly; and
- The commissioning and decommissioning process is understood and safe.

The technology will be supported to identify issues and improvements, for example software upgrades or minor hardware alterations, and where possible, subject to budget, these will be implemented within the project.

Proteus Logic and Control

The local autonomous logic and control capability is a key part of the project solution, as it will optimise the operation of the Proteus technology. Once installed, the solution will be capable of autonomously determining and implementing the most effective configurations and set points in real time, without the need for manual intervention.

It processes network information and monitoring data to determine functions, operation modes and set points. A decision making algorithm (such as a decision tree) will be used to determine the most suitable installation locations, functionality and set points for the Proteus equipment in each deployment, enabling the installation configuration to be tailored to the needs of the network.

Once installed, the technology will be able to continuously react to the directions communicated by the logic in response to changing network conditions. Data and information will be shared with the remote management system.

The remote data management and control system will enable users to track real time performance of the Proteus solution, and implement certain control actions, such as changing modes and set points, or changing the configuration of the technology to validate or enhance performance. This system will not allow real time operational control, as this will be done locally. The management system will also collect and log the historical data, and visualise this so that users can understand historical performance. The data will be available to download so that it can be analysed in more detail.

Trials and Analysis

The trials to demonstrate the Proteus solution and network monitoring will be designed to demonstrate the key requirements of the solution, including its technical performance, its ability to adapt to network requirements, and its ability to be quickly deployed and re-deployed.

The Proteus solution will first be demonstrated on a test network, to ensure correct operation and functionality. Subsequently field trials will involve the installation of the Proteus solution on a selected site, and its operation to alleviate real and simulated network issues, demonstrating the equipment functionality. The equipment will remain installed on a site for approximately 4 months before it is moved to another site. This will enable the demonstration of the mobile nature of the equipment, and its satisfactory use in a wide range of locations.

The trials will be split into three phases:

- **Trial Phase 1:** this will trial the first demonstration solution, to understand its performance against the requirements, and enabling learning to be gathered. This phase is approximately 1 year long, and will be characterised by a process of learning and investigation. Each installation will be in place for approximately 3 months before being moved to an alternative site, enabling the mobility of the solution to be tested, and demonstration at a wide variety of sites.
- **Trial Phase 2:** this will trial both the first and second demonstration solutions, and will prove the performance of the technology against the requirements. This phase is approximately 6 months long, and will be characterised by demonstration and data analysis to prove the technology against the requirements. Each installation will be in place for approximately 3 months before being moved to an alternative site, enabling the mobility of the solution to be tested, and demonstration at a wide variety of sites.

- **Trial Phase 3:** this will use the technology in a representative demonstration, where it is deployed at a site with real or simulated network capacity issues, and with simulated time pressures, limited existing information, and no previous work. The technology will be used to temporarily solve the issue, and characterise it so that a permanent solution can be found. This phase of the trial will last for 6 months, and each installation will be in place for approximately 3 months before moving on the next site.

Selection of trial sites will be determined by a process based upon the following criteria for the first and second phases:

1. Those with a well-known architecture that is suitable for demonstrating the various functions of the equipment;
2. Suitable practical and logistical arrangements for locating the equipment; and
3. Those with network parameters (voltage and demand profiles, equipment temperatures etc.), that can be influenced by the equipment without significant risk of infringing equipment design or statutory limits.

The third phase of trials will use the following criteria for site selection:

1. Suitable practical and logistical arrangements for locating the equipment; and
2. Those with network parameters (voltage and demand profiles, equipment temperatures etc.), that are approaching design or statutory limits such that the ability of the equipment to improve the situation can be assessed.

Site Selection will be done after the inception phase is complete, such that the physical and logistical considerations of the units are well understood.

The trials data will be analysed to assess the performance of the equipment, and its benefits, including a cost benefit analysis of the solution in general.

Peer Review and Recommendations

A key task within the project will be to carry out an independent peer review, by another DNO. This will be an ongoing process throughout the project, and will specifically cover:

- The requirements and design documentation for the temporary flexible capacity solution and network monitoring;
- The analysis of the trial data and the conclusions drawn; and
- The cost benefit analysis for the flexible capacity solution.

This will ensure that Proteus develops deliverables which are relevant and useful not only for WPD, but across the GB distribution networks. It was identified that this role would be best filled by another DNO. UK Power Networks will undertake this role, and are particularly well placed to do so as they have led a number of related innovation projects, most notably Flexible Urban Networks-LV, Distribution Network Visibility and Low Carbon London, bringing with them the experience from these projects.

Proteus will develop recommendations for implementing the learnings of the project into business as usual operation of the network. These recommendations will be intended to be taken advantage of by all GB network operators.

The first part of the recommendations that will be developed will consider the processes and procedures that would enable the temporary capacity solution to be used within the network. This will include selection of the most relevant sites and situations that it can be used, and the procedures for deployment, commissioning, operation, and removal once a permanent solution has been established. Also included will be recommendations for development of the solution into a fully developed product, and options for standalone modules, such that the available benefits can be realised across UK distribution networks.

Secondly, the project will develop recommendations as to how a permanent solution can be selected from a wider range of traditional and innovative methods, including those based on the Proteus functionalities. This will aim to provide information on suitability and limitations of each solution, its likely cost, and the estimated benefits. It is likely that there will be inadequate information on some of the methods in order to provide a fully detailed methodology and where information is missing, this will be highlighted and recommendations for further work made.

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 more cost information available from project partners, the implementation costs are now £9.4m.

Section 3: Project Business Case

3.1. Introduction

The Proteus solution has the potential to bring significant benefits in network capacity issues which are beyond the capabilities of today's business as usual experience in scale, complexity, or solution requirements. In these situations, the Proteus solution can:

- Be deployed quickly to appropriate issues arising on the network;
- Provide a flexible solution which can be autonomously adapted to suit a wide variety of applications;
- Collect relevant data with which to automatically characterise the network issue, and enable permanent solutions, and
- Remain in place, alleviating the issues, while the permanent solution is being designed and planned.

The Proteus business case was carried out in order to quantify the potential benefits of the Proteus methods, if the Proteus project is carried out and the learning implemented throughout the GB networks. These benefits could include financial benefits, capacity released, and carbon savings, which are calculated on an individual scale, a licensee scale, and a GB wide scale, up to 2050. The methodology and results of this assessment is summarised below, and explained in more detail in Appendix C. No Direct Benefits are anticipated during the lifespan of the project.

3.2. Business Case Methodology

The business case compares two cases: Base Case and Proteus Case. These are summarised below:

Base Case	Proteus Case
An extension of today's process for dealing with LV network capacity issues, identified through fuse operation, demand indicators, or customer complaints. • Process: network monitoring, analysis, permanent solution design, and implementation of the permanent solution. • Length of time from identification before power quality is restored to customers: 1 to 12 months • Estimated Cost of investigating and planning permanent solution: £5k • Permanent solutions implemented: A mix of traditional solutions, becoming more costly and disruptive as the network issues become more complex over time.	**The process enabled by the Proteus project.** • Process: deploying a temporary solution which also provides information, and buys time, for a permanent solution to be selected from a list of traditional and innovative solutions. • Length of time from identification before power quality is restored to customers: 2 days • Estimated Cost of investigating and planning permanent solution: £10k • Permanent solutions implemented: A mix of both traditional and innovative solutions, optimised by cost and requirement of the network.

For each case, the costs (including capital, resource, materials, and operation and maintenance) are estimated. For the base case costs, this is based on experience of today's processes. The Proteus costs are estimated based on the cost of equipment today, and assumptions of how this will reduce based on volume production.

The reduction in the period of time where the network is at risk, which is enabled by use of the Temporary Solution, has financial benefits in the form of reduced interruptions, caused by fuse operations or thermal faults. This benefit is estimated based on experience of overloading issues.

Assumptions are made as to the range, mix, and cost of permanent solutions which are implemented in the Base and Proteus cases.

The key applications for the Proteus process will be complex network capacity issues that are brought about by the adoption of low carbon technologies and behaviours within the users of the low voltage electricity network. The business case focuses on applications for issues caused by overloading of the low voltage network.

There are a number of sources which have developed forecasts for the impact of the uptake of low carbon technologies and behaviours. The Proteus business case uses the results of the Transform model to develop its conclusions.

The Transform Model is a techno-economic model initiated by BEIS (formally DECC) to determine the level of electrical network investment required to support the take up of LCTs. It uses a range of scenarios to show the range of likely futures. The graph below shows the cumulative number of substations which are expected to be overloaded over Great Britain scale over the range of scenarios modelled:

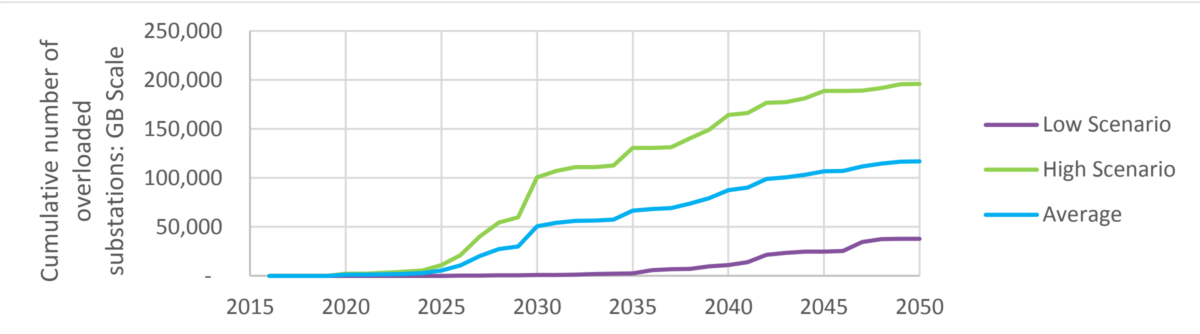

Figure 3.1: The number of substations which are expected to be overloaded over Great Britain scale over the range of scenarios modelled

For the purposes of the business case modelling, the highest and lowest scenarios are modelled to give a range of potential results, and an average is then found.

3.3. Financial Benefits

Single Solution

For the purposes of the business case, an 'individual deployment' of the Proteus solution is a single temporary solution, which is deployed and re-deployed many times. The solution is used at an average of 3 times per year (this will vary dependent on circumstances, but 3 is taken as an average), and has a lifetime of 15 years. The life of the solution will start one year after the completion of the project, at the start of 2022.

The base case for the purposes of the single implementation will represent the process that would be adopted for the three network issues per year if the Proteus project learnings were not available.

The graph below compares the Base and Proteus cases over time, showing cumulative costs over the long term. The space between the curves on the chart represents the estimated cumulative benefits.

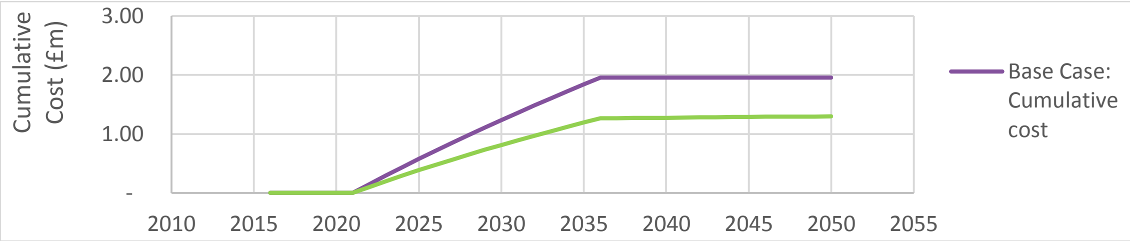

Figure 3.2: Comparison of the cumulative cost of the Base Case and Proteus Case for a single solution scale of the Proteus Solution with a lifetime of 15 years.

The table below shows the Base and Proteus Case cumulative costs for a single solution scale, and the estimated cost benefit of the Proteus Solution over the Base Case.

	Base Case (£m)	Proteus Case (£m)	Estimated Benefit (£m)
2030	1.24	0.81	0.42
2040	1.96	1.27	0.68
2050	1.96	1.30	0.66

GB Scale and WPD Scale

The GB and Licensee scales are calculated using the same base case and Proteus case assumptions described above. The number of deployments in the cases is based on the results of the Transform model, as explained above. This model gives values for GB scale issues. The WPD scale deployment is based on the results of the Transform model, assuming that the issues identified by the model are spread evenly across the networks.

In order for the Proteus case to be applied in each of these sites, multiple solutions will need to be in use at once. It is assumed that there is an initial roll out of equipment, with the average case describing 75 units being adopted across GB in 2022, which can then double each year until the solution numbers reach either the required need predicted by the Transform analysis, or the assumed organisational limit to the number of units adopted, which is just over 1,500 across GB.

In the WPD area, the number of solutions adopted over time is 180, and the total number of sites where the solution is implemented is 8,641 up to the year 2050. For the GB scale, the number of solutions to be used was modelled as 557, and the total number of sites where the solutions is implemented is 26,740.

The table below shows the difference between the Base and Proteus Case cumulative costs for a WPD scale and GB scale implementation. It shows the result of the analysis given the minimum and maximum scenario results from the Transform model, and the calculated average.

	Low Scenario Benefit (£m)	High Scenario Benefit (£m)	Average Estimated Benefit (£m)
WPD Scale			
2030	5.3	53.3	29.3
2040	43.6	112.5	78.0
2050	**95.8**	**167.0**	**131.4**
GB Scale			
2030	16.5	165.1	90.8
2040	134.8	348.2	241.5
2050	**296.6**	**516.7**	**406.6**

Breakeven Analysis

A further step to the assessment of the financial business case is the breakeven analysis. This was carried out to assess the value for money to the customer of the funding requested for the Proteus project. In order to carry this out, the funding of the project and the subsequent roll out of the learnings is compared with the cost benefits over time, and a 'breakeven point' is calculated. This analysis is calculated from the point of view of the customers, and therefore includes funding requested from Ofgem, and funds invested by DNOs.

The diagram below shows the breakeven analysis results for the GB scale roll out of the project learnings. The bars represent the breakeven position of the project, where negative numbers show that the project has not yet broken even. The green positive bars show that the project has gone beyond the breakeven point. In this case, the breakeven point is between 2023 and 2024.

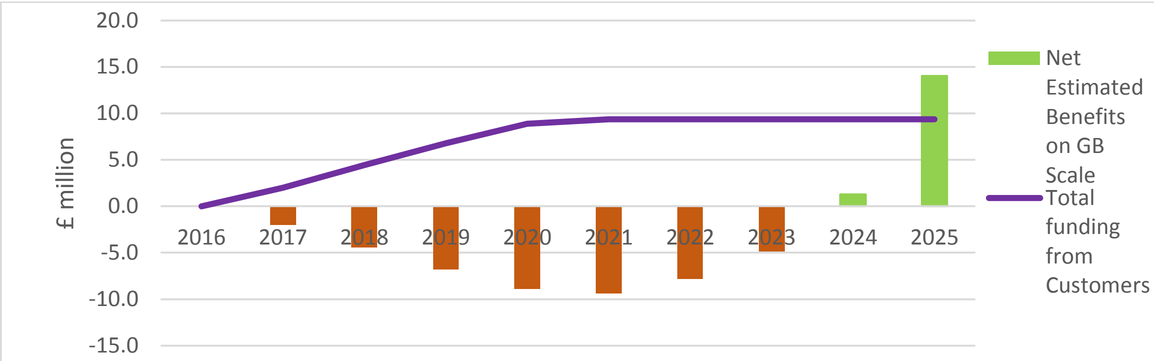

Figure 3.3: Breakeven analysis results, showing the customer investment and estimated benefits of Proteus. The breakeven point occurs between the years 2023 and 2024.

3.4. Capacity Release

The use of the Proteus solution enables the use of network capacity as a result of the operation of the Temporary Solution. Though the permanent solution selected may be different in the Proteus Case when compared to the Base Case, it is assumed that the capacity released in these solutions will be comparable.

It is possible that the Temporary Solution could provide considerable capacity release to the local network while it is installed, where the network situation requires it. The limit for this is the rating of the network conductors themselves, and that of the Temporary Solution equipment. On this basis, it is estimated that while installed, the solution will be capable of releasing an average additional 200 kVA capacity for a distribution substation. This capacity will be available for the duration for which the Temporary Solution is installed, which is assumed to be an average of 3 months, with each solution being deployed 3 times per year.

The table below shows the averaged estimated capacity released due to the implementation of the Temporary Solution, for a single solution, over the WPD network, and at GB scale. As our model uses an uneven and clustered profile of network issues, the numbers in the table below are taken from the average trend line (See Appendix C and figure C.8).

Annual Average Capacity Release (kVA)	2030	2040	2050
Single Implementation	150	-	-
WPD Scale*	16,000	17,000	18,000
GB Scale*	48,000	54,000	58,000

** The GB and WPD scale are the averages of the high and low scenarios.*

The capacity release shown in the table are relatively small, which reflects the fact that the capacity release is temporary, and is removed once a permanent solution is implemented. Therefore, the capacity release is not cumulated over time.

However, as the driver for this solution is to provide valuable, rapid temporary capacity focused in locations where it is needed, in order to connect and manage LCTs and maintain the customer supply and power quality, the value of the capacity that is released is significant.

3.5. Environmental Benefits

The environmental impact of Proteus and the solutions that it enables can be considered in two key ways:

- **Direct Environmental Benefits**, which compares the carbon impact of the Base Case and the Proteus Case; and
- **Indirect Environmental Benefits**, which considers the wider impact of a solution such as that enabled by Proteus.

Direct Environmental Benefits

The assessment of the environmental benefits has been carried out using the Base Case and Proteus Case as described in the sections above.

The key source of environmental benefit of the Proteus Case, when compared to the Base Case, is the prevention of stranded assets. Stranded assets are when network reinforcement is implemented when it was not truly needed, for example if the cause of the issue was only temporary or when a simpler solution would be as effective, but was not apparent with limited information. The Proteus methods will be capable of preventing this happening, therefore saving the associated carbon cost of that reinforcement.

Additional carbon benefits may be seen in the optimisation of the permanent solution developed to network capacity issues. The key carbon cost of the Proteus solution is the embedded and operating carbon of the Temporary Solution itself.

Quantifying environmental impacts is a difficult task, and it is only practical to produce estimated figures. For the purpose of this section of the business case, the carbon dioxide equivalent figures for the aspects above were estimated based on figures for similar activities, and the carbon impact of the base case and the Proteus case estimated. The results of this analysis is given in the table below:

Carbon Benefit (tCO2e)	2030	2040	2050
Single Implementation	7	12	12
WPD Scale*	503	1,358	2,304
GB Scale*	1,555	4,201	7,131

** The GB and WPD scale are the averages of the high and low scenarios.*

Indirect Environmental Benefits

The key objective of Proteus is to enable the adoption of low carbon technologies 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:

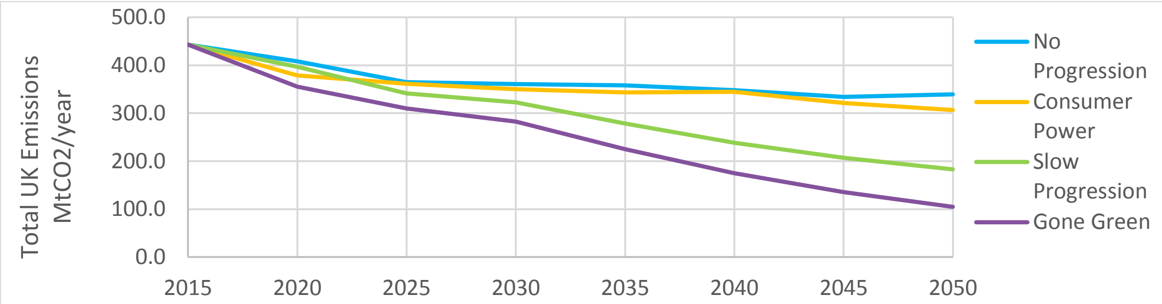

Figure 3.4: Total UK Emissions forecasted up to 2050, from the Future Energy Scenarios developed by National Grid.

Proteus is capable of supporting and enabling these carbon savings, by enabling the adoption of low carbon technologies and behaviours. Without these or similar tools, the uptake of such technologies may be restricted, for example by restricting their affordable connection.

Therefore, though it is not possible to quantify the exact contribution that Proteus makes to the low carbon futures described in the Future Energy Scenarios, some of these benefits can be seen as being enabled by the Proteus methods.

3.6. Other Benefits

There are other significant benefits which are not described as cost, capacity, or carbon benefits. These include:

- **The benefit to the customer of network issues being mitigated quickly:** These issues would otherwise have been causing quality or reliability of supply issues for these customers.
- **Other potential applications of the Temporary Solution:** These include temporary issues, or issues which are reoccurring but rare. In these cases, the Temporary Solution can be used to prevent the need for permanent solutions entirely, while supporting the network and maintaining quality of supply to customers.
- **Other potential applications of the learning developed within Proteus:** The components of the Temporary Solution are able to be used within the development of a permanent solution, and the learning from the project and its application can be used to further develop these components which would support the development of the permanent solution in parallel.
- **Increased network visibility:** The improved network information and data not only enables the optimisation of permanent solution selection and design, but also enables increased visibility of the network for the discovery of any hidden behaviour.

Section 4: Benefits, Timeliness, and Partners

(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

Over the next decade and beyond, greater numbers of customers will access the benefits of low carbon technologies (LCTs), such as photo-voltaics, electric vehicles and heat pumps. These technologies will greatly impact the capacity and performance that is expected from the electricity distribution network. As the demand changes, there is expected to be an increase in technical constraints, where the networks and their equipment are no longer performing within their designed ratings or within the statutory voltage range.

The traditional processes of identifying, characterising, and solving these constraints can be lengthy, and therefore it may be months before the issue is fixed. In the meantime, the issue is ongoing, causing the quality of supply to customers to be affected. With clustering of low carbon technologies many more such constraints and excursions from normal operations can be anticipated.

Proteus aims to develop a process and a solution that solves network issues on a temporary basis, which can be rolled out as soon as an issue is identified, and can remain in place until a permanent solution can be found. It also aims to develop a process by which an efficient permanent solution can be selected from a wider range of potential technologies, including traditional and more innovative methods, thereby potentially providing more appropriate or lower cost solutions.

Contributing to the Carbon Plan

Proteus will deliver a Temporary Solution to thermal and voltage constraints that occur on LV networks as a result of the expected increase in the number of connected LCTs. The projects contribution to the carbon plan is therefore to allow these connections to continue unencumbered by delays as network constraints are removed by traditional reinforcement techniques. The use of LCTs over conventional technologies (Petrol or Diesel vehicles, Gas fired boilers, etc.) will play a major role in the reduction of carbon emissions.

LCT connections to LV networks are generally made without any prior notification to the DNO, meaning that there is not sufficient time to determine the effect on the network before it is realised.

Currently the number of LCT connections is relatively low and the impact is limited, as the existing spare capacity and tolerances available within networks is sufficient to accommodate the changes. However, with the expected increase to the number of LCT connections, and as the existing spare capacity is eroded, significant reinforcement work will be required to allow LCTs to connect.

Without prior notification of connections DNOs will be tasked with planning and operating their networks against a rapidly and significantly changing utilisation profile.

To ensure that networks continue to operate in a safe manner may require pre-emptive reinforcement works, based on assumptions about which LCTs will connect, where and when. However, this may lead to sub-optimal reinforcements, and areas of the network at risk, if the reality does not closely match the assumed position.

In order to achieve the dynamic capabilities of the networks that will be required when a high volume of LCTs are connected, the type of reinforcement works required may, in some cases, be substantial. For example, additional HV feeders, new secondary substations, etc. Hence the time and cost required to plan and implement network projects of this type is greater than for more straightforward work, and the risk associated with reinforcing based on an uncertain system need is more severe.

To counteract this, a process whereby prior notice of connection may be required. However, this may cause delays to those wishing to connect, whilst reinforcement work is carried out. Overall this may lead to an overall reduction in the number of LCTs able to connect to networks, and consequently a lower level of uptake from that required to meet emission reduction targets.

The Proteus solution is designed to enable LCTs connections to continue unencumbered, so that network limitations do not restrict uptake. Network constraints can be identified and resolved rapidly, whilst providing more information to enable an effective reinforcement to be planned and installed.

The additional information obtained by the solution ensures that the maximum use of the existing assets can be obtained, without infringing on design tolerances. In some instances, it may be determined that due to the short term nature of the constraint condition the permanent reinforcement option is less substantial than initially assumed.

The solution therefore contributes to the carbon plan by removing a potential limit on the number of LCTs able to connect, whilst ensuring that network reinforcement is carried out in an effective and efficient manner. The solution is applicable across GB, meaning that the potential carbon benefits are also.

WPD has a proven track record in turning Innovation into Business as Usual. This is demonstrated by the following, which have already been rolled out across the business:

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

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

Releasing Network Capacity

The Proteus solution is intended to relieve thermal and voltage constraints, releasing network capacity and maximising the use of existing assets.

It is estimated that the system will release an average of 200kVA of capacity per use through use of the Power Electronic devices, though this will vary in each deployment. Capacity may also be released up to that of the rating of the battery module (100kW) or that of a connected diesel generator.

The Proteus solution has been developed for the anticipated scenario where the uptake of LCTs is at a scale where the current techniques for releasing this capacity are no longer effective. The existing process relies upon low levels of LCT connections and the existing spare capacity currently available in LV networks such that small scale reinforcement projects can be implemented over the course of several months once a constraint has been identified.

With wide scale adoption of LCTs, and the ongoing erosion of the spare capacity, this approach is no longer suitable without putting network equipment and customers' supplies at risk. Increasing the capacity of LV networks at this point requires more significant reinforcement work on the upstream High Voltage networks, which is both more costly and time consuming than LV reinforcement.

The Proteus project will provide a temporary solution to a given network constraint, until such time as an effective permanent solution can be planned and implemented. The solution will also provide additional information, to inform the reinforcement planning process.

As such it is not appropriate to compare the Proteus solution against other capacity release techniques, as they are complementary. The Proteus toolkit will inform and provide time for the existing techniques to take place efficiently, whilst enabling networks to continue running reliably and safely, absorbing the impact of LCTs.

The solution is designed to be scalable at the point that it is needed, with the project demonstrating the concept and its effectiveness. When the anticipated scenario of an uptake of LCTs beyond the capability of the networks emerges the required number of solutions can be produced and delivered to those locations where they are needed.

Environmental Benefits

The environmental benefits from the Proteus project come from its roles as an enabling technology to ensure that the adoption of LCTs by consumers is not restricted by network constraints. The adoption of these technologies are documented in sections 1.11 and 1.12 of The Carbon Plan[1] as being priorities to reduce emissions and achieve the transition to a low carbon economy. Heating and powering of buildings is estimated to produce 38% of the UKs 2009 emissions, and transport 24%.

The environmental benefits enabled by the Proteus project are outlined in detail in Section 3, Appendix B and Appendix C of this document.

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[1] The Carbon Plan, 2011

Financial Benefits

The Proteus solution is designed to be complementary to other techniques for reinforcing networks to provide additional capability. As such a base case solution cost is still incurred, with a reduced possibility of the networks being operated outside of allowable limits before the permanent solution is installed.

The estimated financial benefits enabled by the Proteus project are outlined in detail in Section 3, Appendix B and Appendix C of this document.

(b) Provides value for money to electricity distribution/transmission Customers

The project costs for each project stage are summarised below:

Project Stage	**Staffing costs**	**Equipment costs**	**Other costs**	**Total costs**
Inception	[redacted]	[redacted]	[redacted]	[redacted]
Phase 1	[redacted]	[redacted]	[redacted]	[redacted]
Phase 2	[redacted]	[redacted]	[redacted]	[redacted]
Total	[redacted]	[redacted]	[redacted]	[redacted]

These costs have been put together on the basis of estimates provided by each partner company. The staffing numbers and costs are detailed in the tables below.

