WESTERN POWER DISTRIBUTION

INNOVATION

NEXT GENERATION NETWORKS

INNOVATION STRATEGY

JULY 2018

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Contents

Executive Summary

This document sets out the detailed Innovation Strategy for Western Power Distribution (WPD). It describes our approach to innovation and describes how we continue to innovate within our business to improve efficiency and set the foundations for smarter network operation and the transition to a Distribution System Operator (DSO). It was originally produced as part of the RIIO-ED1 business plan and has since been reviewed, updated and re-issued annually to reflect changing external factors, business priorities and to incorporate learning from the previous 12 months. The document applies to all four WPD distribution licences of West Midlands, East Midlands, South Wales and South West.

The Innovation Strategy looks at the long term development of our distribution assets, network operations and customer service caused by changing system and customer needs. The Strategy looks through to 2035, yet naturally provides more detail on the shorter term priorities, requirements and proposed initiatives.

Innovation is the process of having new ideas, developing them into practical solutions and implementing them into equipment or processes in order to improve network performance or customer service. It will provide more flexible solutions that are better, cheaper or quicker than the current ways of doing things. The RIIO-ED1 Network Innovation Incentives and the Government's Carbon Plan have and will continue to bring huge change and significant opportunities to innovate. Innovation does not have to be on a large scale; sometimes improvements can be achieved through evolutionary change, involving incremental improvement to existing methods.

We rely on innovation to maintain our position as a frontier performer in network performance and customer service. Innovation is targeted at all of the key outputs safety, cost efficiency, customer service, reliability and environment. In the past innovation has proved beneficial by allowing us to continually improve in these areas. Future innovation will allow us to continue these improvements and will also help us to address the challenges brought about by the Carbon Plan.

Our innovation project portfolio has enabled us to deliver significant learning to the wider business as well as other network operators. We have delivered over 100 innovation projects over the previous and current price control period, which has enabled significant changes in how we operate our business providing benefits to customers. A key example of this is the learning as part of our Low Carbon Networks Hub project that has enabled us to roll out Active Network Management (ANM) across each of our four licence areas.

We continue to innovate and ensure third party access and collaboration on our projects is achieved, most notably through our established third party call for projects. This Strategy also sets out our key priorities and challenges during the remainder of RIIO-ED1.

1 Background

1.1 Introduction to WPD

Western Power Distribution (WPD) delivers electricity to 7.9 million customers over an area of 55,000km^2. This electricity is distributed over 220,000km of overhead lines and underground cables, fed from 185,000 substations. The area served by WPD is shown in Figure 1-1.

Figure 1-1: WPD Distribution Area

Figure 1-2 shows the voltage levels and typical assets we operate across our four licence network areas.

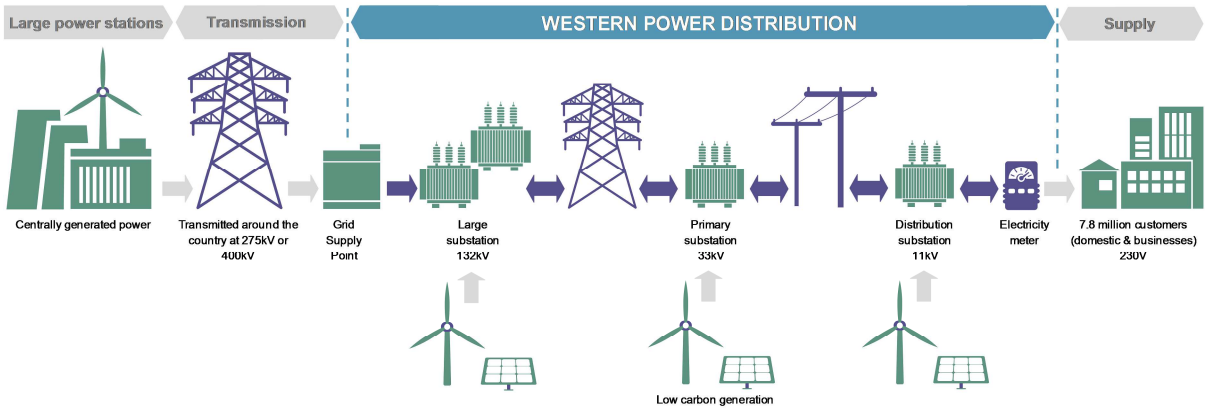

Figure 1-2: WPD Network Operation

1.2 Overview of Innovation Strategy

This document sets out the detailed Innovation Strategy for WPD. It describes our approach to innovation and describes how we continue to innovate within our business to improve efficiency and set the foundations for smarter network operation and the transition to a Distribution System Operator (DSO). It was originally produced as part of the RIIO-ED1 business plan and has since been reviewed, updated and re-issued annually to reflect changing external factors, business priorities and to incorporate learning from the previous 12 months. The document applies to all four WPD distribution licences of West Midlands, East Midlands, South Wales and South West.

The Innovation Strategy looks at the long term development of our distribution assets, network operations and customer service caused by changing system and customer needs. The Strategy looks through to 2035, yet naturally provides more detail on the shorter term priorities, requirements and proposed initiatives.

This document provides all the information that Ofgem requires in an Innovation Strategy for a licenced network operator, namely:

- Evidence of how previous innovation funding has been used effectively and resulted in improved outcomes for consumers;
- The high-level problems and/or challenges which the sector/company expects to face over the period, and the justification for initiating projects to address these;
- The consequences of innovation not occurring;
- The process or methodology by which we will focus on future innovation;
- Demonstration that the problems/challenges have been identified/prioritised and justified in consultation with stakeholders;
- Discussion of the relative priorities, risks, benefits, value for money and potential customer impacts;
- Deliverables and potential deliverables from the research or development or trials, such as defined learning on an issue, revised codes, new charging methodologies etc.;
- A description of our processes for reviewing and updating the Innovation Strategy; and
- A description of our approach to ensuring the efficient roll-out of successful innovation into business as usual (including innovation developed by other DNOs).

This Strategy is one of three annual reports produced that relate to WPD's innovation delivery; the other two are the Network Innovation Allowance (NIA) Annual Project Summary and Environment and Innovation Summary Report, which can be found on our website.

2 Introduction

2.1 Innovation Process

What we innovate?

Innovation is the process of having new ideas, developing them into practical solutions and implementing them into equipment or processes in order to improve network performance or customer service. It will provide more flexible solutions that are better, cheaper or quicker than the current ways of doing things. The RIIO-ED1 Network Innovation Incentives and the Government's Carbon Plan have and will continue to bring huge change and significant opportunities to innovate. Innovation does not have to be on a large scale; sometimes improvements can be achieved through evolutionary change, involving incremental improvement to existing methods.

Why do we innovate?

We rely on innovation to maintain our position as a frontier performer in network performance and customer service. Innovation is targeted at all of the key outputs safety, cost efficiency, customer service, reliability and environment. In the past innovation has proved beneficial by allowing us to continually improve in these areas. Future innovation will allow us to continue these improvements and will also help us to address the challenges brought about by the Carbon Plan.

How do we innovate?

Innovation is core to our business strategy. We have a small innovation team dedicated to exploring innovative ideas including the delivery of smart grid projects. Our projects are predominantly generated from ideas from staff and stakeholders. When our projects involve the installation of equipment on our network or require a change to business processes we do this in the same way as our standard engineering activities using the skills and efficiencies of our engineering teams. We also draw on the expertise of our suppliers and help them develop solutions. Furthermore, we work with a range of research establishments utilising their specialist skills.

2.2 Stakeholder Involvement

Innovation is a key theme of all stakeholder engagement sessions. Our stakeholder engagement process for innovation is the same as for all other areas of our business. Stakeholders understand that innovation cuts across our business and can provide improvements and benefits to all areas. We welcome ideas from our stakeholders and openly encourage them to put forward their suggestions and have, as well as ad hoc involvement, now put in place annual calls for proposals.

2.3 Government and Regulation

Our main sources of innovation funding are managed by Ofgem, the industry regulator. Ofgem has established a variety of funding mechanisms to develop future networks that support the Government's Carbon Plan. We work with Ofgem and the Department of

Business, Energy and Industrial Strategy (BEIS) to support their ambitions, targets and meet their and our obligations.

We also engage with BEIS and Department for Environment, Food and Rural Affairs (DEFRA) on related matters such as Climate Change Adaptation (CCA) that looks at the longer term effects of climate change on the UK electricity industry.

We actively engage in the development of regulatory and legislative policy and our learning from innovation projects informs the proposals we make in our responses to consultations. The results from our projects are published and freely available via our website, which enables all stakeholders to benefit from our learning.

2.4 Innovation Funding within the UK

Ofgem have provided an innovation mechanism for the previous three distribution price control periods as shown in Table 2-1.

Table 2-1: Innovation Mechanism by Year

Mechanism	Years
Innovation Funding Incentive	2005-2010
Low Carbon Networks Fund	2010-2015
Network Innovation Allowance / Competition	2015-2023

The Innovation Funding Incentive (IFI) provided an opportunity to improve the quality of research and development within the UK electricity industry. As part of this mechanism we delivered 62 projects, where a number provided lower Technology Readiness Level (TRL) development to inform further Low Carbon Networks Fund (LCNF) and NIA projects, as discussed in Section 5.1.

The LCNF was designed to support the development of low carbon technologies within the UK electricity industry and facilitate the changes brought about by the Carbon Plan. It contained three elements; large scale projects funded through the competitive process, Tier-2; smaller scale projects that were self-contained, Tier-1, and a discretionary reward where Ofgem have and continue to provide an additional allowance for companies that successfully develop learning that generates benefits for the wider industry.

In RIIO-ED1 the NIA and Network Innovation Competition (NIC) has replaced the previous LCNF schemes. The NIC has a greater value and is funded through an annual competitive competition open to both distribution and transmission companies. We will continue to develop innovation projects through these mechanisms; we also now have an established process for third party participation that involves the publication of an annual Call for Proposals relating to NIC bids and in 2018 also ran a similar Call for NIA project proposals.

