Network Innovation Allowance Annual Summary

Progress and results from 2018/19

UK Power Networks
Delivering your electricity

ukpowernetworks.co.uk

Contents

Foreword

Innovating to make things better for our customers is part of our DNA. Every day, the team at UK Power Networks are innovating, collaborating and finding new and better ways of doing things. We are driven by making our network safer, more cost-efficient and more reliable through smart interventions.

2018/19 once again has been a good year in terms of innovation performance, with UK Power Networks delivering an additional 8 solutions into the business as usual environment, this now brings our total RIIO-ED1 solution transition volume to 30, which is delivering value to the tune of £183m.

As a result of our interactive innovation process and stringent idea challenge process, we continued to maintain our success record in securing funding from the Network Innovation Competition to deliver world class innovation projects.

The purpose of this report is to give you an insight into some of the innovative work undertaken and our key achievements over the last regulatory year spanning 1 April 2018 to 31 March 2019.

The way energy is generated, managed and consumed continues to change at an unprecedented pace. The volume of distributed energy resources connected to our network continues to grow. Distributed electricity generation has more than doubled since 2010, with renewables taking the leading role. Last year was the greenest year since records began in terms of renewable energy generation. We now have more than 9GW and over 160,000 generators of all sizes connected to our three distribution networks.

Consumer interest in electric vehicles continues to rise, with more than 63,000 connected to our three networks as of March 2019 and continuing to grow year on year. The growth of electric vehicles and distributed energy brings wide-ranging challenges and opportunities to our business.

The change associated with the dynamic evolution of our industry will have an impact on every department at UK Power Networks from planning to operations, and everything in between. To remain abreast with this transformation, we are committed to ensuring we have the right people, processes, products and systems in place to continue to run the network safely, reliably and efficiently.

> “2018/19 once again has been a good year in terms of innovation performance.”

We place a high value on seeking out the best ideas to improve our performance for our customers, from start-ups to established industry leaders. We actively support Small and Medium Enterprises (SMEs) to develop and demonstrate their solutions through the Energy Innovation Centre. This continued initiative has also developed the highest volume of cross-network collaboration of any year to date, with the inclusion of gas network partners and cross vector projects now being developed as a norm. A key metric to delivering our corporate vision is to be a respected corporate citizen; this drives our energy to collaborate with research and demonstration centres such as the Power Networks Demonstration Centre, focussing their research towards overcoming our key industry challenges.

To ensure we are able to evidence the value of the RIIO Innovation stimulus and share the great innovations which networks are delivering, we focus on engaging with our stakeholders at key events. In the last year we undertook more than 64 external stakeholder engagement sessions to connect with industry, and conducted our popular Better Networks Forum where we were able to transition several of our solutions to other networks. We continue to promote innovation internally by including innovation content such as presentations and information stands at internal events, working with colleagues to develop ideas, and engaging early with the end users of each innovation solution.

A key objective in achieving our vision to be the best performing DNO Group is to be the most innovative, which means focusing on three key areas:

- **Efficient & Effective** – The top DNO Group in delivering value to network customers through Innovation and the benchmark for best practice;
- **Low Carbon Ready** – Consistently credited as an active facilitator of, and not an obstacle to, the low carbon transition; and
- **Future-Ready** – A future-ready distribution business providing new services, which meet the needs of our changing customers

Innovation is playing a crucial role in making our network safer, more reliable and more efficient. The Network Innovation Allowance has played a vital role in enabling us to create and embed innovative solutions into business as usual processes and to deliver great smart savings for customers.

Ian Cameron, Head of Innovation

> “A key objective in achieving our vision to be the best performing DNO Group is to be the most innovative.”

Should you have an innovative idea please visit our Innovation website and submit an idea.
https://innovation.ukpowernetworks.co.uk/

Innovation at UK Power Networks

Innovation facts and figures

38
Total number of projects in delivery

30
Solutions deployed into BAU in RIIO-ED1

68.6 million
£ value of all projects in delivery

£183 million
£ savings to customers RPTD

28
Industry awards
won for innovation in RIIO-ED1

77%
NIA funding to third parties

35m
£ Invested in Innovation in RIIO-ED1 so far

6
Fast follow projects deployed to BAU

32%
Collaboration projects in RIIO-ED1

How, Why and Where we Innovate

The rapid de-carbonisation of Great Britain's electricity system presents great opportunities and unique challenges to the electricity network. Traditional models are rapidly being left behind, we are balancing an increasingly complex and interconnected electricity network while maintaining focus on our core responsibility of keeping the lights on. It is a change as fundamental to the British electricity network as the advent of broadband was to telecoms. It is a change that UK Power Networks is embracing. Our business ethos is one of innovation and disruption, developing and implementing smart technologies to benefit our customers.

Our innovation strategy[1] sets to prepare the network for the future while delivering a safer, more sustainable, cost-efficient and reliable network for today.

The greatest measure of our success is the benefits this funding unlocks for our customers. Innovation initiatives have saved customers £183m since the beginning of the current regulatory price control period in 2015, which is more than any other UK electricity network by multiples. The business has transitioned 30 innovative solutions into business as usual over the same period, more than any other network operator.

Our Innovative Solutions are at various stages of roll-out. Throughout their life-cycle they undergo a process of assessment, development and monitoring through to a completed roll-out to business as usual. This process is captured in our Innovation life-cycle process, as shown in Figure 1.

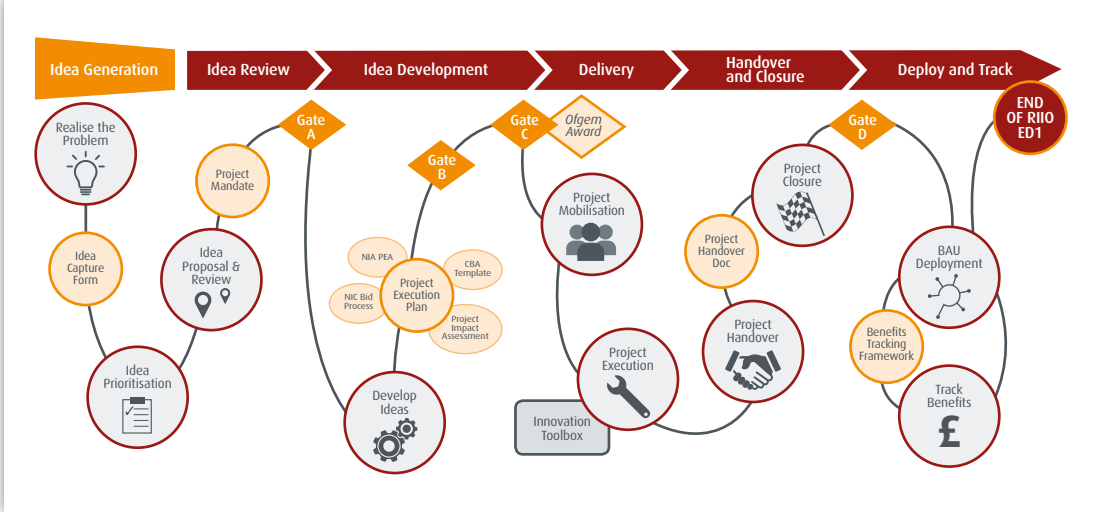

Figure 1: Innovation Life-cycle

[1] Our Innovation Strategy can be found on https://innovation.ukpowernetworks.co.uk/about-innovation/

How we do this is via a focused innovation strategy covering three key strands:

Efficient & Effective: Developing equipment and processes that help us keep the lights on more safely, efficiently or environmentally sustainably

Low Carbon Ready: Enabling low carbon technology such as electric vehicles, renewable energy and domestic or commercial storage to connect to our network

Future Ready: Developing a future-ready distribution business that meets the needs of our changing customers

It is vital that our approach to Innovation deliver customer benefits across all facets of our business. We have worked hard to ensure we have a balanced portfolio which reflects the three strands of our Innovation Strategy across the company, as shown in Figure 2.

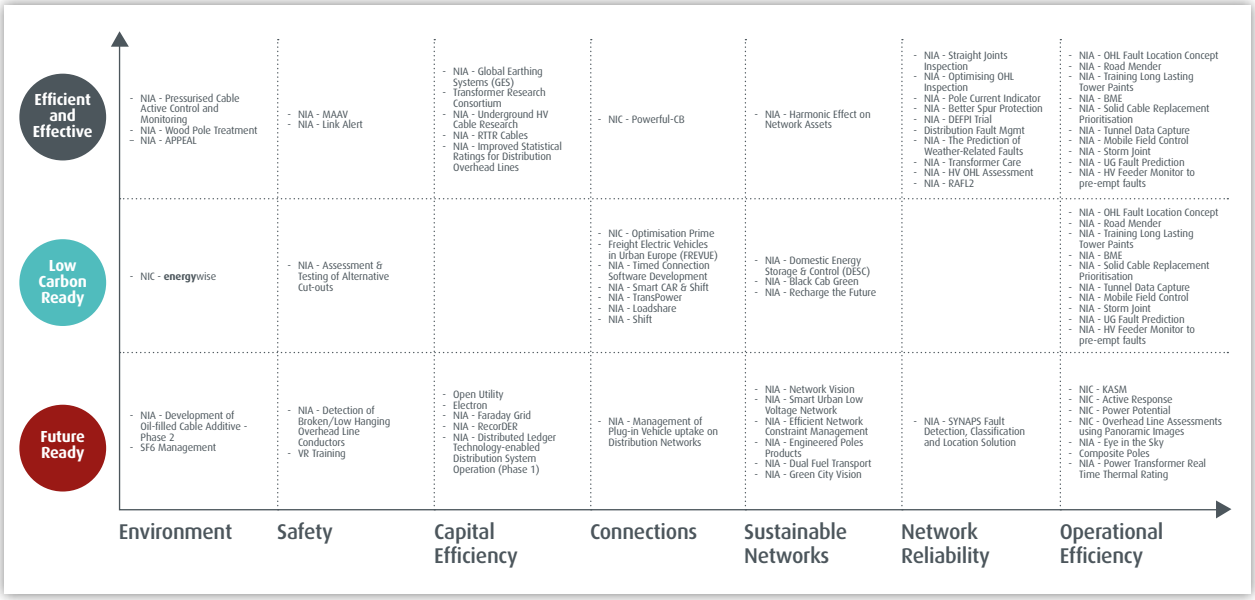

Figure 2: Innovation Portfolio in RIIO-ED1

Collaboration is key to successful innovation. We know the challenge of electric vehicles cannot be tackled alone, so we're collaborating with the key parties involved in the EV roll-out to make it a success. We are working on live projects with vehicle manufacturers, charge point operators, energy suppliers, fleet operators, the Mayor of London, local public bodies and the Government's Office for Low Emission Vehicles.

The time we spent learning about the electric vehicle market and getting to know the industry led to our 2018 NIC bid Optimise Prime, which is a consortium of global brand names including Hitachi, Uber, Royal Mail and Centrica. NIA projects such as Smart Charging Architecture Roadmap & Shift (SmartCAR and Shift) demonstrate our collaborative approach to innovation, listening to energy suppliers and industry and then embarking on research to develop capabilities that could ultimately cut the cost of owning an electric vehicle. Collaboration will enable us to deliver the solutions that will put the infrastructure we need in place at the lowest possible cost to our customers.