WPD Staffing Project Stage	**Staffing numbers (FTE)**	**Staffing hours**	**Average cost per day**	**Total staff cost**
Inception phase	[redacted]	[redacted]	[redacted]	[redacted]
Phase 1	[redacted]	[redacted]	[redacted]	[redacted]
Phase 2	[redacted]	[redacted]	[redacted]	[redacted]
Total	[redacted]	[redacted]	[redacted]	[redacted]

Ricardo Staffing Project Stage	**Staffing numbers (FTE)**	**Staffing hours**	**Average cost per day**	**Total staff cost**
Inception phase	[redacted]	[redacted]	[redacted]	[redacted]
Phase 1	[redacted]	[redacted]	[redacted]	[redacted]
Phase 2	[redacted]	[redacted]	[redacted]	[redacted]
Total	[redacted]	[redacted]	[redacted]	[redacted]

Total Staffing Project Stage	**Staffing numbers (FTE)**	**Staffing hours**	**Average cost per day**	**Total staff cost**
Inception phase	[redacted]	[redacted]	[redacted]	[redacted]
Phase 1	[redacted]	[redacted]	[redacted]	[redacted]
Phase 2	[redacted]	[redacted]	[redacted]	[redacted]
Total	[redacted]	[redacted]	[redacted]	[redacted]

Justification of Project Cost

The project will trial a solution for a scenario that will have a direct impact on LV networks across GB with increasing LCT uptake. The costs expended by the project over its lifetime will provide practical experience and learning directly relevant to the production of a commercial solution.

As circumstances develop, and when the need for the solution arises, the solutions can be produced in a unit by unit manner, such that the estimated benefits are delivered as and when they are required. All of the estimated benefits will be realised within electricity networks, by securing customer supplies and ensuring efficient network development.

Ricardo is committed to financial return for the consumer and proposes that, in addition to the benefits already discussed in detail in this document, a monetary return of up to 5% of the revenue from each PROTEUS unit it sells, limited at up to 120% of the Ofgem funding, is returned to the consumer via WPD. This commitment from Ricardo acknowledges the risk of funding innovative projects, providing a growth on original investment on completion of a successful project, and also the project team's view that PROTEUS can make a difference.

Process to Ensure a Competitive Cost

The project will be delivered using carefully selected project partners and suppliers.

Where possible key partners have been selected that bring valuable experience from recent LCNF/NIC projects. Therefore time spent developing and improving the Proteus building block solutions is not a repetition of work done previously by others. The experience and learning from previous projects will directly benefit this project. For example:

- Turbo Power Systems Ltd (TPS) have been selected to provide the Power Electronics for the project. TPS have supplied this equipment to UKPN's Flexible Urban Networks – LV (FUN-LV) project and as such have developed and produced Power Electronics suitable for use in public distribution networks. The devices used in this project will be an evolution of the existing devices, offering significant improvements such as reduced noise, less weight, lower losses and the ability to operate in a number of different modes. The knowledge acquired on FUN-LV is crucial to allow the development of the Power Electronics such that it is suitable for use on Proteus. Use of an alternative supplier would necessitate significant additional development time and trial units that would not represent the best use of project funds.
- Imperial College will provide the systems logic and control algorithms as they have previously done for FUN-LV. Similarly, the knowledge and experience gained by Imperial College on FUN-LV offers Proteus the opportunity to maximise the development of these systems, building on the previous work.
- ASH Wireless Electronics Ltd are currently engaged providing monitoring equipment to Celsius, a project led by Electricity North West. As such ASH have accrued valuable knowledge and experience with regard to providing data and communication systems appropriate for use on public distribution networks. The use of ASH Wireless Electronics offers Proteus benefits by not repeating elements of the learning curve with a new supplier.

All potential project partners will be subject to a due diligence process prior to contractual agreement, following project award.

A major element of innovation in this project is the packaging, connectivity and integration of the required technologies into mobile and secure units, suitable for use on public distribution networks. The Ricardo group bring a wealth of experience in this area, having worked previously in other sectors, e.g. Automotive, where the integration of discrete components into finished systems is critical to project success. The form of the finished product is of paramount in this application and Ricardo bring valuable expertise from their cross-sector knowledge, together with significant power network knowledge and LCNF/NIC project experience.

Where equipment is available "off the shelf" from a number of suppliers, a competitive tender process will be enacted to enable the most cost effective and most suitable solutions to be obtained. Use of existing suitable WPD Framework Agreements suppliers will be considered if appropriate.

(c) Generates knowledge that can be shared amongst all relevant Network Licensees

Dissemination of project learning and experience is an important part of the Proteus Project. Section 5: Knowledge Dissemination discusses this element in detail.

(d) Is innovative (i.e. 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

The Proteus project is innovative in a number of ways.

The project will trial a toolbox of solutions, some of which are not yet proven on LV networks. For example, UPFCs have been demonstrated in a small number of installations on Transmission systems. On LV networks, where they are sometimes known as Unified Power Quality Conditioners (UPQCs) their use is different and offers unique advantages for correcting voltage problems. Similarly, STATCOMs are commonly used for dynamic voltage control on HV and EHV systems through injection/absorption of reactive power, but their use on LV networks will concentrate on other forms of compensation such as balancing phase currents.

Proteus will provide an Autonomous, Mobile and Flexible package of solutions to network constraints. Each of these 3 properties requires innovation:

- **Autonomous operation**: The communication and monitoring function of Proteus would be put to use as soon as deployed, assessing the best configuration (connection points and operating modes) of the various items available to resolve the immediate problem. The physical connections of the FCU will be made in a manner similar to connection of a generator at a substation. This will allow a simple installation procedure that can be performed rapidly by non-specialist staff. Once installed, Proteus will be capable of autonomously determining and implementing the most appropriate configuration and set points without the need for manual intervention and to adapt these choices as information is gathered over longer periods and in the light of the solutions tried at a specific site. The method used for self-configuration will be undertaken by a simple and pragmatic optimisation algorithm in the first instance, before being refined in later versions. The equipment will be intelligent enough to map the network, monitor conditions, select the best functions and obtain useful data that can inform permanent solution design.

- **Mobile application**: The Proteus boxes will be suitable for transportation around network sites as system needs arise. An integrated approach to development of the solutions is required to ensure these units are fit for purpose in a number of aspects.
- **Flexible solutions:** The project will deliver units that can provide a number of potential functions suitable for the resolution of network constraints. Hence the products must be designed to act in a number of scenarios, using different information and applying alternative solutions.

The business case for the development of the Proteus solution is built upon the anticipated uptake of various LCTs, and their impact on LV networks. The future rate of uptake of these technologies is not known, and it is not currently possible to accurately predict when or where temporary, rapidly deployable solutions will be required. However, the consequences of not being prepared for this foreseeable scenario are significant in terms of the potential impact on customers. Given the time required to develop and trial a solution, it is necessary to begin this process in advance.

Proteus will demonstrate the appropriateness and effectiveness of the solution, producing valuable learning and experience as to its implementation when required.

(e) Involvement of other partners and external funding

Ricardo have been selected as the Lead Partner for the Proteus project as a result of an open call for project ideas made by WPD on their website and various other forums. The project has been developed in response to a specific scenario in the open call from WPD, addressing future challenges with LV network capacity.

From an initial response of 32 applications, this project and one other have been selected to submit the Full Submission Pro-forma (FSP). This selection has been made on the consideration of those ideas that demonstrate the appropriate mix of technology readiness level, innovative concept and system need.

The selection of the additional partners currently enlisted has been carried out on the basis of identifying those elements where there is a significant benefit to the project of the inclusion of a particular company. These benefits are demonstrable through that partner's previous involvement in LCNF/NIC projects producing solutions that are directly relevant to Proteus. In this way the learning and experience previously derived is applied and built upon to deliver a solution without expending additional time and money. The unique nature of the selected partners experience provides a tangible benefit in developing the technologies required by Proteus.

Where a project element has been identified as being available as an "off the shelf" product from a number of potential suppliers, a competitive tendering exercise will be undertaken.

All potential project partners will be subject to a due diligence process following project award and prior to contract award.

Further to the Network Licensee Compulsory Contribution each project partner will contribute to the project in the form of a discounted fee on commercial rates for labour and/or discounted charges for equipment hire and materials.

(f) Relevance and timing

WPD's Innovation Strategy is already delivering new ways of working and improved efficiency.

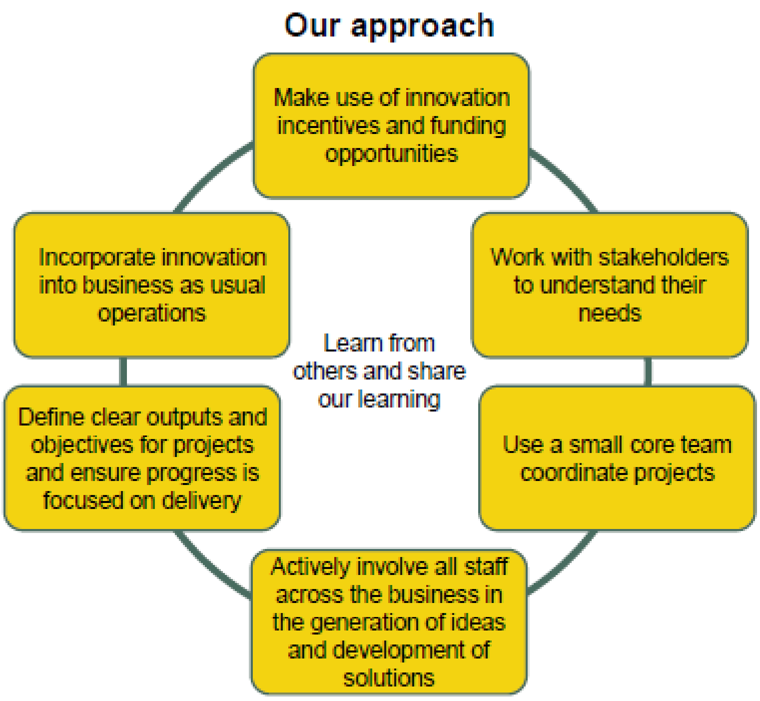

Figure 4.1. WPD's Innovation strategy

The RIIO-ED1 Period, 2015 – 2023, will bring many new challenges including the facilitation of new low carbon technologies. In the WPD business plan it states that:

- We will submit proposals for the Network Innovation Competition leading to a total investment of £100m;
- Innovation in smart solutions will help us accommodate LCT's without the need for high levels of conventional reinforcement; and
- We will use information from more advanced monitoring of the network and data from smart meters to identify where LCT hotspots are emerging so that reinforcement work can be targeted to areas of the network where it is required

Also, following on from Stakeholder engagement workshops, WPD are committed to:

- Reducing the average frequency and duration of power cuts
- Work towards a 12hr power cut restoration standard
- Improve the time taken to connect LCT's

Proteus will develop and trial an enabling solution for the Future Energy Scenarios, as described by National Grid[2]. The emergent scenario is uncertain and unpredictable. In order that the adoption of LCTs is not encumbered by the limitations of the existing electricity network it is necessary to plan ahead for these scenarios.

Targeted reinforcement of the networks is one such activity that will enable the LCTs to be connected. However, understanding where and when to invest effectively is not always possible due to the short timescales under which new network connections can be made.

A flexible, temporary and rapidly deployable solution is useful in allowing time and information to inform and efficient and effective reinforcement process. The Proteus solution is designed to be complementary to existing processes, increasing their flexibility to accommodate changing customer needs.

It is necessary to develop and trial the Proteus solution in advance of the system requirement. This is because at the time that the solution is required for use to resolve constraints on live networks, it must be tried and tested to ensure its effectiveness.

Proteus is based on the technical convergence from a number of previous LCNF/NIC projects. The toolbox of potential solutions represents a mix of techniques shown to be effective either by other projects (e.g. Soft Open Points as demonstrated by FUN-LV, a project led by UKPN) or in different applications. The integration of these techniques into a flexible package is therefore appropriate as a means of obtaining an innovative solution to unpredictable scenarios.

Using EATL's Transform Model, WPD have developed a "best view scenario" This work has derived the likely volume of LCT's and provided a more detailed view of the way LCT's will group together (cluster) on the network and the impact this will have on investment. The Proteus project can build on this and target the identified areas for more detailed monitoring, to fully understand how the uptake of LCT's in such an area is developing and its effect on the network. It is expected that different LCT's will require a different solution whether this be Battery Storage, Soft Open Points, Dynamic Voltage Restorer, UPFC, automated LV networks or asset cooling will be dependent on the individual LV network and the stresses on it.

Also by building on the LV Network Templates and Falcon data, WPD have already identified a number of LV Networks in the East Midlands and South Wales that are close to their capacity at certain times of the day, or at certain times of the year. The idea behind Proteus is that, rather than permanently reinforcing a network for a brief seasonal constraint, the portable toolbox can be deployed for that period to overcome the issue.

(g) Demonstration of a robust methodology and that the Project is ready to implement

This criterion is addressed in Section 6: Project Readiness.

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[2] http://fes.nationalgrid.com/

Section 5: Knowledge Dissemination

5.1. Learning Generated

Proteus aims to enable processes in network operation which will enable network operators and the wider industry to prepare for and enable the future changes and developments in the energy demand of society, particularly as a result of the adoption of low carbon technologies.

The project learnings will build on the findings and development of previous projects, notably Flexible Urban Networks-LV, FALCON, and Celsius. However, they will represent significant incremental learning from these, as well as providing learning on a new aspect, namely the provision of a temporary, mobile network capacity solution. This learning will be relevant for WPD and other GB DNOs, as well as the rest of the industry.

In order for these benefits to be realised, it is considered a central part of the project that the learning and recommendations developed are published and disseminated to the relevant stakeholders.

In particular, the project learning and the recommendations for implementing the knowledge learning into the business as usual processes within network operators must be shared to all appropriate stakeholders.

Proteus will develop a key learning in a number of aspects, including:

Learning Aspect	Products
Trial technology description and testing	Published descriptions of the designed technical solutions, testing specification and results, and the learning obtained, for the trial demonstration solutions.
Trial technology autonomous logic and control	Published specifications of the Logic and Control elements, and the integration requirements
Autonomous logic and control first release testing documentation	Published specifications, testing specification and results, and the learning obtained, for the trial demonstration logic and control.
Trial Documentation	Published site selection, installation considerations, trial methodology, and installation and operation methods for the trial.
Trials Analysis Report	Documentation detailing the achieved trial installation locations, functions used, performance, and associated learning
Proteus Solution Cost Benefit Analysis	Report into the cost benefit analysis process, findings, and conclusions.
Peer Review Report	Report detailing the process and findings of the independent DNO peer review
Recommendations for BAU Process improvements incorporating temporary solutions	Report detailing the relevant existing processes, and recommended improvements incorporating the temporary Proteus solutions.

Selection Methodology recommendations for permanent capacity solutions	Report detailing the relevant existing processes, and recommended improvements incorporating the alternative permanent reinforcement options the project has investigated. Including detail of criteria for selection, expected benefits, and any further work required.

The project tasks are focussed on ensuring that the project learning is useful to GB network operators, and the industry as a whole. This is ensured by the progressive process of development, test, and demonstration, with continual analysis, and assessment.

It will be key to ensure that the project provides robust trial, analysis, and recording of the learnings. A peer review process will be carried out throughout the project. The participation of another DNO within this role will ensure that the outcomes of the project are useful beyond WPD, and that appropriate rigor has been used in their creation.

5.2. Learning Dissemination

The learning generated will be captured formally in the form of project reports, many of which will be part of the SDRC milestone agreed for the project. However, this is not always the most appropriate form in which to disseminate the contents. It is important to tailor the learning dissemination activities to the objectives that they are aiming to achieve, and the stakeholder audience that they are aiming to address.

The objectives of the learning and dissemination activities, and the key stakeholder audiences, are given in the table below:

Learning dissemination objective	Most relevant stakeholder audience
To inform interested stakeholders of the project, and its key benefits	All stakeholder groups, including customers, DNOs, IDNOs, policy makers, academic institutions and research bodies, supply chain suppliers and stakeholders, and other industry bodies.
To disseminate the detail of how the learning from Proteus can be adopted into business as usual practises within network operators	DNOs, iDNOs, Ofgem and wider government
To give access to research and developments within the project, so that they can be used and built on by other parties	Academic and research bodies, DNOs, iDNOs, Ofgem and wider government, supply chain suppliers and stakeholders, and other industry bodies.
To disseminate the development of the technologies and their components included within the project	DNOs, iDNOs, Ofgem and wider government, supply chain suppliers and stakeholders, and other industry bodies.

There are a number of different methods and approaches which can be adopted for dissemination of project learning, including:

- Wide availability of project information and documentation via Learning Portals;
- Events and conferences;
- Project-specific events;
- Publicising project activities and benefits; and
- One-to-one and ad-hoc dissemination.

These methods each offer a number of benefits in meeting the aims and reaching the intended audience for project dissemination. Therefore it is important that the approach adopted includes a combination of these methods. This is described in more detail in the sections below:

Availability of Project Information and Documentation

This will be achieved through the establishment and maintenance of a project website. This is a simple way of ensuring that the information is accessible to all who wish to view and use it.

The website will provide a range of information, including:

- Project information, including aims, completed and planned activities, timescales, and governance.
- Technology and solution information aimed at varying audiences, for example tailored to the general public, or to participants in the energy industry
- A description of key benefits and findings,
- Access to all project documentation, including regular progress reports and the deliverables.

The availability of this information will be publicised during the other project dissemination activities, so that stakeholders are aware where to gain additional information.

Events and Conferences

Industry and academic events are a good opportunity to disseminate projects. Project presentation is an effective way to engage attendees in the project and its findings, and such events can be used as an opportunity for face to face discussions with potential stakeholder groups.

There is also opportunity for the presentations of these events to be filmed, and for the footage to be disseminated on websites and social media feeds. This is a useful way of engaging a wider audience than those who are physically present at the time.

The LCNI conferences held annually are a good example of this, and are attended by a good range of industry, academic, and policy stakeholders. The project team will attend each of these events for the duration of the project. The project will also consider participation in other industry or academic events, for example CIRED.

Project-specific Events

Project specific dissemination events will be organised throughout the project. This will be a significant opportunity to engage the attendees in the project, and to receive their feedback for the remaining activities. These events may take the form of seminars, discussion groups, or interactive workshops.

For each event, the topics and aims will be carefully considered to provide most benefit and effective dissemination. The invitees to these events will be selected based on these objectives. This will be finalised within the project, so that it can be tailored to the project as it evolves. The list below describes the best view of the likely events which will be held.

Timing of event	Event Outline
Early in the project, and at least by November 2017	Initial discussions to UK DNOs to outline the project and receive feedback. This will take the form of either individual visits to organisations, or events where several DNOs are in attendance. The aim will be for a presentation of the aims of the project and its technical solution, and an interactive discussion amongst attendees to gain qualitative feedback to inform the project tasks.
By February 2018	A stakeholder event to present the outcome from the project inception phase whereby the functionality and other design parameters are outlined. Details of the approach for the project trials will be presented to allow discussion amongst participants and incorporation of any additional relevant feedback.
By June 2019	Presentation to stakeholders of the design progression between the Alpha and Beta units, together with the initial learning obtained from the field trials.
By October 2020	Final presentation of learning obtained from the field trials together with the results of the projects cost benefit analysis. This will take the form of either individual visits to organisations, or events where several DNOs are in attendance.
By December 2020	A stakeholder event to present an entire review of the project, from inception to completion. This will include a summary of learning points obtained, areas for further work and the next steps.

One-to-one and Ad-hoc Dissemination

As project learnings are built up, and the project is disseminated, then it will become clearer how each potential key stakeholder will be able to take advantage of them. The detailed discussion and support from the project team may help such stakeholders in developing this picture.

Therefore, the project will offer one-to-one dissemination and discussion sessions where the project learning can be discussed, focussing on the relevance to the stakeholder in particular. It is envisaged that this will be most useful for the GB DNOs, and the offer of these sessions will be actively promoted to them.

It is expected that such activities will be most relevant at the end of the project, but they will be available to stakeholders throughout the project

Publicising Project Activities and Benefits

There should be a particular effort to publicise key project messages, such as project aims and benefits, to a wider audience beyond those who will attend industry and academic events. This audience includes:

- Customers, who will be informed of the innovation activities carried out within the industry, as they are the parties who are funding the work and who should benefit from the outcomes.
- Stakeholders in other industries or fields, who may be interested in the learning which is relevant across sector boundaries, or may be able to contribute to the learning with developments from other industries and their applications in power.
- Other stakeholders, who are not otherwise aware of the project, and who would be interested in learning more.

In order to reach a wide audience of potential stakeholders, press releases and promotion over social media will be carried out throughout the project. Once engaged, these stakeholders can be directed to the project website, so that they can find out more.

Dissemination Programme

The programme of dissemination events is illustrated below:

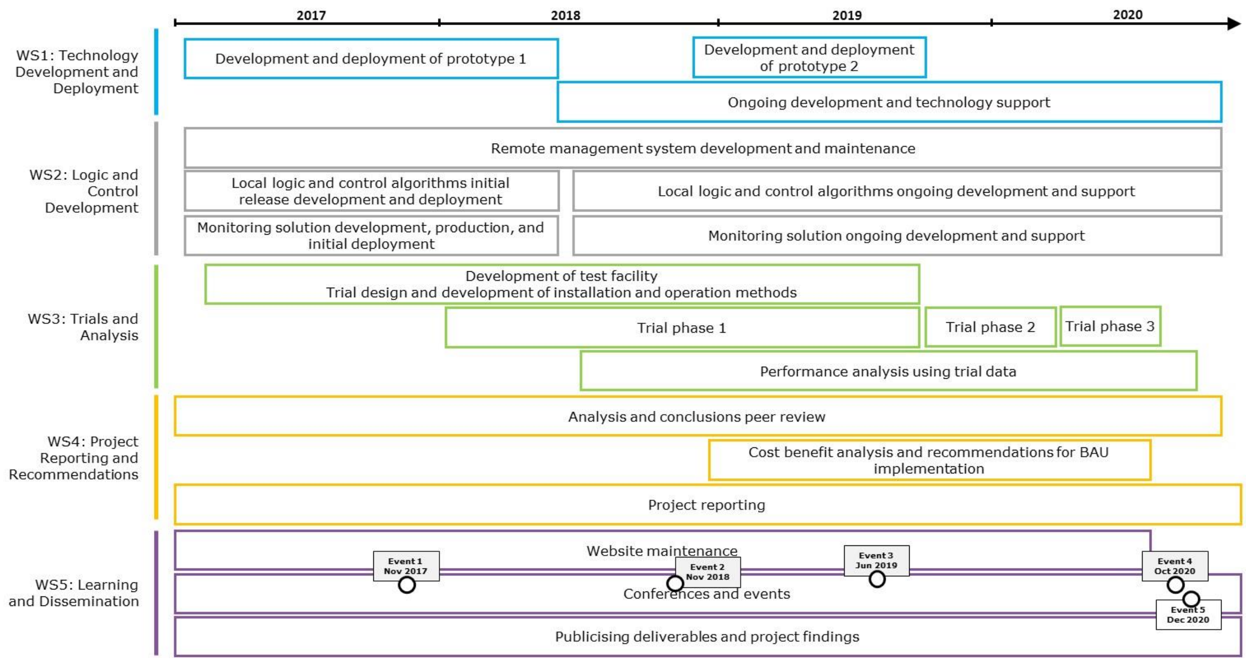


Figure 5.1. Dissemination programme

5.3. Intellectual Property Rights (IPR)

The Proteus project team intend to conform to the default IPR arrangements requested under the NIC Governance Document. As such all partner contracts will acknowledge this requirement when preparing the appropriate Collaboration and sub-contractor Agreements.

Section 6: Project Readiness

Requested level of protection required against cost Over-runs:	0%
Requested level of protection against unrealised Direct Benefits:	0%

6.1. Project readiness

Proteus can begin in January 2017. Its readiness to proceed has been assured by the significant amount of preparatory work already completed to date, so as to develop the technology concept and the project programme.

The key project partners have been identified, and have played a supporting role in the project inception, and therefore have built a good understanding of the project requirements. The initial project tasks are focussed on trial design, development of detailed technology requirements, and procurement of items to be supplied. It will be vital that the project partners continue to collaborate to ensure that the inception stage form a good platform for the rest of the project.

The project lead partner, Ricardo, has already identified its project team, who has significant experience participating and leading projects such as this. They are therefore capable of facilitating a swift project launch.

From previous project experience, it has become evident that a key delay in the launch of a project is the time taken for the contractual details to be agreed between the project partners, and this will be managed by ensuring that contract negotiations begin early following notification of the success of the project.

6.2. Project governance and Resource

Proteus and each of the work packages will be led by Ricardo, with Western Power Distribution acting as project sponsors, providing access to their distribution networks, and providing review and sign off of deliverables. The work packages within the workstreams will be delivered by:

- Ricardo,
- Western Power Distribution (WPD),
- Turbo Power Systems (TPS)
- Imperial College London (Imperial)
- ASH Wireless (ASH)
- UK Power Networks (UKPN); and
- Other technology suppliers, to be identified.

The project governance structure is indicated in the diagram below.

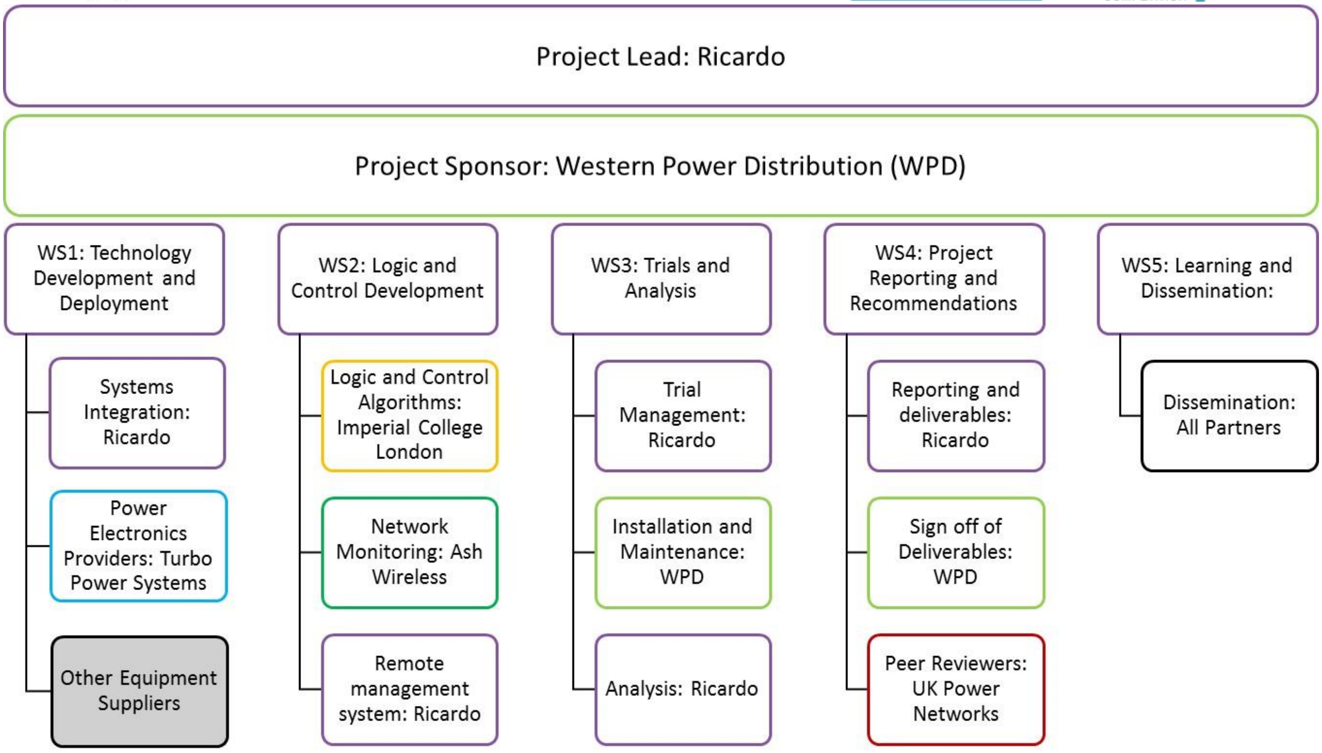


Figure 6.1. Proteus Project Governance Structure

Ricardo

Ricardo will have a number of key roles within the project:

- Programme Management
- Technical concept development through to product delivery
- Trial design and management
- Technical analysis
- Development of recommendations
- Dissemination of learning and results.