We have also previously secured support, and continue to proactively explore non-Ofgem driven funding mechanisms, from the Engineering and Physical Sciences Research Council

(EPSRC), Energy Systems Catapult, Innovate UK and the European Regional Development Fund (ERDF).

Table 2-2 provides and overview of the number of projects we have delivered against the varying, Ofgem driven, funding mechanisms.

Table 2-2: WPD Projects by Funding Mechanism

Mechanism	Number of Projects
Innovation Funding Incentive	62
Low Carbon Networks Fund	19 *13 – Tier-1* *6 – Tier-2*
Network Innovation Allowance / Competition	34 *32 – NIA* *2 - NIC*

2.5 Co-ordinated business approach

To ensure that innovation activity is focussed on suitably supporting the wider business to deliver asset and operational efficiencies to best serve our customers a detailed and co-ordinated approach with the wider business is required. This centres on a close working relationship with the engineering and commercial teams, specifically Policy, Strategy and Distribution System Operation. A number of documents produced by these departments are at the centre of driving our innovation portfolio:

- Distribution System Operability Framework

This document details nine future technical and commercial challenges aligned with the three innovation themes, Assets, Operations and Customers. This document has most recently been used to inform the NIA third party Call for Proposals.

- Shaping Sub-transmission Networks

Each of our four licence areas has a Shaping Sub-transmission document produced and periodically reviewed, which details the forecast requirements of the 33kV, 66kV and 132kV networks based on projected Distribution Generation (DG) and Low Carbon Technologies (LCTs) integration. This data is used to determine and provide justification for the business case produced for new innovation projects, where appropriate, prior to approval.

- DSO Transition Plan

We recognise that the change from a Distribution Network Operator (DNO) to a DSO is essential to driving performance and efficiency from our network and to ensure it can meet the future energy demands of all our customers. Therefore, we have produced a detailed DSO Transition Plan that has a clear plan for the transition; suitable innovation projects are shaped and delivered to support the technical and commercial needs of operating as a DSO.

3 Why we innovate

3.1 External and Industry Trends

The changing global attitude towards fossil fuels is driving customers towards greater electrical solutions for heating and transport. The generation sources which support this increased demand are more renewable and distributed in nature. Creating a passive network that supports this increased electricity usage would be expensive using purely conventional methods. Our Innovation Strategy identifies, investigates and evaluates affordable alternatives. The alternatives may include solutions that postpone expensive investment whilst there is uncertainty. They may also provide long term active solutions to the management of networks.

These new type of loads, coupled with a mismatch of when the energy is needed compared to when renewable DG generates, leads to substantial growth in morning and evening peak demand. The network peaks will be an order of magnitude greater than today. To build the networks large enough to cater for these peaks would lead to significant over capacity in the system most of the time. In certain regions it is also likely that there will be a summertime or daytime peak of generation export due to solar generation. These changes in energy profiles, larger peaks in demand, substantial swings in DG output and a more active energy market will create challenges for us as we manage our network. The installation of monitoring and control systems to regulate Distributed Energy Resources (DER) which includes distributed generation, active demand and flexible storage provides a potential solution but represents a step change in operations from our passive past.

The transition from operating a passive system sized to support maximum demand, to one where DER is actively controlled, dependent on real time and forecast energy flow, is commonly referred to as a DSO. Innovation Projects have helped inform our DSO Transition Plan. Current and future projects will deliver further insight into new roles and responsibilities of the DSO. They will often be critical in advising on the nature and timing of business change.

Innovative solutions can also improve the security of electricity supplies by ensuring generation matches demand in local areas. Solutions could enable sections of the electricity network to be run in isolation for short periods of time. Distribution network technology will continue to advance and we can gain benefits by adopting it. Our experience shows that new solutions available today will become standard in the near future. For example, Active Network Management (ANM) was bespoke when our Low Carbon Hub project started in 2011. ANM is now business as usual and we have a framework agreement in place with three vendors, with seven zones currently active and a plan in place for all of our remaining network to be active by 2021. There will also be an evolution in the capability of LCTs such as Electric Vehicles (EV) and heating solutions, currently being demonstrated by our Electric Nation and FREEDOM projects, respectively. Technology breakthroughs are also likely, for example, in the cost and density of energy storage devices. Network innovations we are developing today will need to adapt or be replaced with new solutions over time as these breakthroughs are realised.

3.2 Customer Focus

Through the deployment of a wide variety of new technologies, such as smart thermostats, solar photovoltaic panels, and EVs, customers are increasingly able to control their electricity usage and spend, as well as the type of power they buy and when they use it. Some customers want the ability to self-generate and sell that power back to the grid. The demand profile for our customers is changing, and is expected to change even more drastically with the forecast uptake in EVs and the decarbonisation of heat in the early parts of the next decade.

As a result of this, we will need to develop commercial models and technical solutions that facilitate customer choice in a cost-effective way, whilst at the same time managing the impact on the networks. We believe that at the forefront of our ability to serve our customers' evolving needs are increased engagement and communication, as well as transparency and efficiency in our plans and priorities. We demonstrate this through active innovation participation in our stakeholder events, which range from DG forums, Member of Parliament (MP) visits to depots and innovation project sites and regional Smart Energy Events.

3.3 Government Policy

Concerns about climate change have led the Government to produce the Carbon Plan setting out the UK's commitment to reducing greenhouse gases by 80% by 2050. New challenges will emerge for DNOs as the Carbon Plan seeks to drive down the levels of carbon released by both heating and transport activities thereby shifting demand from oil and gas to electricity. The scale and pace of the changes are uncertain but we need to be ready to accommodate the changes when they arise. The aspirations within the Government's Carbon Plan will increase demand on the network and there will also be significantly more DG incorporated.

We have already observed the effects that changes to Government policy can have. The feed-in-tariff (FIT) for generation led to a significant increase in the volume of applications for generation connections, with many applications being received just prior to subsidies being reduced as generator developers seek to maximise their returns from incentive mechanisms.

Devolved Government policy in Wales may lead to specific demands and need for innovative solutions. Our plan is flexible and therefore able to accommodate these. We expect that some LCTs will also see a high level of uptake that will be influenced by Government subsidies or incentives. The strength of incentives will alter the speed and volume of uptake.

The impact of new forms of generation and demand will become clearer during RIIO-ED1 and into RIIO-ED2 and our plans need to be flexible to respond to changing circumstances. We will accommodate any changing requirements into our Innovation Strategy as part of the annual review.

3.4 DSO Transition

We recognise that the change from a DNO to a DSO is essential to drive performance and efficiency from our network and to ensure it can meet the future energy demands of all our customers. The enhanced capabilities we are developing will also give our customers the freedom to access other opportunities within the developing energy system.

We see the planning and operation of a more active regional distribution network as a natural extension of its current role and believe DNOs are well placed to lead the management of an efficient and cost effective electricity system at a local level. With DSOs managing the co-ordination of transmission and distribution services at a local level, it enables the GB System Operator (GBSO) to concentrate on balancing the national network using un-conflicted services competitively made available.

There is currently no singular set view of what the future energy system will look like, and Ofgem and BEIS are looking for the industry to provide evidence to support decisions on what this future should look like. Therefore, it is critical that we continue to both commercially and technically innovate to ensure that the DSO is developed efficiently and effectively to best serve the future energy of our customers.

3.5 Managing Uncertainty

A high degree of uncertainty exists with respect to the GB Energy System and it is therefore important that we seek and use key sources of external data and guidance to ensure that we have the best forecasts possible. Whilst we are guided by national scenarios developed by BEIS we also employ organisations such as Energy Savings Trust, Centre for Sustainable Energy and RegenSW to tailor them to the WPD regions. To aid consistency in the development of Operability Frameworks we have aligned future WPD scenarios to those used by National Grid in our Shaping Sub-transmission documents.

The detailed understanding that we gain informs the development of our innovation programme to deliver solutions for the potential problems we expect to encounter. Wherever possible we also ensure that our projects are scalable and capable of providing more generic solutions that can be adopted irrespective of the specific type and level of LCTs that drive increases in electricity usage in the future and can also be transferable to other DNOs.

4 How we innovate

4.1 Scope of Innovation

We always look for better ways of working. We have adopted many innovative ideas into day to day operations that improve the efficiency and effectiveness in the way we deliver our services to customers.

Our track record of innovation and change has been developed from the implementation of good innovative ad-hoc ideas from staff all the way through to formal innovation projects.

Our innovation programme is grouped in to three main categories. These are:

- Assets – Projects in this category collect data from the network to enhance modelling. They also test alternative investment strategies that can defer expensive investments;
- Customers - These projects develop new solutions to enable customers to connect low carbon technologies. They may also involve testing of new customer tariffs or working with communities to provide local energy solutions; and
- Operations - This category of projects demonstrate direct benefits to active network operations from the application of technology.

This programme is then further defined across our innovation developments, described across five broad areas, which have been aligned with the Energy Networks Association's (ENA) Electricity Network Innovation Strategy:

- Network improvements and system operability;
- Transition to a low-carbon future;
- New technologies and commercial evolution;
- Customer and stakeholder focus; and
- Safety, health and environment.

These areas of work are interdependent and progress in one area will often help to enhance innovation development in another.