We collaborated with international partners to look for new technologies that can unlock value from our existing assets. As a result, we are running an NIA trial called Loadshare, which is installing the UK's first load balancer at a distribution network level. This advanced technology has previously only been used on transmission networks but is now being deployed in Colchester, enabling an additional 95MW for customer connections and saving our customers £8m.

We have a responsibility to share the learnings of our innovation projects, which is why in January 2019 we held our first ever Better Networks Forum at the IET London (Fig. 3). More than 100 industry stakeholders attended the Better Networks Forum to learn more about NIA projects in our Efficient & Effective portfolio, with collaborators including the Energy Innovation Centre, EA Technology and Powerline Technologies all hosting stalls.

Figure 3: Better Networks Forum at the IET, London

> "Collaboration will enable us to deliver the innovative solutions that will put the infrastructure we need in place at the lowest possible cost to our customers."

Efficient & Effective

Project Highlights

The nature of electricity production and consumption is changing at an unprecedented pace due to the accelerated drive to decarbonise, digitalise and decentralise the energy sector. As such, networks need to adapt the way they have constructed, connected, operated and maintained their assets to enable increased network performance and reduce carbon emissions.

We, at UK Power Networks, believe one of our core strategic focus areas for innovation 'Efficient & Effective' responds to the aforementioned challenge. It aims to deliver energy at the lowest possible cost for our customers by continually enhancing the reliability, availability and performance of our networks. Efficient & Effective innovation portfolio primarily focuses on:

- replacing our existing assets with smarter equipment, or deferring replacements altogether by delivering and adopting smart innovative solutions;
- introducing artificial intelligence and automation to optimise operations; and
- continuing to deliver clean, safe and secure electricity to our customers at the lowest possible cost.

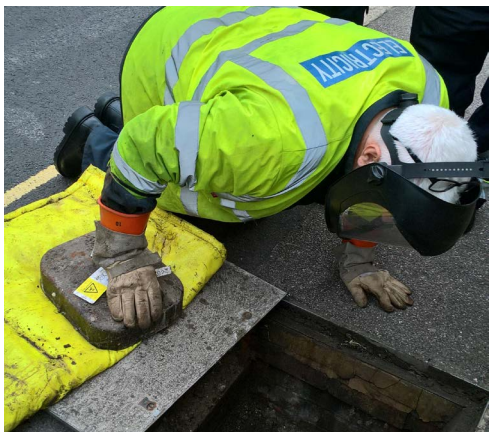

Figure 4: Link box inspection in progress

9%

lower annual domestic charges than the industry average

Underpinning this focus area is the commitment to deliver good business value by maximising the smart savings for customers. As such, the success criteria for our projects is not restricted to the successful demonstration of novel ideas and innovative solutions. In fact the true value of these projects is only realised when such solutions are transitioned and embedded into business as usual activities, which subsequently deliver smart savings for our customers.

Part of our vision at UK Power Networks is to be a respected corporate citizen. This is reflected in our diverse portfolio of innovation projects that deliver measurable social, environmental and safety benefits through our innovation projects, including but not limited to:

- **Link Alert** – the project aims to develop and trial a new generation of link boxes that are more reliable and safer for inspection and operation (Fig. 4);
- **Pressurised Cable Active Control and Monitoring** – this project is producing an active control unit to minimise fluid leakages from cables to enable safer installation and cleaner environment (Fig. 6, 7 & 8);
- **Network Vision** – the project is developing a scalable outage planning tool to provide greater visibility of network outages to our connected customers and enable seamless connection of additional renewable generation to our networks.

Whilst we continue to innovate in a sustainable and cost effective manner, our journey is incomplete without our stakeholders. We aspire to be the benchmark for best practice and disseminate our learnings with the wider industry on a regular basis. This year we hosted our 'Better Networks Forum' to showcase our Efficient & Effective portfolio, with an aim to demonstrate the innovative learnings and solutions delivered to inform the industry, promote collaboration and facilitate benchmarking to create an inclusive innovative fraternity that can together meet the challenges of today and tomorrow for the benefit of our customers and environment.

Figure 5: UKPN Innovation Team at Better Networks Forum

Figure 6: APCU installed on one of the trial site with solar panels to charge batteries

Figure 7 and 8: APCU installed in one of the indoor substation connected to oil tanks to maintain and control oil pressure within fluid filled cables

Pressurised Cable Active Control and Monitoring

Background

Within all GB DNOs there are approximately 6,607 km pressurised cables in operation at 132kV, 66kV and 33kV. These cables were installed since the 1920s, with the majority being installed in the 1960s. As these cables age the likelihood of leaks increases. This can be in joints, ancillary equipment or along the cable itself, due to degradation of materials.

This project is developing an Active Pressurised Control Unit (APCU) (Fig. 9) to maintain cable oil pressure within fluid filled cables to avoid fluid leakages from cables. An APCU is operated by a variable speed pump and pressure valve to create a pressure differential across the unit, sensors on either side of the unit to control the flow of oil into and out of the APCU. This allows pressure of oil inside the cable to be maintained at a constant value, which is expected to avoid cable degradation by simply operating them within their designed pressure.

An early prototype unit was developed for laboratory testing prior to building more rugged units for site deployment. Initial trials and development were completed by Elmeridge Cable Engineering with assistance from Elmeridge Cable Services at their testing facility in Essex, an initial proof of concept trial had to be completed to provide some confidence of reliability before proceeding to live trials. Following extensive testing the APCU was deemed as safe and reliable. Testing proceeded to live circuit trials. APCUs were installed on five circuits doing a live trial on the circuit to maintain oil pressure within the circuits.

Experience To Date

From the trial we learnt that the APCU has maintained the reduce pressure of oil within fluid filled cables (FFC) at all times. Operating them within reduced pressure is expected to improve circuit health by removing the hydraulic stress that traditionally is present in cable systems.

There were occasions during the trial where cable oil pressure was increased, which could have potentially lead towards an oil leakage. The pressure was instead reduced from the APCU maintaining it to the reduced level. Four of the five APCU installed on live system showed a temporary or permanent reduction in fluid lost and decreased pumping rates. One of the units stopped the circuit from leaking entirely which demonstrated the units under trial can successfully reduce the oil pressure when it reaches to a certain level to avoid its failure.

It can be concluded that the APCU is effective in reducing the leak rate of the cables and is safe for installation on the network.

Future Developments

The reduction in leak rate achieved thanks to the APCUs has both environmental and financial benefits. Financial savings are achieved by reducing the costs associated with procurement and processing of cable oil as well as the operational costs of a specialist team deployed to maintain cable pressure.

The findings largely suggest that the APCU could be permanently deployed on the fluid filled cable network with confidence in its safe long-term operation. Greater confidence will follow longer deployment on the network. A review of the existing policies and procedures on maintaining cable oil pressure is undergoing to reflect the project outcomes. UK Power Networks is currently assessing the commercial aspects of procuring this technology in larger volumes.

Project Lead: Maxi.Faridi@ukpowernetworks.co.uk

Figure 9: Picture of an APCU from inside showing the pressure valves and control unit

Mobile Asset Assessment Vehicle (MAAV)

Background

Faults on underground Low Voltage (LV) cables are difficult to detect and locate and are responsible for significant numbers of customer interruptions and customer minutes lost. The MAAV is a very sensitive mobile electric field detector which surveys the carriageways in search of faults from the LV network.

It is assumed that each detection of voltage leakage represents an LV fault on the network. When a fault is detected, a handheld test equipment is used to pinpoint the location of the fault, as well as an acceptable ground reference, to assess the potential difference and locate the fault location itself. Fault data, including: voltage; harmonic information; location; and weather data are collected. The data is recorded using a laptop computer in the vehicle and stored in a database for analysis.

Ultimately, the MAAV aims to proactively identify LV faults by detecting voltage leakage, allowing the network operator to prioritise the asset replacement programme. Early intervention enables by the MAAV is a more efficient way to address LV faults in a planned manner (Fig. 10).

Experience To Date

The project carried out two complete surveys covering the Central London Area within 4-6 months' timescale. The MAAV detected 155 energised structures (i.e. street furniture being energised) over the course of: the first survey at 65 locations; and 21 new locations during the second survey with over 100 new energised structures. On most of the occasions, where an LV fault was identified and fixed after the first survey, a voltage leakage was no longer detected during the second survey.

Every time an energised surface was found, an underlying fault was present. Through this project we have significantly improved our understanding of LV faults. Faults can be grouped into six general types:

1. **LV cable phase fault** – faulted low voltage phase conductors represent reliability, safety and losses concerns.
2. **Faulted LV conductors** – they often manifest themselves to us as fuse operations, open circuit faults and customer interruptions.
3. **LV cable neutral fault** – high impedance and open neutrals give rise to elevated voltage when current passes through the high impedance fault, as dictated by Ohm's Law.
4. **Lighting column phase fault** – while maintenance of public lighting is not generally the responsibility of UK Power Networks, voltage appearing on lighting columns may represent failed cables or connections on either council equipment or UK Power Networks' distribution cables.
5. **Lighting column neutral fault** – high impedance return pathways on lighting circuits gives rise to voltage on the lighting column as a result of a common bond to the neutral and the earthing configuration of the column.
6. **Customer side phase fault** – these are faults which are located behind the customer's meter and often represent significant safety hazards for customers and the public.

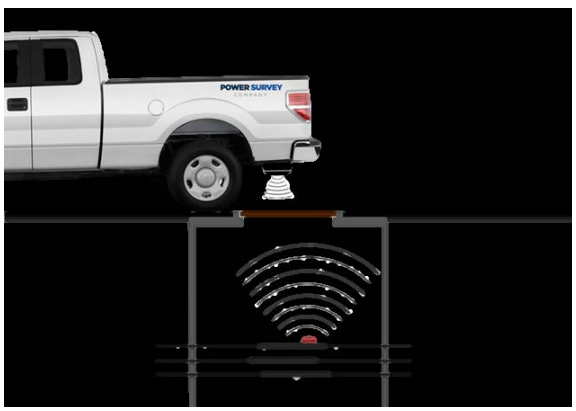

Figure 10: A schematic on how MAAV detect signals from developing defects

Following the project findings, it can be concluded that MAAV has been successful in detecting contact voltage from the surveys carried out as part of the trial leading towards an LV cable failure.

Future Developments

Based on the results of this project UK Power Networks has elected to deploy the MAAV to cover all three license areas. This has been adopted by business as usual already and following guidelines on contact voltage has been introduced within UK Power Networks:

- Contact voltage Investigation and Mitigation guide;
- Contact voltage end to end process; and
- Analysis of Contact Voltage losses in LV network.

Currently, there are two MAAVs deployed within our three license areas. UK Power Networks is also supporting other DNOs to build a business case for MAAV and helping them make a decision on the potential adoption of this solution into their business. Specifically, Scottish and Southern Electricity Networks (SSEN) has requested a demonstration of the MAAV within their area of operations, and a two-day survey was carried out by UK Power Networks' MAAV on their network. This received a good feedback and SSEN are now in process to assess their business case for MAAV. Following this demonstration, another request from Electricity North West (ENWL) has been made to demonstrate MAAV within their area of operations which will take place in near future.