NIC projects have generally been led by the network operator partner, and for this reason it should be noted that Ricardo has not led an NIC project previously. However, 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, as detailed in Appendix E, and summarised in the table below:

Area	Summary of expertise (more detail is available in Appendix E)
Project and programme leadership	Ricardo has developed and led a wide variety of projects and programmes in the energy sector. These have included: Directional Earth Fault Passage Indicators, Smart Urban LV Networks, Flexible Urban Network Low Voltage, Distribution Network Visibility, 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 • Distribution Network Visibility 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. • Distribution Network Visibility - 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.
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: • Distribution Network Visibility 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: • Distribution Network Visibility: Following successful delivery of the project, Ricardo also 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

Ricardo have identified the key project personnel within the project, including:

- Project Director – will support the project through advice and guidance, and will provide senior sign off in the quality assurance process to review project activities and deliverables. Also, will act as senior sponsor within Ricardo.
- Technical Director – a dedicated senior technical support for the project, providing significant relevant experience and advice.
- Project Manager – will manage the project tasks and ensure that deliverables and outputs are delivered on time, and to a high quality.
- Project Technical Lead – will lead the technical tasks, carrying out and coordinating the tasks within the project.
- Technology Integrator Lead – will coordinate the development of the technology solution, including selecting and managing suppliers, and carrying out the technology integration task.

These personnel have been specifically selected as they have significant experience and expertise in electricity networks, product engineering and design, software development and delivery, and data analysis required to fulfil these roles.

Western Power Distribution

WPD deliver electricity to over 7.8 million customers over a 55,500 km^2 service area, employing 6000 staff. WPD's network consists of 220,000 km of overhead lines and underground cables, and 185,000 substations, over 4 license areas.

WPD's role on the project will be that of the network licensee partner, and will:

- Provide network information to inform the site selection process;
- Transport and Connect equipment to the network in a safe and controlled manner;
- Review equipment requirements and specifications;
- Perform equipment acceptance and witness testing;
- Review system performance, benefits and results; and
- Assist in the dissemination of project learning.

Turbo Power Systems (TPS)

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 Flexible Urban Networks – LV (FUN-LV) LCNF project.

TPS will provide the power convertors and associated electrical equipment for use on Proteus. The devices used in this project will be an evolution of the FUN-LV devices, offering Proteus opportunity for significant improvements such as reduced noise, less weight, lower losses and the ability to operate in a number of different modes.

Imperial College London (Imperial)

Imperial college, through their Consultancy division, have over 25 years' experience in helping organisations create value for their businesses by developing practical and innovative solutions based on expertise and testing facilities at Imperial College London.

Proteus will utilise expertise from the Control and Power Research group to provide the systems logic and control algorithms as they have previously done on FUN-LV. These systems will be an extension of those developed under the FUN-LV project, offering increased autonomy and functionality, as well as refining those previously developed.

ASH Wireless (ASH)

ASH Wireless Electronics Ltd is a creative electronics design consultancy who are experts in wireless technologies. ASH work at every stage from idea to finished product, from product development and software design right through to prototyping and production. ASH are a primary technology provider to the ongoing Celsius and Directional Earth Fault Passage indicator projects, and prior to these projects performed the same role on the Distribution Network Visibility project.

ASH will provide the sensing, measurement and network monitoring systems to Proteus. These systems will provide bespoke functionality to this project, but are based on systems that have been trialled and proved in similar applications.

UK Power Networks (UKPN)

UK Power Networks are the DNO for London, the South East and East of England, covering more than 29,000 km^2. UK Power Networks have 8.1 million customers, 5000 employees and 184,000 km of overhead line and underground cables.

UK Power Networks will act as a peer reviewer of the project's results and benefits documentation, to ensure that the findings are relevant and applicable to all UK DNOs.

6.3. Project Plan and Tasks

The project team is confident that the project can start in a timely manner. During the development of the Proteus Full Submission Pro-forma (FSP) engagement has been undertaken with each of the key suppliers. This has included discussion on:

- Scope of supply;
- Interfaces to other project partners and suppliers;
- Allocation of suitable resource without compromising other projects;
- Timescales; and
- Anticipated Costs

The project plan includes an initial inception phase during which each of these elements will be formally specified and agreed. This phase is crucial to the effective delivery of the project, and for this reason it has been allocated a 9-month timescale (Jan 17 – Sep 17) to ensure that it is completed in the depth required.

The project will utilise a RASIC (Responsible, Approves, Supports, Informs, and Consulted) tool during its life to ensure that it is delivered

Task	Description / Approach	Scope of Work	Deliverables	Ricardo	TPS	ICL	ASH
Project management	To manage entire programme including all organisations contracted to the programme	All necessary activities to manage entire programme and be the Lead interface with WPD. To organise key meetings for the consortium such as gateway meetings. Manage production of all appropriate project reporting.	Deliver programme on time and on budget. Manage supply chain and internal resources. Regular programme and deliverable updates	R	I	I	I
Specify Proteus system	Provide system and sub-system level specification of entire Proteus system	Develop Proteus system specification to meet WPD requirements	Specification, price, availability all understood	R	C	C	C
Failure Mode Analysis	Conduct a Failure Mode Analysis with respect to any effects to the LV network should a failure happen to any of the Proteus systems connected to the network	FMA Process to include WPD input	FMA report	R	S	S	S

Figure 6.2. Example section of Proteus project RASIC

Please see appendix G for the detailed project plan.

6.4. Basis of Project Information

The project information has been produced on the following basis:

1. A top down and bottom up costing exercise, using knowledge and experience gained on other Innovation projects, and incorporating reasonable levels of contingency.
2. Indicative prices have been obtained from project partners for their scope of supply.
3. Data used in the business case to estimate the project benefits have been obtained from credible and citable sources.
4. Some sensitivity analysis has been performed in the business case to demonstrate a likely range on the benefits that will be obtained.

The project team will continually asses and review the data used to determine project costs and estimated benefits throughout the project, and particularly after the inception phase and phase 1 are complete, sharing the findings in the relevant project reports.

The project is not dependant on a specific level of LCT uptake in the trial area in order to deliver learning. The performance of the demonstration units for all capacity improvement techniques can be assessed using existing network conditions.

6.5. Project and Programme Risks

The project will be conducted in line with the Ricardo Product Development System. This is a managed process ensuring that the project progresses through a series of formal review gateways. See Appendix I for more information.

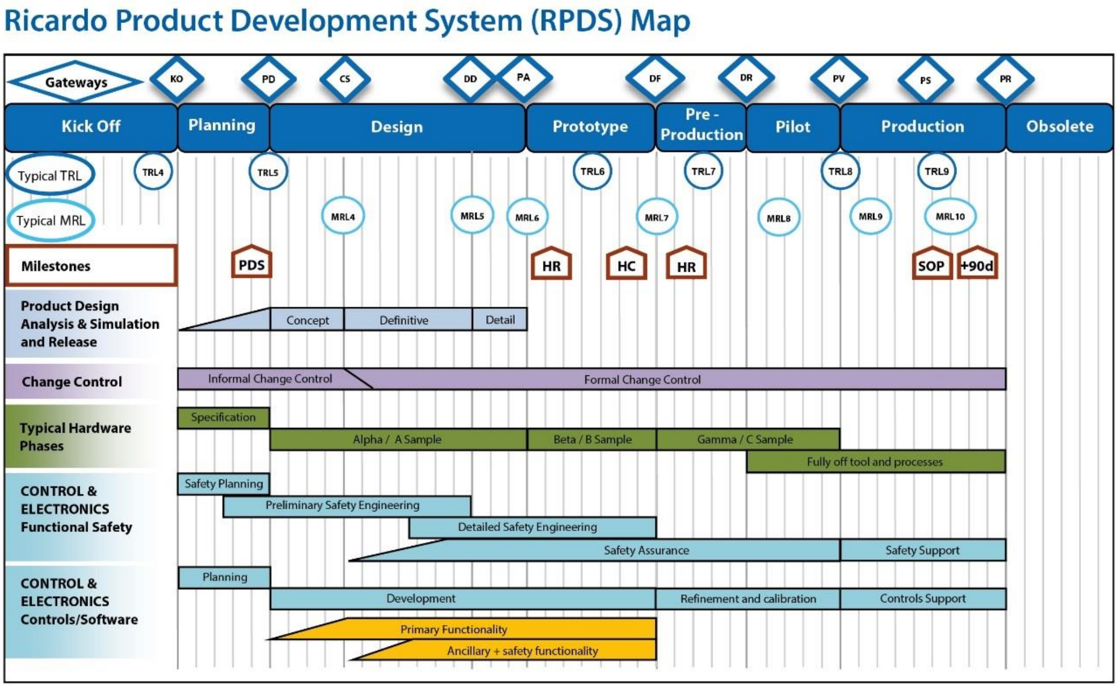


Figure 6.3. Ricardo Product Development System Map

A project risk register (See Appendix H) has been started and will be maintained throughout the project. This tool enables the early identification and tracking of risks, such that resolution strategies can be adopted to mitigate the risk. This include circumstances where cost overruns outside of the allowable tolerances or the need to suspend the project are likely.

The project team, led by the Ricardo Project Manager will conduct regular review meetings to ensure effective risk management and early identification of issues takes place.

Section 7: Regulatory issues

It is not expected that Proteus 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

8.1. Customer Benefit

Proteus aims to enable solutions that will provide fast temporary autonomous solution to network capacity issues, and provide a methodology for appropriate permanent solutions to be selected, including traditional and innovative methods.

It is envisaged that Proteus will have a positive impact on the design and operation of GB electricity distribution networks, by providing the following outcomes:

- A faster and more effective short term response to network capacity issues, and
- A methodology to select permanent solutions from potential traditional and innovative solutions.

This will have the following benefits to customers

- Reduction in interruptions, including reduction in fuse operations due to overloads and faults due to thermal overloading of assets,
- Faster solution of voltage issues, and
- Potentially lower cost or more functional permanent solutions.

The project will also deliver a positive customer impact in enabling, within the capability of the developed solution, the uptake of LCTs, and the associated changes to load magnitudes and profiles, to continue without significant change to the existing connection process. Customers will continue to be able to adopt LCTs without applying in advance for a connection, and without an adverse effect on their supply security or quality.

8.2. Project Interaction with Customers

Proteus does not aim to engage or involve any network customers as part of the key project deliverables or learnings. However, as the project will involve the installation of equipment on the distribution network, which covers areas where the network equipment is most visible and closest to customers, it will be necessary to ensure that customers are informed and that the project does not cause any unnecessary negative impact for them.

The visual and audible impact of the solution will be carefully considered during design, to attempt to minimise the negative impact for the immediate surrounding area.

One way of limiting any negative impact will be to carefully select trial sites, avoiding those which are likely to cause issues due to proximity to residential buildings, blocking pathways or roads, or otherwise causing negative impacts.

The normal practice for informing local customers of network activities will be adopted within the project. That is to identify those customers who will most likely be affected by the work, and to write to them to inform them of the details and to give contact details where there is an issue.

If issues are reported, and they cannot be addressed simply within the project, then there is scope for the solution to be moved to an alternative site. It is expected that in the business as usual operation of the equipment, where the solution is alleviating critical network issues, then educating the customers of these real benefits may make them more accepting of the solution. The project will consider how this would be best achieved in BaU and document this in SDRC 9.5.

Section 9: Successful Delivery Reward Criteria (SDRCs)

Work stream 1 & 2: Solution Development and Deployment			
Criteria	**Deliverable**	**Evidence**	**Date**
SDRC9.1	System functionality and specification summary	Summary of unit design parameters and performance requirements	November 2017
SDRC9.2	First demonstration technology design and learning summary	Summary of activities so far and issues, solutions, and other associated learning from Demonstration solution 1.	August 2018
SDRC9.3	Initial findings following trials of Logic and Control Systems	Report summarising the design of the Logic and Control systems in use, and the findings following initial field trials	August 2019
SDRC9.4	Final Trials Analysis Report	Report detailing the trial installation locations, functions used, performance, and associated learning.	April 2020
SDRC9.5.1 **SDRC9.5.2** **SDRC9.5.3**	Solution Benefits and Adoption into BaU recommendations	Reports detailing: 1. The cost benefit analysis process, findings, and conclusions. This will detail the costs and benefits of a business as usual Temporary Solution based on the learnings of Proteus. 2. The relevant existing processes for addressing network capacity issues, and recommended improvements incorporating the temporary Proteus solutions. 3. The relevant existing permanent solution selection processes, and recommended improvements incorporating the alternative permanent reinforcement options the project has investigated. Including detail of criteria for selection, expected benefits, and any further work required.	September 2020
SDRC9.6	Summary of learning dissemination activities	Summary and evidence of the learning dissemination activities throughout the project, including maintaining a project website, attending and holding events, and offering direct one-to-one dissemination.	December 2020

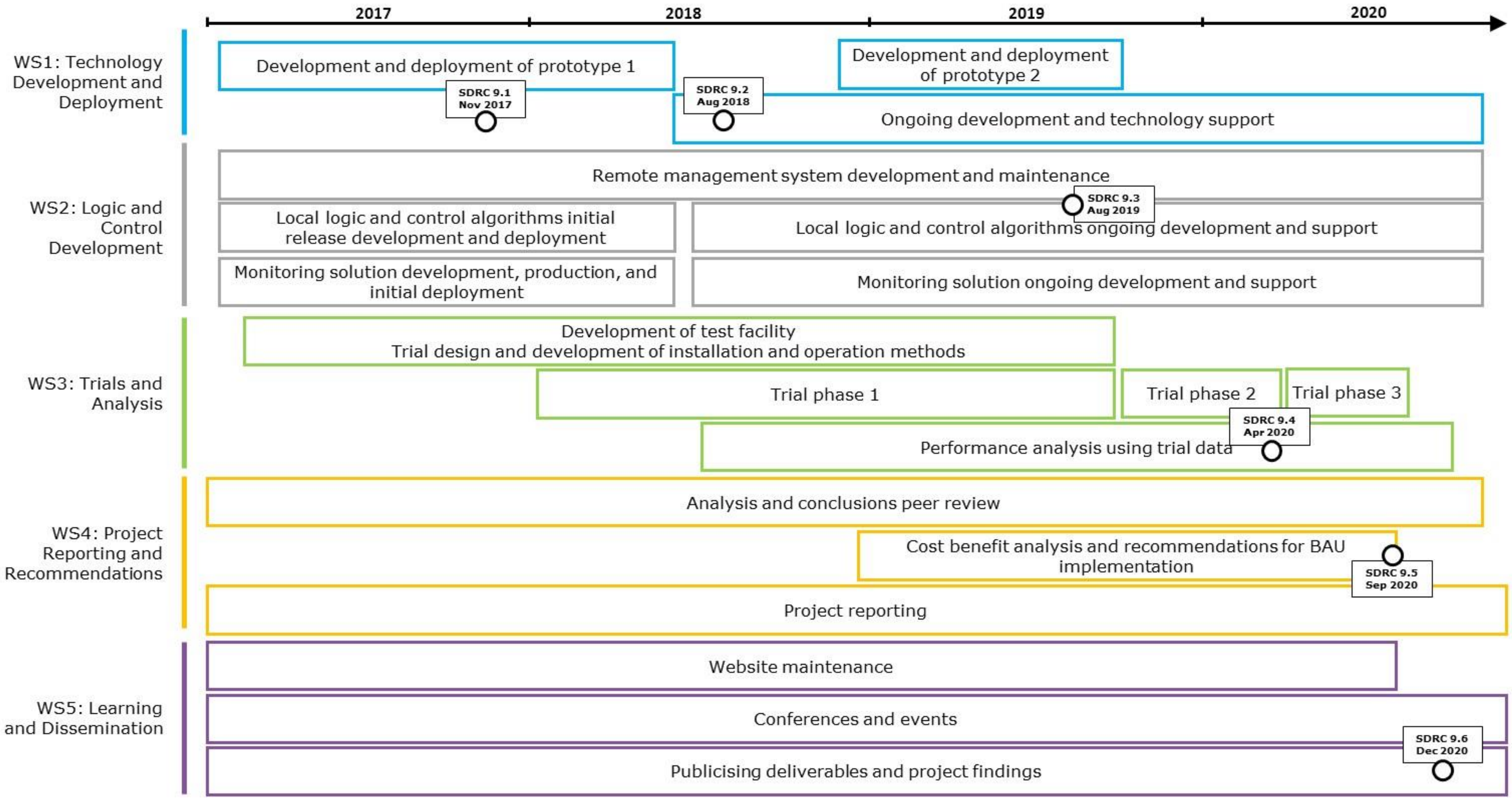


Figure 9.1. Programme of Project SDRCs

Section 10: List of Appendices

Appendix Number	Title
Appendix A	Project Full Submission Spreadsheet (Separate Document)
Appendix B	Benefits Tables
Appendix C	Detailed Project Business Case and Benefits Description
Appendix D	Technical Appendix
Appendix E	Ricardo Skills and Experience
Appendix F	Related Projects
Appendix G	Project Programme
Appendix H	Project Risk Register and mitigation plan
Appendix I	Ricardo Product Development System
Appendix J	Project Costs

Appendix B: Benefits Tables

B.1. Financial Benefits

The table below summarises the estimated financial benefits of the Proteus project and its learnings. Note that there are no estimated benefits stated for the year 2020, as the project will still be underway at this time. In accordance with the NIC guidance documentation, this is shown in 2016/17 prices and stated in NPV terms using a discount rate of 3.5% for the first 30 years and 3.0% thereafter. The space between these curves represents the benefit of using the Proteus Case over the Base Case.

	Cumulative estimated net financial benefit (NPV terms; £m)							
Scale	**Method Cost**	**Base Case Cost**	**Benefit**				**Notes**	**Cross-references**
			2020	**2030**	**2040**	**2050**		
Single Solution	1.30	1.96	-	0.42	0.68	0.66	For the purposes of the business case, an 'individual deployment' of the Proteus solution is a single Temporary Solution, which is deployed and re-deployed many times over its 15 year lifetime. The number of sites covered is 45.	These figures are based on estimated costs and projections for future energy network issues. The description of the methodology and assumptions is provided in Appendix C.
Licensee scale	1.30	1.96	-	29.3	78.0	131.4	The number of solutions is 180, and the total number of sites where the solution is implemented is 8,641. The figures represent an averaged view of the range of assumptions modelled. The range of benefit modelled in 2050 is £95.8m – £167.0m.	These figures are based on estimated costs and projections for future energy network issues. The description of the methodology and assumptions is provided in Appendix C.
GB rollout scale	1.30	1.96	-	90.8	241.5	406.6	The number of solutions to be used was modelled as 557, and the total number of sites where the solutions is implemented is 26,740. The figures represent an averaged view of the range of assumptions modelled. The range of benefit modelled in 2050 is £269.6m – £516.7m.	These figures are based on estimated costs and projections for future energy network issues. The description of the methodology and assumptions is provided in Appendix C.

B.2. Capacity Released

The table below summarises the estimated capacity released by the implementation of the Proteus methods. Note that there are no benefits stated for the year 2020, as the project is still underway at this time. As our business case model uses an uneven and clustered profile of network issues, the numbers in the table below are taken from the average trend line (See figure C.8).

	Annual average capacity released (kVA)							
Scale	Method Cost	Base Case Cost	Benefit				Notes	Cross-references
			2020	2030	2040	2050		
Single Solution	1.30	1.96	-	150	-	-	For the purposes of the business case, an 'individual deployment' of the Proteus solution is a single Temporary Solution, which is deployed and re-deployed many times over its 15-year lifetime. The number of sites covered is 45.	These figures are based on estimated costs and projections for future energy network issues. The description of the methodology and assumptions is provided in Appendix C.
Licensee scale	1.30	1.96	-	16,000	17,000	18,000	The number of solutions is 180, and the total number of sites where the solution is implemented is 8,641. The figures represent an averaged view of the range of assumptions modelled. The range of benefit modelled over the period is up to 28,000kVA.	These figures are based on estimated costs and projections for future energy network issues. The description of the methodology and assumptions is provided in Appendix C.
GB rollout scale	1.30	1.96	-	48,000	54,000	58,000	The number of solutions to be used was modelled as 557, and the total number of sites where the solutions is implemented is 26,740. The figures represent an averaged view of the range of assumptions modelled. The range of benefit modelled over the period is up to 84,000kVA.	These figures are based on estimated costs and projections for future energy network issues. The description of the methodology and assumptions is provided in Appendix C.

B.3. Environmental Benefits

The table below summarises the estimated environmental benefits of the implementation of the Proteus methods. Note that there are no estimated benefits stated for the year 2020, as the project will still be underway at this time.

	Estimated Cumulative carbon benefit (tCO_2e)							
	Method Cost	Base Case Cost	Benefit				Notes	Cross-references
			2020	2030	2040	2050		
Single Solution	1.30	1.96	-	7	12	12	For the purposes of the business case, an 'individual deployment' of the Proteus solution is a single Temporary Solution, which is deployed and re-deployed many times over its 15-year lifetime. The number of sites covered is 45.	These figures are based on estimated costs and projections for future energy network issues. The description of the methodology and assumptions is provided in Appendix C.
Licensee scale	1.30	1.96	-	503	1,358	2,304	The number of solutions is 180, and the total number of sites where the solution is implemented is 8,641. The figures represent an averaged view of the range of assumptions modelled. The figures represent an averaged view of the range of assumptions modelled. The range of benefit modelled in 2050 is 1,659tCO2e – 2,949tCO2e.	These figures are based on estimated costs and projections for future energy network issues. The description of the methodology and assumptions is provided in Appendix C.
GB rollout scale	1.30	1.96	-	1,555	4,201	7,131	The number of solutions to be used was modelled as 557, and the total number of sites where the solutions is implemented is 26,740. The figures represent an averaged view of the range of assumptions modelled. The range of benefit modelled in 2050 is 5,134tCO2e – 9,128tCO2e.	These figures are based on estimated costs and projections for future energy network issues. The description of the methodology and assumptions is provided in Appendix C.
Other Environmental Benefits	The key objective of Proteus is to enable the adoption of low carbon technologies and behaviours, which combined has the potential to greatly reduce carbon emissions of the UK. The Future Energy Scenarios developed by National Grid has developed a view on the carbon benefits of the adoption of such technologies, with carbon emissions reductions ranging from 103.6MtCO_2/year in the 'No Progression' scenario, to 338MtCO_2/year in the 'Gone Green' scenario. As the adoption of low carbon technologies and behaviours increases, there is a change in energy use will result in a change in the requirements placed on the electricity distribution networks. Proteus will provide the networks with the tools to cope with a key aspect of this impact; the increase in occurrence and complexity of LV network capacity issues. Therefore, though it is not possible to quantify the exact contribution that Proteus makes to the low carbon futures described in the Future Energy Scenarios, it is considered that Proteus could enable, and therefore be attributed with, some of the benefits of the low carbon future it is supporting.							

Appendix C: Detailed Project Business Case and Benefits Description

C.1. Introduction

Proteus Applications

The Proteus solution has the potential to bring significant benefits in network capacity issues which are beyond the capabilities of today's business as usual experience in scale, complexity, or solution requirements. In these situations, the Proteus solution can:

- Be deployed quickly to address appropriate issues arising on the network;
- Provide a flexible solution which can be autonomously adapted to suit a wide variety of applications;
- Collect relevant data with which to automatically characterise the network issue, and enable permanent solutions, and
- Can remain in place, alleviating the issues, while the permanent solution is being designed and planned.

The assessment of the business case is based on the occurrence of these network capacity issues, and in particular, on applications for the overloading of network assets.

The trigger for these applications will be the increased uptake of LCTs and the change in electricity use habits of customers. The nature and impact in this change in energy use over time is not easy to predict, but assumptions about this are required in order to evaluate the business case.

There are a number of sources available which have investigated this topic, including:

- **The DS2030 studies** recently undertaken for the Smart Grid Forum (Workstream 7) considered two demand and generation scenarios, the first was dominated by significant uptake of LCT connections (including heat pumps and electric vehicles), whilst the second considered less new LCT demand, but more embedded generator connections (such as PV and wind). The studies identified that between 24% and 33% of urban LV distribution substations are likely to become overloaded by 2034 in system intact conditions. For both scenarios the critical parameter was found to be maximum demand which occurred on winter evenings. For rural LV networks the issues identified were associated with both overvoltage and overload by 2034.
- **The future energy scenarios (FES)** identified by National Grid identifies uncertainties in the timescales associated with the adoption of LCTs, as reflected by the four energy scenarios looking forward to 2030. These range from "Gone Green" which meets the GB renewable targets by increasing distributed generation and use of heat pumps to "No Progression" where there is less increase in DG and less of a switch from gas heating to heat pumps. However all scenarios result in an increase in peak electricity demand which will be seen across the network including the LV systems.
- **The Transform Model**, is a techno-economic model initiated by DECC to determine the level of electrical network investment required to support the take up of LCTs. It uses a range of scenarios to show the range of likely futures, and in all of these futures, there is a significant increase in capacity issues which will be experienced across the GB network before 2050.

The Proteus business case uses the results of the transform model to develop its conclusions. The graph below shows the cumulative number of substations which are expected to be overloaded over Great Britain scale over the range of scenarios modelled:

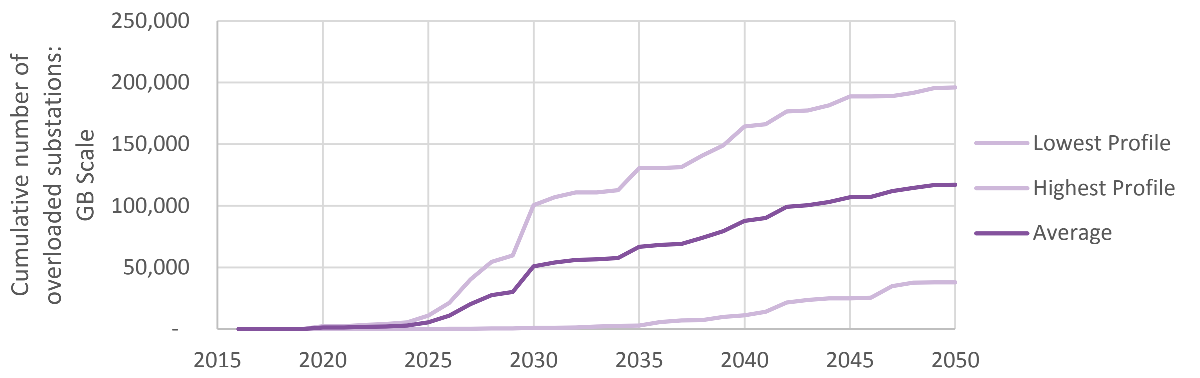


Figure C.1: The number of substations which are expected to be overloaded over Great Britain scale over the range of scenarios modelled

This shows a wide range of potential futures. For the purposes of the business case modelling, the highest and lowest scenarios are modelled to give a range of potential results, and an average is then found.

Note this does not represent the number of sites where Proteus Temporary Solutions are predicted to be deployed. This is calculated by the business model using roll out and deployment assumptions; it is assumed that there will be an initial roll-out period, with up to 25 units being in use by the end of the first year in the GB scale average scenario. The roll out allows volumes to be doubled each year until there is enough units to provide solutions to all relevant network issues, up to a maximum realistic roll out total of 550 units. This is based on 3 units being available per depot, and represents the maximum roll out only. The estimated GB scale deployment is shown in Figure C.2 below.