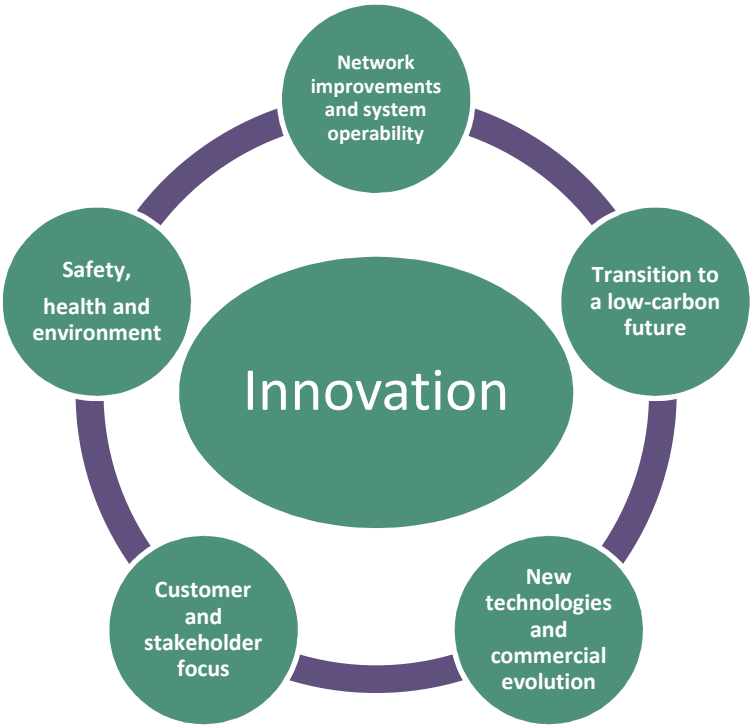

Figure 4-1: Electricity Network Innovation Themes

Our existing portfolio of innovation projects has already shaped how we are thinking about the future. We will continue to innovate and carry out new projects that will build upon what we have already learnt from the projects we and other DNOs have delivered. A current snapshot of our programme can be seen below.

Figure 4-2: Future Networks Programme

4.2 Stages of Innovation

Projects will continue to deliver additional knowledge across all output areas. The project portfolio will remain balanced across multiple areas:

- Working at various stages of development spanning higher Technology Readiness Levels (TRL) 3 to 8;
- Exploring both technology and commercial solutions;
- Covering the whole range of asset types and network voltages;
- Assessing risk, with no projects carrying unnecessary risk; and
- Utilising a variety of external funding mechanisms to supplement our own R&D budget.

Lower TRL projects will generally be carried out by external research partners under supervision of WPD engineers. Higher TRL projects which, in the shorter term, are more likely to produce a solution for our network or processes will mostly be delivered in-house using business as usual teams.

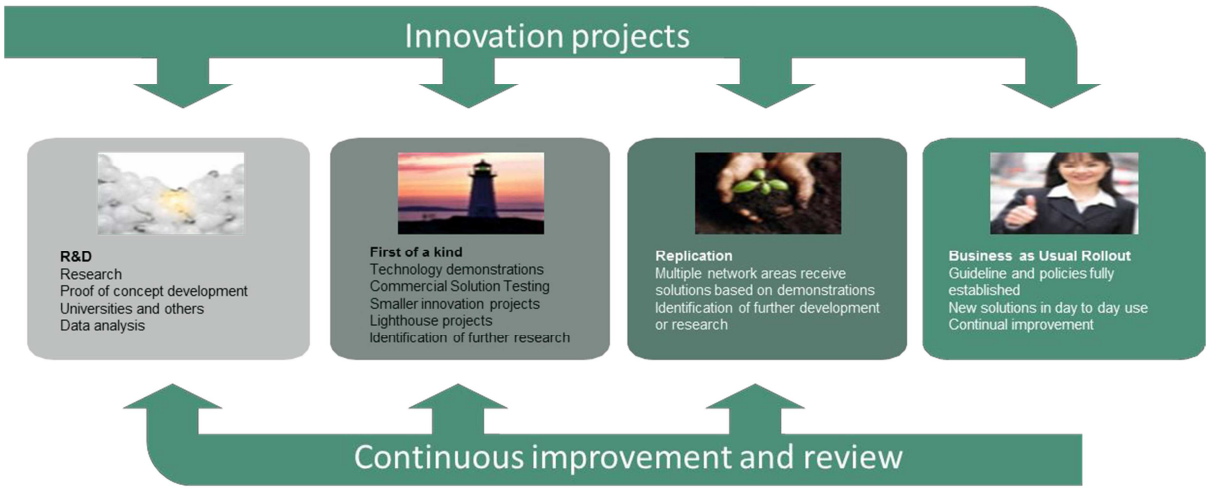

Figure 4-3: WPD Process of Innovation

The full 'research to implementation' timescale can often be between five and 10 years. That is why we focus internal teams on higher TRL stages, building on knowledge from earlier studies outside our own organisation.

4.3 Innovation Objectives

The principal objective of our innovations and our portfolio of innovation projects is to support our key three pillars, Assets, Operations and Customers. These objectives can be distilled down to the following key elements:

- Developing new smart technologies that will accommodate increased load and generation at lower costs than traditional reinforcement;
- Ensuring that a network is technically and commercially developed to deliver the required flexibility to support current and future system needs;
- Delivering solutions that are compatible with the existing network;
- Enabling solutions that can be quickly transitioned to become business as usual; and
- Providing value for money.

4.4 Funding the innovation programme

For RIIO-ED1 we have been allocated an NIA of 0.5% of total regulated revenue, around £58m throughout the total, eight year period. We also work with partners to provide innovative proposals for larger projects to be funded through the NIC. This is done through an annual Call for Proposals in response to specific challenges we identify.

We will also continue to make use of any other available funding sources where appropriate, in particular national and EU mechanisms.

In addition to NIA and NIC projects we also continue to support research and development in partnership with other DNOs; this is principally co-ordinated through the Collaborative Energy Portfolio (CEP).

4.5 Approach to Innovation

The way we approach innovation is fundamental to delivering against our objectives effectively and efficiently. Our approach is:

- Actively involve staff from across the business in the generations of ideas, development of solutions and implementation of projects;
- Working with a wide range of stakeholders to understand their needs;
- Making use of a wide range of innovation incentives and funding provided by the government, regulator and other funding mechanisms;
- Defining clear objectives for each project so that delivery can be focussed and progress can be accurately tracked;
- Using a small core delivery team to co-ordinate innovation projects;
- Avoiding theoretical research or innovation that doesn't not have clear objectives and benefits;
- Incorporating innovative solutions into existing equipment and processes; and
- Sharing what we learning with other organisations and learning from others.

4.6 Generating Ideas

Generating innovation project ideas is critical to the success of a portfolio of balanced projects, specifically ensuring we generate learning and outputs that meet the requirements of our future business operations and our stakeholders. Our ideas come from a wide variety of sources both internally and externally.

Internally we ensure that staff is engaged in innovation project activities through regular dissemination, an example is in the company's internal magazine, which provides staff the opportunity to understand that we're actively developing innovative project proposals and delivering these. We also ensure that our core team delivering innovation projects are all regionally located to enable staff the opportunity to regularly discuss problems and challenges they identify whilst carrying out their role with the aim of working to identify innovative solutions and drive change.

We also actively explore external involvement in the generation of ideas for new projects through a variety of mechanisms:

- Releasing NIA and NIC Third Party Calls to the wider industry to identify potential projects and solutions as identified in our DSOF document;
- Identifying learning and best practice development from other DNOs' projects that can be either integrated in to our business as usual practices or developed further through innovation trials;
- Interacting with wider stakeholder groups such as community energy groups and DG operators' forums to understand their needs and challenges to shape our project programme; and
- Investigating activities and innovations being developed outside of our direct industry to understand what can be learnt and adopted to improve our wider business operation.

4.7 Selecting and Prioritising Ideas

In order to appropriately prioritise our innovation programme and select the correct breadth of projects to ensure a suitable balance is achieved we group and assess each project against the five broad areas. They are then assessed against the innovation objectives and subsequently prioritised.

Key elements used to select and prioritise a project are the positive impacts of a project on our customers and the cost benefit analysis outcome.

4.8 Developing plans for Innovation

Innovation in smart solutions will help us to accommodate LCTs through RIIO-ED1 and into RIIO-ED2. Our RIIO-ED1 business plan set out expectations for how smart interventions will reduce our investment plans by £128m across the period.

Our innovation plans are regularly reviewed against new information from UK industry, worldwide research, learning from Network Innovation projects and outputs from the Open Networks Project.

We take account of other ideas and initiatives external to the business which can be jointly developed with our ideas. In some cases this allows us to utilise funding from other bodies. We also look for ideas that follow on from earlier Innovation projects to maximise the benefits of investments already made.

We look to collaboratively plan for innovation through the CEP initiative overseen by the ENA, which enables DNOs to work collaboratively where it makes sense for businesses and customers.

4.9 Stakeholder engagement for Innovation

Our stakeholder engagement process for innovation is the same as for all other areas of our business. Innovation is a key theme of all stakeholder engagement sessions. Stakeholders understand that innovation cuts across all areas of our business and provides improvements and benefits to all business areas. Innovation remains a key theme for our Customer Panel. The panel helped us to prioritise future projects. In addition to innovation projects the panel supports our work to assist the distributed generation community.

In addition to our stakeholder engagement process, we look for feedback on innovation at other panels and groups wherever possible. We work closely with RegenSW, a renewable energy group in the South West of England, who are keen to support the introduction of renewable generation across their area.

We use the Distributed Generation forums, now run by the ENA, to seek other views and to compare our initiatives with those of other DNOs. We support the Major Energy Users Council (MEUC) and have presented our innovation proposals to them for comment and feedback.

4.10 Collaboration

Collaboration with other LNOs

We look to collaborate both with our distribution network colleagues but also with transmission and gas network operators and system operator, where appropriate. We do this by participating in ENA working groups that enable close collaboration and interaction with all network operators. Two key current collaboration elements are:

- Open Networks

The Open Networks Project is a major energy industry initiative that will transform the way energy networks work, underpinning the delivery of the smart grid. The project brings together nine of the UK and Ireland's electricity grid operators, respected academics, Non-Government Organisations (NGO), Government departments and Ofgem.

- Collaboration Energy Portfolio

The Collaboration Energy Portfolio is a consortium of DNOs looking to identify common problems and challenges to deliver collaboratively funded projects that deliver a solution to be developed, trialled and reported that benefit the whole electricity industry.

Third Party Collaboration

To ensure that we enable and encourage third party collaboration and interaction we proactively seek both NIA and NIC project ideas through Calls for Proposals, which are currently in their third year. This provides an opportunity for organisations that have a long standing relationship with the electricity industry but also organisations that have historically focussed on other areas to proactively be involved in electricity innovation, often bringing a wider perspective to new problems and challenges in the industry.