Project Lead: Maxi.Faridi@ukpowernetworks.co.uk

Figure 11: Highly sensitive sensors are installed at the back of the MAAV to detect developing defects

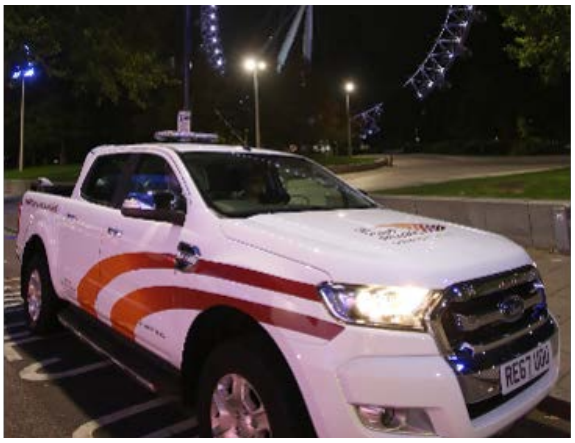

Figure 12: MAAV in action doing survey close to London Eye in carriage ways in search of potentially developing defects

> "Every time an energised surface was found, an underlying fault was present... we have significantly improved our understanding of LV faults."

SYNAPS Fault Detection, Classification & Location Solution

Background

81% of all faults across UK Power Networks occur on the low voltage (LV) network. LV underground cable faults are particularly difficult locate and expensive to fix. They account for 23% of all LV faults, and account for 52% of LV fault costs. The SYNAPS (Synchronous Analysis and Protection System) project is an important first for distribution networks, as it aims to validate technology which can predict the location of an underground cable fault before it manifests to consequently affect customers.

SYNAPS uses state-of-the-art advanced statistical signal processing and machine learning algorithms to identify unique features of LV feeder cable faults (including early transient or so called 'pecking' faults). A high sample rate detector is then employed to identify faults, when a manifesting fault is detected the sensor records the fault waveform and transmits to the server software for further processing. The server software classifies fault type and location (target accuracy 3m) utilising Powerline Technologies (PLT) proprietary algorithms.

The project is split into two phases. The key objective of Phase 1 was to test the SYNAPS system in a controlled environment. This took place at the Power Networks Demonstration Centre in 2018. Phase 2, the live network trial, will run throughout mid-2019.

Type 1 Fault:
Arcing, transient

0.50-5kA, 5-60ms duration

Type 2 Fault:
Open-circuit

2-10kA peak, 100-500ms duration

Figure 13: Samples from Phase 1 – PNDC testing

Experience To Date

In Phase 1, the project successfully determined that the SYNAPS system can reliably detect transient faults on an LV cable, and that it could locate faults on an LV network with a level of precision better than existing technologies. The project developed a classification system for two distinct types of faults that do not tend to blow LV fuses; primarily because no technology is currently available that enables the DNOs to detect or locate such faults. The two categories of faults are as follows:

Type 1 Faults: An arcing, transient fault resulting in minimal damage to the cable. High peak current (0.5-5kA). Voltage on either side of the fault, partial voltage collapse with high frequency components. Duration 0.005-0.06 seconds.

Type 2 Faults: An open-circuit fault with significant damage to the cable. Very high peak current (2-10kA). Voltage on either side of the fault sustained partial voltage collapse with high frequency collapse. Duration 0.1-0.5 seconds.

The project has thus far concluded that the SYNAPS system was able to successfully predict the location of Type 1 and Type 2 faults to within 4.2 metres (Fig. 13).

Future Developments

The next step in the project is to test out the SYNAPS system on a live network. Throughout summer 2019, circuits at UK Power Networks and Scottish and Southern Energy Networks will be selected for analysis by the SYNAPS system. The project complete in late summer 2019 and we look forward to sharing the results and learnings with our stakeholders.

If successful, this project could potentially save networks across GB a significant proportion of costs spent on fixing faults by enabling LV faults to be located with a much higher degree of accuracy.

Project Lead: Rona.Mitchell@ukpowernetworks.co.uk

Low Carbon Ready

Project Highlights

The transition to a low carbon future is revolutionising the way we produce, distribute and consume electricity. The volume of carbon emitted in producing electricity in Britain has fallen 40% in just six years. More and more renewable energy sources are connecting to our networks (over 7GW connected between 2011 and 2018) and consumers are beginning to engage proactively in the energy market, self-generating, storing and trading their electricity.

In addition to this, domestic customers and commercial businesses start choosing electric vehicles (EVs) versus traditional internal combustion engine vehicles, which is reflected in more than 12,500 residential charge points and over 5,000 publicly accessible charge points connected to our networks, adding an additional 150MW of load. The electrification of transport is expected to accelerate over the upcoming years; in just 12 months (from March 2018 to February 2019) we have seen a 44% increase of the amount of charge points across the UK, with approximately 52% being installed in UK Power Networks' license areas. And up to 4.1 million of EVs are expected to be on the road across our networks by 2030.

These changes are driven by increased awareness in global issues such as climate change and air quality challenges, government de-carbonisation policies[2] and wider environmental targets[3], and advances in energy generation and battery technologies combined with decreasing costs that are making them more accessible and wide spread.

As a local trusted network operator, we have a key role to play in facilitating the transition to a low carbon energy system and the electrification of transport and heat, ultimately reducing carbon emissions and improving the air quality for the communities we serve. The **Low Carbon Ready** strand in our Innovation strategy focuses specifically at innovative solutions that enable low carbon technologies such as renewable energy, domestic or commercial storage and electric vehicles to connect to our network.

Figure 14: Fleets may be among the first to impact networks

We do this by:

- investigating the evolving needs and expectations of our customers;
- improving our understanding of the future uptake of different technologies; and
- developing new technical and commercial solutions that can connect low carbon technologies and EVs cheaper and faster.

Ultimately optimising the existing network infrastructure, avoiding expensive reinforcement when it is not needed and keeping costs low for our customers.

Building on previous projects like Black Cab Green, Recharge the Future and Timed Connections Software Development, the Network Innovation Allowance continues to play a crucial role in allowing us to keep the electrification of transport moving at the lowest possible cost for our customers. In 2018/19 we have focused on exploring how EVs can support the network at certain times and can participate in flexibility markets by changing their charging patterns (smart charging) or releasing the electricity stored in their batteries (through vehicle to grid technology, V2G). The **Smart Charging Architecture Roadmap (SmartCAR)** project has strategically shaped our market-led position on smart charging informed by a wide consultation with industry and policy stakeholders.

[2] E.g. the UK has committed to reduce the national carbon emissions by at least 80% from 1990 levels by 2050 in the Climate Change Act 2008 and has signed the Paris Agreement in 2015 to limit global temperature rises to below 2°C.
[3] Including the British Government's Road to Zero Strategy announcing plans for at least half of all new vehicles, and as high as 70%, to be ultra-low emission by 2030, combined with local air quality regulations and congestion charges.

While the **Shift** and **TransPower** projects are designing the customer value proposition of smart charging and V2G in preparation for their trial phases respectively.

Smart Charging Architecture Roadmap (SmartCAR) and **Shift** aim to support UK Power Networks enable the market for smart charging. Building on the learning from SmartCAR, Shift will run trials to develop different approaches to smart charging. It will assess the technical and commercial requirements to enable the benefits of smart charging for UK consumers.

TransPower is exploring the opportunities associated with the V2G technology in four areas: buses; fleets; on street; and domestic. It supports our contribution to four V2G projects funded by InnovateUK delivering a total of 650 V2G chargers in UK Power Networks license areas.

The Network Innovation Competition (NIC) has been also crucial to investigate how to address some of the big challenges faced by networks, consumers and fleet operators in the transition to a low carbon future. We are entering the trial phase for our **Powerful-CB** project that will test a new type of circuit breaker that will facilitate more Combined Heat & Power (CHP) generators connecting to the network. We have also successfully completed **energywise** in September 2018 showing how network operators can work with trusted intermediaries to engage with those customers who need us the most and support them reduce or shift their energy consumption. Finally, in early 2019 together with Hitachi and the project partners we kicked off our new NIC project **Optimise Prime** that seeks to understand and minimise the impact the electrification of commercial vehicles will have on distribution networks to facilitate the transition to electric fleets.

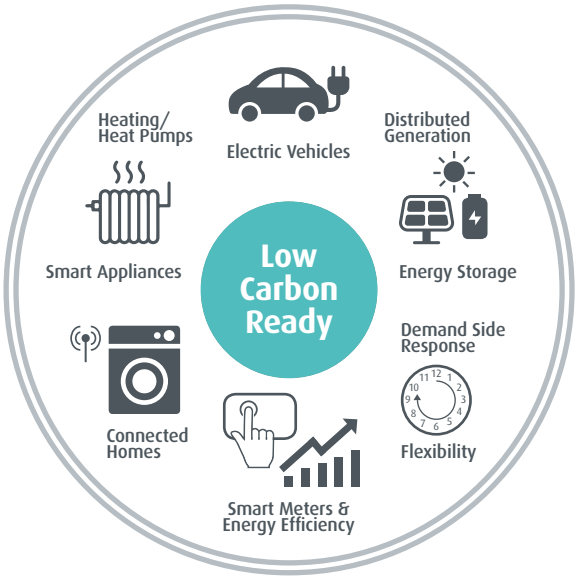

Figure 15: The Low Carbon Ready strategic focus

Powerful-CB is building a new solid-state circuit breaker, a Fault Limiting Circuit Breaker (FLCB) that is 20 times faster than existing units, allowing many more DGs to connect before the network needs to be upgraded due to fault level constraints.

energywise has engaged with vulnerable and fuel poor customers to support them in maximising the benefits of smart meters, energy saving and Demand Side Response opportunities.

Optimise Prime is the world's biggest EV trial involving 3,000 commercial electric vehicles to test and develop technical and commercial solutions to save customer costs and enable the faster transition to electric for commercial fleets and Private Hire Vehicle (PHV) operators.



Figure 16: UK Power Networks collaborating with key stakeholders to enable the decarbonisation of transport

Smart 'Charging Architecture Roadmap' & 'Shift'

Background

Smart charging has huge potential to help manage the additional demand that electric vehicles will place on the network. Flexible charging could reduce overall peak demand and reinforcement needs and facilitate electric vehicle uptake at lower cost. But up until now there has been little research into how network operators and the electric vehicle industry can work together to unlock and share the benefits with customers.

We set out to address these open questions with two NIA projects, Smart Charging Architecture Roadmap (SmartCAR) and Shift. Both of these projects are investigating longer-term potential approaches for smart charging in which the market can take the lead in managing EV loads and provide flexibility to the network.

Firstly smart Charging Architecture Roadmap looked at potential mechanisms for smart charging and developed UK Power Network's smart charging strategy, Now Shift is running trials to investigate the market-led approaches to smart charging. Working in collaboration with partners in the electric vehicle industry, including chargepoint operators, energy suppliers and aggregators, we are supporting consumer choice and free markets by developing customer propositions based on network price signals.