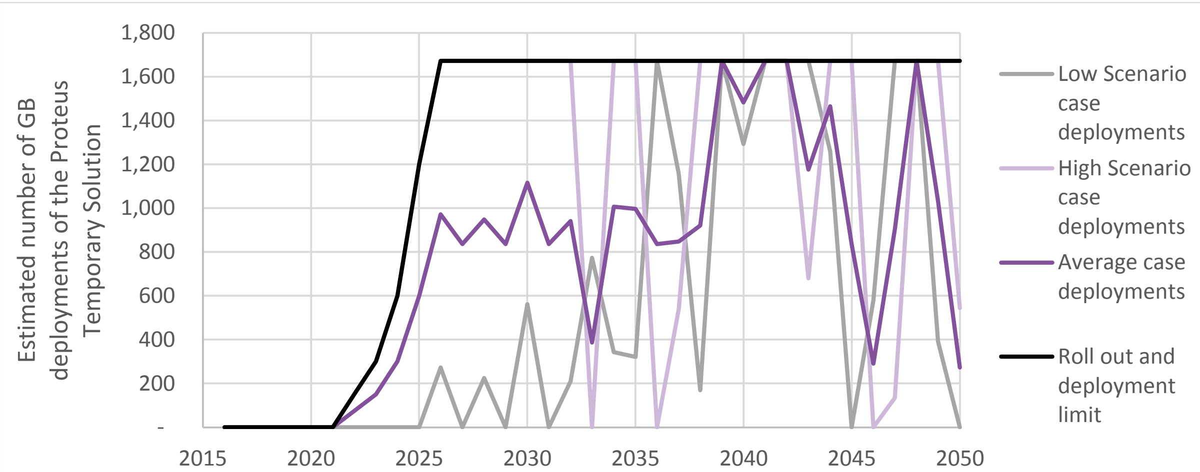


Figure C.2: The estimated number of GB deployments in the high, average, and low cases. The roll out limit assumptions are also shown in black.

The roll out and deployment limit assumptions for the WPD are scaled based on the proportion of GB feeders that are within WPD operational areas. This is around 32%.

Base Case and Proteus Case

The business case compares two cases: Base Case and Proteus Case. These describe the process used for dealing with network constraints of the type identified as Proteus applications.

The Base Case represents an extension of today's 'business as usual' approach to dealing with network issues such as network overload and voltage complaints. This involves deploying network monitoring and carrying out analysis to characterise the issue, and then selecting and designing a traditional permanent solution, such as network reinforcement. However, due to the changing network requirements, this approach will have a number of key issues associated with it, such as increased waiting time for the implementation of a solution, the increased cost of the permanent solution to solve more complex issues, and the possibility that the permanent solution implemented will not be appropriate to solve the issue.

The Proteus Case is the process enabled by the Proteus project, where a Temporary Solution is deployed soon after the issue is identified, and this provides information, and buys time, for a permanent solution to be selected from a list of traditional and innovative solutions. Proteus provides the practical network support to allow an effective connect and manage approach to Low Carbon Technologies (LCTs) to be applied.

The characteristics of the Base and Proteus Cases are shown in the table below. Note that these values are assumptions made for the purposes of the business case, and the true figures will not be known until the Proteus project learnings have been fully collated.

	Base Case	Proteus Case
Length of time from identification before power quality is restored to customers	**3 to 12 months** This is due to the need to develop and plan the permanent solution, including establishing access and wayleaves.	**2 days** This includes the deployment time and the time taken for the equipment to make an initial assessment of the network requirements and configuring itself to meet them.
Customer Interruptions	**Up to 360 individual customer interruptions, with many customers being interrupted multiple times.** Customer interruptions will be caused by overloading networks, due to fuse operations or increased fault rates.	**1 or 2 customer interruptions** This is possible as the Temporary Solution will prevent outages, for load and generation within the capability of the solution.
Cost of investigating and planning permanent solution	**Approximately £5k** This includes equipment and resource taken to carry out monitoring, analysis, design and planning.	**Approximately £10k** This includes the Temporary Solution and monitoring (spread out over multiple deployments), and the resource to install and maintain it, as well as to use this information to select and develop a permanent solution

	Base Case	Proteus Case
Permanent solutions implemented	This will be a mixture of: • Simple traditional solution costing approximately £5k, • Reinforcement, costing approximately £30k for substation reinforcement or replacement, and £70k for cable reinforcement, • Complex or high cost solution, costing approximately £150k The mix of these solutions will change over time, with the simpler, low cost solutions becoming less available, and the complex solutions being needed more and more.	This will be a mixture of: • Simple traditional solution costing approximately £5k, • Reinforcement, costing approximately £30k for substation reinforcement or replacement, and £70k for cable reinforcement, • Complex or high cost solution, with a reduced cost of approximately £100k • Non-traditional solution, costing between £2k and £60k. • Doing nothing, which represents the cases where it is discovered that he issue is a temporary one, or where is can be solved through very simple means. This represents the prevention of stranded assets that would have been installed in the base case. The mix of these solutions will change over time, with the traditional low cost solutions becoming less available, and the complex and innovative solutions being needed more and more.
Additional Benefits of the Proteus Case (not included as financial benefits)	• Improved network quality, including voltage and harmonics • Increased network visibility, which will support in identifying hidden and emerging issues in the local area • Control of Islanded networks • Management of fault level	

Cost of investigating and planning permanent solution

For each case, the costs for the investigation stage are estimated. For the base case, this includes monitoring, analysis, and selection and design of a permanent solution. For the Proteus case, it includes implementation of the Temporary Solution, and selection and design of a permanent solution using the improved network information provided by the Temporary Solution.

For the base case costs, this is based on experience of today's processes. The Proteus costs are estimated based on the cost of equipment today, and assumptions of how this will reduce based on volume production. It is assumed that one Temporary Solution will cost £250k, and will be used on average 3 times per year for its lifetime of 15 years.

The base case cost is estimated to be £5k, and the Proteus case is £10k. This figure is per implementation, and includes capital cost (spread out between the number of applications), resource cost, materials, and operation and maintenance of any equipment used in this part of the process.

Avoided Cost due to Faster Solution of Issue

A key difference between the base and Proteus cases is that in the Proteus case the issue is solved, with the use of the Temporary Solution, much earlier in the process. This means that there is a significant reduction in the period of time where the network is at risk.

The financial benefit of this takes the form of reduced interruptions, caused by fuse operations or thermal faults, and reduced thermal damage to equipment. This benefit is estimated based on experience with existing overloading cases, and is assumed to grow steadily over time with the complexity of issues, and potentially the introduction of new measures, such as new incentives or penalties, or measures to enable constraining of distributed generation or controlling load.

This is estimated to be approximately £14k per issue in 2022, increasing to £26.5k in 2050.

Difference in cost of Permanent Solutions

Assumptions are made as to the range, mix, and cost of permanent solutions which are implemented in each case. This mix is likely to change over time; simple, low cost solutions become less available as the limits of the networks are pushed further, and the issues become complex. The resulting effect of this is that the solutions become more costly over time.

In the Proteus case, it is assumed that a proportion of the permanent solutions selected will be different to those selected in the equivalent base case applications. These will include traditional solutions where the design of the solution has been further optimised, a selection of innovative solutions, and in some cases the discovery that the issue is temporary or can be solved through a simple rearrangement or other simple measure.

Therefore, the mix of permanent solutions enabled by the Proteus solution is generally less costly than in the base case.

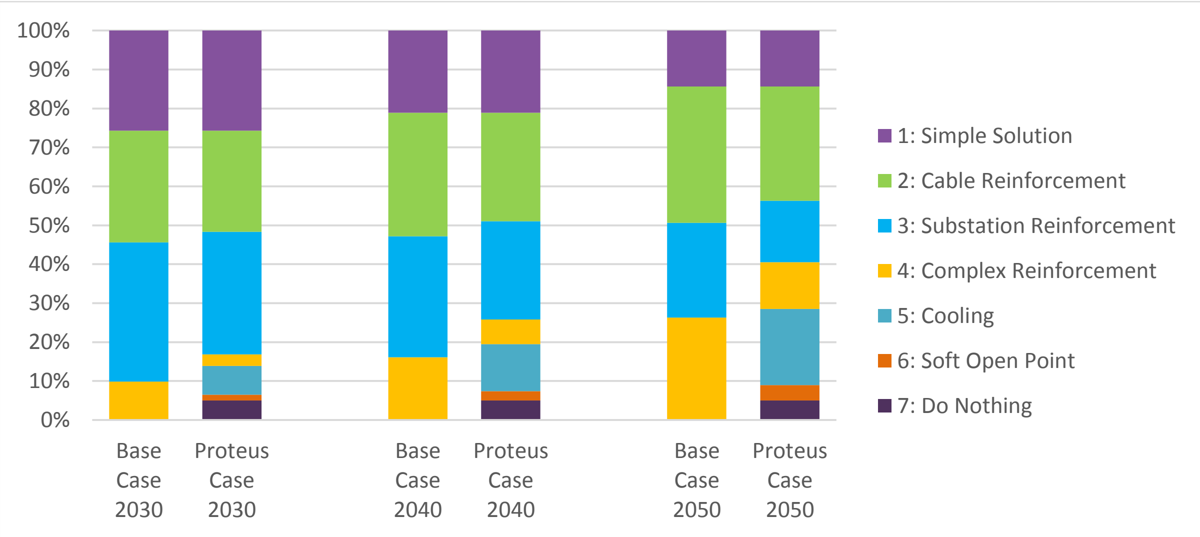


Figure C.3: Assumed mix of permanent solutions for the Base Case and the Proteus Case

Business Case Aspects

There are four aspects to the business case developed for Proteus:

- Financial business case
- Capacity Release

- Environmental Benefits
- Other Benefits

The methodology, assumptions, and results of this analysis is detailed in the sections below.

C.2. Financial Business Case

Single Solution

For the purposes of the business case, an 'individual deployment' of the Proteus solution is a single Temporary Solution, which will be deployed and re-deployed many times. The solution will be used an average of 45 times over its lifetime, which is based on being used 3 times per year over 15 years. The life of the solution will start one year after the completion of the project, at the start of 2022.

The base case for the purposes of the single implementation will represent the process that would be adopted for the three network issues per year if the Proteus project learnings were not available.

The graph below compares the Base and Proteus cases over time, showing cumulative costs of the process from discovery of a network issue, to implementing a solution, and the maintenance of that permanent solution over the long term. In accordance with the NIC guidance documentation, this is shown in 2016/17 prices and stated in NPV terms using a discount rate of 3.5% for the first 30 years and 3.0% thereafter. The space between these curves represents the benefit of using the Proteus Case over the Base Case.

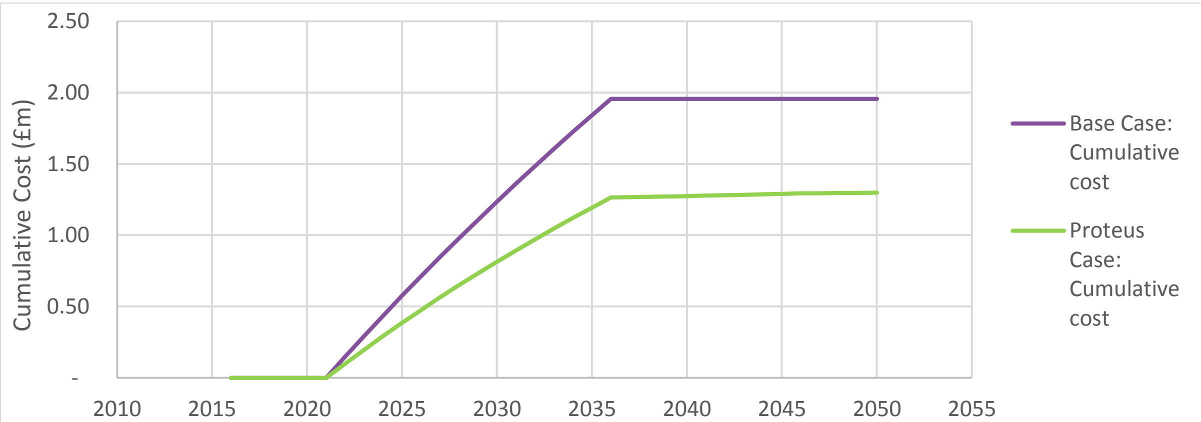


Figure C.4: Comparison of the cumulative cost of the Base Case and Proteus Case for a single solution scale of the Proteus Solution.

The table below shows the Base and Proteus Case costs for a single solution scale, and the estimated cost benefit of the Proteus Solution over the Base Case.

	Base Case (£m)	Proteus Case (£m)	Benefit (£m)
2030	1.24	0.81	0.42
2040	1.96	1.27	0.68
2050	1.96	1.30	0.66

As stated above, the assumptions for the numbers of applications for the Proteus solution are based on the Transform model. The results of the model are given as GB-wide figures of numbers of substations which will become overloaded due to the changing demand on the electricity network.

The WPD scale deployment numbers are based on the assumption that these occurrences are spread evenly throughout the distribution network areas. It has been calculated that the WPD networks account for approximately 32% of the GB networks based on numbers of LV feeders.

Proteus is an enabling technology which allows substations requiring uprating to be correctly identified, ensuring that investment expenditure is made in the correct locations and that the risk of stranded assets is minimised.

The Transform Model produces a range of likely results, which has been used in the business model analysis to represent the uncertainty of the future network issues.

In order for the Proteus case to be applied in each of these cases, multiple solutions will need to be in use at once. Each solution has the same assumptions of cost, use, and development of permanent solution associated with it as is listed above for the single implementation scale business case.

The graph below compares the average cumulative costs for the Base and Proteus cases over time for a WPD scale deployment. In accordance with the NIC guidance documentation, this is shown in 2016/17 prices and stated in NPV terms using a discount rate of 3.5% for the first 30 years and 3.0% thereafter. The space between these curves represents the estimated benefit of using the Proteus Case over the Base Case.

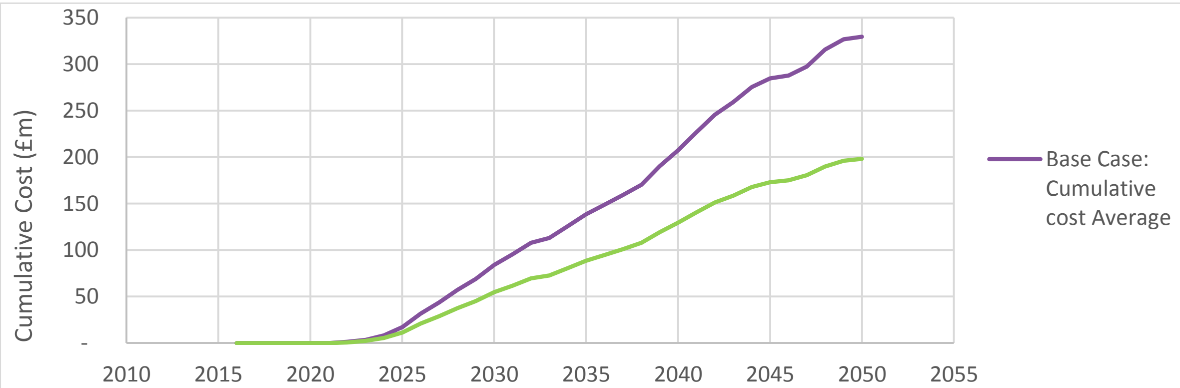


Figure C.5: Comparison of the cumulative cost of the Base Case and Proteus Case for a WPD scale implementation of the Proteus Solution.

The table below shows the Base and Proteus Case costs for a WPD scale implementation. It shows the result of the analysis given the minimum and maximum scenario results from the Transform model, and the calculated average.

	Low Scenario Benefit (£m)	High Scenario Benefit (£m)	Average Benefit (£m)
2030	5.3	53.3	29.3
2040	43.6	112.5	78.0
2050	**95.8**	**167.0**	**131.4**

GB Rollout Scale

As explained above, the assumptions for the numbers of applications for the Proteus solution are based on the Transform model. The Transform Model produces a range of likely results, which has been used in the business model analysis to represent the uncertainty of the future network issues.

In order for the Proteus case to be applied in each of these cases, multiple solutions will need to be in use at once. Each solution has the same assumptions of cost, use, and development of permanent solution associated with it as is listed above for the single implementation scale business case.

The graph below compares the average cumulative costs for the Base and Proteus cases over time for a GB scale deployment. In accordance with the NIC guidance documentation, this is shown in 2016/17 prices and stated in NPV terms using a discount rate of 3.5% for the first 30 years and 3.0% thereafter. The space between these curves represents the estimated benefit of using the Proteus Case over the Base Case.

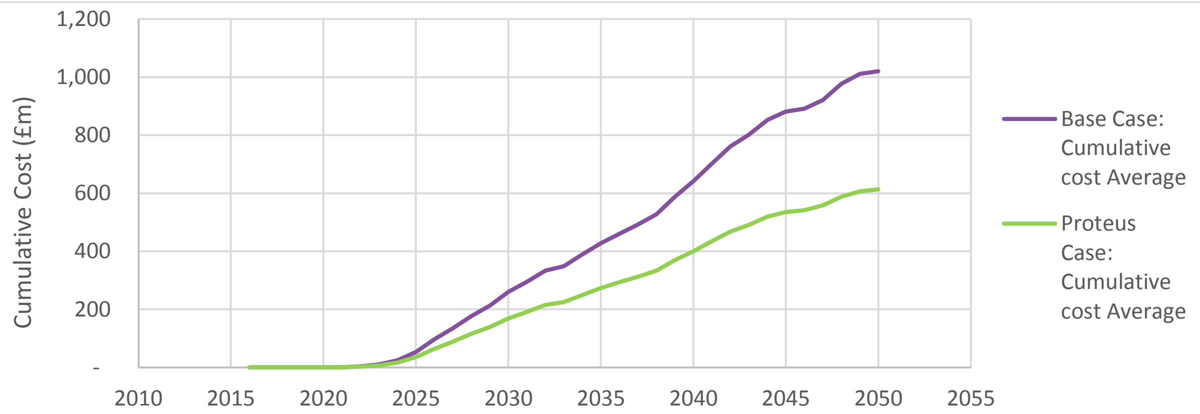


Figure C.6: Comparison of the cumulative cost of the Base Case and Proteus Case for a GB scale implementation of the Proteus Solution.

The table below shows the Base and Proteus Case costs for a GB scale implementation. It shows the result of the analysis given the minimum and maximum scenario results from the Transform model, and the calculated average.

	Low Scenario Benefit (£m)	High Scenario Benefit (£m)	Average Benefit (£m)
2030	16.5	165.1	90.8
2040	134.8	348.2	241.5
2050	**296.6**	**516.7**	**406.6**

Breakeven Analysis

A further step to the assessment of the financial business case is the breakeven analysis. This was carried out to assess the value for money to the customer of the funding requested for the Proteus project.

In order to carry this out, the funding of the project and the subsequent roll out of the learnings is compared with the estimated cost benefits over time, and a 'breakeven point' is calculated. This analysis is calculated from the point of view of the customers, and therefore includes funding requested from Ofgem, and funds invested by DNOs, but not those contributions made by the other project partners.

For the purpose of this analysis, it is estimated that the work to implement the learnings of the project into business as usual practises will cost an estimated £500k. This includes integration with IT systems, and training and changing of standards and practises. Note that this is a high level estimate for the purpose of this analysis only.

The benefits included in this analysis were the average scenario benefits for the GB scale roll out of the Proteus learnings, as calculated under the financial business case. The values used for funding, and those representing the benefits are actual values, meaning that they are not discounted over time.

The diagram below shows the breakeven analysis results for the GB scale roll out of the project learnings. The bars represent the breakeven position of the project, where negative numbers show that the project has not yet broken even. The green positive bars show that the project has gone beyond the breakeven point. In this case, the breakeven point is between 2023 and 2024.

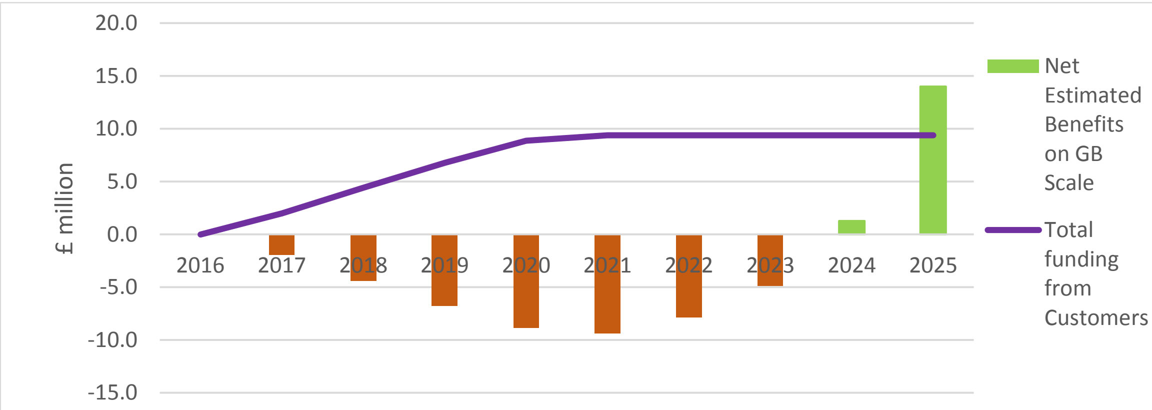


Figure C.7: Breakeven analysis results, showing the customer investment and estimated benefits of Proteus. The breakeven point occurs between the years 2023 and 2024.

C.3. Capacity Release

The use of the Proteus solution enables the use of network capacity as a result of the operation of the Temporary Solution. Though the permanent solution selected may be different in the Proteus Case, when compared to the Base Case, it is assumed that the capacity released in these solutions will be comparable.

It is possible that the Temporary Solution could provide considerable capacity release to the local network while it is installed, where the network situation requires it. The limit for this is the rating of the network conductors themselves, and that of the Temporary Solution equipment. On this basis, it is estimated that while installed, the solution will be capable of releasing an additional 200 kVA capacity for a distribution substation. This capacity will be available for the duration for which the Temporary Solution is installed, which is assumed to be an average of 3 months, with each solution being deployed 3 times per year.

The graph below shows the estimated capacity released due to the implementation of the Temporary Solution at GB scale in the average case. This graph illustrates the clustered and uneven characteristic of this profile, which mirrors the profile of estimated installations.

While it is expected that the deployment of the Proteus units will have this characteristic, the specifics of the shape such as which years will have particularly low or high deployment are unpredictable.

In order to produce representative figures for capacity release for individual years, a trend line is used. This trend line is calculated from 2025, which takes out the roll out period of the technology.

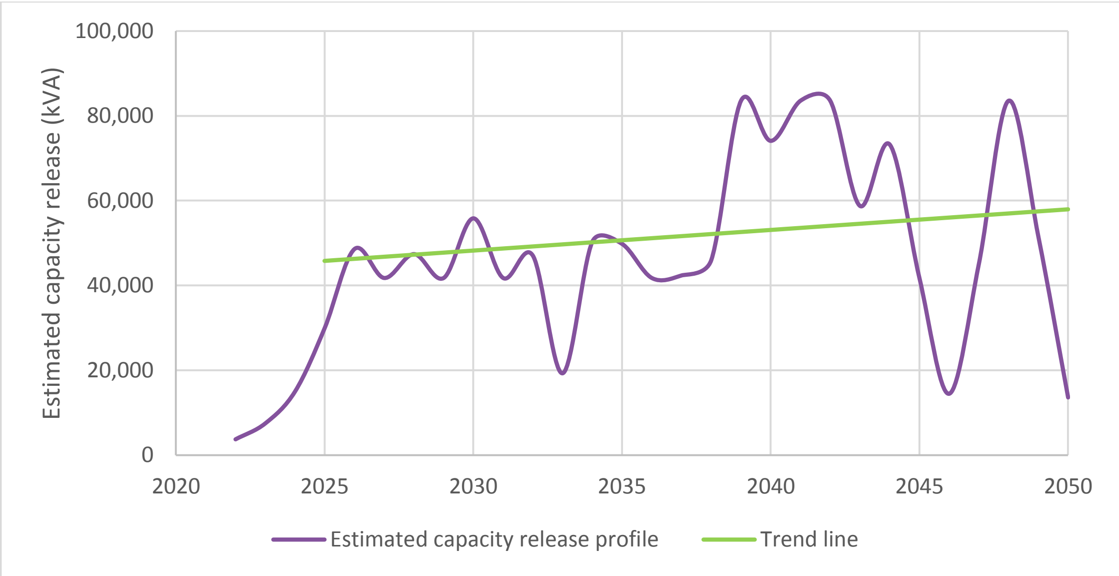


Figure C.8: Annual Estimated Capacity Release over GB scale, average case

The table below shows the estimated capacity released due to the implementation of the Temporary Solution, taken from the trend lines of each profile as described above, for a single solution, over the WPD network, and at GB scale.

Annual average Capacity Release (kVA)	**2020**	**2030**	**2040**	**2050**
Single Implementation	-	150	-	-
WPD Scale				
Low Scenario	-	7,000	14,000	20,000
High Scenario	-	23,000	20,000	16,000
Average	**-**	**16,000**	**17,000**	**18,000**
GB Scale				
Low Scenario	-	22,000	42,000	63,000
High Scenario	-	72,000	61,000	50,000
Average	**-**	**48,000**	**54,000**	**58,000**

C.4. Environmental Benefits

The environmental impact of Proteus and the solutions that it enables can be considered in two key ways. These are described further in the sections below.

- **Direct Environmental Benefits**, which compares the carbon impact of the Base Case and the Proteus Case; and
- **Indirect Environmental Benefits**, which considers the wider impact of a solution such as that enabled by Proteus.

Direct Environmental Benefits

The assessment of the environmental benefits has been carried out using the Base Case and Proteus Case as described in the sections above.

The key source of environmental benefit of the Proteus Case, when compared to the Base Case, is the prevention of stranded Assets. Stranded assets are when network reinforcement is implemented when it was not truly needed, for example if the cause of the issue was only temporary or when a simpler solution would be as effective, but was not apparent with limited information available. The Proteus methods will be capable of preventing this happening, therefore saving the associated carbon cost of that reinforcement.

Additional carbon benefits may be seen in the optimisation of the permanent solution developed to network capacity issues. This is achieved through the availability of more detailed network and Temporary Solution performance data, and the availability of time to develop solutions while the network is supported by the Temporary Solution. This may include the selection of alternative of innovative solutions, or the optimisation of the design of traditional permanent solutions.

The other key environmental impact of the Temporary Solution is the embedded and operating carbon of the Temporary Solution itself. The Proteus Temporary Solution will have improved carbon impact when compared to the equivalent process used in the base case to investigate a network issue and implement a solution.

Quantifying environmental impacts is a difficult task, and it is not practical to attempt to develop accurate figures. For the purpose of this part of the business case, the carbon dioxide equivalent figures for the aspects above were estimated based on figures for similar activities, and the carbon impact of the base case and the Proteus case estimated. The results of this analysis is given in the table below:

Carbon Benefit (tCO2e)	**2020**	**2030**	**2040**	**2050**
Single Implementation	-	7	12	12
WPD Scale				
Low Scenario	-	91	747	1,659
High Scenario	-	914	1,968	2,949
Average	**-**	**503**	**1,358**	**2,304**
GB Scale				
Low Scenario	-	283	2,311	5,134
High Scenario	-	2,828	6,092	9,128

Average	**-**	**1,555**	**4,201**	**7,131**

Indirect Environmental Benefits

The key objective of Proteus is to enable the adoption of low carbon technologies and behaviours, which combined has the potential to greatly reduce carbon emissions of the UK.