We also attend a variety of well-established events, such as CIRED and Utility Week Live to ensure that we facilitate a suitable opportunity for individuals and organisations to interact with our innovation and wider business teams to discuss existing and future projects.

5 Innovation Progress

Our approach to innovation is that it should be an embedded activity and innovations should be developed from small-scale innovations through to trialling as major innovations and finally be integrated in to business as usual activities. We continue to take this approach to innovation. This section provides an overview of some of the completed early stage projects, how we have further developed these in to either major projects or developed them in to business as usual activities; most notably we have done this through developing Demand Side Response (DSR) services from our ENTIRE project, which has now been adopted across 18 zones to provide asset reinforcement deferring DSR for the winter of 2018/19.

5.1 Innovation Performance to Date

5.1.1 Completed Projects

Early Stage Innovation

Through the IFI mechanism we delivered 62 projects, some of which have been taken on to future LCNF and Network Innovation projects and some which delivered significant learning and supported our existing business process and procedures. Example of this are the Condition Based Risk Assessment project, which delivered a tool to determine the optimum replacement triggers for network assets and optimise maintenance periods based on condition and the Management of Electricity Distribution Network Losses, which investigated the concept of making distribution networks as energy efficient as economically possible; this work created a set of recommendations which are being address through our Losses Strategy.

Our LCNF Tier-1 portfolio saw us deliver 13 projects. A significant number of these projects focussed on the changing behaviour of customers and their use of the network, specifically around the integration of distributed generation and how this would be technically and commercially enabled. Our Community Energy Action project enabled our network data to be shared with third parties to inform on their energy use and to potentially inform how network constraints and reinforcement requirements could be avoided. This work informed our OpenLV project, focussing on facilitating third party access to network data and the potential benefits that can be realised.

Major Projects

Through the LCNF Tier-2 mechanism we have delivered five projects. These projects have investigated a range of network issues from developing 11kV fault current limiter technology to rewiring of customers' homes with Direct Current (DC) systems.

LV Network Templates

The LV Templates project was used to evaluate how Low Voltage (LV) electricity networks can best accommodate the low carbon future requirements. In 2011, 951 substation sites in South Wales were fitted with data monitors and communication equipment. The project also required voltage monitors to be fitted at the ends of the LV circuits that are fed from these substations. This required over 3,500 monitors to be installed to collect the data and send it remotely back to WPD. The project monitored energy usage and used statistical clustering techniques to identify more accurate patterns in electricity consumption. This allowed us to develop new planning assumptions and embed them in templates that can be used to facilitate more accurate network planning.

This project ended in 2013 and demonstrated that low voltage solar generation normally generates onto the network at around 80% of its rating. We have now altered our design assumptions to reflect this, which has increased the volume of photo voltaic (PV or solar generation) that can be accepted onto the network. It was also shown that voltage rise effects from PV are less than expected. Both these results have been used within the business and will influence national design policies and solar generation acceptance criteria. We published network templates data making it available for all DNOs to use in planning LV network solutions. The final project reports published in the autumn of 2013 provide full template data and conclusions. We have used the results from the LV Templates project to inform future ways of designing networks. This will allow us to better predict the effect of low voltage generation and load and ultimately enable us to accept more on to our existing network. We will also incorporate the learning from Scottish and Southern Energy's (SSE) 'Thames Valley Vision' project in our implementation. Scottish Power Energy Networks' (SPEN) 'Flexible Networks for Low Carbon Future' project will also provide additional knowledge on the acceptance of low voltage generation and the design of flexible ratings.

We published a discussion paper on the possibility of harmonising statutory voltage limits with those in the rest of the EU. The paper has been presented to industry groups including BEIS (DECC at the time of presentation), the Welsh Assembly Government and Ofgem. As a result of our findings the ENA has established a Statutory Voltage Limits working group, which we chair, that is considering the adoption of lower and harmonised voltage limits. We have already reduced the voltage within the wider South Wales area. We collected data through 2015 so that the impact of the voltage reduction on energy consumption could be measured, which was reported in 2016. The findings of the Electricity North West (ENW) 'CLASS' project has also confirmed the validity of our work.

Lincolnshire Low Carbon Hub

The Lincolnshire Low Carbon Hub was designed to test a variety of new and innovative techniques for integrating additional low carbon generation onto electricity networks with limited capacity. We offered dynamic line rating solutions and alternative connection agreements on this project.

When the Lincolnshire Low Carbon Hub project was originally proposed it was predicted that the solution would be replicable across the UK electricity industry in around two locations per DNO licence area. We will deploy the solution in more locations than originally predicted and we have already identified 21 sites across our four license areas along with a detailed roll out plan; currently nine of these zones are live. The amount of generation that has been offered and accepted at these sites is over 200MW.

Further detail can be found on the Active Network Management section of our website.

FALCON

Project FALCON was focused on providing an understanding of the dynamic nature of the utilisation of the 11kV network. The aims of FALCON were to facilitate the installation of low carbon technologies by delivering faster and cheaper connections on the 11kV network. It assessed a number of alternative solutions to conventional network reinforcement. Four technical and two commercial intervention techniques were designed and tested to address network constraints.

The project developed a prototype modelling tool using real-time data to inform network planning decisions, rather than traditional indicators such as total demand and generic engineering guidelines. The project demonstrated a Scenario Investment Model (SIM) planning tool for both 11kV network design and strategic forecasting. The concept of a SIM type tool for day to day and strategic planning is being further developed beyond FALCON.

The FALCON telecommunications solution, based on mesh radio, supported the engineering and commercial trials. The solution will be further evaluated under future telecoms NIA projects. Although the project is formally closed we are continuing to collect data from the engineering trials. The data collection and mesh radio infrastructure will also be used to support new innovation projects without the need to recreate a monitored network.

The uptake of DSR within the FALCON project exceeded the planned 9MW target. This has been achieved through a mix of bilateral contracts and services provided through aggregators. Uniquely, the service was offered as complementary to the National Grid Short Term Operating Reserve (STOR) service, meaning that customers could engage with us and National Grid at different times. As a result of our findings the ENA has established a DSR Shared Services working group.

The engineering trials within the FALCON project demonstrated and explored four innovative techniques aimed at relieving technical constraints on an 11kV network. The techniques trialled were dynamic asset rating, automatic load transfer, meshed network and energy storage. The trialled techniques are alternatives to conventional reinforcement, the conventional engineering remedy to network constraints.

The energy storage trial installed systems at five distribution substation locations on one 11kV feeder and provided valuable learning on site selection and installation challenges. Operational performance demonstrated; effective peak-shaving at both individual substation and feeder level; limited voltage management through reactive power output; and the potential to satisfactorily react to grid frequency (one example of an ancillary service).

BRISTOL

The BRISTOL project aimed to provide an innovative approach to operating networks utilising battery storage in a customer's premises. The battery systems stored output from PV generation and utilised it in many ways. A DC network for lighting and USB type charging, an inverter controlled by the customer and WPD and new tariffs helped manage the PV generation locally. The project also addressed issues associated with the large-scale deployment of PV generation.

In this project WPD worked with:

- Bristol City Council who deployed the technology at its sites;
- Knowle West Media Centre who coordinated customer engagement;
- Siemens who provided the technology; and
- University of Bath who were our academic partner.

The technologies were implemented in five schools, one office and 26 homes; all connected to 13 distribution substations.

The project tested the coordination of a local micro-grid and has also provided an excellent storage and DC power test bed. The BRISTOL solution is not immediately ready for rollout by DNOs as it will require further refinement and standardisation, as a proportion of the installation is beyond the customer's meter.

FlexDGrid

The connection of generation to urban 11kV networks can lead to fault levels that exceed the rated capability of existing networks. Traditionally, higher rated assets would need to be installed to enable the generation to connect, but this project investigated alternative ways to accommodate the connection of generation.

The FlexDGrid project was based in Birmingham and sought to explore the potential benefits from three complimentary methods:

- Enhanced fault level assessment;
- Real-time measurement of fault level; and
- Fault level mitigation technologies.

The project has now provided data which will change how we calculate fault level and will be used to alter design principles.

Real time measurement of fault level has shown that the enhanced fault level assessment calculations are correct and will allowed us to more accurately categorise load and generation effect on fault level. The principal outcome of the FlexDGrid project has been the updating of the WPD policy on the modelling of the network in respect of fault level, updating principles, providing additional guidance when modelling DG and the operation of protection and switchgear devices.

5.1.2 Network Innovation Projects

Network Innovation Allowance

We continue to innovate on smaller scale projects through the NIA mechanism. To date we have or are delivering 32 projects; these are detailed in Table 5-1 identified across our five broad areas.

Table 5-1: NIA Projects to date

Network Improvements and System Operability	Transition to a Low Carbon Future	New Technologies and Commercial Evolution	Customer and Stakeholder Focus	Safety, Health and Environment
Voltage Control System Integration – D-SVC Phase 2	Electric Boulevards	Energy Control for Household Optimisation (ECHO)	Carbon Tracing	Losses Investigation
Improved Statistical Ratings for Distribution Overhead Lines	Solar Storage	Sunshine Tariff	Carbon Portal	Airborne Inspection
Voltage Reduction	Electric Nation (formerly CarConnect)	SYNC		SF6 Alternatives
Time Series Data Quality	LV Connect & Manage	Entire		LV Sensitive Earth Fault Protection
Telecoms Analysis	Electric Vehicle Emissions Testing	HV Voltage Control		
Superconducting Cables	LV Plus	Smart Energy Isles		
Common Information Model	Industrial and Commercial Storage	Visibility Plugs & Socket		
Time Series data Tool Feasibility	FREEDOM			
DEDUCE	Hydrogen Heat & Fleet			
Primary Networks Power Quality Analysis				

Key to our portfolio is the split of projects across our three themes. Key learning across all three themes has been developed, an example for each is:

- Assets – Improved Statistical Ratings for Distribution Overhead Lines

This project, in partnership with all other DNOs has taken learning from real-time thermal ratings projects and looked to investigate if an improved permanent rating for overhead lines can be developed, meaning there isn't the need for additional monitoring equipment such as weather capturing technology. The project, through a real-system trial has shown that ratings of lines can be increased on a permanent basis, creating additional network capacity and deferring reinforcement requirements.