Experience To Date

SmartCAR engaged more than 20 stakeholders including energy suppliers, aggregators, EV manufacturers as well as BEIS, Ofgem and OLEV, to inform the assessment of different smart charging models. In general, all stakeholders support an approach to smart charging in which customers and/or service providers coordinate EV battery charging in response to network price signals.

The project was created in line with UK Power Networks' smart charging strategy, which is to pursue market-based approaches through 3rd parties rather than having DNO-led control of EV charging (Fig. 17 & 18). In addition, the project identified "core" IT system functions that are common to all of the possible smart charging approaches, such as real-time monitoring of the

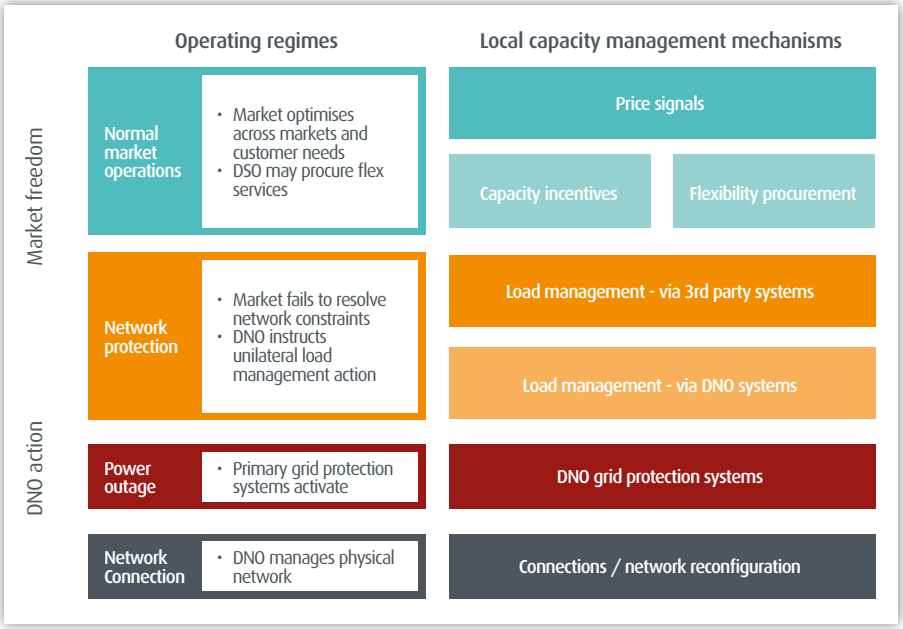

Figure 17: Hierarchy of smart charging mechanisms

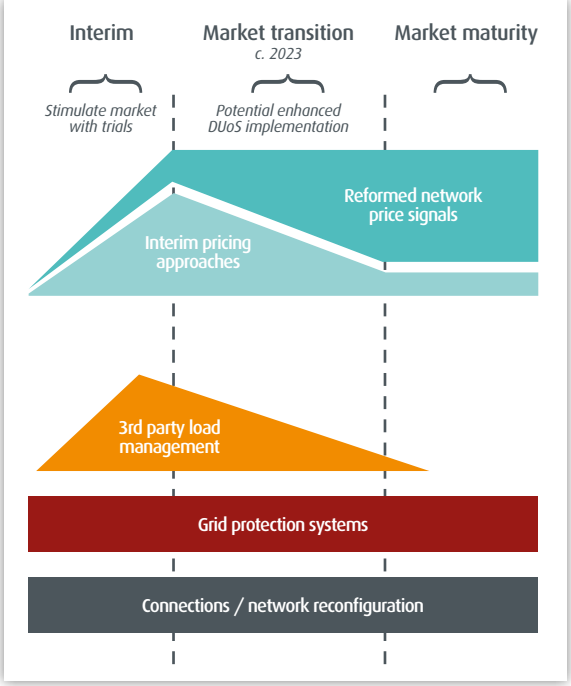

Figure 18: UK Power Networks' market-led smart charging strategy

low voltage network achieved through substation telemetry, and the ability to forecast network constraints.

We have also assessed the potential benefits of smart charging in relation to the uptake in demand due to EVs and the need for reinforcing the network. This assessment has revealed that there is a positive business case for smart charging. We are therefore satisfied that smart charging will be the most economic solution to managing electric vehicle uptake at lowest cost for consumers.

Once we had established the theory we then set out to see how it works in practice. Shift mobilised a residential smart charging trial on our low voltage network to develop and offer a real world price based solution. To date, Shift has focused on exploring LV network needs and flexibility services that can deliver against these needs (Fig. 19), as well as identifying the value of LV flexibility for networks. Recruitment for trial participants is in progress.

Future Development

Shift will now set out to specify the detailed commercial models that need to be tested as part of the trials. We are seeking input from both market stakeholders and network customers through a mix of face to face meetings with key stakeholders and consumer focus groups, workshops and online surveys. In parallel to this, we will be selecting the most suitable participants to take part in the trials. Once recruitment is complete we will collect participants' charging data over a 12 month period.

Trial findings will provide networks and the wider industry with valuable insights on how customers respond when asked to provide LV flexibility services, and on the practicalities of a market-led approach to smart charging. They will also inform Ofgem's longer-term access and network charging reform.

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SmartCAR stakeholders

Energy UK
pod POINT
Elaadnl
chargepoint
beama
Imperial College London
NISSAN
ovo energy
Scottish & Southern Electricity Networks
Office for Low Emission Vehicles
chargemaster
Ford
WESTERN POWER DISTRIBUTION
Serving the Midlands, South West and Wales
octopus energy
SMMT DRIVING THE MOTOR INDUSTRY
nationalgrid

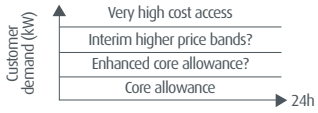
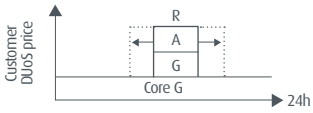
Potential models	Flexibility procurement	Core capacity + raising block price	Core capacity + ToU DUoS
Approach summary	• Customers have access to utilise all capacity as required • Providers are contracted to reduce or limit demand when requested during pre-determined availability windows	• Customers receive core capacity allowance and can pay extra for an additional firm allowance • DSO publishes rising block pricing bands if required (may be profiled) • Customers have access to additional capacity (for a price, or an equivalent 'boost' button) • Service provider optimises charging schedules, balancing needs vs. cost	• Customers receive core capacity allowance • Customers have access to additional capacity, that may be subject to peak pricing within a time window • DSO publishes peak pricing shape (static or dynamic mechanisms) • Service provider optimises charging schedules, balancing needs vs. cost
Illustration			
Pros	• Certainty of response • Customer compensation • Similar to existing flex products	• Provides customer choice • Protects 'normal' users • Avoids secondary peak risk	• Provides customer choice • Protects 'normal' users • Similar to existing DUoS red band
Cons	• EV users may pay less than non EV users (not equitable) • Complex metering/baselining	• Uncertain response	• Uncertain response

Figure 19: Examples of commercial products that can deliver smart charging services to network

TransPower (V2G)

Background

As electric vehicle (EV) penetration increases, the industry faces new challenges and opportunities in planning and operating distribution networks. Vehicle-to-grid (V2G) technology enables bi-directional energy transfer from and to EVs, exploiting the storage potential of the batteries they contain. V2G supports the integration of EVs whilst offering additional forms of flexibility for the energy system at a local and national level. Put simply, V2G technology enables EVs to be used as mobile batteries providing energy and power benefits to both car owners and the energy system.

UK Power Networks is leading an NIA project called TransPower to evaluate the technical, commercial and customer proposition of V2G technology to the distribution network. The project runs from April 2018 until October 2021 and provides a coordinated approach to UK Power Networks' contributions on several V2G Innovate UK competition projects. Specifically, the project will investigate network impact and flexibility services for several different vehicle customer segments from domestic, to commercial and public charging through demonstrator trials and collaborative research and development.

Experience To Date

The project has conducted a V2G Global Review that includes over 50 trials world-wide with physical deployments of V2G and that provides valuable insights on V2G telecommunication systems, grid connections and battery degradation[4]. We have recognised the level of uncertainty on future revenues and sensitivity to technology costs for the business case of V2G and completed a preliminary study on the value of V2G to our network and customers. The study explores the future expansion of this technology and quantifies the potential value from services such as reinforcement deferral and voltage management. The early findings demonstrate that the extra capacity made available from the ability to export from a vehicle battery could play an important role in the next five years while local EV penetration is still low. In the early stages of deployments of V2G, we are leading the way in developing and testing the planning and connection considerations for this technology and have produced a 'Network Guidance for V2G' report. This guidance is the first step to bridge the gap from existing and developing network needs to the capabilities of various vehicle segments e.g. domestic cars, fleet vans and buses.

Future Developments

In the coming year, our project plans to launch the first-of-a-kind specifications for several flexible services that we can begin testing on each of the domestic, fleet and bus V2G trials. Building on our experience from the SmartCAR project[5] we will continue to develop the architecture design for dispatching requests from these assets to support network constraints. The first round of domestic installations in the UK have already begun on our networks and we expect more of these to be in the ground delivering benefits to newly recruited customers this year. We also expect to have completed our first tranche of fleet surveys and installations at our test sites as well as several operational depots. For buses we will be conducting tests at our trial site in Iver and progressing the connection arrangements for our central London demonstration V2G bus garage. We are focusing on how our customers respond to commercial propositions through behavioural surveys on our collaborative research project. Finally, we are also exploring a pilot solution for on-street V2G.

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Figure 20: Wallbox V2G domestic charger. Marco Landi, Innovate UK (left); Shaun McHugh, Octopus Energy (middle); Thazi Edwards, UK Power Networks (right)

[4] http://www.smarternetworks.org/project/nia_ukpn0033/documents
[5] https://www.ukpowernetworks.co.uk/internet/en/news-and-press/press-releases/UKs-first-smart-charging-market-for-electric-vehicle-drivers.html

Powerful-CB: Power Electronic Fault Limiting Circuit Breaker

Background

The challenge for Powerful-CB includes the Government's Carbon Plan, Clean Growth Strategy and DECC's Community Energy Strategy, which highlights the importance of combined heat and power (CHP) in achieving the UK's carbon targets; this includes the Mayor of London's target to generate 25% of London's heat and power requirements locally by 2025.

A key enabler of this de-carbonisation is the growth of district heating and distributed generation (DG) in the form of CHPs. However, fault level constraints are becoming a barrier to connecting new DG in urban areas such as London. With plans for increased local generation, the already limited headroom in substations will be quickly exhausted. In one scenario, London will see a greater than six-fold increase in connecting CHP by 2031, with 73% of LPN substations requiring fault-level reinforcement. Traditional reinforcement as a connection solution is time consuming and costly which makes new DG unattractive to customers.

LPN also has unique physical and operational constraints, namely lack of space for new equipment, and a dependence on running several transformers in parallel to provide security of supply. Unfortunately, this means that smart solutions that would work in other types of network are unsuitable or of limited use in LPN and GB networks with comparable density.