The future energy scenarios (FES) identified by National Grid has 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. These range from "Gone Green" which meets the GB renewable targets by increasing distributed generation and use of heat pumps to "No Progression" where there is less interest and activity in this area. The graph below shows the total carbon emissions for the UK in each of the four scenarios:

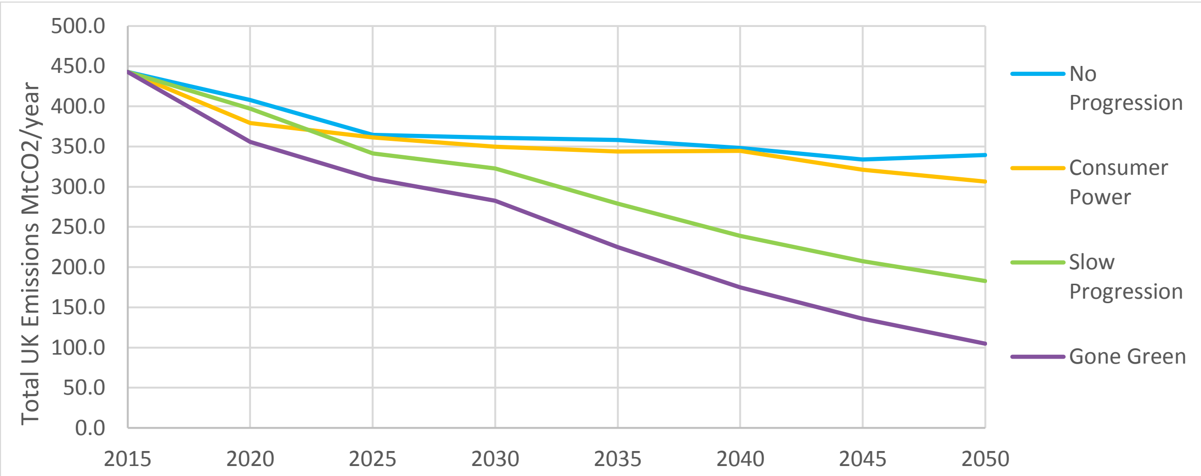


Figure C.9: Total UK Emissions forecasted up to 2050, from the Future Energy Scenarios developed by National Grid.

The graph shows that in every scenario, there is a significant reduction in carbon emissions in 2050 compared to today, which ranges from 103.6MtCO_2/year in the 'No Progression' scenario, to 338MtCO_2/year in the 'Gone Green' scenario.

As the adoption of low carbon technologies and behaviours increases, there is a change in energy use, which in turn will result in a change in the requirements placed on the electricity distribution networks. Proteus will provide the networks with the tools to cope with a key aspect of this impact; the increase in occurrence and complexity of LV network capacity issues. Without these or similar tools, the uptake of such technologies may be restricted, for example by restricting their affordable connection. Alternatively, the cost of supply may be increased due to the need to implement costly solutions, and the quality and reliability of supply may reduce.

Therefore, though it is not possible to quantify the exact contribution that Proteus will make to the low carbon futures described in the Future Energy Scenarios, it is considered that Proteus could enable, and therefore be attributed with, some of the benefits of the low carbon future it is supporting.

C.5. Other Benefits

There are other significant benefits which are not described as cost, capacity, or carbon benefits.

The most notable being the benefit to the customer of network issues being mitigated quickly. These issues would otherwise have been causing quality or reliability of supply issues for customers. Within the process enabled by Proteus, the network issue can be 'solved' from the point of view of the customer, through deployment of the Temporary Solution very soon after the issue is discovered. This may take several months in the base case.

There are other potential applications of the technology components of the Proteus Temporary Solution, for example for temporary issues, or issues which are reoccurring but rare. In these cases, the Temporary Solutions can be used to prevent the need for permanent solutions entirely, while supporting the network and maintaining quality of supply to customers.

There are also other potential applications of the learning and technology developed within Proteus. The components of the Temporary Solution can be used within the development of a permanent solution, and the learning from the project and its application can be used to further develop these components which would support the development of the permanent solution in parallel.

Another benefit of the solution is increased network visibility. The improved network information and data made available by the Temporary Solution not only enables the optimisation of permanent solution selection and design, but also enables increased visibility of the network for the discovery of any hidden behaviour, thus allowing permanent solutions to be optimised further.

Appendix D: Technical Appendix

D.1. Introduction

The Proteus technical solutions provide two key improvements on the methods used to solve network capacity and constraint issues:

- **The Temporary Solution**, which can be quickly deployed and has the capability of providing a range of network capacity solutions. Monitoring and analysis is also deployed to gather the data required to understand, configure and solve the constraints.
- **Selection of the permanent solution**, which is improved by using the information gathered by the Temporary Solution, and by using the time released by the Temporary Solution while the issue is not causing immediate issues to customers to plan and implement an appropriate solution.

These two aspects are described in more detail below.

D.2. Temporary Solution

Temporary Solution Requirements

The Temporary Solution will be capable of meeting the following high level requirements:

- **Deployable** – the solution will be mobile, and will be able to be easily transported, placed at, and connected into the network at the required sites.
- **Flexible** – the solution will be able to adapt to the requirements of the sites, including the following capabilities:
  - Control of real and reactive power flows of the substation feeders;
  - Control of voltage, harmonics, or unbalance on substation feeders;
  - Connection of additional generation or storage;
  - Control of the loading of the network assets;
  - Retrofit cooling of network assets; and
  - Equalisation of network loading with nearby connected substations.
- **Connected** – Network and solution operational data will be communicated and stored in a data management module, to enable performance to be analysed. The data collection will include all data required to develop a tailored permanent solution to the network issue.
- **Autonomous, with remote management** – the solution will be autonomous, to control its operation, to maximise benefits and maintain safety. The operation of the units can be remotely monitored, and the settings, such as operating mode, will be remote configurable.
- **Re-deployable** – Once the solution has no longer needed at that site, it can be easily disconnected and moved from another site, or stored for the next requirement.

Temporary Solution Components

The total Flexible Capacity Solution is made up of the following key component parts:

- **The Flexible Capacity Unit (FCU) and optional generator and storage module** – this will be deployed at a 'key' point on the distribution system, which is identified as the substation which is directly experiencing issues, or is in the best location in the network to implement solutions. This unit will form the core of the solution. The optional storage and generation modules can be used in conjunction with the FCU when needed.
- **The Dispersed Capacity Unit (DCU)** – this incorporates some of the functionality of the FCU, and is designed to be deployed at another strategic part of the network,

for example at adjacent substations, link boxes, or directly onto cables or overhead lines. It will not always be used, but can provide network intervention in a more flexible location than the FCU.

- **Network diagnostics and autonomous control** – this will be capable of characterising the network on an ongoing basis, and assessing the most appropriate intervention for the Temporary Solution to take, including location, configuration and settings. This capability is hosted locally to the FCU, and will process information from the FCU, DCU and remote monitoring systems, and additional monitoring capability which can be installed at strategic locations within the network.
- **Remote monitoring and management system** – this will enable remote system performance tracking, control of modes and settings, and access to data and information with which to understand the network issues and design a permanent solution.

These are indicated on the diagram below, and explained in more detail in the following sections:

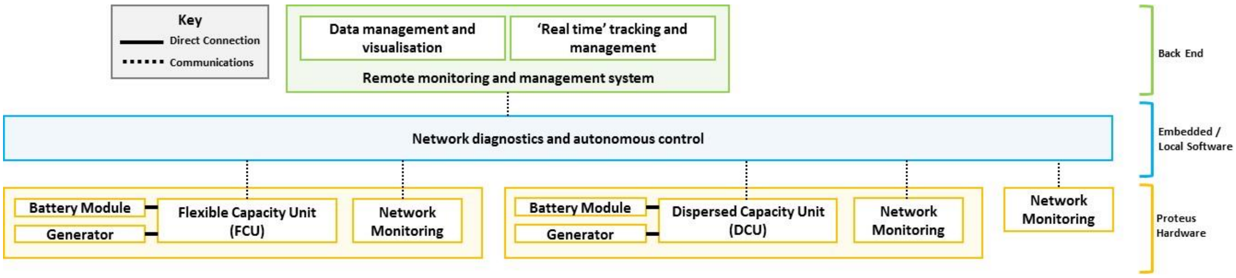


Figure D.1: Components of the Temporary Solution enabled by Proteus

The Flexible Capacity Unit (FCU)

The Temporary Solution will be based around a FCU, located at a key point on the network, which is capable of managing power and voltage through the assets, connecting energy storage or generation, and providing retrofit cooling for substation assets. The FCU contains a number of key components that can be configured in combination to meet a wide range of site components. These components include:

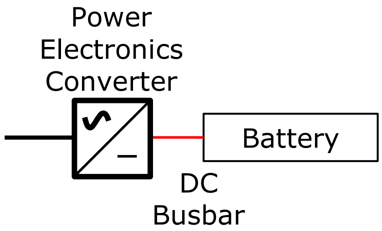
- Power electronics
- Transformer
- Flexible LV board
- Cooling
- Battery
- Generator

These can be configured via remote controllable circuit breakers to deliver a wide range of functionality. This includes the following:

Battery system

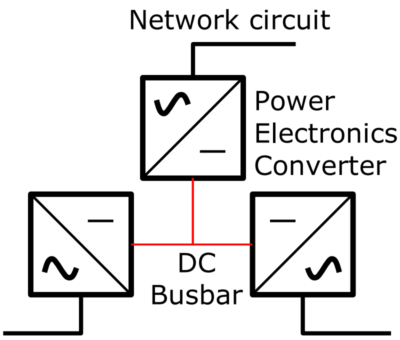
Energy storage is used to manage the loading of the network, for example by storing energy when the load is low, to be used when the demand rises.

Battery systems operate on direct current (DC) power, so a converter is needed when connecting to the AC network.



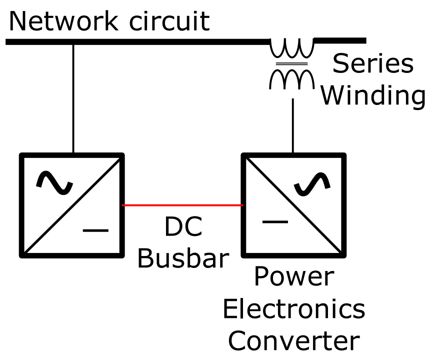
Soft Open Point (SOP)

A SOP is made up of a number of power electronics converters, with a DC (direct current) Busbar between them. Each converter can be connected to a circuit, enabling a fully controllable flow of real and between them (and reactive power injection), without passing fault current. The SOP may be used to connect circuits across system boundaries, and can provide other benefits such as control of voltage, harmonics and phase



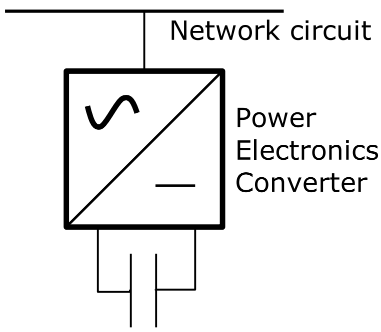
UPFC (Unified Power Flow Controller)

A UPFC is made up of two power electronics converters, connected with a DC Busbar. The device interfaces to the AC network using a shunt connection on one side, and a series winding on the other. This enables flexible real and reactive power control, and can be used in conjunction with an additional generator or storage to control network assets to within their capacity thresholds.



STATCOM (static synchronous compensator)

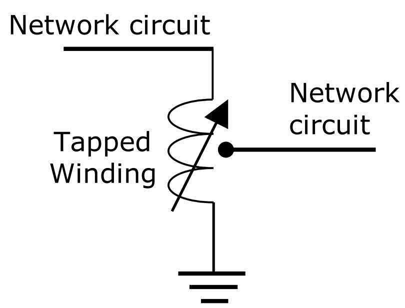
A STATCOM is made up of a power electronics converter that injects compensation currents for several problems including phase-imbalance, harmonics, flicker and low power factor.



Voltage Regulator

A voltage regulator can take a number of forms, including a tapped winding (see diagram). It can also be power electronics based.

It is capable of controlling network voltage in real time.



Asset Cooling

The capacity of network assets to carry load is closely related to temperature. If an asset becomes too hot, it may experience accelerated aging and damage. Therefore, if asset cooling can be used to reduce the temperature of an asset, then it is protected from these issues, and additional network capacity may be released.

Figure D.2: Descriptions and simplified diagrams of a battery system, 3 port SOP, UPFC, STATCOM, Voltage Regulator and Asset cooling

This equipment will be connected and arranged to enable easy configuration of the unit to meet the specific requirements of the site. This will be achieved using a flexible LV Busbar arrangement. The diagram below is a high level representation of the potential arrangement of the FCU. This is an initial high level view, and the details will be developed within the inception phase of the project.

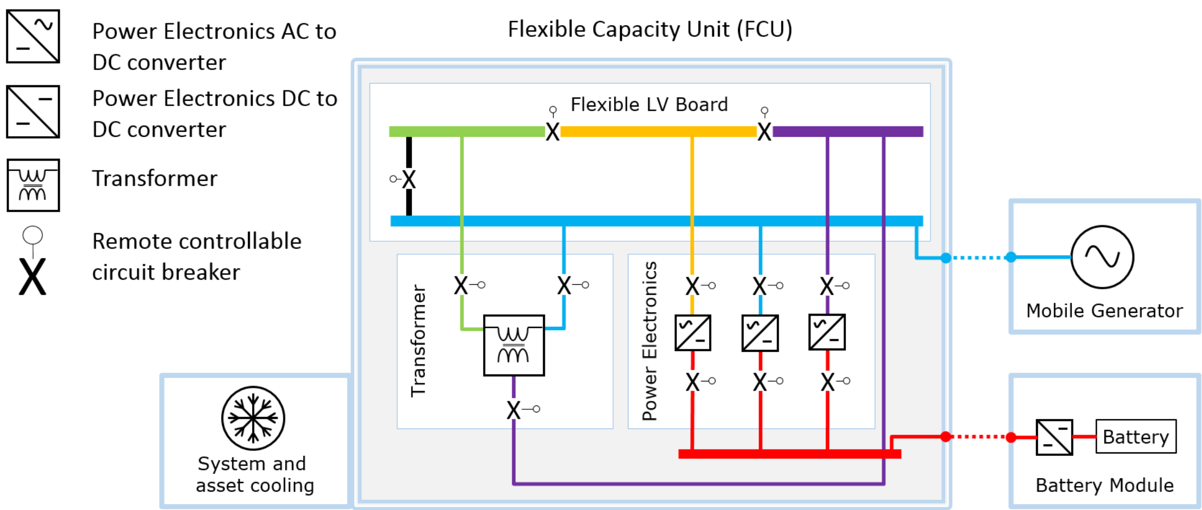


Figure D.3: High level arrangement of a Flexible Capacity Unit (single line diagram to represent three phases)

The flexible Busbar arrangement in combination with the remote controllable circuit breakers enables each of the components within the unit to connect in series or separately to the LV board at the substation. This enables the configuration of the unit into a wide range of potential solutions.

For example, by connecting up the three power electronics devices, and separating the different sections of the board, then a three port SOP can be used. However, by disconnecting one of the power electronics devices, and using the transformer, then the unit can be used as a UPFC.

The FCU will be connected into the network via an LV board, link box, supplies pillar etc. The configuration of this connection will be an important consideration on commissioning of the equipment, as this will dictate the degree of flexibility once the unit is operational. The intention is to integrate the unit in such a way that is can self-configure and adopt any one of its core functions, for example those listed in Figure D.2.

The diagram below shows a possible configuration of the FCU connected into the LV board at a candidate substation. Different sections of the FCU Flexible LV board are connected to the Substation LV board; the green section is connected to the transformer LV output, and the blue is connected to the LV busbars. The yellow and purple sections are each connected to an LV feeder, which have been selected as they connect to nearby substations.

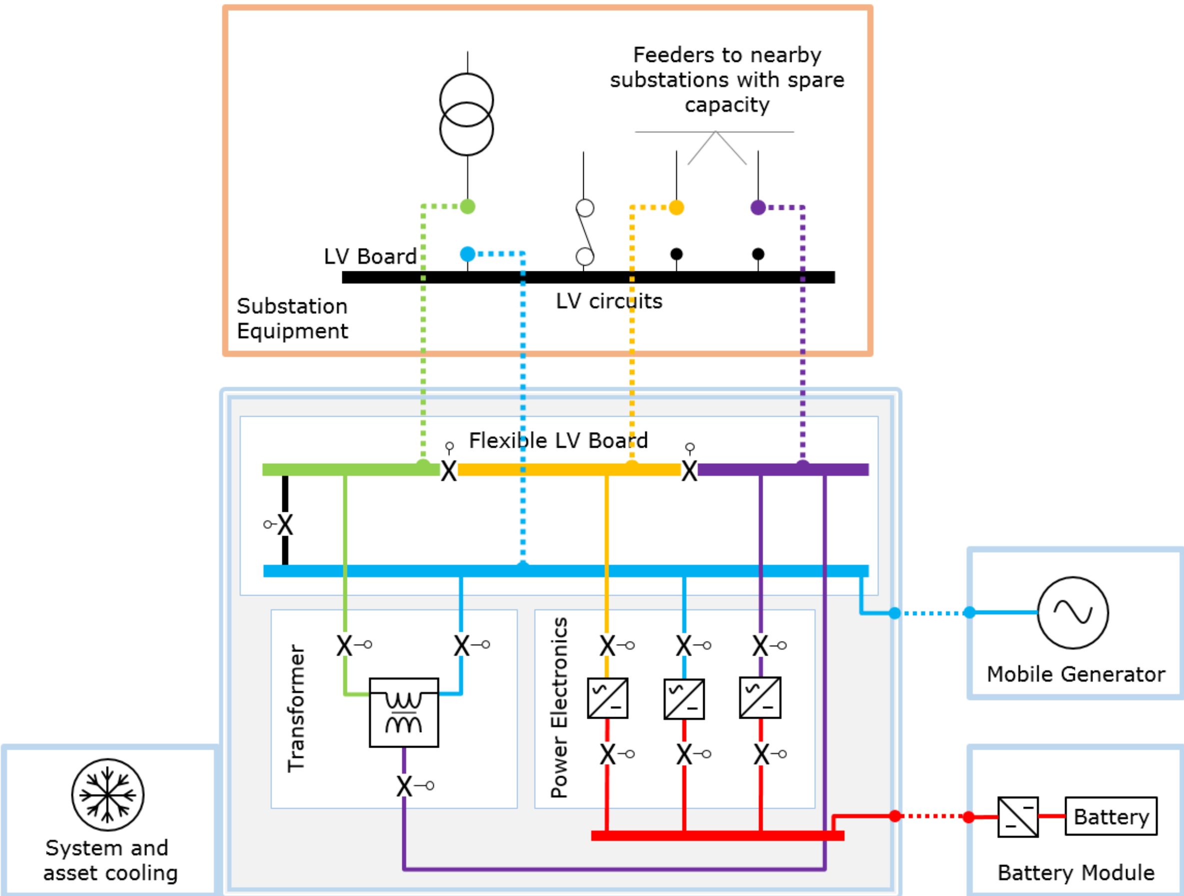


Figure D.4: An example configuration of a FCU solution, using a 3-port SOP and a battery module (single line diagram to represent three phases)

The precise configuration of this connection will depend on the issue, and the site characteristics. This will be determined during the commissioning process.

The Dispersed Capacity Unit

As well as the FCU, an additional unit, known as a DCU, may be connected to the network, which will be capable of managing voltage and power flows through a smaller package of equipment with reduced functionality compared to the FCU.

The equipment contained within a DCU will be a subset of the equipment within a FCU. This is likely to be two power electronics devices, that can be used as a 2-port SOP, a dSTATCOM, and power electronics based voltage regulator, or a means by which to connect batteries or generation.

The DCU will be designed to be quickly deployable, and contained so that is can be left for short periods installed onto the network.

The combination of functions which will be needed for each issue will vary, and it will be part of the commissioning process to determine the most appropriate combination of units for a given situation.

Network Diagnostics and Autonomous Control

The Temporary Solution will be capable of self-configuring, by assessing the characteristics and state of the network, and analysing which solution would be the most appropriate to deploy.

In order to do this, the network diagnostics capability creates a model of the local network, and uses data collected from the Temporary Solution units, and additional monitoring equipment which is installed at strategic locations within the network. This monitoring equipment will be easily retrofit-able, and will monitor asset temperature and three phase power, including voltage, current, real and reactive power, harmonics, and asset temperature. This monitoring equipment will have GPS timestamping and location technology to enable accurate timing and tracking of measurements.

The autonomous control system will then assess the most appropriate configuration and settings for the equipment to be installed in order to correct the issue. It will then send the instructions to the connected equipment to change the configuration and operate to the desired settings and parameters.

This process will be carried out autonomously, with the equipment and sensors communicating to each other wirelessly. This will be achieved through machine-to-machine meshed wireless and non-steering mobile telephone connectivity. This communication will be designed to be low-bandwidth, and suitable for locations with challenging connections.

The capability to configure and re-configure on an ongoing basis makes the Temporary Solution particularly applicable for issues which are dynamic in time, where loading, voltage, and other network parameters can change significantly within a relatively short space of time.

Remote Monitoring and Management System

A remote monitoring and management system will enable the following:

- **Remote tracking of Temporary Solution performance**: The information and data collected by the local autonomous network diagnostic and autonomous control will be fed back to the remote monitoring system, which will provide visual dashboard for high level tracking, and data analysis and download for in-depth understanding.

- **Management of the Temporary Solution:** It will be possible to view the system configuration in real time and change settings, such as switch it on or off, changing the mode, and setting the set points. The real time control is still handled locally, and safeguards will be put in place to prevent settings to be set which could potentially endanger the network or the equipment.

Illustrative Example Network Installations

Some example applications of Proteus equipment in constrained LV networks are described below. In each instance additional monitoring equipment is installed strategically around the network to understand the cause and effect of the constraint, and also to monitor the impact of the Proteus equipment.

Case Study 1:

In this instance a cluster of Photo-Voltaics and/or Electric Vehicles creates an unforeseen overload condition on the LV network. It is identified that an adjacent substation has capacity to share the additional power flow from the PV or to the EV. The location of available open-points and the disposition of loads along the feeder means that a SOP at the feeder-end is the preferred solution. If required additional support from a battery and chiller can be provided.

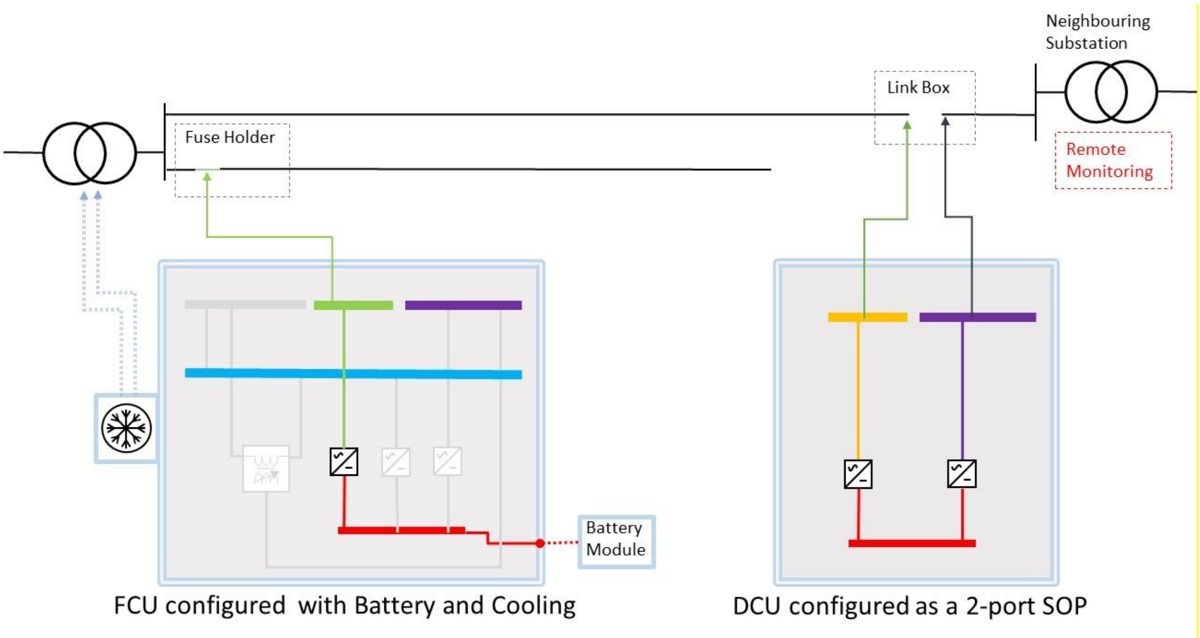


Figure D.5: Example Proteus installation – [Case Study 1]

Case Study 2:

In this scenario, an overload situation has occurred as per the previous example and again using a SOP to share capacity with an adjacent substation is identified as a good solution. A feeder from the adjacent substation runs to a close by link-box and the SOP can be configured from two inverters in the FCU and connected at the target substation. It is also identified that one feeder has a large imbalance in phase current (caused by a large number of loads on one phase) which is causing excessive transformer heating.

The third inverter in the FCU is configured as a STATCOM and used to inject currents to correct the phase imbalance.

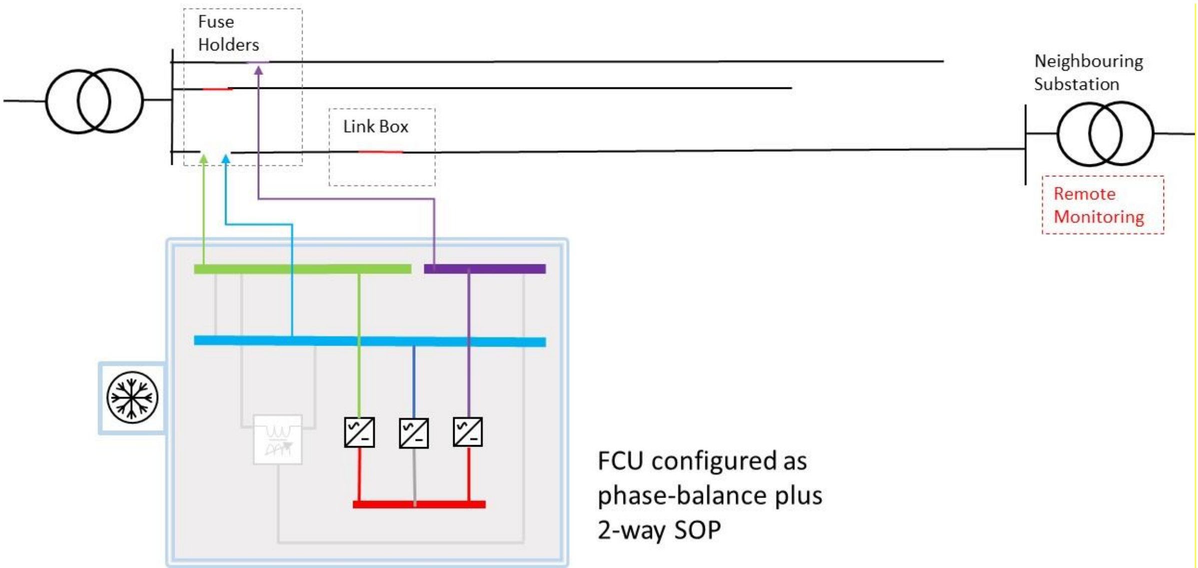


Figure D.6: Example Proteus installation – [Case Study 2]

Case Study 3:

In this scenario a cluster of Photo-Voltaic connections has created an unforeseen over-voltage condition on one feeder. The other feeders are heavily loaded and at lower voltage. Voltage correction specific to this one feeder is required. Proteus has identified that a UPFC should be used to perform series voltage subtraction to lower the voltage on the affected feeder. The UPFC offers fast acting dynamic voltage response, which is useful in the event of passing clouds causing a brief drop in generation output. If the PV are clustered on one phase in particular, phase current re-balancing at the feeder-end can also be employed using a STATCOM in a DCU.

(The use of series voltage injection by the UPFC involves real power exchange and so the shunt connection must be active to provide for that. The transformer in the FCU is envisaged to have two windings with a turns-ratio of about 5:1 which is suitable for acting as a series connection transformer.)