- Customers – FREEDOM

FREEDOM, in collaboration with Wales and West Utilities, installed 75 hybrid heat pumps in to domestic properties. This project aimed to demonstrate that these specific types of heat pumps could be used to transfer the primary energy source of home heating to electricity from gas, using gas exclusively when there are constraints on the electricity network, avoiding expensive additional asset installation to move to a purely electrified system. FREEDOM has shown that the technology and control systems are suitable to facilitate this whilst offering an energy cost saving to customers.

- Operations – ENTIRE

Utilising existing generation and load connections to provide DSR, in this case, demand turn-down and generation turn-up, to manage peaks on the network were trialled as part of ENTIRE. This project built on learning from our LCNF Tier-2 project, FALCON, and has demonstrated the value and benefit of customers operating flexibly to remove the excessive peaks on the network. The success of this project has seen 18 zones selected to utilise DSR to avoid peaks during the winter of 2018/19.

Network Innovation Competition

Larger projects are delivered through the NIC funding mechanism. We currently have two NIC projects, OpenLV and EFFS.

- OpenLV

This project will trial and demonstrate an open, flexible, platform that could ultimately be deployed to every HV/LV substation in Great Britain. The project uses three methods to demonstrate the platform's ability to provide benefits to DNOs, customer and innovative service providers.

- EFFS – Electricity Flexibility and Forecasting System

EFFS will explore forecasting arrangements required to build a DSO system capability. It will determine system requirements incorporating common standards and will collaborate with other DSO readiness projects, enabling enhancements to be made to an existing system to deliver and prove DSO system capability.

5.2 Current Priorities

In order to deliver a suitable network for the future that operates efficiently and economically a number of technical and commercial challenges must be managed and overcome. Below is a description of five of our current priorities for innovation.

5.2.1 Preparing for the future smart enablers

We have been assessing the scale of future network investment requirements by modelling different scenarios. The Centre for Sustainable Energy (CSE) compared the output from the Smart Grid Forum Transform model to socio-economic and house stock information that they held. This refined our plans to make them more specific to local circumstances. For example, forecasts of heat pump installations were reduced in areas where the housing stock is not suitable for their installation and electric vehicles' demands were increased in those areas where early adoption is likely. We will compare the CSE forecasts with the activity levels that we are actually observing to update our forecasts.

Using this detailed analysis we are increasing the size of selective transformers and cables where there is greatest likelihood of demand growth. We are also investing in communication infrastructure to improve our understanding of the real time status of the distribution network, utilise metering data and enhance the sophistication of the control of our network.

Investment in these enabling solutions will provide an essential foundation for the rollout of many smarter solutions supporting the transition to a DSO. Deploying such "smart enablers" and having individual innovative solutions fully developed will allow us to be ready for the mass adoption of LCTs by customers. This three step approach is illustrated in the diagram below, annotated with how we make use of regulatory innovation incentives.

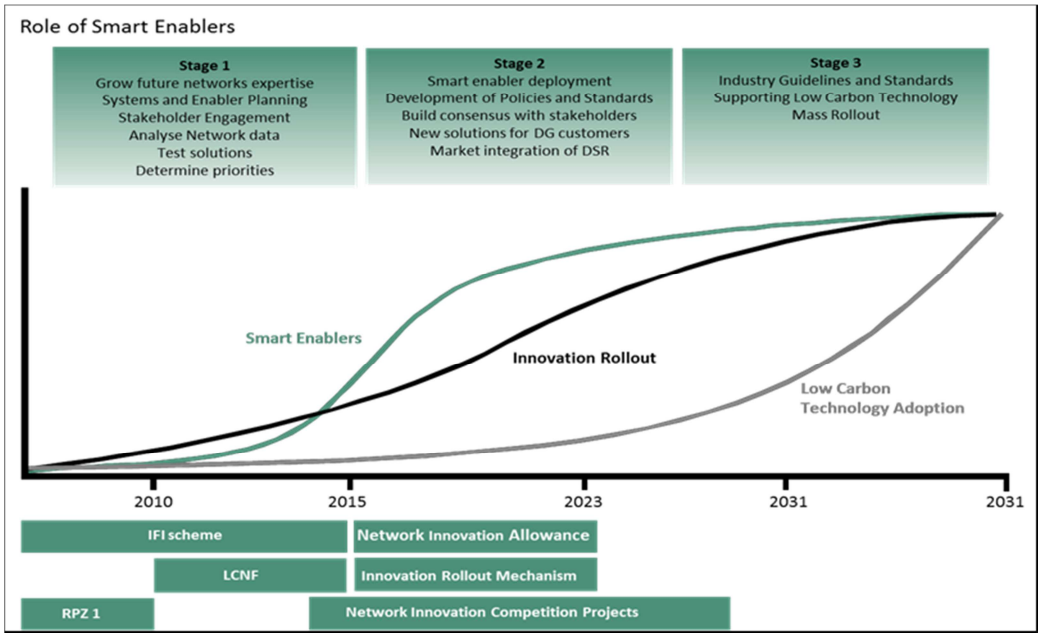

Figure 5-1: Role of Smart Enablers

5.2.2 Preparing for Distribution System Operator

Operating an active system will require new DSO capabilities to be developed:

- Understanding historic and real time energy flows;
- Forecasting future energy volumes across the network under different scenarios;
- Actively reconfiguring the system dependent on need;
- Contracting/despatching DSR through commercial arrangements;
- Coordinating DSO operations with the TSO; and
- Maintaining a platform for energy suppliers, communities and other market participants to have visibility of network congestion.

We are using our innovation funding to test a variety of new capabilities. A snapshot of our innovation priorities related to DSO is shown in Table 5-1.

Table 5-2: DSO Priorities

Data Integrity	Market Integration	IT Systems	Customer Propositions	Equipment
Alignment of Data – Common Information Model	WPD Regional Energy Scenarios	Power System Modelling	DSR products by customer segment	Telecommunications readiness
Energy and Utilisation Data – MWh not MW	WPD Operability Framework	Energy Management and Forecasting	DSM tariff structure	Transducers and measurement equipment
Network Connectivity	DSR Shared Service (link to TSO)	Time Series Data Storage and Visualisation	Alternative Connection Agreements	Settlement and metering data for Network Operations
	Visibility Platform (link to aggregators/ suppliers)	LV Connectivity/GIS	Managed Connection Agreements	Managed Connection Interface Devices
	Network Charging Methodology	Settlement and Billing		Active Network Management Technology

The new DSO competences must be delivered whilst ensuring sufficient capacity exists to meet customer needs and to guarantee safe asset loadings are not exceeded. Markets have an important role to play in matching demand with generation. DSO tariffs and price signals can encourage energy suppliers or others to help alleviate constraints.

Work that we have already completed to offer alternative generation connections as business as usual and to offer DSR through projects has helped us understand some of the features of DSO.
DSO actions will need to be coordinated with the Transmission System Operator (TSO) to ensure the overall electricity system is efficient. Sharing of forecasts and jointly balancing the overall system using a more iterative approach will be required. This is a new area for us as most of our previous work has been completed in isolation affecting our network only.

5.2.3 Driving value from smart metering

The smart meter programme will provide every household with the option of having a smart meter fitted. We will be able to use the aggregated data from these meters to provide us with some additional information. This data will provide us with details of electricity usage that may assist in refining network planning templates.

5.2.4 Demand side management and demand side response

DSR is a term used for agreements designed to encourage customers to make short-term reductions in energy demand triggered by an instruction from a DNO. This could include Industrial and Commercial (I&C) organisations turning off or deferring consumption for a period of time. Alternatively, they could start up on site generation to displace load and potentially export power back to the network. In domestic households DSR may become more prevalent as smart appliances that communicate with the smart meter are developed.

Demand Side Management (DSM) is a subset of DSR and is more passive in nature. DSM can be based on time of use tariffs or time dependent connection agreements. In I&C organisations DSM measures include savings made as a result of improvements in the energy efficiency of processes, but can also include predetermined time of use tariffs that influence usage patterns and the scheduling of processes. In domestic households energy efficient appliances will reduce demand but time of use tariffs are likely to provide the bulk of DSM.

We are engaging with domestic and I&C customers to test different commercial arrangements, determine the scope of terms and conditions and understand the practical implications of applying DSM and DSR. Different approaches will be required for domestic and business customers.

5.2.5 Identifying and delivering solutions from earlier projects

To ensure that we learn as much as possible from each of the innovation projects we have assigned specific individuals as points of contact for the other DNOs and their suite of projects. These staff is responsible for ensuring that we capture and apply the knowledge gained from other DNOs and assimilate it, with our own knowledge, into business as usual.

Completed innovation projects provide an excellent source of knowledge to help develop future networks and applications. For example our own projects have delivered solutions for Alternative Connections, Voltage Reduction and STATCOMs. From other DNOs we have identified solutions using equipment such quad-boosters and large scale energy storage.

5.3 Future Innovations

Considering our current priorities and the work we have undertaken with our stakeholders as well as our NIA and NIC third party calls we have identified a number of future projects to be delivered through our innovation programme out to RIIO-ED2.

5.3.1 Small Scale Projects

Table 5-3 highlights 21 new small scale projects to be delivered throughout the second half of RIIO-1. The eight projects highlighted in purple have been proposed as part of our third party NIA call in 2018 and the remaining 13 have been developed either internally or through interaction with our wider stakeholders.