Powerful-CB will use advanced power electronics technology to develop a new type of circuit breaker, a Fault Limiting Circuit Breaker (FLCB) that is 20 times faster than existing units. This high speed operation provides extra protection for the electricity network, allowing many more DGs to connect before the network needs to be upgraded due to fault level constraints. The design of the device also allows for a much smaller footprint than existing fault level mitigation technologies.

The project will develop and trial the device at a primary substation under a number of different running arrangements. In the future, installing the device will help deliver a long-term solution for multiple DG connections to substations that have fault level and physical space constraints.

London will become the first city in the world to host the Powerful-CB device, which could revolutionise the way energy is distributed, and could help keep down electricity connection costs for CHP customers. We estimate that by 2050, FLCBs could save customers across GB £403m in network reinforcement costs. We also estimate that by 2050, FLCBs could enable 462MW of DG connections that would otherwise have been unfeasible due to constraints. Finally the release of network capacity can enable the uptake of CHP connections which can potentially contribute towards meeting future carbon budgets. We estimate that the increase in CHP has the potential to deliver 3814 kt.CO2 cumulative reductions in carbon emissions by the year 2050, equivalent roughly to the emissions emitted by 800,000 vehicles taken off the roads for one year.

Experience To Date

One of the primary focus areas of the project for 2018-19 has been the development of the FLCB device itself. We have continued to work closely with our partner, ABB, to ensure that the device is ready for the trial installation in summer 2019 – participating in design, build and type testing of the device, with the first two being complete in early 2019.

Figure 21: Pilot installation using three MV panels for the FLCB

We also completed the design work required for the preparation of the network demonstration which will enable the FLCB to integrate into the existing network. This included civil and mechanical design to prepare the building for the installation of the FLCB, and other switchgear as well as electrical design to interface the device to the existing network (Fig. 21).

UK Power Networks has commenced site works at the trial site to enable the installation of the FLCB device and other equipment. This includes works to prepare the building and basement comprising of installation of structural steelwork, cable trays, new flooring, steel walls, small power and lighting and cutting/drilling holes in the floor for terminating cabling to the equipment.

A key learning from this year is the complexity in coordinating work between teams based in different countries and the importance of frequent coordination meetings. It is important to provide support and flexibility in order to avoid long term impact when unplanned events occur.

Future Developments

In 2019-20 the project is progressing into the installation and trial phase; we will complete installation and commissioning of the FLCB device at the trial site during the third quarter of 2019. Following the successful energisation of the FLCB, the trial period will commence and is expected to run under a number of arrangements until August 2021. During the trial, the device will be monitored and data validated to assess its performance on the network.

In addition to this, based on our experience, we will publish a learning report, SDRC 9.1.1, on FLCB device development for substations. During the trial period we will also update the Safety Case to include any further learnings from device development, installation, energisation and early learnings from the trial.

As part of the Powerful-CB project, known as Method 2, we were set to trial another FLCB device at a customer generator site. Due to the unfortunate withdrawal of one of our project partners, Method 2 has been removed from the scope of the project. However we still intend to build upon the learnings generated from our engagements with customers willing to participate in such a trial. As such UK Power Networks is collaborating with Western Power Distribution on an NIA project called EDGE-FCLi (Embedded Distributed Generation Electronic – Fault Current Limiter interrupter). The scope is similar to that of Method 2 and we aim to deliver similar benefits to the customers once the project is complete.

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energywise

Background

The Vulnerable Customer and Energy Efficiency (VCEE) project, also known as energywise, ran from January 2014 to September 2018. It carried out two trials to explore how residential customers who may be struggling with fuel bills can better manage their household energy usage and consequently their electricity bills. This was done by changing the way they interact with and use electricity while simultaneously supporting Distribution Network Operators (DNOs) in managing (peak) load reduction.

Experience to date

The project delivered key learnings on the following topics:

- the extent to which this residential customer group is able and willing to engage in energy saving campaigns and Time of Use (ToU) tariffs;
- the benefits that they can realise from their change of behaviour in household energy management;
- the challenges and successful approaches to engaging with these groups of customers to achieve these aims; and
- whether their reduction in demand, and shifting demand away from network peak periods may benefit the electricity network by deferring or avoiding network reinforcement.

The project involved two trials: Trial 1 involved the installation of smart meters in participants' homes, as well as the provision of energy efficiency devices and advice. Trial 2 focused on designing and trialling Time of Use tariffs/rebates. Prepayment customers were offered Bonus Time, a dynamic, non-punitive pioneering Critical Peak Rebate designed specifically for this customer group. In Bonus Time, customers who reduced their demand were rewarded with additional credit on their meters. Credit customers were offered HomeEnergy Free Time, a static, non-punitive Time of Use tariff, where customers chose to receive free electricity on either Saturdays or Sundays between 9-5pm.

If the reductions observed in the energywise trials (Trial 1 energy savings and Trial 2 Bonus Time) were realised by all households classified as fuel poor within the UK Power Networks' licence areas, an estimated annual reduction in electricity consumption of 86 GWh could be achieved in total (enough to provide electricity to more than 21,000 homes over a year) and a network peak reduction of 27 MW.

Key achievements to date

The project designed and executed two successful trials:

Trial 1 identified the magnitude of energy savings and the impact on the electricity network when customers have access to smart metering solutions, affordable energy saving devices and energy saving advice. Participants saved an average of £14 annually and reduced their consumption by an average of 3.3%. These savings translate to an average peak demand reduction of 23W during the evening peak window (17:00-22:30) which represents about a 5.2% reduction in average evening peak demand per household and reflects the capacity for meaningful engagement with energy savings by the trial participants.

Trial 2 focused on encouraging customers to shift their electricity use at certain times through Time of Use tariffs/rebates. On average the ToU tariff achieved a 2.2% reduction in weekday evening peak demand but also a 22.2% increase in the weekend peak and yielded an average saving of £6.24 per year. The Critical Peak Rebate scheme earned customers rebates ranging from £3 to £111 per year, with the average rebate comprising £37 per year. The top 10% of households (those most engaged and responsive) achieved average demand reductions of 18.7%.

Budget	£5.49m (£3.32m LCNF Tier 2)
Start/End Dates	January 2014 – September 2018
Project Partners	British Gas, University College London, Bromley by Bow Centre, Tower Hamlets Homes, Poplar HARCA, CAG Consultants, Element Energy, National Energy Action

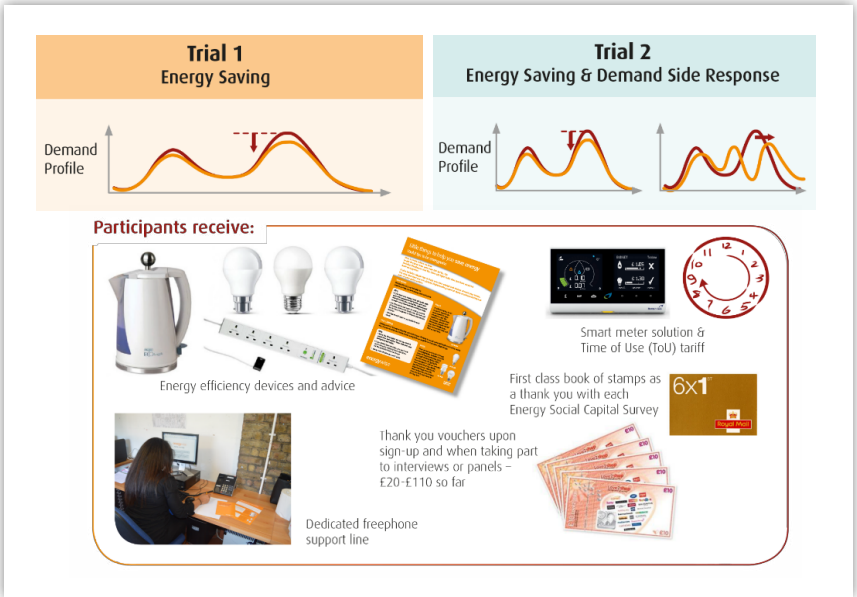

Figure 22: Interventions for energywise participants

The trials were supported by surveys to provide insight into many variables relating to participants' demographic information, ownership of energy-consuming devices and data collection on where participants find (trusted sources of) energy related information. The project generated valuable learnings around customer engagement strategies and explored a set of intervention measures tailored to the specific resources and needs of the trial area community. energywise demonstrated that it is possible to engage with disadvantaged customer groups provided that they are engaged and supported in an appropriate way along their customer journey.

Future Developments

Moving forward the project partners will continue to disseminate key project learning with other DNOs, the wider energy sector and policy makers. UK Power Networks will work together with key business users from Customer Services and Smart Grid Development teams to maximise the benefits the project has provided such as informing today's and tomorrow's Consumer Vulnerability Strategies and informing business approaches on how to support customers participation in energy saving and DSR opportunities at scale through community actors. The project will also inform the upcoming Firefly NIA funded innovation project (2019-2020), which is looking at how DNO-led interventions can deliver a holistic approach at energy efficiency as alternative to network reinforcement.

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Optimise Prime

Background

With businesses buying 58% of all new vehicles in the UK, it is expected that commercial vehicles will determine the speed of the transition to low carbon transport. Compared to vehicles used for domestic purposes, commercial EVs[6] will have a much greater impact on the electricity network. Therefore, it is important that network operators, technology providers, fleet and transport companies work together to test and implement the best approaches to the EV roll-out for commercial enterprises, while keeping costs low for network customers.

Optimise Prime is the world's biggest trial of commercial EVs. It seeks to understand and minimise the impact the electrification of commercial vehicles will have on distribution networks. It will develop technical and commercial solutions to save customer costs and enable the faster transition to electric for commercial fleets and Private Hire Vehicle (PHV) operators.

Led by global data technology solutions provider Hitachi Vantara and UK Power Networks, this three year project will involve up to 3,000 electric vehicles from Royal Mail, Centrica and Uber, supported by distributor Scottish and Southern Electricity Networks, Hitachi Europe and Hitachi Capital Vehicle Solutions. It will be split into three trials, reflecting the three partner fleet use cases:

- **Trial 1: Home Charging (British Gas)** – A field study of charging behaviour and flexibility with a return to home fleet.
- **Trial 2: Depot Charging (Royal Mail)** – A field study of charging behaviour and flexibility with a depot-based fleet. Additionally, testing of profiled connections.
- **Trial 3: Mixed Charging (Uber)** – A study based on analysis of journey data from electric PHVs.

Figure 23: The Optimise Prime Trials and project partners

[6] Commercial EVs are defined as vehicles used for business purposes, including the transport of passengers and goods.

Experience To Date

At the end of 2018, Optimise Prime has been awarded £16.6m funding from Ofgem via its Network Innovation Competition, with additional £18m funded through partner contributions. The project launched in early 2019 and we have now completed the project mobilisation phase with the contractual arrangements being signed in mid-March 2019. Together with the project partners we are focusing on the programme design and the build phase. These include the solution architecture and the build of the common Internet of Things (IoT) platform that will interface with the DNOs and the fleet and PHV operator partners, the site selection for the depot-based trial, the requirements for the depot optimisation tool and for the network flexibility model.