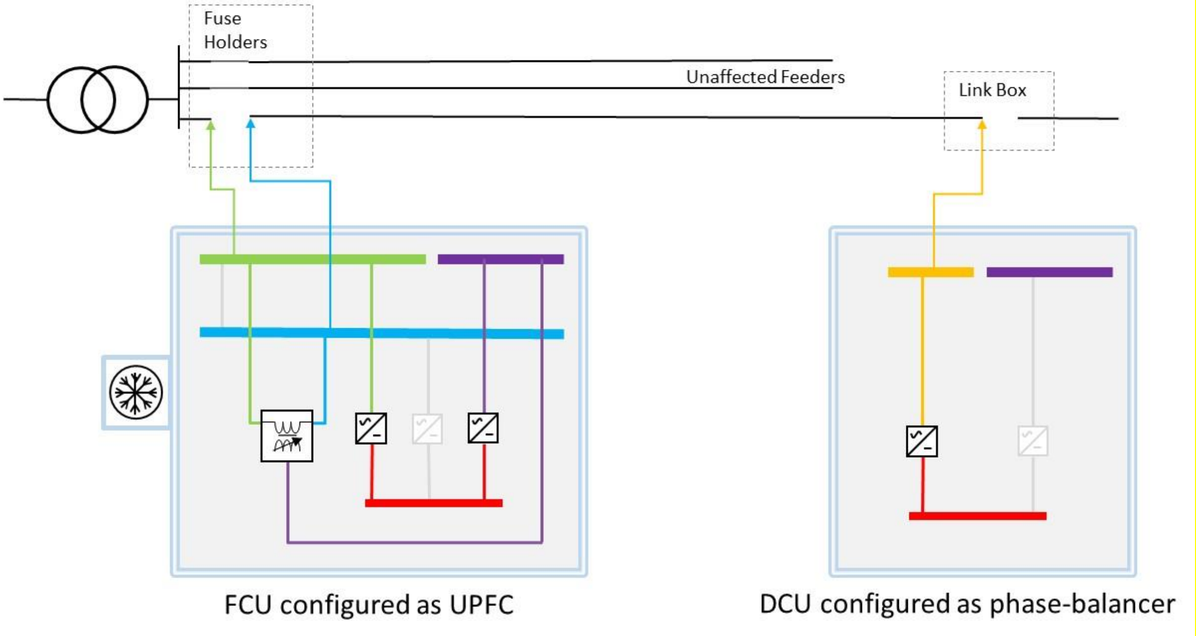


Figure D.7: Example Proteus installation – [Case Study 3]

D.3. Selection of the Permanent Solution

The key advantages that the installation of the Temporary Solution has in the selection of the permanent solution are:

- **Provision of more detailed information:** Permanent solutions to network issues will be developed through information and data collected by the FCU, DCU, and the associated monitoring equipment. This selection can be based on an optimisation of the cost and benefits, given the detailed understanding of the network requirements, and can include selection from conventional and innovative options.
- **Buying of time while mitigating issues and risk to the network:** The Temporary Solution being in place will mitigate the network risk and customer issues associated with the capacity problem. This buys time for the permanent solution to be selected, designed, and implemented, and means that more care can be taken to ensure that the selection and design is optimised.

The selection of the permanent solution can be made from a wider range of potential solutions, including traditional solutions, and more innovative ones. There has already been significant work into the development of innovative network capacity methods. Proteus aims to build on this understanding, and develop a methodology for assessing and selecting the most suitable solution for a given network issue. Proteus will not aim to implement any permanent solutions within the project, however where issues are identified, WPD may use the learnings from the Proteus project to implement permanent solutions.

Examples of the additional options for flexible network capacity are given in the table below, as well as an indication of the most relevant and recent development for that technology from within the GB network.

Solution	Description	Previous Development
Unified Power Flow Controller (UPFC)	Enables dynamic control of voltage and power, and can be used in conjunction with an additional generator or storage to control network assets to within their capacity thresholds.	The use of these units has been developed at Transmission Voltages at a small number of sites worldwide, and their use at Lower Voltages described and modelled in various academic papers
Energy Storage	Battery storage systems, which can be used to smooth a power profile.	The use of these units has been trialled within the FALCON project.
Remote Controlled Circuit Breakers and link box switches	Can provide a simple controllable connection between two adjacent substations, to enable equalisation of the load between them. This is useful where an adjacent substation has available capacity.	The use of these units has been trialled as part of the FUN-LV project.
Soft Open Points	Provides voltage control, improve phase unbalance, and reduce harmonics. Can be used to provide a controllable connection between adjacent substations, where the power flow between the circuits is closely controlled. Can connect across network boundaries without passing fault current.	The use of these units has been trialled as part of the FUN-LV project
Voltage Regulators	Can provide a means of controlling the voltage level on the network, maintaining it to within allowed limits.	The use of these units has been in widespread industrial use for many years and will be developed further for networks applications as part of Proteus.
Retrofit Cooling	Provides cooling of network assets. As the temperature of the asset is often a limiting factor to its capacity to carry power, actively cooling the asset can increase their capacity to carry load.	The use of these units will be trialled as part of the Celsius project.
STATCOM	Provides dynamic balancing of phase voltage and current.	The use of these units has been developed at Transmission Voltages at various sites worldwide for dynamic voltage control. dSTATCOMs have been described, modelled and demonstrated for LV applications.
Network Reinforcement	This involves replacing existing network equipment, or adding additional equipment, in order to raise the overall capacity of the network. This solution can be costly and disruptive.	Traditional method

Appendix E: Ricardo Skills and Experience

E.1. Introduction

Ricardo is a global strategic, technical and environmental consultancy. It is also 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 in our core product areas of engine, transmission, vehicle, hybrid and electrical systems, environmental forecasting and impact analysis.

Ricardo will have a number of key roles within the project:

- Programme Management
- Technical concept development through to product delivery
- Trial design and management
- Technical analysis
- Development of recommendations
- Dissemination of learning and results.

The skills and experience of Ricardo in each of these areas is summarised below.

For more information about Ricardo, go to www.ricardo.com/en-GB/

For more about the Energy practice, go to http://ee.ricardo.com/cms/ppa-energy/

E.2. Programme Management

This project will be led by Ricardo's Energy Practice, with 16 years' experience in the energy industry. Our team, formally known as PPA Energy, comprises a group of highly experienced professionals specialising in technical, economic and management consultancy services for the energy sector, with particular emphasis on the power sector, renewable energy, and future networks. We have worked with a broad range of clients, including multi-lateral lending agencies, governments, regulators, electricity and network companies, natural resources companies and private developers in over 90 countries.

Approximately half of our work is located within the UK, with clients including DNOs, Ofgem and organisations such as the Electricity Networks Association (ENA) and Energy Technologies Institute (ETI). Our experience has included several electricity network innovation projects, both in partnership with network companies and other organisations, and the development of our own original concepts.

We aim to have a methodical and organised approach to project management, whilst allowing the flexibility for a project and its concept to evolve. This is essential for innovation projects, as their nature means that they are not concrete, but will need to change as knowledge is built up.

Again, as an established consultancy firm within the energy industry, we have significant experience in project management and coordination of innovation projects. This includes overall coordination of entire projects or work packages, as well as management of individual contributions that we are making.

Ricardo has developed and led a wide variety of projects and programmes in the energy sector. This has included technology development and trial projects.

An example of Ricardo providing active partner and lead roles in previous major network innovation projects includes the role within Flexible Urban Networks – Low Voltage (FUN-LV). FUN-LV is funded through the Ofgem Low Carbon Networks Fund (LCNF), and is being led by UKPN. It is a 3-year project that started in January 2014.

Ricardo is a major partner in this project, providing technical expertise, site selection and analysis for the solution design and validation. We also manage one of the work packages, 'Network Awareness and Process Improvement' on behalf of UK Power Networks, which is responsible for a number of activities including the development of the power electronics algorithms by Imperial College London.

Another example is Ricardo's role in Distribution Network Visibility (DNV). DNV was led by UKPN, and was funded through the Ofgem Low Carbon Networks Fund (LCNF). The project was undertaken in three stages between 2010 and 2013, and the concepts are being developed into normal practise in a Business as Usual project.

Ricardo was closely involved in the management and execution of the project, through membership of the project Steering Committee and regular technical and project management meetings and programme management of the BAU integration phase.

E.3. Technical Concept Development Through to Product Delivery

Concept Development and Product Delivery

Ricardo has significant expertise within the electricity industry, and one of our specialty areas is that of electricity network innovation. The process of conceiving specific and useful technical concepts, and developing them through feasibility, demonstration and then on to business as usual is illustrated in the diagram below. We have experience in developing, leading and supporting network innovation projects at all of these stages.

Concept	**Feasibility**	**Proof of Concept**	**Prototype**	**Demonstration**	**Business as Usual**
Developing ideas through understanding complex network requirements and problems	Ensuring the viability of a concept, including desk-top studies and analysis, market research and pre prototype trials	Drawing on industry experts, using network data to build models, conducting laboratory and initial field testing	Deploying within the target environment, refining the concepts, tailoring the solution to meet the needs of the network	Proving the solution within a BAU environment, scrutinising the solution details, business case and the evaluation of the risks	Bridge the gap between innovation and normal practices. Integrating the solution into normal business and operation.

Figure E.1: Concept Development Lifecycle, from initial concept, to business as usual.

Ricardo has capabilities in niche manufacturing of high performance products. This has generally been focussed on electrical, electronics, and mechanical components for the automotive industry.

Within the energy industry, 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.

Experience with Technologies Relevant to Proteus

Ricardo also has experience in technical projects which relate to technologies and components that will be used within the Proteus project.

For example, as mentioned above, Ricardo has a major role in the FUN-LV project. This project aims to defer the need to reinforce networks by enabling load to be autonomously shared between heavily loaded substations and those nearby that have spare capacity. The project uses a mix of innovative power electronic controllers and switching devices to interconnect or mesh areas of the distribution network in London and Brighton. FUN-LV is developing the innovative techniques necessary to monitor and autonomously control real and reactive power flows in real time whilst improving power quality in terms of unbalance, harmonics and power factor.

Ricardo is a major partner in this project, providing programme management, technical expertise, site selection and analysis for the solution design and validation. The technologies used in this project, particularly the power electronics and the remote controllable circuit breakers are directly related to components within the Proteus Temporary Solution.

Ricardo also has a major role in the Celsius project, which is led by Electricity North West. Celsius will deploy monitoring into approximately 520 distribution substation sites, and this data will be used to develop a detailed understanding of the factors that impact asset temperature. The project will also identify a number of potential retrofit cooling technologies, and trial them within monitored substations. The collected data can be compared with data collected before the intervention, enabling a direct 'before and after' comparison.

Ricardo is supporting the development of the monitoring technology, and leading the technical analysis within Celsius. Proteus will use monitoring technology similar to that used in Celsius, and we are working with the project partners who are supplying the technology within Celsius to develop the network monitoring and diagnostics solution for Proteus. Proteus will also use the learning about retrofit cooling technologies to add to the recommendations of the project.

E.4. Trial Design and Management

Many innovation projects involve a trial or demonstration of technologies. Ricardo has specific experience in this area, including the design of trials, site selection, and trial management.

Experience in designing and managing technical trials on GB electricity networks includes activities within the Distribution Network Visibility (DNV) project. Ricardo led the technical trials of advanced and non-invasive monitoring systems on LV-33kV systems.

Within the FUN-LV project, Ricardo led the site selection and trial design process. This was an involved process, identifying candidate substations and deploying monitoring and analysing available data to select the most suitable locations. We have also provided ongoing support to the project trials and data validation.

As part of Celsius, there is a trial including 520 LV network sites. Ricardo has scoped the technical programme, designed the site selection process, validated the selection, and has a key role in the development of trial designs, installation methodologies, and training.

E.5. Technical Analysis

Ricardo has significant expertise in the collection, management and visualisation of data. For example, Ricardo leads 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. This data is stored, analysed and visualised as part of a package developed by Ricardo.

Through our involvement in electricity network projects, we have gained significant experience in receiving and analysing network data. We have a particular specialty in developing the data into useful, actionable information, which can be of use to network operators and planners. We have been involved in a number of network projects that support this, including the Distribution Network Visibility project, which is described below.

Within the Celsius project, Ricardo is leading the collection, validation, visualisation, and analysis of the monitoring data for 520 sites. This is using similar tools and techniques as the air quality data handling, and the technical expertise of Ricardo personnel to analyse and developing into usable, actionable information.

The DNV project included the visualisation and analysis of network data from 10,000+ sites. For this project, Ricardo provided technical support, validation and advice in business process, and Capula Ltd provided services in database upgrade and software delivery.

E.6. Development of Recommendations

A key deliverable for the Proteus project is the recommendations for implementation of learning into everyday business practises. This is vital as it is the mechanism by which the learnings are leveraged into wider benefits to the customers.

Within the DNV project, Ricardo supported the development of significant business as usual recommendations. This was then developed to an implementation project, and Ricardo had a key programme management role within this work.

Within Celsius, Ricardo has a key role in the development of the business as usual recommendations, including the tools and specifications needed to leverage the project learning, and any required changed to the industry-wide engineering recommendations.

Ricardo also have in-depth knowledge of engineering recommendations of codes. For example, we have a key role in the project to modify UK Technical Codes to incorporate EU legislation

E.7. Dissemination of Learning and Results.

An important part of Proteus is dissemination of the learning and results. The main channels through which this takes place is through attending events, hosting events, direct communications, and release of documentation and press releases.

Ricardo have had a significant role in the HubNet programme, which is made up of several academic institutions who form a hub for energy network research. As part of this role, Ricardo has significant experience in running academic and dissemination events.

Ricardo have also attended, contributed to, and presented at key industry events such as the LCNI conference and CIRED.

Appendix F: Related Projects

F.1. Introduction

Proteus will aim to build on the learning of related innovation projects, thereby leveraging the work already been done, and maximising the benefits from the project.

This section lists that most relevant key innovation projects that have been identified, the most important learning points from the point of view of Proteus, and how the learning will be transferred between the projects.

F.2. My Electric Avenue

My Electric Avenue was an LCNF Tier 2 project which was awarded funding in November 2012, and formally commenced in January 2013. The project was carried out by EA Technology, who is a third party 'non-DNO'. As part of the project outcomes, learning about the successful running of an Ofgem-funded innovation project by a non-DNO partner. Therefore it is important that the Proteus project partners take these learnings on board.

Some examples of these learnings are listed below, with the reaction to them within Proteus.

My Electric Avenue learning point	Proteus reaction
A partnership approach between the third party and DNO is essential. It is of note that despite being led by a third party, significant DNO resource is still required to support partnership delivery of the project.	The Proteus team will be led by Ricardo, but WPD is fully committed as a project partner. A WPD project manager has been identified, and time for management and review roles, as well as installation and management, has been included in the project.
It is important to have independent evaluation of the trial and the technology in order to provide confidence that the Project recommendations are fair and un-biased.	As well as ongoing review by WPD, UK Power Network has been identified as a peer review partner, who will review the project methodologies and conclusions.
The DNO contribution is compulsory at a minimum of 10%. The third party should also make a contribution to the project to ensure full alignment in the delivery.	Ricardo is fully committed to the project and its success, and is making a contribution to the project through a reduction in rates, which totals £363k.

F.3. Flexible Urban Networks-Low Voltage (FUN-LV)

FUN-LV is funded through the Ofgem Low Carbon Networks Fund (LCNF), and is being led by UKPN. It is a 3-year project that started in January 2014.

FUN-LV project aims to defer the need to reinforce networks by enabling load to be autonomously shared between heavily loaded substations and those nearby that have spare capacity. The project uses a mix of innovative power electronic controllers and switching devices to interconnect or mesh areas of the distribution network in London and Brighton. FUN-LV is developing the innovative techniques necessary to monitor and autonomously control real and reactive power flows in real time whilst improving power quality in terms of unbalance, harmonics and power factor.

The project involves developing the techniques to make this a reality, and trialling and demonstrating the technologies at 36 trial sites in London and Brighton. This includes trialling Soft Open Points (SOP), which will be trialled in operational networks for the first time.

The key technologies which are being trialled within FUN0LV are Soft Open Points, which are made up of power electronics devices, and remote controllable circuit breakers. These technologies form key components of the Proteus Temporary Solution, though they are being utilised in a significantly different way than in FUN-LV.

The learning from FUN-LV will be important input into the design of the Proteus solutions. This learning will be bought into the project by Ricardo and TPS, who have a significant role within FUN-LV. TPS provided the SOP equipment for FUN-LV, and therefore have developed the technology learning from that project. Within Proteus, particular care will be taken to review these learnings and to ensure that it is leveraged fully.

F.4. Celsius

Celsius is a Network Innovation Competition project run by Electricity North West. It started in January 2016. The project is investigating a more accurate way of managing network assets taking into account temperature as well as loading.

Celsius will deploy monitoring into approximately 520 distribution substation sites, and this data will be used to develop a detailed understanding of the factors that impact asset temperature. The project will also identify a number of potential retrofit cooling technologies, and trial them within monitored substations.

Celsius will produce tools and specifications for the use of project learnings in the business as usual practises, including a simple 'Thermal Ratings Tool', which will predict operating temperature based on asset characteristics and environment, indicate reaming capacity, and recommend interventions, including retrofit cooling technologies, if a potential issue is found. Celsius will also produce plans and specifications for the implementation of the project learnings into the BAU operation of networks.

There are a number of key learning areas within Celsius which are, and will be, relevant to Proteus. Two of the project partners of Celsius, Ricardo and ASH Wireless, also have key roles within Proteus, and therefore learning can be effectively shared between the projects.

The key areas where the Celsius project is Proteus are:

- **Network monitoring and diagnostics:** The Proteus Temporary Solution includes the gathering of network data through the solution equipment itself, and through additional monitoring where needed. The Proteus monitoring will be based on the Celsius monitoring, but there are some key additions to the functionality which are needed. The Proteus monitoring solution will be provided by project partners ASH Wireless, who have also developed the Celsius solution, and will therefore be able to ensure learning and development is taken into account.
- **Network data collection, visualisation, and analysis:** The remote monitoring and management system within the Proteus Temporary Solution will be based on the data management back end system that has been developed by Ricardo for

Celsius. Again, a number of developments will be required, but the learning can be transferred effectively through the use of shared personnel.

- **Technology installation processes:** As part of Celsius, a process and associated tools have been developed for the deployment of technology into substations. This was a challenge, as the equipment and installation methodology must be applicable in a wide range of potential sites. This methodology and tools are being developed by Ricardo, and therefore the learning can be effectively shared between the projects.
- **Asset temperature and retrofit cooling learning:** The key deliverable of Celsius will be the learning about LV asset temperature and retrofit cooling technologies. These will be developed later in the project, and therefore are not yet known. However, they will be relevant for Proteus, particularly in the development of the network diagnostics part of the Temporary Solution, and as a potential input into the development of the selection methodology for permanent solutions. Within Celsius, these outputs are being developed by Ricardo, and therefore the project learning can be transferred throughout the projects.

F.5. Flexible Approaches for Low Carbon Optimised Networks (Falcon)

Falcon was led by WPD, and ran from November 2011 to September 2015. It investigated how new network techniques work in practice. It involved a network trial in Milton Keynes, and a simulation which aimed to predict likely load increases and potential constraints.

Falcon trialled six interventions to mitigate network constraints bought about by the adoption of low carbon technologies:

- **Technical Interventions**, including Dynamic Asset Rating, Automated Load Transfer, Meshed Networks, and Energy Storage
- **Commercial Interventions**, including Distributed Generation, and Demand Side Management

This learning is particularly relevant for Proteus as part of the development of the selection methodology for the permanent solution. Each of the interventions trialled by Flacon are potential permanent solutions to network capacity issues, and therefore the learning should be incorporated in to the Proteus recommendations.

The learning developed by Falcon will be transferred to Proteus both directly through WPD personnel, and also through a review of the documentation so that learnings can be identified and discussed.

F.6. Other Projects

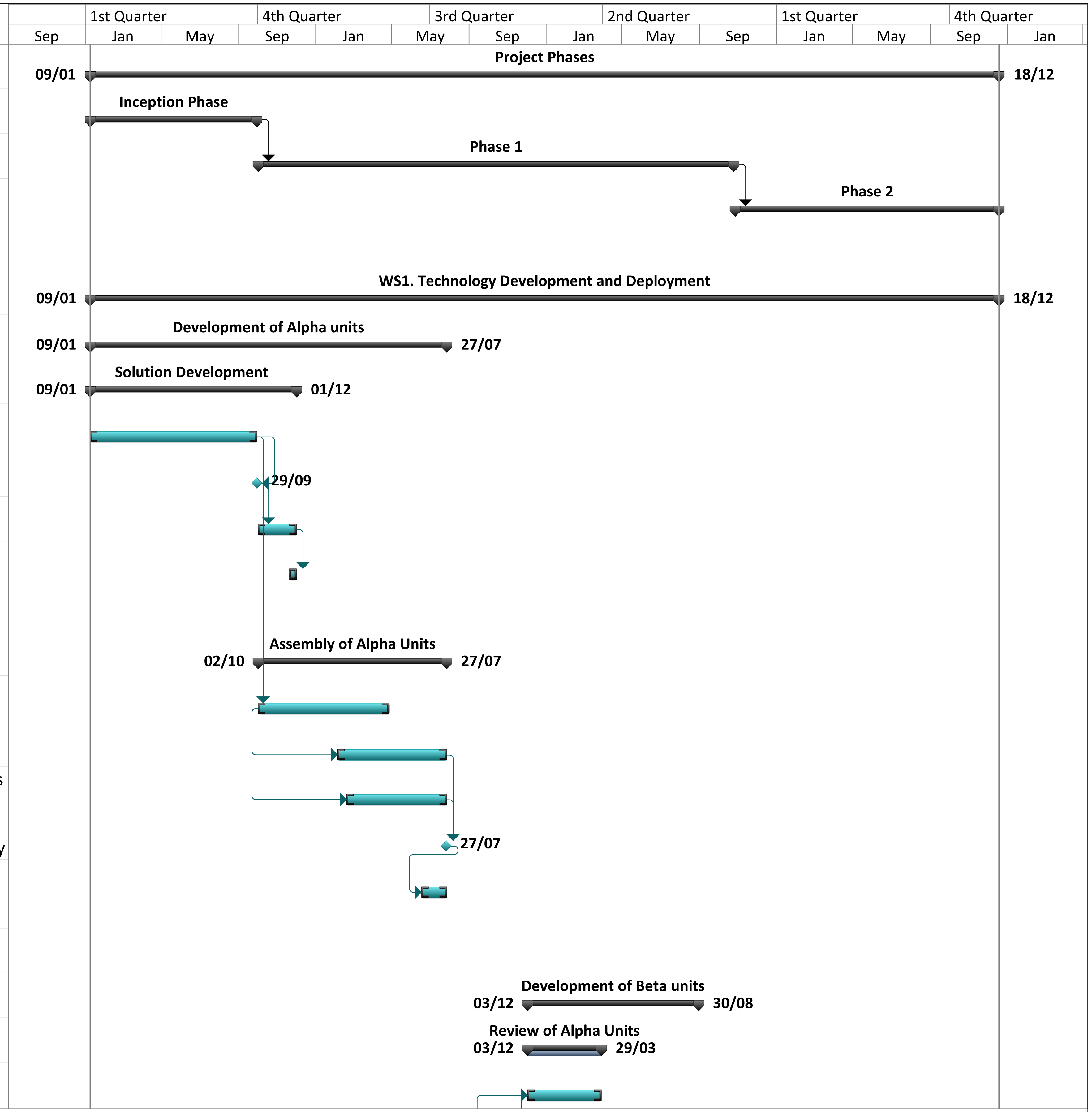
There are a number of other projects which are related to the activities of the Proteus project, and which will develop learning which should be taken into account within in the project.

In order to bring the learning from these projects into Proteus, there will be a process of literature review, gathering of relevant learnings, and bringing them into the project. This will be carried out early in the project, reviewed and updated as the project progresses. In particular, the learning from these projects is particularly relevant to the activity to develop the methodology for the selection of the permanent solution to the capacity issue, including innovative methods as well as traditional ones. The literature review will be reviewed and updated when this activity is due to start. The key project that have been identified are listed in the table below.

Project	Comment
New Thames Valley Vision (NTVV)	NTVV is being led by Southern Electric Power Distribution, and begun in January 2012. It is due to end in March 2017. NTVV will use data intelligently to identify and predict network stress points to enable more informed decisions. It will evaluate a new network and planning environment, automated demand side response, voltage control, and energy storage. The key relevant objective to Proteus is to Understand 'where and how power electronics (with and without energy storage) can be used to manage power factor, thermal constraints and voltage to facilitate the connection of renewables on the LV network'
Distribution Network Visibility (DNV)	DNV was led by UK Power Networks, and was funded through the Ofgem Low Carbon Networks Fund (LCNF). The project was undertaken in three stages between 2010 and 2013, and the concepts are being developed into normal practise in a Business as Usual project. Relevant learning includes network analysis and the development of actionable information. Ricardo had a major role in this project, and therefore the learning will be transferred.
Low Carbon London (LCL)	LCL was led by UK Power Networks, and is now complete. It developed a new approach to distribution network management to meet growing demand from emerging low carbon technologies. It focused on carbon reduction and the need to reduce dependency on conventional reinforcement. The solutions trialled included commercial solutions such as multipartite contracts between EDF Energy Networks, National Grid, aggregators, suppliers, and customers, and Time of Use tariffs. The technical solutions included active network management system, and an operational data store. Learning from this project could support Proteus in the inclusion of these solutions as permanent solutions.
Customer led network revolution (CLNR)	CLNR was led by Northern Power Grid, and is now complete. It tested a range of customer-side innovations (innovative tariffs and load control incentives) alone and in combination with network-side technology (including voltage control, real time thermal rating and storage). Learning from this project could support Proteus in the inclusion of these solutions as permanent solutions.
Smarter Network Storage (SNS)	SNS started in January 2013, and is being carried out by UK Power Networks. It is trialling how energy storage could be used to defer traditional network reinforcement and evaluating additional benefits that can be gained to maximise the value, and make storage a more cost-effective alternative. Learning from this project could support Proteus both in the use of storage within the Temporary Solution, and its use as a permanent network capacity solution.
Capacity to Customers (C2C)	C2 was led by Electricity North West, and is now complete. The C2C Method is a new form of demand response which releases capacity through a combination of innovative network management technologies in conjunction with new customer commercial arrangements. Learning from this project will be incorporated into Proteus through the inclusion of these methods as permanent solutions to LV network capacity issues.