Table 5-3: Future Small Scale Projects

Stochastic Load Flow	Virtual Telemetry	OHL Director	Power Electronic FCL	Robot Trades
Network Islanding		On-street EV Charging	Power Electronic FLM	Wildlife Protection
Harmonic Mitigation		LV Fault Location	Self-System Design	Advanced Vegetation Management
Virtual STATCOM		MVDC	New Build Standards	Airborne: Defect Analysis
Visual Data Processing		5G Design	LCT Response	Simulation Training

Third Party Led

Power Electronic Fault Current Limiter

Increasingly with the connection of any large scale generation (1MW or greater) the rise of fault level (short circuit current) is becoming a constraint, due to the contribution to fault level from the new connecting generator.

Solutions have been developed to this problem that involves installing a large fault current limiter at the primary substation, remote to the location of the generator connection. These solutions, whilst providing a system wide benefit to fault level often have long lead times, beyond that of a normal, non-constrained, new connection and where the fault level issue is solely due to the new connecting generator another, more localised solution is often preferred. This project will investigate the suitability of a small-scale power electronic fault current limiter, installed at the customer's point of connection; meeting their connection requirements whilst ensuring that no additional stress is seen on the wider network.

Visual Data Processing

As the proliferation of PV generation and LCTs continues on the network, specifically the LV network, understanding the volume and density of connections is increasingly difficult.

This project will focus on the utilisation of existing data and future data such as from smart meters to develop algorithms and analysis techniques to determine the levels DG and LCTs on a specific network. This work would also include the ability to predict future DG and LCT network connection hotspots to inform future investment decisions.

Virtual STATCOM

The need to dynamically manage localised network voltage issues is only set to increase as the utilisation of the system continues to see vast changes in its operation throughout the day, due to differing power profiles caused by the output of DG and utilisation of LCTs, such as the charging of EVs.

Static Var Compensators (STATCOMs) as was installed as part of the Lincolnshire Low Carbon Hub has shown that the injection and absorption of reactive power (VArs) is an effective mechanism to accurately control the voltage on the wider network. This project will investigate, through dynamic power system analysis modelling, the availability and suitability to use existing devices connected to the network to vary their power factor, which in turn will vary their reactive power contribution to the system. The use of single party and multi-party systems will be investigated to determine the applicability of 'virtual STATCOMs' as an alternative to asset investment.

Harmonic Mitigation

New technologies connecting to the system beyond the meter are increasingly power electronics in their nature. The connection of these power electronic devices brings new challenges in suitably managing the power quality of the system, principally due to the harmonic content of these technologies.

The solution to harmonic issues on the network has historically been provided by tuned devices (harmonic filters) that are designed specifically for the network they're connected. As the harmonic content on the network becomes more diverse and variable, by the plugging in of EVs and operation of PVs varying with the weather, the need for a more dynamic solution is required. This project will test the availability of using power electronic devices already connected to the system, where they are not operating at one hundred percent for their primary purpose, for instance an oversized inverter as part of a PV installation, to operate as a harmonic filter to mitigate either the effects of its own harmonic contribution or that of the wider system if required.

Stochastic Load Flows

Historically worst-case modelling methodologies have been employed, which often meant unrealistic network scenarios were considered because of the data available. As more network data, with greater granularity is available the opportunity to refine and improve the system modelling procedures becomes possible.

Recently modelling of the current and future system, such as in our Shaping Sub-Transmission Networks documents, has been carried out on a time series basis, however, to do this for wider technical requirements like new connection application modelling and shorter term investment planning it is unachievable. Developing stochastic load flows will enable a single snapshot analysis to be undertaken that considers the time series data implications through modelling, typically 48 scenarios, for a day's network analysis. This project will develop these stochastic load flows and assess their suitability and accuracy against time series data analysis providing a set of principles and procedures to be followed for differing network scenarios.

5G Design

Real-time data collected from the network back to a central system traditionally focussed on enabling long term planning to be undertaken, where the data was used retrospectively and to take control actions when a fault had occurred on the network. With the use of active network management schemes and other flexibility services the need for real-time data is now prevalent.

This project will conduct a number of studies and experiments relating to communications technologies to understand the technical and infrastructure requirements to facilitate this mass increase in real-time data collection from the network.

LV Fault Location

Locating faults on the LV network typically relies on significant manual network reconfiguration to isolate a faulted section of network and then, where underground, locate the specific fault location by digging several trial holes increasing the time and cost of the repair.

This project will investigate an update to existing LV monitors, where an algorithm is used to enable the location of a fault to be identified. The algorithm utilises self-learning technology to calculate impedances in the system to reduce the requirement for third party data, such as cable and overhead line type, which has been common place in previous fault location tools.

OHL Director

As the utilisation and requirements of the distribution network increase so too does the need for localised network monitoring. The overhead network has historically been difficult to capture data, due to the construction of the system and the availability of equipment throughout the network to gather data.

This project will trial a device that is capable of self-powering operation to provide real-time voltage, current and power flow information. This information will be used to more accurately assess network operation, such as hidden generation output and directional fault detection to more quickly identify the location of faults.

Internal

Airborne Defect Analysis

The use of airborne technology has been significantly developed, including through our Airborne Inspections project. Having the ability to more accurately and efficiently detect defects on our overhead networks will provide significant benefits in optimising our maintenance and investment programmes.

This project will focus on the use of airborne survey techniques to understand where, previously difficult to assess and investigate, assets have defects and can be pro-actively maintained or repaired to mitigate the risk of transient or permanent faults developing on the system.

Network Islanding

As the operation of the network becomes increasingly decentralised the benefits to understanding the requirements and operational restrictions of an islanded, disconnected from the main network, system will provide significant benefits to customers in, amongst other scenarios, black start conditions.

This project will look to identify an area of network where there is a suitable amount of controllable distributed generation, to understand, through system modelling, how this can and should be used to balance the load on the islanded system.

Virtual Telemetry

The installation of transducers to detect the operation of the network, in terms of directional power flow and current levels, can often be expensive and prohibitive and the need for a virtual solution, to a reliable accuracy, would add significantly increased network knowledge to aid operation and control.

Virtual Analogues will build on our previous NIA projects looking at time series data analysis. This project will look to use available direct and third party data to create pseudo analogue data, such as directional power flows and voltage levels; this data will support the further flexibility operations of our network.

On-street EV Charging

As the proliferation of EVs continues the need for additional charging solutions will intensify. To date EV charging has centred on a car parking environment or within driveways of homes. A great number of the current housing stock does not have driveways and this project will investigate a solution to this challenge.

The solution will centre on the development of new or utilisation of existing, in a different format, technology to provide the dense power requirements of EV charging in a small form factor that makes it suitable and applicable for installation on pavements, grass verges etc. for the purpose of on-street charging.

New Build Standards

As the heating and transport options for homes move towards electrification the need for new build standards of the network to support these domestic and commercial properties is required. This project will build on the learning generated from our previous losses initiatives.

The project will look at a range of suitable solutions and standards based on the proposed infrastructure to ensure that the new building solutions are fit for purpose and suitably designed to ensure that they are operated as efficiently and effectively as possible.

Wildlife Protection

Operating a vast overhead network unfortunately means that from time to time animals come in contact with these lines, often with fatal consequences to the animal and significant disruption to customers.

We will investigate and trial a project that looks to protect and discourage animals from contact with our overhead line assets. This will involve working with animal experts to understand how a suitable solution or our most contacted assets can be implemented and a trial will be undertaken to understand its benefit.

Advanced Vegetation Management

Tree growth, if not mitigated, can have significant operational consequences to the performance of our network. Tree trimming is currently managed on a timed basis to ensure that the trees and other foliage do not contact our assets and cause outages; this activity is both cost and time intensive.

This project will look to, using airborne analysis, understand the height and type of trees and foliage under and next to our overhead lines. This will then be referenced against a previous set of analysis to understand the growth rates of trees etc., which will enable us to move to a more articulate solution of the timing and planning of tree trimming activities.

MVDC

The use of power electronics on the distribution network can have a great benefit. Principally the use of such technologies removes a number of technical issues when trying to operate a complex and interconnected system; it also enables an artificial flow of energy to be created removing potential system constraints.

The 11kV network will be used to demonstrate the benefit of Medium Voltage Direct Current (MVDC) systems. This will focus on providing network interconnections where it was not previously possible, due to differing vector groups, fault level issues or such to understand the benefits for new connecting customers as well as the security of supply for existing customers.

Simulated Training

Training in all DNOs is focussed on a class room and workshop environment and then being trained on-site with an experienced member of staff. As the variety and nature of equipment on the distribution network vastly increases the needs and processes for training staff to operate, inspect and maintain these assets will change.

This project will look at how training on new and infrequently operated assets can take place in a simulated environment. As new technologies, previously unused on distribution networks, are connected these training solutions will be invaluable both for training new staff and using them for experienced staff as refresher training on the operation and maintenance of these technologies.

Robot Trades

A large part of our business is centred on staff operating, maintaining and repairing our physical assets to ensure the supplies to customers is as reliable as possible. The repairing of faults and the physical locating of faults is often a time consuming and physical exercise.

This project will explore the capabilities of robots to identify faults on the LV network, expose the faulted cable and prepare the cable to be repaired. This will have benefits to both the safety of the operational staff from locating and exposing faulted assets and will also reduce the time taken for customers supplies to be reconnected.

Power Electronic Fault Level Monitor

As the connection of distribution generation on the HV network continues to increase so too does the variability of the fault level on the system, which is currently difficult to understand in real-time.

Building on the developments of through the FlexDGrid project, where a mechanical FLM device was developed and tested, this project will focus on the use of power electronic technologies to develop a small form factor, accurate FLM, which can be quickly installed and is portable to be re-deployable as the needs of the network change.

Self-System Design

The connection of new properties to the network and new LCTs to existing properties is set to continue to increase, which creates a significant challenge in relation to DNOs providing connection designs and specifications.

This project will investigate and trial the development of an LV, mass-market, self-system design functionality, whereby customers, through a series of online design inputs will be able to design the connection offer and type they require and be provided with an instantaneous quote for the work. This will provide a significant time saving for customers looking for new and advanced connections.