The fleet partners are also working on the procurement of their vehicles, with 30 EVs currently on the road for Royal Mail (and other 85 already ordered) and 250 EVs for Uber. Early insights on the high level design be shared in late August 2019 followed by the Solution Build report in early 2020.

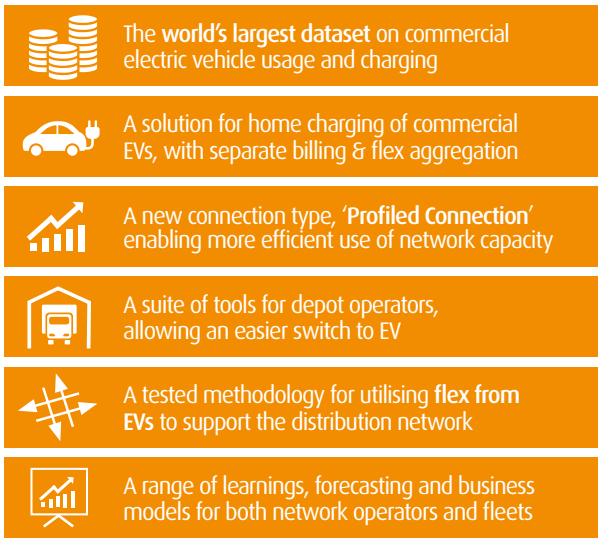

Figure 24: Key project outputs

Future Developments

The project will deliver a comprehensive understanding of the impact that electrification of commercial vehicles will have on distribution networks. It will explore opportunities to minimise this impact, such as optimising network and charging infrastructure, providing network flexibility services, testing technical and commercial solutions to save customers £207m by 2030. Figure 24 provides an overview of outputs generated by the project.

Optimise Prime is also playing a key role for meeting the UK's carbon reduction targets, since the accelerated adoption of commercial EVs is expected to save 2.7m tonnes of CO2, equivalent to London's entire bus fleet running for four years. The flexibility provided by the project will also free up enough capacity on the electricity network to supply a million homes.

In the coming year, we will focus on the development of our profiled connections tool, the requirements of the interface of UK Power Networks' systems with the project platform and on the definition of flexibility products (specifically, building on UK Power Networks' Flexibility Programme and the products designed in our innovation EV projects Shift and TransPower). The project partners will continue to procure the EV volumes required for the trials and to develop the IoT platform, the depot planning tool and depot optimisation system.

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Future Ready

Project Highlights

Future Ready

The third area of strategic focus for UK Power Networks innovation portfolio is to deliver projects, which contribute to being a future-ready distribution business. This means providing new services, which meet the needs of tomorrow's customers. These link in particular to two of the six high-level objectives in our innovation strategy 'Facilitate a low carbon system' and 'Lead trials on DSO capabilities'.

We have two NIA projects that take strides forward in facilitating a low carbon system from different perspectives.

Network Vision is developing a scalable integrated tool for network Outage Planning which enables greater visibility for customers affected by those outages, such as low-carbon generators. At 33kV and above, renewable generators will be able boost their output and revenue by optimising maintenance to coincide with a planned outage.

Green City Vision improves our whole-system understanding of the future energy needs associated with the de-carbonisation of heat and more generally with the 2050 carbon targets. It helps us to further understand what the optimal scenarios are for the de-carbonisation of the energy system, while keeping costs down for customers and what the impact will be on UK Power Networks. Particularly, what is the proportional split between the electricity and gas network utilisation, also considering the introduction of other energy vectors such as hydrogen.

We began Network Innovation Competition (NIC) projects in 2017 and 2018 which are key to our preparation for a future DSO (Distribution System Operator) role as outlined in the UK Power Networks DSO strategy – FutureSmart). The last year has been key to trial preparation in both projects, building the foundation for trials in 2019. This links to our objective to lead trials on DSO capabilities to ensure safe, reliable and cost effective networks.

Power Potential is implementing a Distributed Energy Resources Management System to enable generation connected to our network in the South East to offer their services and access a new revenue stream by providing active and reactive services to the transmission system operator. A complex system integration and customer trial, this is an example of how a DSO system can open up a new service and market – a world-first regional reactive power market to manage transmission voltage (Fig. 25).

Active Response is preparing to demonstrate innovative ways in which network operators can maximise the capacity of their existing assets by moving spare capacity to where it is needed, using advanced automation (Soft Open Points) and installing new power electronic devices (Soft Power Bridges) to deliver capacity without the cost, time and carbon impact associated with traditional reinforcement.

Figure 25: National Technology Awards 2019

Network Vision

Background

Planning network outages is a complex process that involves many different competing priorities including planned maintenance, new customer connection requests, and major new works such as upgrading substations or transformers and responding to the demands of the national transmission system and critical infrastructure such as rail. Short notice events such as storms, or even incidents like a power line being damaged in a road accident, add a further layer of unpredictability that must be managed.

This project is developing a scalable network Outage Planning, Tracking and Integration Tool to serve UK Power Networks and our customers. The project will enable an extra 1,080 MWh of renewable generation and save customers up to £1m a year by enabling more large-scale capital investment projects to go ahead through optimising resources.

The project will enable renewable generators connected at 33kV and above to see what future network outages could affect them. It will mean that they will be able to plan their own schedules much further in advance, for example by conducting their own maintenance at the same time as a planned outage in their area.

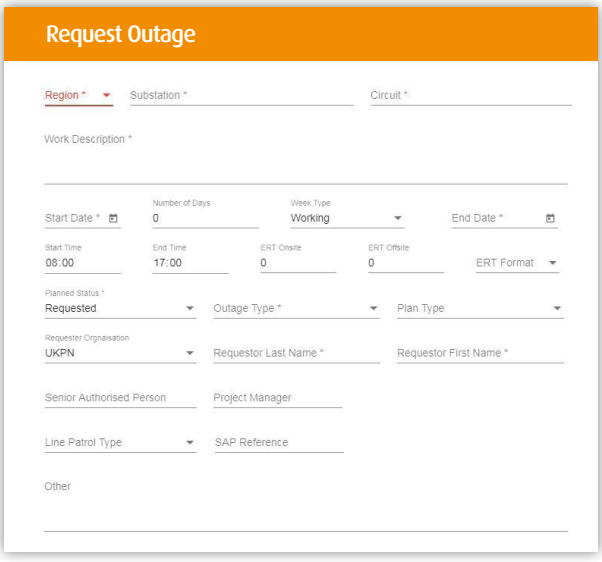

Figure 26: Outage request form in the Network Vision tool

> The work being done by this project is valuable not only to ourselves, but to our wider stakeholders.

Experience To Date

In the 2018/2019 regulatory year, Cyient were selected as the key delivery partner for the project. In total, the project held 12 workshops and engaged with more than 50 stakeholders. The tool now has basic functionality, and particular care is being spent on the user interface to ensure that it delivers exceptional user experience.

The project was short-listed for the Innovation Award at the 14th British Renewable Energy Awards, which reassures us that the work being done by this project is valuable not only to ourselves, but to our wider stakeholders.

Future Developments

Over the next year, the project will further develop the Outage Planning, Tracking and Integration Tool. Features will include automatic notifications to users and streamlined scheduling for bulk outage requests from external parties, such as National Grid (Fig. 26). This will be completed with intensive stakeholder engagement, to ensure that the user interface meets our customers' needs. The tool will go to a live trial later this year. If successful, it will be rolled out to the wider business.

This will deliver benefits to renewable generators and to UK Power Network staff, helping us to become more efficient in the work that we do on a day-to-day basis.

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Green City Vision

Background

To date there have been limited studies on the impact of de-carbonisation of heat on the electricity network and on whole system/cross sector modelling. More widely, solutions to de-carbonisation of heat have so far proven unsatisfactory when modelled, leading to very high costs for consumers or unreliable modelling outputs in terms of heat, power and transport. These approaches have failed as they tend to be focused on gas or electricity in isolation (i.e. on a single energy vector).

Ultimately, to make sure that we plan effectively for RIIO-ED2 and we continue to contribute to the wider industry and policy discussion, it is important to keep our position on electrification of heat up to date and improve our understanding of impacts based on latest industry developments. Whole-system considerations on optimal solutions for de-carbonisation of heat are needed to inform RIIO-ED2 planning.

The 'Green City Vision' project is a joint project led by Wales and West Utilities' (WWU) and in collaboration with Scottish and Southern Electricity Networks (SSEN) and UK Power Networks (UKPN) that aims to use Pathfinder Simulator to assess low-cost, technically feasible solutions to produce a 2050 green city scenario. The project encompasses a system approach, taking into account heating, electricity and transport, and assesses a reference city against defined technology scenarios to inform future investment strategies for both the gas grid and electricity network. The project is designed to be highly collaborative, drawing and building upon the inputs from both the gas and electricity networks as well as a range of other local stakeholders.

Green City Vision Project Partners

Collaboration is Key

WALES&WEST UTILITIES

Progressive energy

Scottish & Southern Electricity Networks

UK Power Networks Delivering your electricity

Experience To Date

Swindon has been identified as a representative city for Great Britain for the average size, good mixture of demographics, and as a large metropolitan town with rural surroundings. We have successfully modelled the future energy scenarios for Swindon using Pathfinder. The modelling showed that achieving an 80% reduction in carbon emissions by 2050 relative to 1990 requires balancing available low carbon technologies and different energy sectors to minimise system disruption and cost to consumers (Fig. 27).

By analysing different scenarios which provide synergies between the gas and electricity networks, we now have an improved understanding of the whole system implications and benefits of the update of different low carbon technology options.

The most achievable pathway to de-carbonisation will require a wide range of solutions, such as the electrification of transport, partial electrification of heat and the deployment of bio-methane and hydrogen.

For example, Figure 28 shows the implication of achieving the 2050 low carbon compliance targets on the electricity network. The effect of electrifying transport creates a more dynamic system with increased peak and overall demand. On top of the transportation effect, the installation of hybrid Air Sources Heat Pumps also contributes to the increased demands of the system, although these effects can be reduced by the introduction of disruptive energy vectors such as hydrogen.

Local and national policy frameworks must be aligned, informed by impartial analysis and be capable of promoting the magnitude of change required. This is fundamental to successfully meeting the carbon targets within the Swindon area and in similar cities at national level.

Future Developments

It is expected that gas and electricity network operators could adopt, replicate and refine the model in order to plan effectively for RIIO-ED2 and continue to contribute to the wider industry and policy discussion. In particular, the findings of this project are expected to inform future policy on strategies for the de-carbonisation of heat by providing a better understanding of its impact on the electricity and gas networks. In addition, we will work together with our key business users in Business Planning to monitor the benefits of the model.