Appendix G: Project Programme

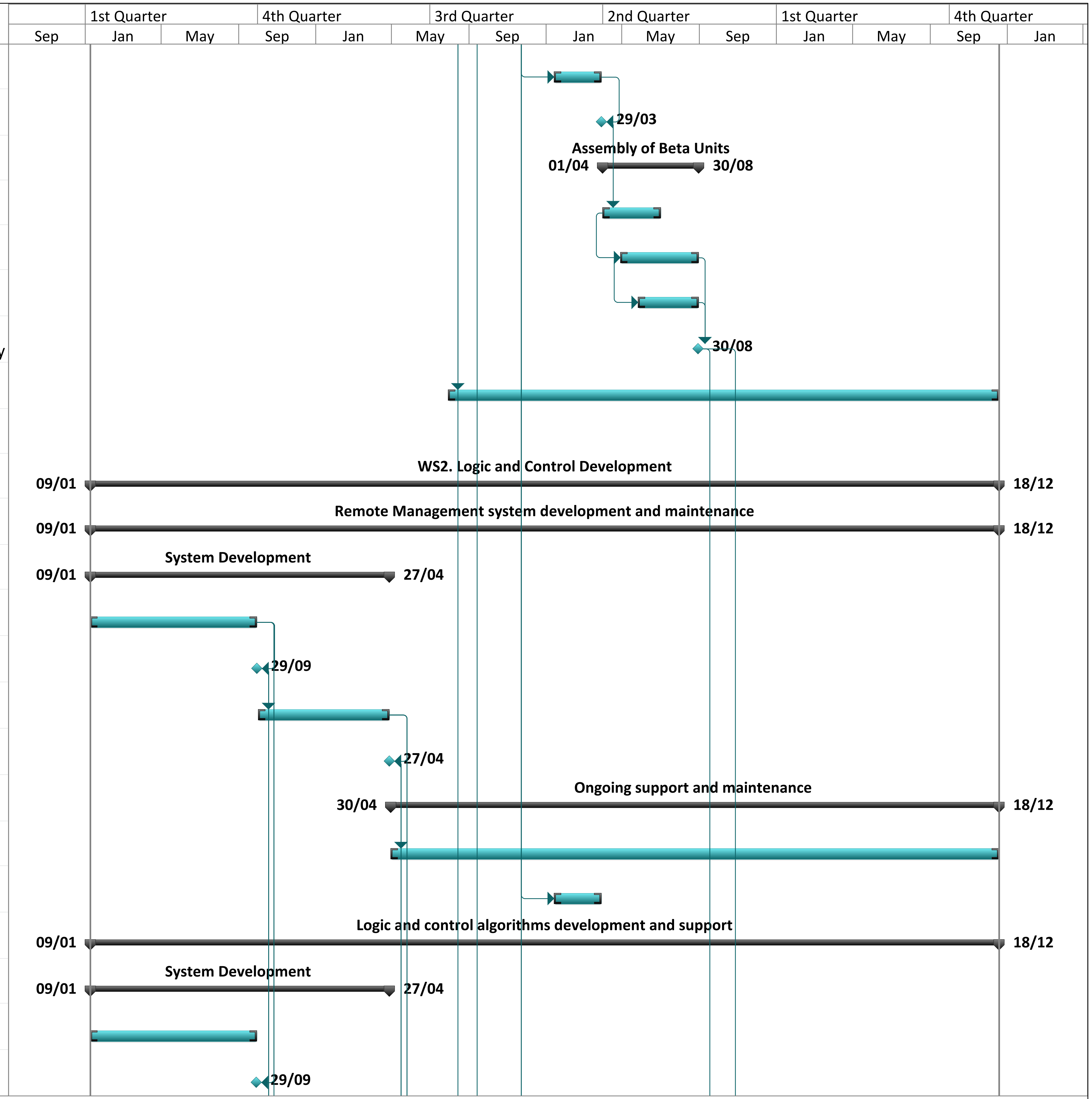
ID	Task Name	Duration	Start	Finish	Predecessors
1	**Project Phases**	**1030 days**	**Mon 09/01/17**	**Fri 18/12/20**	
2	Inception Phase	190 days	Mon 09/01/17	Fri 29/09/17	
3	Phase 1	540 days	Mon 02/10/17	Fri 25/10/19	2
4	Phase 2	300 days	Mon 28/10/19	Fri 18/12/20	3
5					
6	**WS1. Technology Development and Deployment**	**1030 days**	**Mon 09/01/17**	**Fri 18/12/20**	
7	**Development of Alpha units**	**405 days**	**Mon 09/01/17**	**Fri 27/07/18**	
8	**Solution Development**	**235 days**	**Mon 09/01/17**	**Fri 01/12/17**	
9	Detailed Specification of components (Alpha)	190 days	Mon 09/01/17	Fri 29/09/17	
10	Specifications Complete -Alpha (Milestone)	0 days	Fri 29/09/17	Fri 29/09/17	9FF
11	Tendering of hardware	45 days	Mon 02/10/17	Fri 01/12/17	10
12	Review of project budget	10 days	Mon 20/11/17	Fri 01/12/17	11FS-10 days
13					
14	**Assembly of Alpha Units**	**215 days**	**Mon 02/10/17**	**Fri 27/07/18**	
15	Component production (Alpha)	150 days	Mon 02/10/17	Fri 27/04/18	9
16	Unit Integration (Alpha)	125 days	Mon 05/02/18	Fri 27/07/18	15SS+90 days
17	Factory Acceptance Testing (Alpha)	115 days	Mon 19/02/18	Fri 27/07/18	15SS+100 days
18	Alpha Units Assembly (Milestone)	0 days	Fri 27/07/18	Fri 27/07/18	16FS-1 day,17FS-1 day
19	First Development design review summary document (Deliverable)	30 days	Mon 18/06/18	Fri 27/07/18	18FS-29 days
20					
21	**Development of Beta units**	**195 days**	**Mon 03/12/18**	**Fri 30/08/19**	
22	**Review of Alpha Units**	**85 days**	**Mon 03/12/18**	**Fri 29/03/19**	
23	Development of improvements	85 days	Mon 03/12/18	Fri 29/03/19	85SS+49 days



Project: Project1
Date: Thu 04/08/16

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

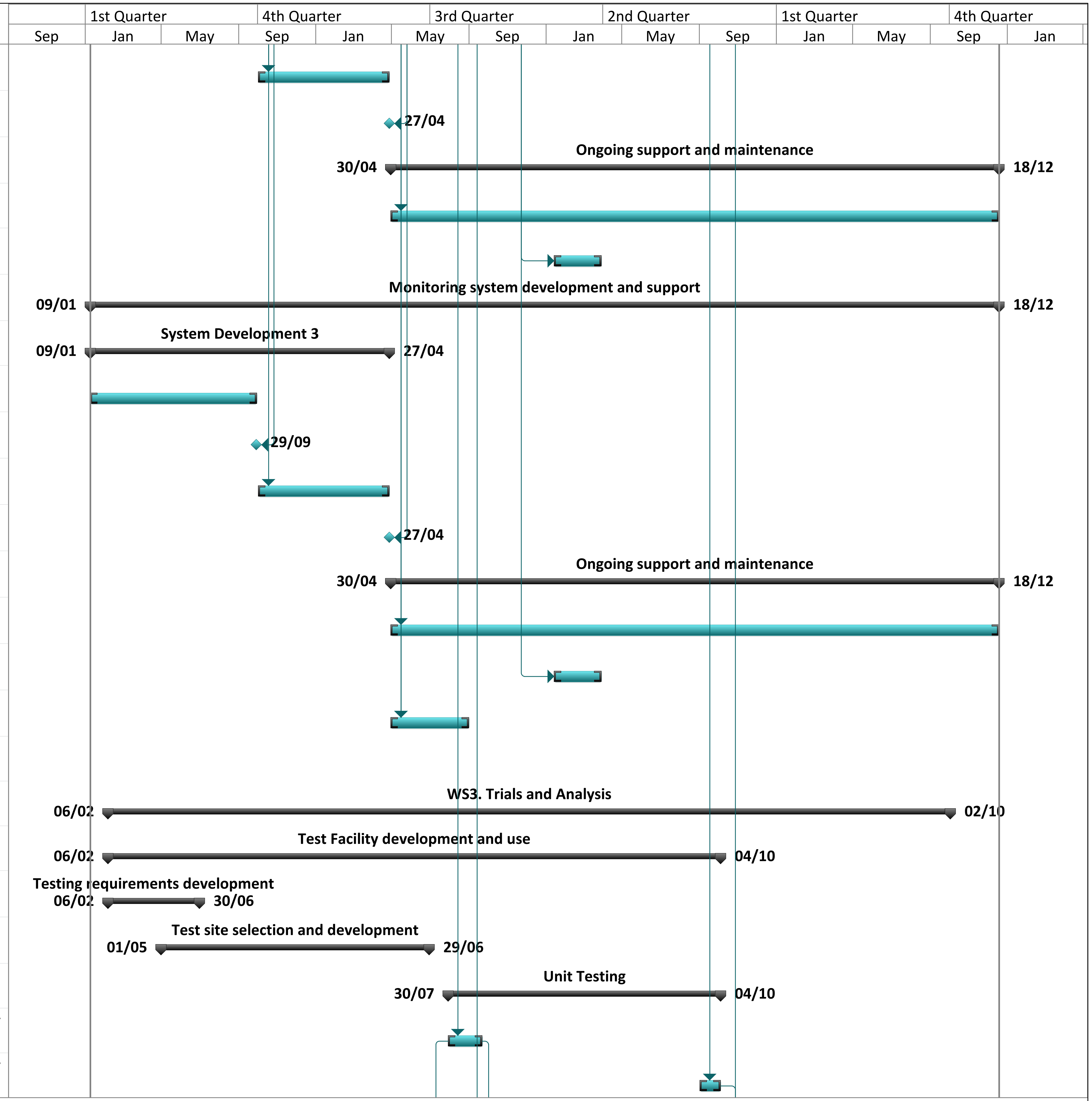
ID	Task Name	Duration	Start	Finish	Predecessors
24	Update specifications	55 days	Mon 14/01/19	Fri 29/03/19	23SS+30 days
25	Specification Complete - Beta (Milestone)	0 days	Fri 29/03/19	Fri 29/03/19	24FF
26	**Assembly of Beta Units**	**110 days**	**Mon 01/04/19**	**Fri 30/08/19**	
27	Component production	66 days	Mon 01/04/19	Mon 01/07/19	25
28	Unit Integration	90 days	Mon 29/04/19	Fri 30/08/19	27SS+20 days
29	Factory Acceptance Testing	70 days	Mon 27/05/19	Fri 30/08/19	28SS+20 days
30	Beta Units Assembly Milestone	0 days	Fri 30/08/19	Fri 30/08/19	28FS-1 day,29FS-1 day
31	Ongoing development and technology support	625 days	Mon 30/07/18	Fri 18/12/20	18FS+1 day
32					
33	**WS2. Logic and Control Development**	**1030 days**	**Mon 09/01/17**	**Fri 18/12/20**	
34	**Remote Management system development and maintenance**	**1030 days**	**Mon 09/01/17**	**Fri 18/12/20**	
35	**System Development**	**340 days**	**Mon 09/01/17**	**Fri 27/04/18**	
36	Specification of Remote Management system	190 days	Mon 09/01/17	Fri 29/09/17	
37	Specification Complete - Alpha (Milestone)	0 days	Fri 29/09/17	Fri 29/09/17	36FF
38	System production and testing	150 days	Mon 02/10/17	Fri 27/04/18	37
39	Testing Documentation Complete - (Milestone)	0 days	Fri 27/04/18	Fri 27/04/18	38FF
40	**Ongoing support and maintenance**	**690 days**	**Mon 30/04/18**	**Fri 18/12/20**	
41	Support and Maintenance	690 days	Mon 30/04/18	Fri 18/12/20	39
42	Specification and testing documents updates	55 days	Mon 14/01/19	Fri 29/03/19	23SS+30 days
43	**Logic and control algorithms development and support**	**1030 days**	**Mon 09/01/17**	**Fri 18/12/20**	
44	**System Development**	**340 days**	**Mon 09/01/17**	**Fri 27/04/18**	
45	Specification of Logic & control algorithms	190 days	Mon 09/01/17	Fri 29/09/17	
46	Specification Complete - Alpha (Milestone)	0 days	Fri 29/09/17	Fri 29/09/17	36FF



Project: Project1
Date: Thu 04/08/16

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

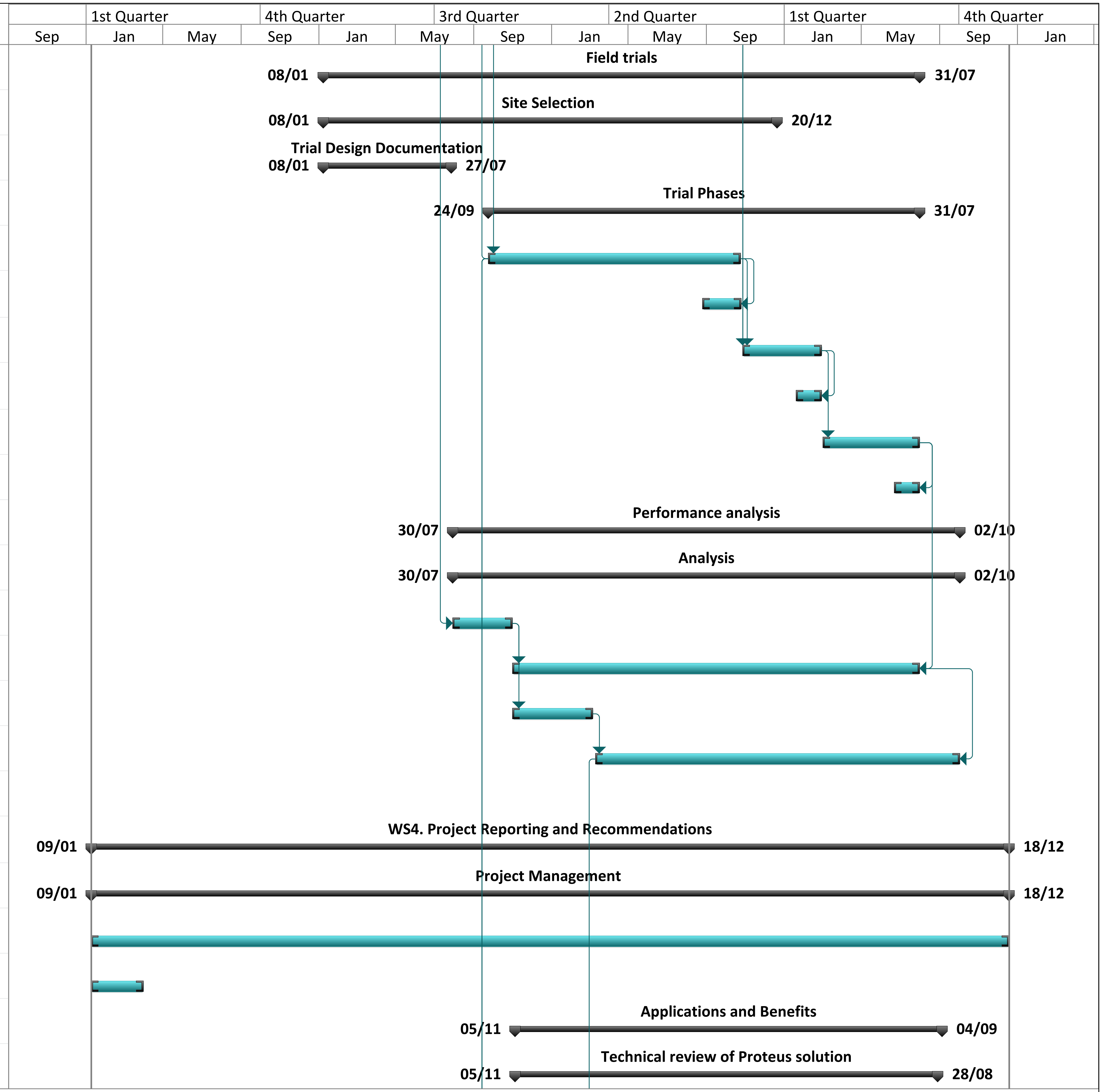
ID	Task Name	Duration	Start	Finish	Predecessors
47	System production and testing	150 days	Mon 02/10/17	Fri 27/04/18	37
48	Testing Documentation Complete - (Milestone)	0 days	Fri 27/04/18	Fri 27/04/18	38FF
49	**Ongoing support and maintenance**	**690 days**	**Mon 30/04/18**	**Fri 18/12/20**	
50	Support and Maintenance	690 days	Mon 30/04/18	Fri 18/12/20	39
51	Specification and testing documents updates	55 days	Mon 14/01/19	Fri 29/03/19	23SS+30 days
52	**Monitoring system development and support**	**1030 days**	**Mon 09/01/17**	**Fri 18/12/20**	
53	**System Development 3**	**340 days**	**Mon 09/01/17**	**Fri 27/04/18**	
54	Specification of monitoring system	190 days	Mon 09/01/17	Fri 29/09/17	
55	Specification Complete - Alpha (Milestone)	0 days	Fri 29/09/17	Fri 29/09/17	36FF
56	System production and testing	150 days	Mon 02/10/17	Fri 27/04/18	37
57	Testing Documentation Complete - (Milestone)	0 days	Fri 27/04/18	Fri 27/04/18	38FF
58	**Ongoing support and maintenance**	**690 days**	**Mon 30/04/18**	**Fri 18/12/20**	
59	Support and Maintenance management	690 days	Mon 30/04/18	Fri 18/12/20	39
60	Specification and testing documents updates	55 days	Mon 14/01/19	Fri 29/03/19	23SS+30 days
61	Software system development summary document	90 days	Mon 30/04/18	Fri 31/08/18	48,57,39
62					
63	**WS3. Trials and Analysis**	**955 days**	**Mon 06/02/17**	**Fri 02/10/20**	
64	**Test Facility development and use**	**695 days**	**Mon 06/02/17**	**Fri 04/10/19**	
65	**Testing requirements development**	**105 days**	**Mon 06/02/17**	**Fri 30/06/17**	
67	**Test site selection and development**	**305 days**	**Mon 01/05/17**	**Fri 29/06/18**	
71	**Unit Testing**	**310 days**	**Mon 30/07/18**	**Fri 04/10/19**	
72	Alpha Unit Testing	40 days	Mon 30/07/18	Fri 21/09/18	70,18FS+1 day
73	Beta Unit Testing	25 days	Mon 02/09/19	Fri 04/10/19	70,30FS+1 day



Project: Project1
Date: Thu 04/08/16

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

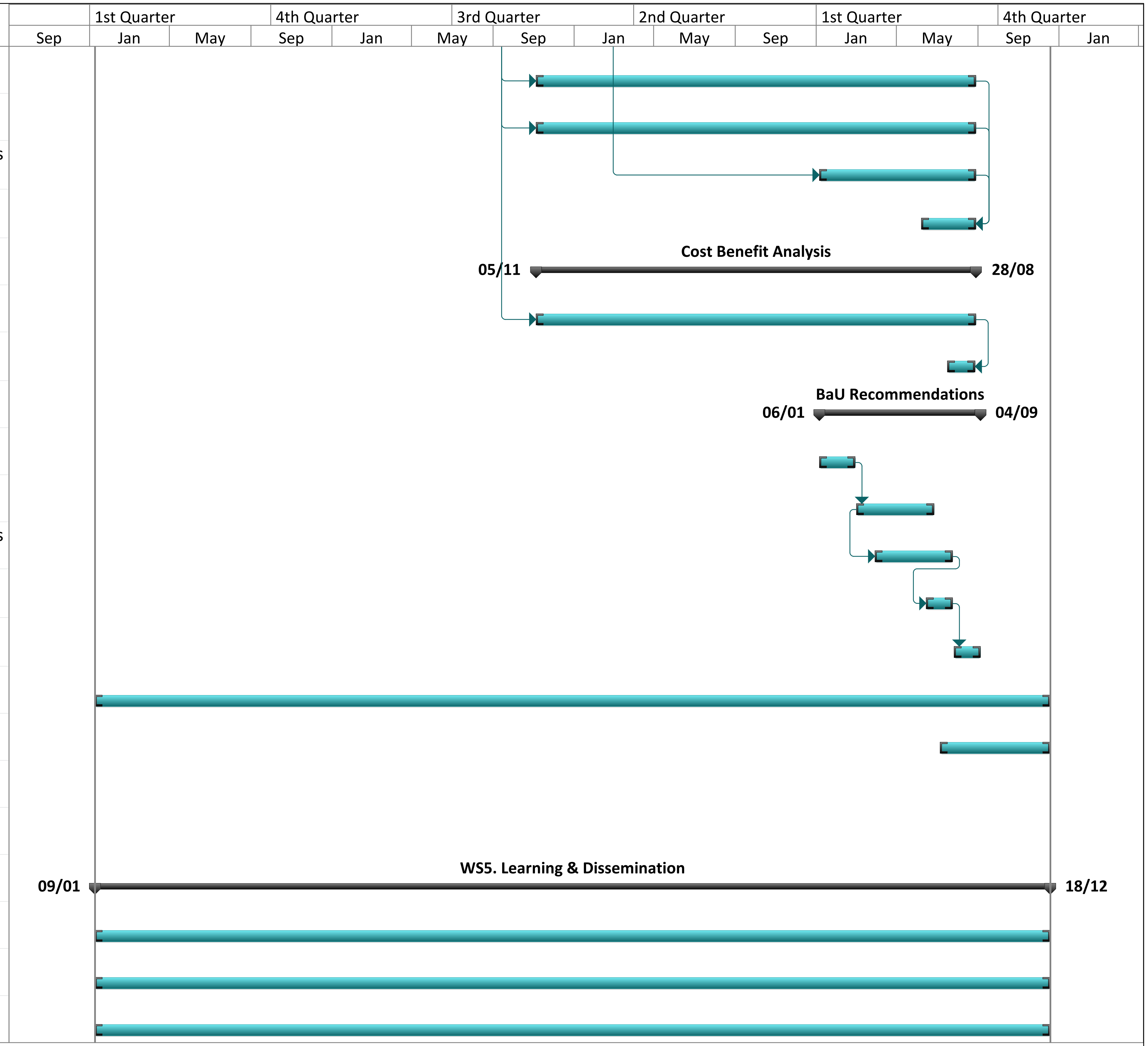
ID	Task Name	Duration	Start	Finish	Predecessors
74	**Field trials**	**670 days**	**Mon 08/01/18**	**Fri 31/07/20**	
75	**Site Selection**	**510 days**	**Mon 08/01/18**	**Fri 20/12/19**	
80	**Trial Design Documentation**	**145 days**	**Mon 08/01/18**	**Fri 27/07/18**	
84	**Trial Phases**	**485 days**	**Mon 24/09/18**	**Fri 31/07/20**	
85	Trial phase 1 (Alpha Units only)	284 days	Mon 24/09/18	Thu 24/10/19	77,72
86	Trial phase 1 report (Deliverable)	45 days	Mon 26/08/19	Fri 25/10/19	85FF
87	Trial phase 2 (Alpha and Beta Units)	90 days	Mon 28/10/19	Fri 28/02/20	78,73,85,30
88	Trial phase 2 report (Deliverable)	30 days	Mon 20/01/20	Fri 28/02/20	87FF
89	Trial Phase 3 (Alpha and Beta Units, stressed conditions)	110 days	Mon 02/03/20	Fri 31/07/20	87,79
90	Deliverable: Trial Phase 3 report	30 days	Mon 22/06/20	Fri 31/07/20	89FF
91	**Performance analysis**	**570 days**	**Mon 30/07/18**	**Fri 02/10/20**	
92	**Analysis**	**570 days**	**Mon 30/07/18**	**Fri 02/10/20**	
93	Data Validation and Moniotoring	68 days	Mon 30/07/18	Wed 31/10/18	72SS
94	Data Gathering	457 days	Thu 01/11/18	Fri 31/07/20	93,89FF
95	Data analysis tool development	90 days	Thu 01/11/18	Wed 06/03/19	93
96	Data analysis	410 days	Mon 11/03/19	Fri 02/10/20	95,94FF+45 days
97					
98	**WS4. Project Reporting and Recommendations**	**1030 days**	**Mon 09/01/17**	**Fri 18/12/20**	
99	**Project Management**	**1030 days**	**Mon 09/01/17**	**Fri 18/12/20**	
100	Project Management Activities	1030 days	Mon 09/01/17	Fri 18/12/20	
101	Project Set-Up	60 days	Mon 09/01/17	Fri 31/03/17	
102	**Applications and Benefits**	**480 days**	**Mon 05/11/18**	**Fri 04/09/20**	
103	**Technical review of Proteus solution**	**475 days**	**Mon 05/11/18**	**Fri 28/08/20**	



Project: Project1
Date: Thu 04/08/16

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

ID	Task Name	Duration	Start	Finish	Predecessors
104	Review of solution applcaitions	475 days	Mon 05/11/18	Fri 28/08/20	85SS+30 days
105	Review of performance	475 days	Mon 05/11/18	Fri 28/08/20	85SS+30 days
106	Develop permenant solution recommendations	170 days	Mon 06/01/20	Fri 28/08/20	96SS+215 days
107	Solution technical review document	60 days	Mon 08/06/20	Fri 28/08/20	104FF-30 days,105FF-30
108	**Cost Benefit Analysis**	**475 days**	**Mon 05/11/18**	**Fri 28/08/20**	
109	Cost Benefit analysis of installations	475 days	Mon 05/11/18	Fri 28/08/20	85SS+30 days
110	Deliverable: Cost Benefit Analysis	30 days	Fri 17/07/20	Thu 27/08/20	109FF-30 days
111	**BaU Recommendations**	**175 days**	**Mon 06/01/20**	**Fri 04/09/20**	
112	Identify BAU Tool Methodology	40 days	Mon 06/01/20	Fri 28/02/20	
113	BAU Tool Development and Delivery	85 days	Mon 02/03/20	Fri 26/06/20	112
114	BAU Tool Validation	85 days	Mon 30/03/20	Fri 24/07/20	113SS+20 days
115	BAU Tool Methodology and Validation Report	30 days	Mon 15/06/20	Fri 24/07/20	114FS-30 days
116	Develop BAU Tool User Guide (Deliverable: User Guide)	30 days	Mon 27/07/20	Fri 04/09/20	115
117	Peer Review	1030 days	Mon 09/01/17	Fri 18/12/20	
118	Closeout	120 days	Mon 06/07/20	Fri 18/12/20	
119					
120					
121	**WS5. Learning & Dissemination**	**1030 days**	**Mon 09/01/17**	**Fri 18/12/20**	
122	Website Development	1030 days	Mon 09/01/17	Fri 18/12/20	
123	Conferences and Events	1030 days	Mon 09/01/17	Fri 18/12/20	
124	Workpackage management	1030 days	Mon 09/01/17	Fri 18/12/20	