LCT Response

Forecasting and preparing our network, specifically the LV system, for a significant change in operation, both in terms of maximum demand and profiles has significant challenges, particularly due to the availability for customers to connect new LCTs and notify the DNO once the connection is complete.

To ensure that the network continues to be suitable and applicable for the needs of the customer this project will look at a technology solution that can be rapidly deployed either on the HV or LV network when a networks load profile and magnitude changes due to the connection of a significant amount of LCTs. This technology will be used as an enabler whilst other, permanent, solutions such as reinforcement or DSR are implemented.

5.3.2 Major Innovation Projects

The figure below shows the areas we will explore and develop through the NIC. Many are still at a conceptual stage and build upon anticipated learning from existing projects. The scope of each project will become clearer as current knowledge learned in WPD and other DNOs is revealed. This may also lead to different projects that have not yet been conceived.

These areas specifically focus on technology solutions to support the changing needs and requirements of a distribution network. Technical and commercial developments to support such changes as to transition from a DNO to a DSO are captured in our NIA project portfolio.

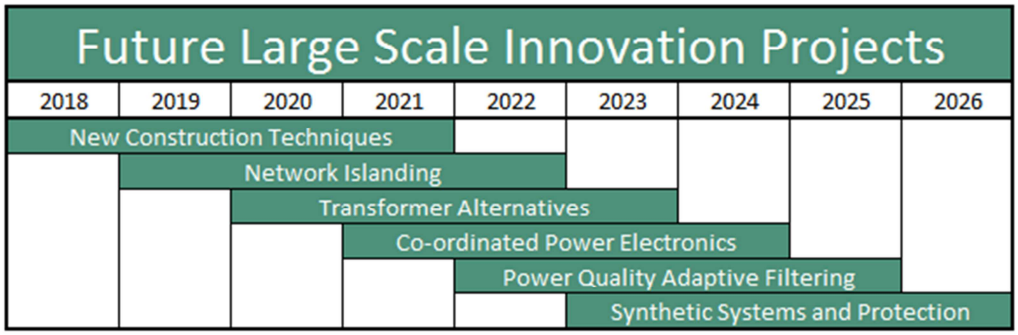

Figure 5-2: Future Large Scale Projects

New Construction Techniques

The building of new substations, overhead lines and cable installations is becoming increasingly difficult due to several factors such as planning restrictions, public opposition and escalating costs. Therefore, it is important that new and alternative techniques for construction are considered.

Under this area, the opportunity to develop and trial new construction techniques, which look to minimise the cost, time and disruption to install new network assets will be explored. Such trials will include new infrastructure installation techniques along with new types of asset that facilitate expedited installation.

Network Islanding

With an increasing level of generation on all voltage levels of the network; the opportunity to utilise this generation to provide supplies to customers in outage and fault conditions must be explored. This project will investigate and trial the engineering and commercial elements associated with safely operating an islanded network.

Facilities will be developed to allow an isolated area of network to be maintained through the continuation of operation of distributed generation. This will involve producing and updating existing generation protection philosophies and developing appropriate commercial arrangements to suitably manage the process and enable a network trial.

Transformer Alternatives

Utilising learning to be generated as part of Network Equilibrium and the installation of a 33kV Flexible Power Link (FPL), alternatives to traditional voltage transformation will be developed. It is forecast that the ability to provide greater levels of network interconnection will be required to support the future needs of the distribution network, not only where there are two networks at the same voltage but also at points where geographically close networks of different voltage levels are present.

Throughout this project alternatives to traditional transformers will be developed, trialled and tested. As the interconnection of two or more distinct networks can have significant engineering challenges, the use of alternative solutions aims to eliminate these connection constraints. Greater levels of network interconnection will provide significant increases in network flexibility, operability and security to existing and proposed customers.

System Co-ordination of Power Electronics

All DNOs are currently developing and trialling power electronics such as STATCOMs, batteries and FPLs. Many of these devices provide apparent and reactive to the system or from one section of network to another. As the number of these power electronic devices increases so will the need for them to be carefully considered and co-ordinated.

In order to ensure that power electronic devices connected to LV, HV and Extra High Voltage (EHV) networks can successfully co-ordinate the project will aim to develop a co-ordination and operation architecture for these technologies. Their performance and hierarchy of operation will also be investigated. This project will look to deliver industry learning on how to successfully integrate multiple power electronic devices in a single, connected, network effectively.

Power Quality Adaptive Filtering

It is well understood that the addition of power electronic devices at all levels of the distribution network contribute, to a greater or lesser extent, harmonics to the system. Technology such as inverters connected at generation sites, STATCOMs, batteries and other technologies all produce harmonics that are then distributed along the system. As these devices increase in their density of network installation the cumulative harmonic effect will become significant.

This project will assess different options to mitigate the harmonic distortion on the network, which will involve the design and trial of specific harmonic filters and also the utilisation of existing power electronic devices to operate specifically to destructively interfere with pre-existing network harmonics. The project will assess the effectiveness of each harmonic limiting option as well as the effects of potential harmonics on the system.

Synthetic Systems and Protection

National Grid has released evidence to show that fault level in all areas of the UK is likely to fall, due in part to large rotating centralised generation plant being replaced by localised distributed generation.

We will investigate, through the trialling of a variety of technologies and solutions, the ability to support existing HV and EHV networks for the instance that there are significant variations in fault level. The focus of this project will be the network 'strength', where key consideration will be the future requirements of system wide protection and system inertia.

5.3.3 Our plans for RIIO-ED2 and beyond

In RIIO-ED2 the transition detailed in the Carbon Plan will be well underway and there will be more certainty over the eventual levels of LCTs. This will help us improve our forecasts for demand growth and distributed generation connections.

By RIIO-ED2 smart meters will have established a new communications link to each customer. Customers will have developed a deeper understanding of their energy consumption and will be more receptive to participating in initiatives that reduce their energy consumption. This will provide future options for more DSR when the volume of LCTs is anticipated to grow further.

By the end of RIIO-ED2 some of the domestic LCTs installed during RIIO-ED1 will be coming towards the end of their useful lives. Future generations of these technologies will provide additional services for customers and by working with manufacturers we will encourage the development of features that will also enhance our ability to manage the network.

Whilst no-one can be certain about the way that electricity usage will develop over this long period, we will continue to review our plans with our stakeholders to ensure that we have the best informed view available. Our plans will remain flexible and we will monitor developments and react appropriately to address changing requirements.

6 Governance Arrangements

All innovation projects are delivered as part of the Future Networks Programme. The Programme is the delivery mechanism for the Innovation Strategy detailing ongoing and new projects. All business innovation projects are delivered from the area of the business that has the specific expertise to also be able to develop the idea.

On an individual basis projects are approved in line with our financial approvals process. All projects and works are subject to the same controls and authorisations as other engineering projects in the business. NIA projects are subject to project level approval by the Future Networks Manager. Projects registered in NIC are subject to project level authorisation by the Operations Director.

Project process is tracked through normal monthly business reporting arrangements. For each major project this includes the preparation of a balanced score card detailing progress against milestones, significant issues and summary financial reporting. All major projects have a nominated senior management sponsor and progress review group.

Projects also undergo regular review by the progress review groups of each major project and by the Future Networks Manager for smaller projects. Reviews include an assessment of the risks that exist to the overall success of that project. These risk assessments allow appropriate decisions to be made to mitigate their impact.

Innovation projects are delivered in line with regulatory governance requirements and regular reports are provided to review the progress of individual projects against their targets. Six-monthly reviews are made publicly available for all our LCNF and NIC projects and any NIA project with a value greater than £1.5M.

Major projects are managed in accordance with recognised project management methodologies. There is a suite of standard documents and templates which are tailored for the specific requirements of each project and all covered under a wider project governance guidelines document.

6.1 Research partners and supplier arrangements

We have links with a wide range of universities, research establishments and manufacturers, both in the UK and across the world (e.g. Hitachi in Japan and the Electric Power Research Institute in the USA).

We monitor UK and worldwide research to identify concepts and developments that may provide benefits to us in the future. We are active members of CIRED, the forum where the international electricity community meets. To maximise the effect of research and innovation we actively participate in industry wide forums. These forums bring together the best industry knowledge in a cost effective way to pool and manage research which is of use to all DNOs.

Through the ENA, the DNO trade body, we also actively participate in a variety of groups and panels which review and develop industry wide learning. The issues and challenges facing WPD are the same as those for other network operators and we share knowledge wherever possible.

We proactively support knowledge sharing and the development of best practice guides which can benefit the whole industry. It is important that we learn from others and do not spend time or energy duplicating effort on topics which have been well researched. Benefits for the industry and society can be more effectively applied when the specialist experience gained from running innovation projects is shared.

Staff in our Innovation Team reviews other DNO projects in tandem with their own work to deliver our projects. They become our key contact to other DNO dissemination events and ensure we learn as much as we can from the other projects which are being undertaken. We have allocated one person as the key contact to each other DNO group.

We support research that is led by suppliers and manufacturers and share our knowledge and experience to help them develop solutions. Providing this support enables us to influence the research so that it provides a benefit to us.

We work with UK based Small and Medium-sized Enterprises (SMEs), who are playing an increasingly important role in the delivery of new technologies and solutions.
We also provide feedback on the limitations of existing products so that they can be improved. Partners can also trial products or solutions on our network which generates useful practical experience for the developer and allows us to understand how the products can be integrated into existing systems.

Our academic partners enable us to draw on the specific expertise which they have which enables us to cover a wide range of topics and specialisms with people who have in depth knowledge.

Some projects include technology which is not from the electricity industry and we work with partners who might not be obvious choices but provide us with the best resource.
We choose product suppliers using our well established procurement systems. We use the Utilities Vendor Database system, Achilles and have worked with Achilles to develop new product codes to cover elements of network innovation.

6.2 Managing risk and future uncertainty

We identify and control project specific and generic (programme wide) risks. Dedicated project management staff periodically review and control risks for individual projects.