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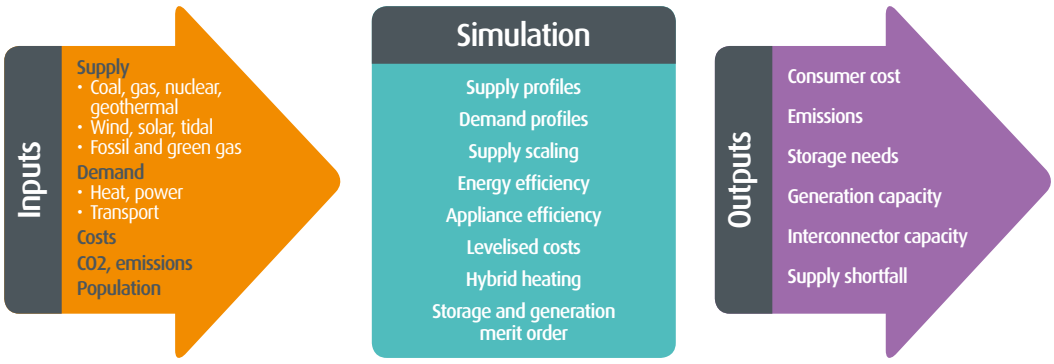

Figure 27: Pathfinder Modelling Overview

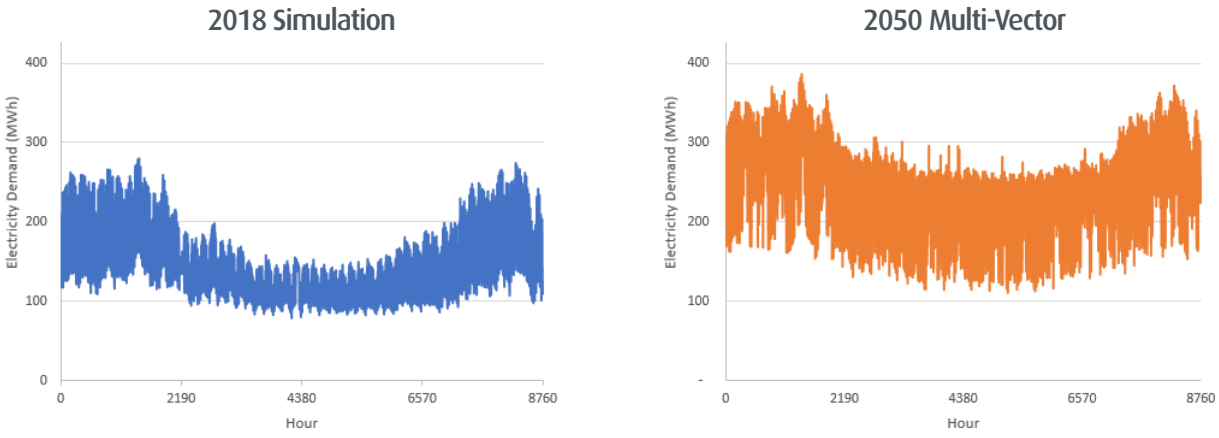

Figure 28: The effect of Electrification of heat on electricity network from the Pathfinder model

Power Potential (TDI 2.0)

Partners

Power Potential develops the technical capability and commercial framework to enable generators on the distribution network to contribute to managing voltage constraints on the transmission network. By developing a world-first regional reactive power market based on introducing a 'Distributed Energy Resources Management System' (DERMS), it creates a new revenue stream for DER to compete with the transmission alternative. Power Potential is a NIC project being jointly delivered with National Grid Electricity System Operator (ESO), and is a key demonstrator of UK Power Networks creating a 'Distribution System Operator' (DSO) capability.

UK Power Networks
Delivering your electricity

nationalgridESO

Experience to date

In 2018/19, the project set out the trial contracts between UK Power Networks and National Grid ESO, and between UK Power Networks and each Distributed Energy Resource (DER). Detailed technical requirements were set out for participating DER, including details of the signal exchange which is being facilitated by logic upgrades to the UK Power Networks remote terminal unit at each customer site.

There has been significant customer engagement on the range of customer queries. For each customer, offline calculations determined the allowed operating range of each DER to keep the distribution network safe, and these were offered to customers in a variation to relax their connection agreement.

Power Potential involves developing the DERMS software hosted by UK Power Networks and complex integration between National Grid ESO and UK Power Networks' control systems, as well as upgrades to the remote terminal units at customer sites. In 2018, the project adopted a staged delivery approach for the trial, and set out trials calendar for customers. The interim version of DERMS system was proven in testing with a network simulator in the cloud, and the infrastructure was set up for delivery of the systems for trial.

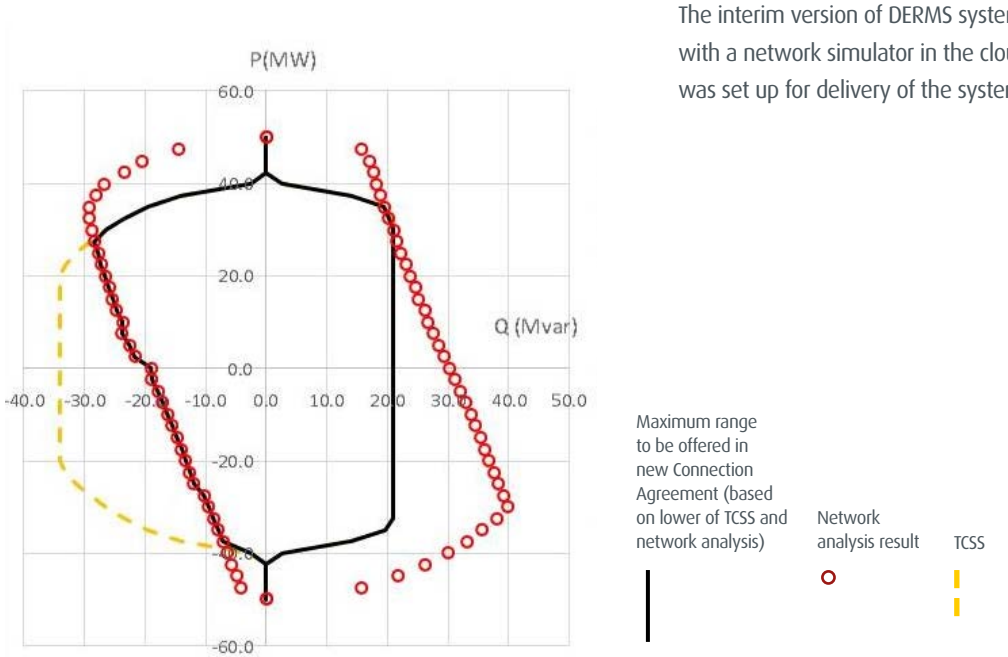

Figure 29: Example of a customer PQ envelope

Future Developments

In 2019/20, the project enters its trial phase. We are signing up DER customers to contracts, laboratory testing with them, and completing the DER commissioning so they can offer active and reactive power services in the trial.

Completing the build and test of the DERMS Interim Solution proves the system integration and the technical ability of DER to deliver services. Then we will complete build and test of the DERMS Full Solution. This introduces the commercial functionality to allow DER to submit price bids. It also brings fuller integration with the PowerOn network management system to facilitate load flows and state estimation – so DERMS can recalculate active and reactive power services from DER both for day-ahead offer and in real time. This will be the basis for planning the transition of the solution to business-as-usual after the trial.

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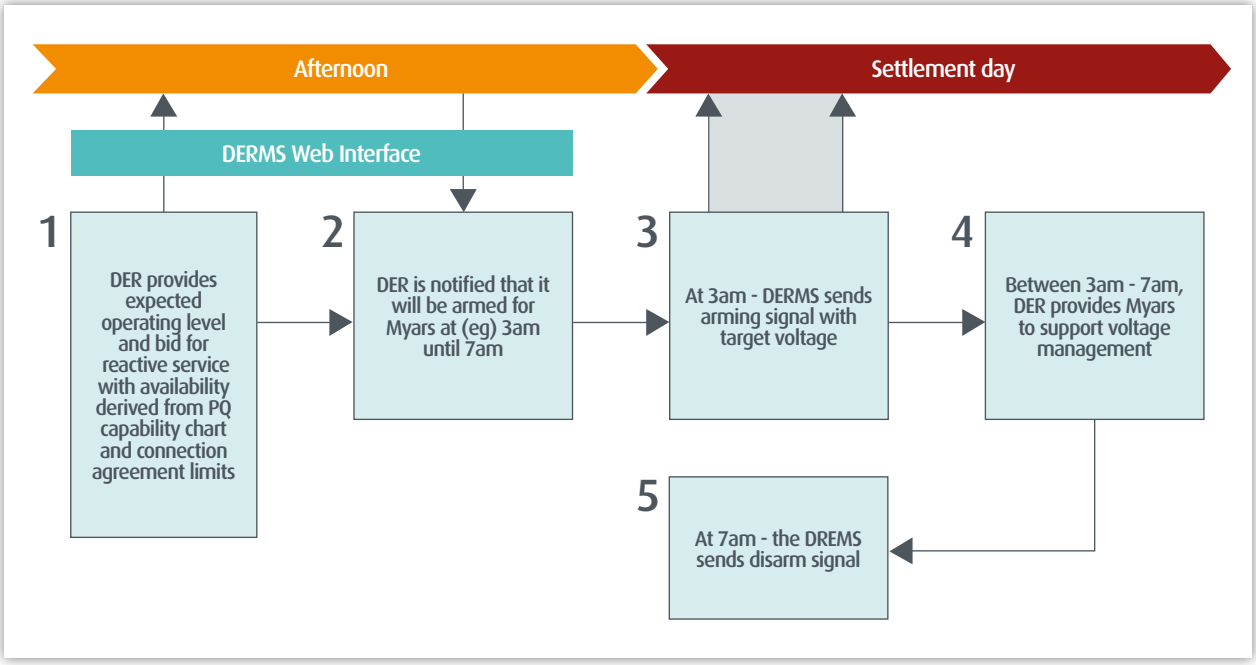

Figure 30: Reactive Power Service flow

Active Response

Background

By 2030 it is anticipated there will be up to 4.1m electric vehicles in use across London, the East and South East of England where UK Power Networks delivers electricity – including London's buses and taxis. The charging of these vehicles could significantly increase peak demand for electricity. In order to accommodate this increased demand, UK Power Networks would traditionally reinforce the existing network assets to provide more capacity. Upgrading an electricity substation, or adding entirely new substations and cabling when customers need more power, takes time, costs money, and can cause roadworks, which can sometimes be disruptive to customers. Ultimately, this cost would be borne by the electricity customers.

The Active Response project, which runs from January 2018 to November 2021, aims to demonstrate innovative ways in which network operators can maximise the capacity of their existing assets. By using advanced automation and installing new power electronic devices we can connect networks together and move spare capacity around to where it is needed, reducing the need for time-consuming and sometimes costly reinforcement (refer to high level schematic in Fig. 31). We estimate that by 2030 Active Response solutions could save customers £271m in reinforcement costs. This is equivalent to approximately £9.34 from every electricity customer's bill by 2030. The project methods also enable Carbon Savings of 19,592 tCO2 eq. and Capacity Benefits of 4.2 GVA by 2030.

The project will demonstrate two methods of the advanced automation solution and new power electronic devices through a series of project trials, which will start in 2019 and finish in 2021. The proposed methods include:

1. **Network Optimise** – optimisation and automatic reconfiguration of High Voltage (11kV) and Low Voltage networks in combination, using remote control switches and Soft Open Points (SOPs) (Fig. 32); and
2. **Primary Connect** – controlled transfers between primary substations using a Soft Power Bridge (SPB) to share loads and optimise capacity (Fig. 33).