Project: Project1
Date: Thu 04/08/16

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

Appendix H: Project Risk Register and Mitigation plan

RISK REGISTER

Risk Ref. No.	Risk Status	Risk Frequency	Owner	High Level Definition "There is a risk that..."	Impact	Probability	Proximity	Rating	Raised by	Raised on	Risk Start Date	Target Date	Last Updated	Review Date	Cause "...because of..."	Effect "...leading to..."	Mitigation Action Plan	Signs that the risk is about to occur or become an Issue	Issue ID	Comments
Next No.	Dropdown list	1=Timebound/One-off 2=Ongoing/Recurring 3=Not started	Responsible for mgmt.	Details of the Risk	Score 1-5 (see guide)	Score 1-5 (see guide)	Score 1-5 (see guide)	Auto Calculated	Who raised the Risk?	when was it raised?	When does this risk become relevant (eg: installation risks will not occur until the after the procurement process)	Target Date for Resolution	Last date the risk was updated	Date risk rating should be reviewed	What will Trigger the Risk?	What will happen if it occurs?	How will this Risk be avoided?		ID of Issue Risk has transferred to	
R001	Assigned	2	REE	Project costs for high value items are significantly higher than expected	5	3	2	30	SCT	06/04/2016	13/04/2016	10/06/2016	04/08/2016	01/09/2016	Submission of higher than anticipated costs from suppliers	Difference between project costs as submitted in ISP and FSP	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.	concerns raised from suppliers in initial discussions		
R002	Assigned	2	REE	Some aspects of the technical solutions are not achievable to the desired specification within the project budget.	4	3	1	12	SCT	06/04/2016	01/01/2017	31/12/2020	04/08/2016	01/09/2016	Project team not able to implement all specified techniques	The project will not be able to investigate all of the intended techniques	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.	Concerns raised from suppliers in initial discussions. Issues encountered in device development.		
R003	Raised	2	REE	Device development is more complex than initially assumed	4	3	1	12	SCT	06/04/2016	01/01/2017	31/12/2020	04/08/2016	01/09/2016	Some techniques require more resource than anticipated to deliver	Potential overspend on device development, or scope reduction	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.	Concerns raised from suppliers in initial discussions. Issues encountered in device development.		
R004	Assigned	2	REE	Solutions do not deliver anticipated benefits	4	3	1	12	SCT	06/04/2016	01/01/2017	31/12/2020	04/08/2016	01/09/2016	Techniques are not useful in solving network constraints	Lower than anticipated value delivered	Some trialled techniques have already demonstrated benefits. The funding mechanism is for innovation projects where the outcome is uncertain, and is structured accordingly.	Trials do not allow improved performance.		
R005	Assigned	2	REE	Partner/Supplier performance is not adequate	4	2	2	16	SCT	06/04/2016	01/01/2017	31/12/2020	04/08/2016	01/09/2016	Supplier under performance	Outputs delayed, potential overspends	Robust procurement process. Suitable incentivisation of suppliers where required. Shared responsibility for SDRCs.	Substandard or delayed deliverables		
R006	Assigned	2	REE/WPD	External perception of poor performance may impact future innovation project awards	5	2	1	10	SCT	06/04/2016	01/01/2017	31/12/2020	04/08/2016	01/09/2016	Project does not deliver tangible outputs	Obtaining funding for future innovation projects is difficult	Effective management of project and external stakeholders.	Feedback at dissemination events		
R007	Assigned	1	REE	Suitable equipment suppliers cannot be found	5	2	3	30	SCT	06/04/2016	13/04/2016	10/06/2016	04/08/2016	18/08/2016	Potential suppliers are not available for this project	Project must be delayed or rescoped	Realistic requirements specified at FSP. Good understanding of supply chain capability.	Lack of interest from potential suppliers during Inception phase		
R008	Assigned	2	REE	Transportable solution not achievable as equipment too large/heavy/has too high losses	5	2	1	10	SCT	06/04/2016	01/01/2017	31/12/2020	04/08/2016	01/09/2016	Project team not able to implement transportable solution	Project must be rescoped	Realistic requirements specified.	Concerns raised from suppliers in initial discussions. Issues encountered in device development.		
R009	Assigned	1	REE	The project business case is not justifiable	5	3	3	45	MD	26/05/2016	26/05/2016	08/08/2016	04/08/2016	18/08/2016	Analysis fails to find a valid Business Case	Project will not receive Ofgem approval to proceed	Early investigation of Business Case and thorough presentation of evidence	Unable to find reasonable evidence for presentation of business case		
R010	Assigned	1	REE/WPD	Failure to agree project contracts between WPD, REE and other partners	5	2	2	20	MD	26/05/2016	01/10/2016	01/01/2017	04/08/2016	25/08/2016	Contract talks fail to produce a solution	Project cannot proceed	Early discussion of contractual arrangements between partners. Heads of terms letter to be sent to WPD from Ricardo.	Significant areas of dispute in early contract talks		
R011	Assigned	3	REE	A partner/supplier may withdraw from the project	4	3	2	24	SCT	27/07/2016	01/10/2016	01/10/2017	04/08/2016	01/10/2016	Indication from partner/supplier that they will not continue with the project	Partner/Supplier must be replaced	Robust procurement/due diligence process. Suitable incentivisation of suppliers where required.	Partner/Supplier shows unwillingness to engage with project		
R012	Assigned	3	REE/WPD	Suitable sites for demonstration of solution are not available	5	2	1	10	SCT	27/07/2016	01/10/2017	01/02/2018	04/08/2016	01/10/2017	Site Selection process indicates that there are no suitable sites for trials	Trials cannot proceed	Site requirements are developed in accordance with Design process and typical site conditions	Initial site selection process indicates a low number of suitable sites		
R013	Assigned	1	REE/WPD	Lack of business support for the project from key departments	4	2	2	16	SCT	27/07/2016	01/10/2016	01/01/2020	04/08/2016	25/08/2016	Unavailability of resources during project delivery	Project suffers delays or cannot proceed	Stakeholder engagement plan to be enacted during early stages of project, including members of SMT and identification of project sponsor	Resources show unwillingness to engage with project		
R014	Assigned	2	REE	Changes to key personnel	4	3	1	12	SCT	27/07/2016	01/10/2016	31/12/2020	04/08/2016	01/09/2016	Transfer of resource away from project	Possible delays during handover period	Comprehensive project documentation is maintained. Induction pack produced for new resources	Restructuring of one of the project partners		
R015	Assigned	3	REE	The size of the developed units are too large and are not suitable for installation	5	2	1	10	SCT	27/07/2016	01/01/2017	01/10/2017	04/08/2016	01/01/2017	Minimum size of designed units is too large for maximum size outlined from site selection process	Trials cannot proceed	Design process includes consideration from the site selection process in terms of available space	Design indicates a large production unit		

WESTERN POWER DISTRIBUTION INNOVATION

RISK REGISTER

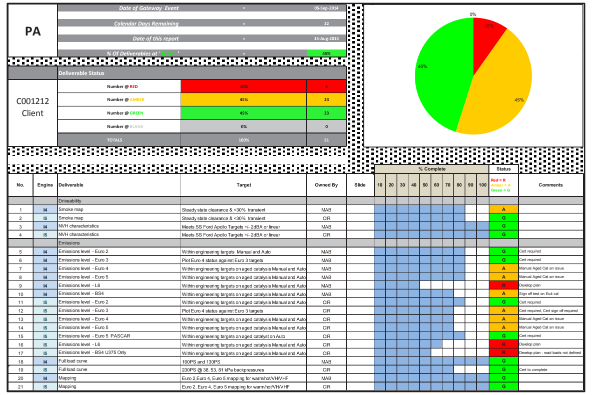
Risk Ref. No.	Risk Status	Risk Frequency	Owner	High Level Definition "There is a risk that..."	Impact	Probability	Proximity	Rating	Raised by	Raised on	Risk Start Date	Target Date	Last Updated	Review Date	Cause "...because of..."	Effect "...leading to..."	Mitigation Action Plan	Signs that the risk is about to occur or become an Issue	Issue ID	Comments
Next No.	Dropdown list	1=Timebound/One-off 2=Ongoing/Recurring 3=Not started	Responsible for mgmt.	Details of the Risk	Score 1-5 (see guide)	Score 1-5 (see guide)	Score 1-5 (see guide)	Auto Calculated	Who raised the Risk?	when was it raised?	When does this risk become relevant (eg: installation risks will not occur until the after the procurement process)	Target Date for Resolution	Last date the risk was updated	Date risk rating should be reviewed	What will Trigger the Risk?	What will happen if it occurs?	How will this Risk be avoided?		ID of Issue Risk has transferred to	
R016	Assigned	1	REE	The specification and build of the units takes longer than anticipated	4	2	1	8	SCT	27/07/2016	01/01/2017	01/10/2017	04/08/2016	25/08/2016	Delays to project programme	Project suffers delays	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.	Delays to project plan timescales		
R017	Assigned	1	REE	Equipment/supplier costs are underestimated in RFIs	4	2	1	8	SCT	27/07/2016	01/10/2016	01/10/2017	04/08/2016	25/08/2016	supplier/equipment costs indicated during inception phase are larger than to RFI	Project costs rise outside of tolerances	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.	Concerns raised from Partners/suppliers inception phase		
R018	Assigned	1	REE	IPR deter some suppliers from involvement	4	3	1	12	SCT	27/07/2016	01/01/2017	01/10/2017	04/08/2016	25/08/2016	Supplier indicates they are unwilling to participate due to IPR conditions	Partner/Supplier must be replaced	Early discussion of IPR requirements with Key project suppliers/partners. Alternative suppliers identified	Concerns raised from Partners/suppliers inception phase		
R019	Assigned	3	REE	Integration of equipment and systems is not achievable	4	2	1	8	SCT	27/07/2016	01/01/2017	01/10/2017	04/08/2016	01/01/2017	Incompatibility between systems uncovered in inception phase	Project suffers delays or cannot proceed	Collaborative design process enacted during inception phase with all key project partners	Concerns raised from Partners/suppliers inception phase		
R020	Assigned	3	REE	The communications system is not adequate for the transfer of the required volumes of data	5	2	1	10	SCT	27/07/2016	01/01/2017	01/10/2017	04/08/2016	01/01/2017	Communications system design proves inadequate for the volume of data detailed during inception phase	Project suffers delays or cannot proceed	Collaborative design process enacted during inception phase with all key project partners	Concerns raised from Partners/suppliers inception phase		
R021	Assigned	3	REE/WPD	Control system/algorithms etc. are not properly tested prior to installation on live system	4	2	1	8	SCT	27/07/2016	01/10/2017	01/10/2017	04/08/2016	01/10/2017	Systems not properly tested prior to start of trials	Equipment does not perform as expected	Units are tested in laboratory and test environment. Sufficient time included in project plan to ensure sufficient testing occurs	Late delivery of control system/algorithms		
R022	Assigned	3	REE/WPD	Solution has unintended impact on the LV network causing network failure, under performance/failure of customer equipment etc.	5	2	1	10	SCT	27/07/2016	01/04/2018	01/04/2018	04/08/2016	01/04/2018	Initial trials demonstrate unacceptable network conditions	Loss of supply, damage to customers equipment/lost production time etc.	Units are tested in laboratory and test environment. Sufficient time included in project plan to ensure sufficient testing occurs	Customer complaints during field trials		
R023	Assigned	3	REE	Solution does not meet UK standards (CE marking, G59, Harmonic limits etc.)	5	2	1	10	SCT	27/07/2016	01/01/2017	01/10/2017	04/08/2016	01/01/2017	Equipment fails to meet relevant requirements	Equipment cannot be installed	Early discussion of relevant standards during inception phase. Time and budget included to ensure suitable testing is completed.	Identification that a requirement is not achievable		
R024	Assigned	3	REE	Catastrophic failure of equipment damages network equipment or causes injury	5	1	1	5	SCT	27/07/2016	01/01/2017	31/12/2020	04/08/2016	01/01/2017	Catastrophic failure of equipment	network equipment is damaged or an individual is injured	Failure Mode Analysis completed early in project and recommendations incorporated in the design process	unsatisfactory performance of equipment in testing or field trials.		
R025								0												

Appendix I: Ricardo Product Development System

RPDS Gateway Reporting

RPDS uses a standard reporting format to ensure a common approach to gateways

- Single page gateway reporting using phase tracking report
- Clear gateway status indicator and gateway countdown timer
- Structured phase requirements based on best practise product development and specific product and client requirements
- Clear targets specified where appropriate
- Use of hyperlinks to supporting data of objective achievement
- Progress indicator to show achievement towards the gateway
- Defined RAG status based on approved countermeasure plans

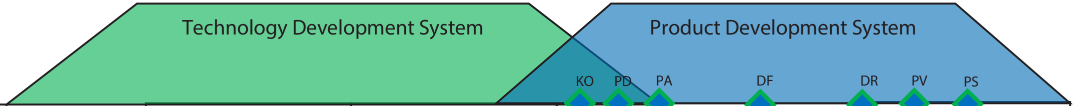


R	**Gateway deliverable not achieved** Countermeasures not defined or approved
A	**Gateway deliverable not achieved** Countermeasures defined and approved
G	**Gateway deliverable achieved**

Glossary of Terms

APQP	Advanced Product Quality Planning
BoM	Bill of Material
BSFC	Brake Specific Fuel Consumption
CAD	Computer Aided Design
CET	Cold Evaluation Trip
CFD	Computational Fluid Dynamics
CS	Concept Selection Gateway
DD	Definitive Design Gateway
DF	Design Freeze Gateway
DfMA	Design for Manufacturing Assembly
DFMEA	Design Failure Mode Effect Analysis
DR	Design Release Gateway
DVP	Design Validation Plan
EGR	Exhaust Gas Recirculation
FEA	Finite Element Analysis
FMEA	Failure Mode Effect Analysis
GSQA	Gear Shift Quality Assurance
GWPD	Group Wide Project Delivery
HC	Hardware Confirmation Milestone
HET	Hot Evaluation Trip
HiL	Hardware in the Loop
HR	Hardware Ready Milestone
ICA	Industrial Capability Analysis
IP	Intellectual Property
J#1	Start of Production
KO	Kick Off Gateway
MRL	Manufacturing Readiness Level
PA	Product Approval Gateway
PD	Product Definition Gateway
PDS	Product Design Specification
PFMEA	Process Failure Mode Effect Analysis
PPAP	Production Part Approval Process
PR	Product Retirement Gateway
PS	Product Sign Off Gateway
PSW	Part Submission Warrant
PV	Product Validation Gateway
QA	Quality Assurance
QFD	Quality Function Deployment
RPDS	Ricardo Product Development System
RTDS	Ricardo Technology Development System
SCMP	Software Configuration Management Plan
SDP	Software Development plan
SOP	Start of Production
+90d	90 days after SOP milestone
SW	Software
TRL	Technology Readiness Level

Ricardo Technology Development System (RTDS) - RPDS Integration



Lifecycle Phase	Opportunity Identification and concept synthesis	Fundamental and Applied R&D		Technology Development		Tech Demo	Product Development		Product Validation and sign off	Production
Ricardo TRL Level	TRL 0	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Activity Type	Market Analysis	Fund. Research	Applied Research	Technology Demonstration and Development			Product Development			Production
Product Stability	N/A				Low	Medium	High + Change Control		Total	
Test and Use Environment	None			Laboratory		Simulated & Controlled Test		Test + Real	Real World	
Responsibility RTDS or RPDS	Strategy/MS	**Technology Development System**						**Product Development System**		
Sponsorship	MS		PG/TC							PP

Technology Readiness Level (TRL)

<TRL 0> Basic Principles observed and reported
Paper studies and scientific studies have been under taken

<TRL 1> Basic Research: Initial scientific research begins
Principles are qualitatively observed. Focus is not on applications.
Paper and scientific studies undertaken

<TRL 2> Speculative applications have been identified
Application specific simulations or experiments have been performed

<TRL 3> Analytical and lab studies have physically validated predictions of individual technology elements or components which are not yet integrated or representative

<TRL 4> Technology components and/or basic subsystems have been validated in lab or test house environment
Basic concept observed in other industry sectors

<TRL 5> Technology components and/or basic systems have been validated in relevant environment - potentially through a mule or modified production vehicle

<TRL 6> Model or prototype of the system have been demonstrated as part of a vehicle which can simulate and validate all system specifications within an operational environment (e.g. Test track)

<TRL 7> Multiple prototypes have been demonstrated in an operational environment

<TRL 8> Test and demonstration phases have been completed to customers' satisfaction. Technology has been proven to work in its final form and under all expected conditions

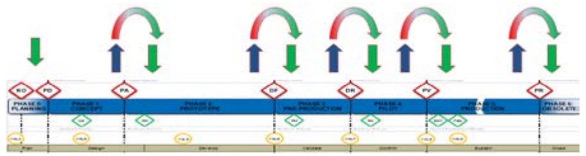
<TRL 9> Real world deployment and performance of the technology is a success

PRODUCT DEVELOPMENT SYSTEM

Ricardo plc
Version 1.7
29th August 2014

Delivering Excellence
Through Innovation & Technology

RPDS Introduction



RPDS is a series of Phases and Gateways based on Ricardo and industry best practise

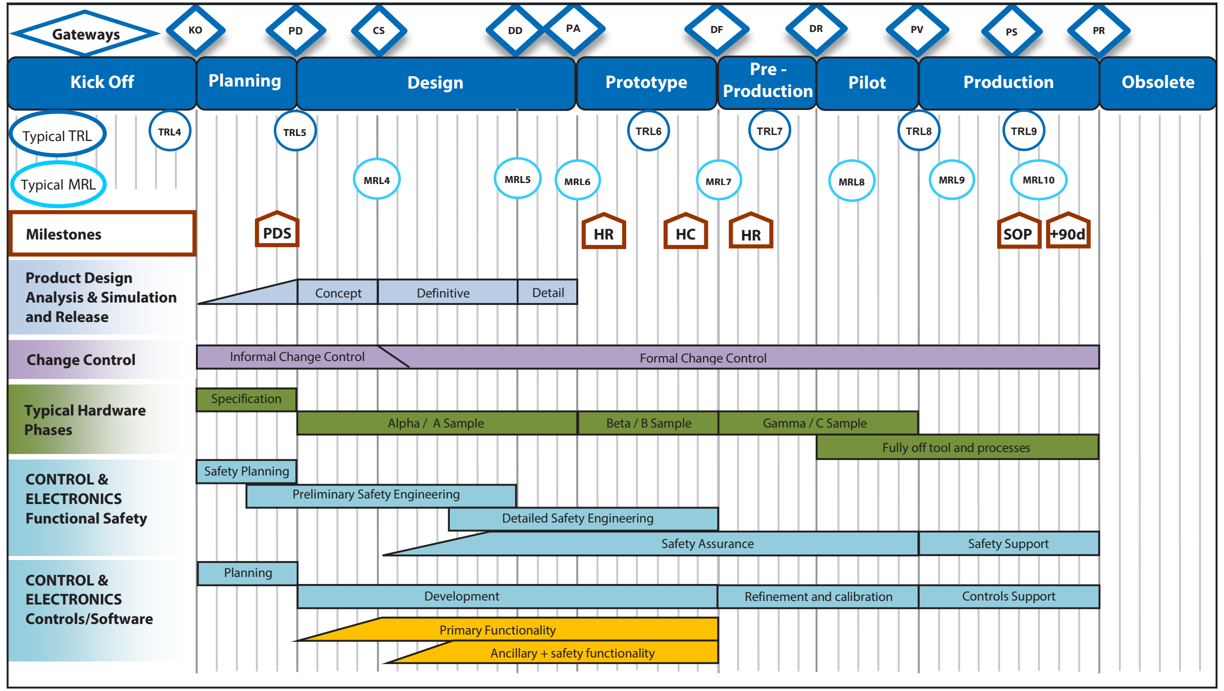
- Specifying RPDS appropriately will increase certainty of delivery and identify risk
- Stages having defined inputs and outputs that combine to give a full product lifecycle process
- Typical Ricardo projects may only use part of the Product Development Lifecycle
- Entry and exit from the process possible at any point dependant on product maturity
- Gateways are formal events with an independent chairperson to be defined at the start of the project
- Milestones are significant events during product development and are likely to be reviewed by the project team
- Milestones can be utilised as appropriate dependant on project requirements

RPDS User guide reference material supports definition of technical function stage activities and gateway requirements

RPDS Help and Resources

- Although Product Development and the principles within the Ricardo Product Development System are not new to our organisation, there is a new integrated approach to Product Development and new terminology
- All key documents in support of the RPDS can be found on RWorld under Knowledge in Engineering and Operations along with specific functional processes
- Ricardo Product Development System implementation support is available from the Quality Director - Phil Hore (PRH), Dave Penwarden (DPAP) or your Engineering Manager

Ricardo Product Development System (RPDS) Map



Manufacturing Readiness Level (MRL)

<MRL 1>	Basic Manufacturing Implementation Identified
<MRL 2>	Manufacturing Concepts Identified
<MRL 3>	Manufacturing proof of concept developed
<MRL 4>	Capability to produce the technology in laboratory environment
<MRL 5>	Capability to produce prototype components in a production relevant environment
<MRL 6>	Capability to produce system or subsystem in a production relevant environment
<MRL 7>	Capability to produce systems, subsystems or components in a production representative environment
<MRL 8>	Pilot line capability demonstrated Ready to begin low rate production
<MRL 9>	Low Rate production demonstrated Capability in place to begin full rate production
<MRL 10>	Full rate production in progress and lean production practises in place

RPDS Gateways

<KO> Kick Off

Product need identified and quantified, project begins

1. Technology selected
2. Business case in place
3. Sponsors identified
4. Product need identified
5. Product tools identified
6. Stakeholders
7. Gateway approvers
8. Hardpoint data identified
9. Resources identified
10. Consider who is making the product
11. Lesson learnt

<PD> Product Definition

Required product attributes comprehensively defined

1. Benchmark activity completed
2. Product specification initially released
3. Confirm product specification proposed satisfies identified product need
4. Plan in place for product development

<CS> Concept Selection

Evaluate alternative solutions to produce a product concept meeting the requirements of the Product Design Specification

1. Product Concept selected
2. Product Specification updated
3. Confirm selected product specification satisfies identified product need
4. Product virtual evaluation plan defined
5. Updated plan in place for product development

<DD> Definitive Design

Investigation and optimization of the concept specification to produce a detailed design of every new or modified component

1. Product 3D Design completed
2. Simulation and analysis to support product design successfully completed
3. Product specification updated
4. Updated plan in place for product development

<PA> Product Approval

Theoretical functional verification of product achieved, commitment to hardware approved

1. Product fully defined in virtual world
2. Simulation and analysis to verify product functionality successfully completed
3. Product specification updated
4. Physical product functional verification plan defined
5. Updated plan in place for product development

<DF> Design Freeze

Practical functional verification of product achieved in prototype form, design intent now frozen

1. Prototype physical functional verification programme successfully completed
2. Product specification updated
3. Suppliers engaged
4. Confirmation that frozen design intent meets product specification
5. Updated plan in place for product development

<DR> Design Release

Practical functional verification of multiple production intent products achieved in full operational environment, commitment to production

1. Production intent physical functional verification programme successfully completed
2. Production methodology and facilities now fully defined
3. Product specification final release
4. Updated plan in place for product development

<PV> Product Validation

Total product validation programme successfully completed, commitment to ramp up manufactured volume approved

1. Product validation now wholly completed
2. All relevant product legal compliance documentation complete
3. Complete production facility in place and functionality confirmed
4. Updated plan in place for production

RPDS Gateways

<PS> Product Sign Off

Product has been demonstrated to continue to operate within determined limits at initial production rate

1. Production process confirmed to keep product within defined limits at full rate
2. Product confirmed to work in "real world"
3. Updated plan in place for remainder of product lifecycle
4. Cost data pack updated
5. Acceptance confirmed

<PR> Product Retirement

Product determined to be no longer fit for purpose, product closeout begins

1. Formal agreement of asset register
2. Tooling disposal
3. Warranty support
4. Spares obligations

RPDS Milestones

<PDS> Product Design Specification

Required product attributes comprehensively defined

<HR> Hardware Release

Development Phase hardware available for test and development

<HC> Hardware Confirmation

Confirm production intent hardware meets required specifications. No further hardware changes required

<SOP> Start of Production

Start of production and volume ramp up

<+90d> + 90 Days

90 days after J#1

RPDS Hardware Levels

Alpha / A Sample	Initial design. Not necessarily mechanically representative parts. Low volume hand-assembled or built using a prototype line. Sufficient functionality to exercise H/W or system in order to achieve core/basic system functionality. Some functionality may not be available.
Beta / B Sample	Production intent design; Mechanical parts likely to be manufactured using soft tools. Manufactured on a prototype or general purpose low volume production line. Suitable for Design Validation tests. Full functionality available. Updated to support H/W or system development/evolution. System is feature complete.
Gamma / C Sample	All components fully off-tool. Made using the intended volume production manufacturing process, early parts may not be at full volume rate. Pre-production parts used for Design Validation and Process Validation tests. Verification & Validation completion, OBD calibration

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**NIC Funding Request**												
2			2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	**Total**				
3	**Cost**	*From Project Cost Summary sheet*											
4		Labour	11.57	54.08	150.17	150.77	94.71	-	461.29				
5		Equipment	-	1,201.09	607.45	1,262.09	23.36	-	3,093.99				
6		Contractors	269.24	1,963.23	649.78	1,621.15	391.82	-	4,895.22				
7		IT	-	-	-	-	-	-	-				
8		IPR Costs	-	-	-	-	-	-	-				
9		Travel & Expenses	11.08	67.97	22.06	46.54	8.46	-	156.11				
10	Payments to users & Contigency		27.77	296.37	118.56	277.49	38.53	-	758.71				
11		Decommissioning	-	-	-	-	-	-	-				
12		Other	-	8.00	8.00	8.00	-	-	24.00				
13		**Total**	319.66	3,590.74	1,556.02	3,366.04	556.88	-	9,389.32				
14													
15	**External funding**	*Any funding that will be received from Project Partners and/or External Funders - from Project Cost Summary sheet*											
16		Labour	-	-	-	-	-	-	-				
17		Equipment	-	72.46	10.02	75.53	0.86	-	158.87				
18		Contractors	19.91	138.42	43.80	111.36	34.23	-	347.72				
19		IT	-	-	-	-	-	-	-				
20		IPR Costs	-	-	-	-	-	-	-				
21		Travel & Expenses	0.79	4.40	1.46	3.00	0.61	-	10.26				
22	Payments to users & Contigency		2.04	20.40	5.22	17.98	3.40	-	49.04				
23		Decommissioning	-	-	-	-	-	-	-				
24		Other	-	0.31	0.50	0.22	-	-	1.03				
25		**Total**	22.74	236.00	60.99	208.09	39.10	-	566.92				
26													
27	**Licensee extra contribution**	*Any funding from the Licensee which is in excess of the Licensee Compulsory Contribution - from Project Cost Summary sheet*											
28		Labour	-	-	-	-	-	-	-				
29		Equipment	-	-	-	-	-	-	-				
30		Contractors	-	-	-	-	-	-	-				
31		IT	-	-	-	-	-	-	-				
32		IPR Costs	-	-	-	-	-	-	-				
33		Travel & Expenses	-	-	-	-	-	-	-				
34	Payments to users & Contigency		-	-	-	-	-	-	-				
35		Decommissioning	-	-	-	-	-	-	-				
36		Other	-	-	-	-	-	-	-				
37		**Total**	-	-	-	-	-	-	-				
38													
39	**Initial Net Funding Required**		*calculated from the tables above*										
40		Labour	11.57	54.08	150.17	150.77	94.71	-	461.29				
41		Equipment	-	1,128.63	597.44	1,186.56	22.50	-	2,935.12				
42		Contractors	249.34	1,824.81	605.98	1,509.78	357.59	-	4,547.50				
43		IT	-	-	-	-	-	-	-				
44		IPR Costs	-	-	-	-	-	-	-				
45		Travel & Expenses	10.28	63.57	20.60	43.55	7.85	-	145.85				
46	Payments to users & Contigency		25.72	275.97	113.34	259.51	35.13	-	709.67				
47		Decommissioning	-	-	-	-	-	-	-	Check Total = to Initial Net Funding request			
48		Other	-	7.69	7.50	7.78	-	-	22.97	in Project Cost Summary			
49		**Total**	296.91	3,354.73	1,495.02	3,157.95	517.78	-	8,822.40	**OK**			
50													
51	**Direct Benefits**	*from Direct Benefits sheet*											
52		Total	-	-	-	-	-	-	-				
53													
54													
55													
56	**Licensee Compulsory Contribution / Direct Benefits**		*from Project Cost Summary sheet*										
57		Labour	11.57	54.08	150.17	150.77	94.71	-	461.29				
58		Equipment	-	149.12	45.56	34.00	0.63	-	229.31				
59		Contractors	7.25	59.59	27.28	52.57	19.66	-	166.35				
60		IT	-	-	-	-	-	-	-				
61		IPR Costs	-	-	-	-	-	-	-				
62		Travel & Expenses	0.30	1.83	0.59	1.25	0.23	-	4.21				
63	Payments to users & Contigency		0.75	7.98	3.19	7.48	1.04	-	20.44				
64		Decommissioning	-	-	-	-	-	-	-	of Total Initial Net Funding Required			
65		Other	-	0.22	0.22	0.22	-	-	0.65	**OK**			
66		**Total**	19.87	272.81	227.00	246.28	116.27	-	882.24	Check that **Total** is = or > than			
67										Total Direct Benefits			
68										**OK**			
69	**Outstanding Funding required**		*calculated from the tables above*										
70		Labour	-	-	-	-	-	-	-				
71		Equipment	-	979.50	551.88	1,152.56	21.87	-	2,705.81				
72		Contractors	242.09	1,765.22	578.70	1,457.21	337.93	-	4,381.15				
73		IT	-	-	-	-	-	-	-				
74		IPR Costs	-	-	-	-	-	-	-				
75		Travel & Expenses	9.98	61.74	20.00	42.29	7.62	-	141.64				
76	Payments to users & Contigency		24.98	267.99	110.14	252.04	34.09	-	689.23				
77		Decommissioning	-	-	-	-	-	-	-	Check that Total is =to			
78		Other	-	7.47	7.29	7.57	-	-	22.33	Total Outstanding Funding required			
79		**Total**	277.05	3,081.92	1,268.02	2,911.67	401.51	-	7,940.16	**OK**			
80													
81	balance	7,820.11	0.00	4,461.15	3,254.53	381.44	(1.89)	0.01	7,820.11				
82	interest		0.00	61.41	38.58	18.18	1.90	(0.01)	120.05				
83									7,940.16	(0.00)			
84											click this button to calculate the NIC funding request		
85		Bank of England interest rate		0.5%		**NIC FUNDING REQUEST £**			**7,820.11**				
86		interest rate used in calculation		1.0%									
87		RPI adjustment	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/2024	2024/2025		
88		Index	267.5	275.8	284.3	293.1	302.2	311.6	321.2	331.2	341.5		
89		Annual inflation	3.10%	3.10%	3.10%	3.10%	3.10%	3.10%	3.10%	3.10%	3.10%		
90	*n.b the NIC Funding Request calculation should use the Bank of England Base rate plus 0.5% on 31 June of the year in which the Full Submission is made.*												