Generic innovation risks such as the application of new technology to the distribution network are controlled through close liaison with our Policy Team. This means that new technologies either fit into existing policies and standards or the team develop new policies and standards as a part of the innovation process. The diligence of setting policies at this stage also ensures the long term operation of new technologies by ensuring that new innovations are ready for business as usual deployment at an early stage.

In some cases the risks are associated with uncertainties such as the take up of LCTs or the low carbon transition. Future uncertainty risk is mitigated by regular review of forecasts and identification of tipping points for wider application or a commitment to higher volumes. An example of a tipping point for transport would be a motor manufacturing devoting a whole factory to the production of electric vehicles.

6.3 Tracking benefits

All smart grid projects are regularly reviewed to ensure the benefits they deliver are in line with those predicted at the time of approval. Smaller projects are reported annually in our innovation summary report. Major projects report progress including benefits delivery as part of their regular reporting regime.

All projects delivering against our key outputs have their benefit measured against those outputs. Benefits' tracking is carried out at all stages of the project, from initiation to completion.

6.4 Keeping the strategy up to date

Our innovation plan is subject to review to ensure that it continues to provide solutions in line with business requirements. We review our plans with our stakeholders to ensure that we allow them to challenge our proposals and shape what we do. Our plans will remain flexible so that we are able to address changing demands.

External factors will influence our plan and feature as part of the review process. We will take account of results from our trials and other DNO projects. Manufacturers will often develop products through DNO trials and will we assess their suitability for adoption as part of our review process.

Our review will also take into account existing Government incentives and potential changes which may impact on customer behaviour.

The Innovation Strategy is approved annually by the Operations Director.

7 Delivering benefits from innovation

We deliver innovation through an in-sourced model with a small team of specialists using the resources of our operational teams to deliver tools or products onto the network. The Innovation Team works alongside the company's Policy department where they interact with equipment specifiers and technical experts of the wider business. Once trials are successfully completed, the outputs are taken forward and replicated across our network.

As outputs are delivered, they are developed into new learning that can be taken forward and developed as business as usual. Outputs obtained from other DNO projects are fed into this process to ensure that we gain maximum benefit from innovation projects.

All solutions rolled out from innovation follow the same route as our other policies and techniques introduced into the company. Policies are reviewed by the senior network managers before they are introduced. The rollout process includes implementation plans and, where appropriate, training and dissemination sessions. We monitor all the projects as they develop and make use of learning and outcomes as they are reported.

Our IFI Regional Power Zone (RPZ) project developed a practical application for Dynamic Line Ratings (DLR) on our 132kV overhead lines. The project results have been embedded into business as usual and are documented in a dynamic line rating policy.

Our Lincolnshire Low Carbon Hub project developed a practical application of Active Network Management which is part of our Alternative Connections policy suite. Alternative Connections are available to all generation customers seeking a connection where significant reinforcement is required.

Export limitation devices have been developed by manufacturers to locally balance generation and demand, however due to the lack of an industry standard, the variance in the quality and method of operation of these devices is wide. We developed a policy for acceptance of these schemes which outlines the minimum requirements to achieve compliance with the new WPD policy. This policy was circulated to the other DNOs and following further refinement was developed in conjunction with manufacturers to form a new UK standard, ENA Engineering Recommendation G100.

All projects produce new or revised WPD policies for use during the project lifetime. These policies are always written in such a way that they can be extended to apply beyond the project and in a larger geographic area if the solutions trialled turn out to be successful.

Appendix A: Previous Projects and their Outputs

Our Tier 2 projects registered and completed under the LCNF have produced a wide range of outputs in the form of standards and specifications which are replicable within the UK electricity industry. In some areas the knowledge has created a requirement for more research and work in a particular area.

Table 7-1: Outputs from previous Tier-2 Projects

Project	Aspect	Policy/Standard	Note	Further Work
LV Templates	Connection of PV	Changes to planning tool parameters	Additional diversity added to enable connection of 20% additional PV	
	Energy Saving	11kV Tap Change Control Settings	Tap changer target voltage adjusted to measure impact on consumption and losses	For DECC to assess the potential for broadening of LV statutory voltage thresholds
	Templates	Ten standard substation profiles	Profiles to enable DNOs to model their networks more effectively	Comparison with results of other LCNF projects.
Low Carbon Hub	Connection of DG	Active Network Management (ANM)	ANM is one of our Alternative Connection solutions which are BAU	
	Voltage Control		Dynamic Voltage Control (DVC) solution prototyped	DVC will be fully developed for BAU as part of Network Equilibrium
	FACTS	FACTS Policies for I&M and Ops		
	Telecoms	Policies developed for fibre optic installation on wood pole lines		
SoLa BRISTOL	Micro-grid control			Further work is ongoing with universities to study the coordination of micro grids
	DC Installations		Clarification of UK wiring regulations	

	Export Limiting Devices	Policy on export limiting devices developed. Now BAU		
	Home Energy Storage standards			Further work under NIA & ENA working groups
FALCON	Engineering Trials	Battery policies for I&M and Ops at Distribution Substations	Automated Load Transfer, Network Meshing, Dynamic Asset Rating and Energy Storage.	
	Commercial Trials	Commercial arrangements with customers	Despatch of Distributed Generation and signalling of demand reduction by I&C customers	Conclusions will feed into business rollout of DSR
	Telecommunications	Standard for wood pole telecoms masts	Development of Data Network configuration recommendations and evaluation of WIMAX radio links	Conclusions will feed into future Telecommunications for Smart Grid projects
	Scenario Investment Model (SIM)		The SIM has been developed as a pre- production software system to advise on optimum network designs involving innovative techniques	Relevant aspects of the SIM will be further developed beyond FALCON under NIA and other sources
FlexDGrid	Modelling	Fault Level Policies for Application and Connection		Continued revision of modelling processes and procedures
	Measurement	Specification for Fault Level Monitors		Further development of improved FLM technology
	Mitigation	Specification and policies for I&M and Ops for Fault Current Limiters		

Appendix B: Business Change from Innovation Projects

The table below shows the changes we have made as part of our business that has been a direct result of outputs and outcomes of our innovation portfolio.

Table 7-2: Business Change from Innovation

Business Change	Relevant Project
Active Network Management	The Lincolnshire Low Carbon Hub through its development on an initial ANM scheme enabled the three types of alternative connections to be developed and the wide scape roll out of ANM.
STATCOM	Through the trial of the first STATCOM on WPD's network as part of the Lincolnshire Low Carbon Hub, companywide policies have been created enabling STATCOMs to be offered for voltage constraint issues relating to new connects and asset reinforcement schemes.
Fault Current Limiter	The FlexDGrid project trialled two different FCL types, which enabled a technology to be selected that is now part of a wider company policy enabling FCL solutions to be proposed where fault level increases are restrictive top the connection of new technologies and also operating arrangements.
Fault Level Monitor	As with the FCLs, the FLM was developed and tested as part of the FlexDGrid project. The FLM enables real-time fault level information to be gathered that enables control engineers more information when making operational decisions. The data has also enabled fault level soft-intertrip schemes to be offered to customers.
Fault Level Modelling	Through the data collected and advanced modelling mechanisms testing as part of FlexDGrid, the process we use to model new and connected generation, as well as the wider fault level studies, has been updated in a policy covering all four licence areas to more accurately understand the network.
Voltage Reduction	The LV Networks Templates project, whilst monitoring a wide area of network in the South Wales has enabled a significant voltage reduction programme to take place in the area, enabling the reduction in losses and greater headroom for generation to connect.
EV Connection Methodology	Through a number of our Electric Vehicle projects we have developed EV connected network system design standards to be developed.
Domestic PV Integration	Our PVs in Suburbia project looked at the impact of dense domestic PV on the LV and 11kV network. This learning enabled new assumptions on the impact of PV and enabled us to integrate more in to the existing network prior to the need for network reinforcement.
Transformer and Cable Sizing	The learning generated as part of our Losses Investigation project has enabled us to understand that installing larger transformers and cables will reduce the system losses and have therefore removed some of our lower materials sizes from our approved list.
Signposting data for Flexibility	The learning from our DSR trials as part of Entire has enabled us to investigate 18 zones across our network that will utilise DSR services to avoid reinforcements that would be required for winter peak management.

Glossary

Abbreviation	Term
ANM	Active Network Management
BEIS	Department for Business, Energy and Industrial Strategy
CCA	Climate Change Adaptation
CEP	Collaborative Energy Programme
CSE	Centre for Sustainable Energy
DC	Direct Current
DEFRA	Department for Environment, Food and Rural Affairs
DER	Distributed Energy Resource
DG	Distributed Generation
DLR	Dynamic Line Rating
DNO	Distribution Network Operator
DSM	Demand Side Management
DSO	Distribution System Operator
DSOF	Distribution System Operability Framework
DSR	Demand Side Response
EHV	Extra High Voltage
ENA	Energy Networks Association
EPSRC	Engineering and Physical Sciences Research Council
ERDF	European Regional Development Fund
EU	European Union
EV	Electric Vehicle
FIT	Feed-In Tariff
FPL	Flexible Power Link
GB	Great Britain
GBSO	Great Britain System Operator
HV	High Voltage
IFI	Innovation Funding Incentive
LCNF	Low Carbon Networks Fund
LCT	Low Carbon Technology
LV	Low Voltage
MEUC	Major Energy Users' Council
MP	Member of Parliament
MVDC	Medium Voltage Direct Current
NGO	Non-Government Organisation
NIA	Network Innovation Allowance
NIC	Network Innovation Competition
OHL	Overhead Line
PV	Photo Voltaic
RIIO-ED1	Price Control Period 2015-2023
RIIO-ED2	Price Control Period 2023-2028
RPZ	Registered Power Zone
SIM	Scenario Investment Model
SPEN	Scottish Power Energy Networks
SSE	Scottish and Southern Energy
STATCOM	Static Var Compensator
STOR	Short Term Operating Reserve
TRL	Technology Readiness Level
TSO	Transmission System Operator
UK	United Kingdom
WPD	Western Power Distribution

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