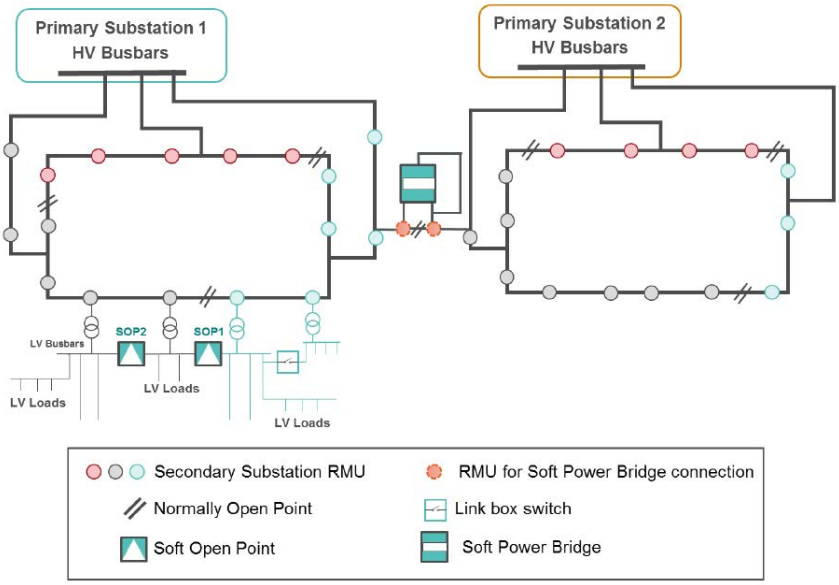

Figure 31: Active Response High Level Schematic

Experience To Date

Over the past 18 months, the project has made great progress and developed excellent learning that has been, and continues to be shared with industry stakeholders. Key progress has been made in developing a site selection methodology, which has been applied when selecting the trial locations. In addition, progress has been made with approving the detailed design for the SOPs and SPBs.

Moreover, following a comprehensive procurement process, the project team has selected a supplier to develop and deliver the advanced automation solution. The learnings associated with these activities have been shared through; public conferences, such as the Low Carbon Networks Innovation conference, and published project reports, in the form of project progress reports and detailed learning reports, which are available on UK Power Networks' Innovation website.

Some of the specific key learning points have been summarised in the bullet points below:

- Across industry there is a high demand for products using Silicon Carbide technology, which are used in the SOPs and SPBs, therefore lead times for these products can be highly variable;
- Robust monitoring processes are required for determining voltage phase angle differences across open points on the HV network. When performing network monitoring for the purpose of trial site selection, projects should consider whether offline simulations can validate site measurement data; and
- When considering the advanced automation solution design, the interaction between existing 11kV post fault automation schemes and the Active Response capacity management optimisation needs to be considered early in the solution design phase to ensure smooth business-as-usual transition.

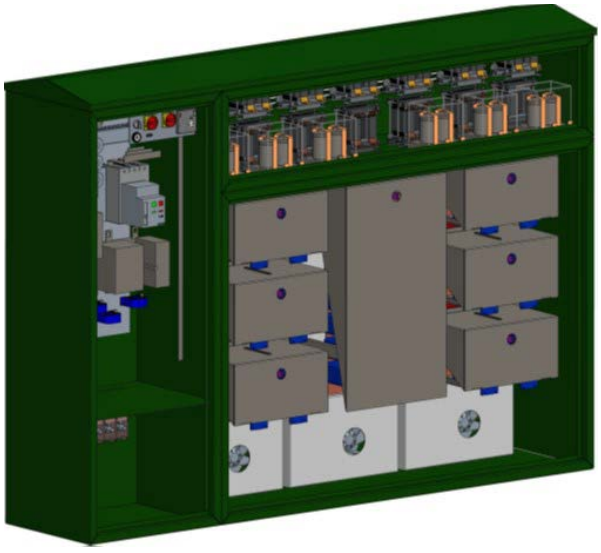

Figure 32: Active Response Soft Open Points

Future Developments

The project is progressing into the build and test phase for the advanced automation solution, SOPs and SPBs. For each of these components we will develop detailed test strategies and test plans. These test strategies will need to articulate the interdependencies to ensure the critical interfaces between software and hardware are validated. The SOPs and SPBs will be tested in a factory environment as well as a third party testing facility. Furthermore, the advanced automation solution will be tested in an offline test environment prior to commissioning the live environment. Following the successful testing of the solutions, the project will commence trials which will demonstrate the value of the solutions in offline and live environments.

Considering the highly innovative nature of the advanced automation system, SPBs and SOPs, it is expected the project will develop extensive learning which will be shared with the industry. The project team including all project partners (Scottish Power Energy Networks, CGI, Ricardo Energy and Environment, and Turbo Power Systems) are committed to sharing learning during the project, therefore will continue to actively share learning through six monthly project progress updates, presentations at industry conferences, written papers for conferences and specific workshops with peer Distribution Network Operators (DNOs).

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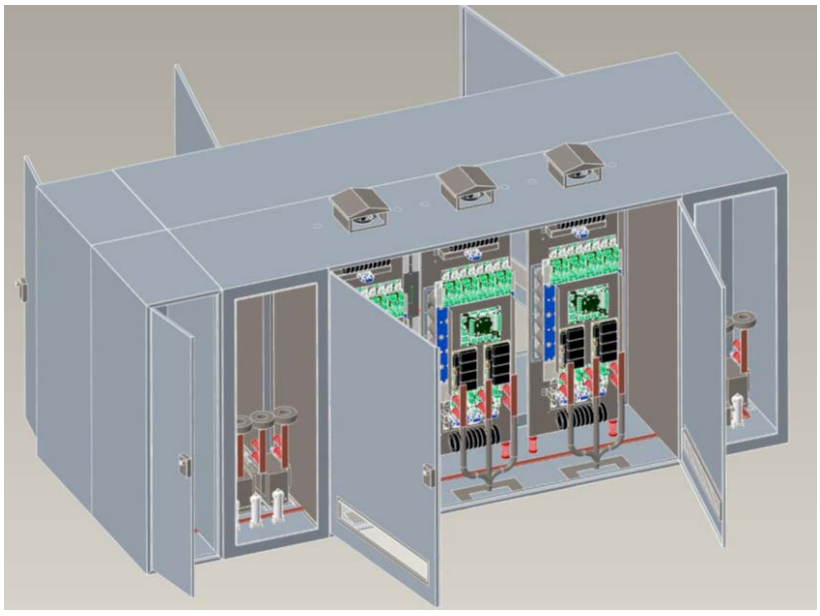

Figure 33: 3D representation of Soft Power Bridge

Complete NIA project portfolio

Our Network Innovation Allowance Portfolio

Efficient & Effective

NIA_UKPN0047	HV Feeder monitoring to pre-empt faults	Network improvements and system operability	02/2019 - 02/2022	£2,256,371
NIA_UKPN0046	Underground fault predictive model and earthing assessments	Network improvements and system operability	02/2019 - 02/2021	£692,887
NIA_UKPN0044	HV OHL Assessment	Network improvements and system operability	01/2019 - 09/2020	£408,378
NIA_UKPN0042	Storm Joint	Network improvements and system operability	10/2018 - 11/2020	£188,586
NIA_UKPN0040	Transformer Care	Network improvements and system operability	08/2018 - 02/2020	£161,000
NIA_UKPN0038	Real Time Thermal Ratings – Cables	Network improvements and system operability	06/2018 - 12/2020	£284,625
NIA_UKPN0031	Link Alert	Safety, health and environment	02/2018 - 05/2020	£248,600
NIA_UKPN0024	Pole Current Indicator	Network improvements and system operability	05/2017 - 11/2018	£282,685
NIA_UKPN0023	Harmonic Effect on Network Assets (HENA)	Network improvements and system operability	03/2017 - 06/2018	£441,000
NIA_UKPN0022	Global Earthing Systems (GES)	Network improvements and system operability	03/2017 - 03/2019	£483,000
NIA_UKPN0020	Mobile Asset Assessment Vehicle (MAAV)	Safety, health and environment	07/2016 - 06/2018	£544,322
NIA_UKPN0019	OHL Fault Location Concept and Directional Earth Fault Passage Indication	Network improvements and system operability	05/2016 - 05/2019	£2,871,000
NIA_UKPN0012	Pressurised Cable Active Control and Monitoring	Network improvements and system operability	09/2015 - 03/2019	£1,075,600

Low Carbon Ready

NIA_UKPN0045	Shift	Transition to low carbon future and ED - New technologies and commercial evolution	01/2019 - 05/2021	£1,295,500
NIA_UKPN0036	Timed Connection Software Development	Transition to low carbon future and ED - New technologies and commercial evolution	05/2018 - 07/2019	£400,000
NIA_UKPN0034	Smart Charging Architecture Roadmap	New technologies and commercial evolution	04/2018 - 02/2019	£428,413
NIA_UKPN0033	TransPower	Transition to low carbon future	04/2018 - 10/2021	£1,345,000
NIA_UKPN0029	Assessment & Testing of Alternative Cut-outs	Safety, health and environment	11/2017 - 01/2019	£765,080
NIA_UKPN0028	Recharge the Future	Transition to low carbon future	10/2017 - 01/2019	£239,750
NIA_UKPN0027	LoadShare	Transition to low carbon future	09/2017 - 05/2019	£2,418,081
NIA_UKPN0026	Black Cab Green	Transition to low carbon future	08/2017 - 08/2018	£175,000
NIA_UKPN0021	Domestic Energy Storage & Control	Transition to low carbon future	09/2016 - 06/2018	£625,700

Future Ready

NIA_UKPN0043	Faraday Grid Deployment Trial	New technologies and commercial evolution	10/2018 - 10/2021	£534,985
NIA_UKPN0041	Dual Fuel Transport	Transition to low carbon future	09/2018 - 01/2020	£165,382
NIA_UKPN0039	Engineered Poles Products	Network improvements and system operability, ED - New technologies and commercial evolution, ED - Safety and health and environment	07/2018 - 01/2020	£224,834
NIA_UKPN0037	SYNAPS Fault Detection, Classification & Location Solution	Network improvements and system operability and ED - New technologies and commercial evolution	06/2018 - 09/2019	£679,854
NIA_UKPN0035	Network Vision	Customer and stakeholder focus	05/2018 - 05/2020	£975,800
NIA_UKPN0030	Development of Oil-filled Cable Additive- Phase 2	Network improvements and system operability	11/2017 - 12/2019	£1,988,128
NIA_UKPN0007	Detection of Broken/Low Hanging Overhead Line Conductors	Network improvements and system operability, ED - Safety and health and environment	02/2014 - 10/2019	£772,900
NIA_UKPN0001	Power Transformer Real Time Thermal Rating	Network improvements and system operability	06/2014 - 12/2018	£1,820,853

#GoodToGreat

If you would like to get in touch or provide feedback, please email us innovation@ukpowernetworks.co.uk

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UK Power Networks
Delivering your electricity