# Network Innovation Allowance Annual Summary

## Progress and results from 2019/20

UK Power Networks
Delivering your electricity

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# Contents



Front graphic created by Utility Survey Exchange Ltd

# Foreword

Innovation is fundamental to how UK Power Networks operates. It is an openness to brilliant new ideas and better ways of working that has enabled us to continue delivering outstanding service for our customers year on year. Innovation is a driving force behind our performance, ensuring we are the safest, most reliable and most cost-efficient electricity network in the UK, leading the way in tackling the Net Zero challenge.

The last 12 months have seen our diverse team continue to work closely with colleagues across our business to create and embed innovative solutions delivering real benefits for our customers. We now have a total of 40 innovative solutions embedded as business as usual, saving a total of £232m, more than any other GB network. This report outlines the work our innovation team undertook in the regulatory year from 1 April 2019 to 31 March 2020.

A key focus in 2019-20 has been to deepen our relationship with our stakeholders to help give us access to even greater ideas and ensure we are solving the challenges that matter the most. Our stakeholders have selected four key priorities for us to focus:

1 **Meeting our customers' evolving needs** by improving existing services and shaping new ones
2 **Tackling the Net Zero challenge** by reducing the environmental impact of our operations and enabling our country's net zero transition
3 **Ensuring no one is left behind** testing and re-testing our services to ensure no-one is excluded, aiming to be recognised as a force for good for our highly diverse communities
4 **Helping customers in vulnerable circumstances** and ensuring nobody is left behind during the complex energy transition

Innovation is critical in delivering impact across all of these priorities, and we recognise that for our innovation initiatives to be successful, they must be informed and guided by our stakeholders throughout. We are committed to applying best practices of stakeholder engagement at all levels: when shaping our Innovation Strategy, assessing and reviewing our innovation portfolio, when scoping a project and finally over the lifetime of the project.

Earlier this year we released the third version of our Innovation Strategy in RIIO-ED1 to reflect our stakeholder priorities, including revision of our three innovation pillars as below:

1 **Net Zero ready**, an enabler of the low carbon transition, connecting electric transport, heat, generation and storage at the lowest cost, as well as ensuring sustainability of our operations to tackle the Net Zero challenge
2 **Future Ready**, a future-ready distribution system providing new services, to meet our customers' evolving needs, whilst at the same time ensuring no one is left behind as a result of the energy system transition
3 **Efficient and effective**, delivering value to customers and the business through innovation by enhancing network performance and reliability at the lowest possible cost

> "A key focus in 2019-20 has been to deepen our relationship with our stakeholders"

As part of this review we undertook a thorough review of our innovation processes and procedures to understand how we could improve and, most importantly, how we could make it easier and more accessible for third parties to engage and collaborate with us. You can view and download our **2020 Innovation Strategy here**.

The Network Innovation Allowance continues to play a significant role in enabling us to innovate, to find the best ideas from brilliant small and medium-sized businesses to global corporations so we can deliver benefits to our customers.

If you have an idea we would love to hear from you. Email **innovation@ukpowernetworks.co.uk**


**Ian Cameron**
Head of Customer Services and Innovation

# Innovation at UK Power Networks

# Innovation facts and figures

**40**
Total number of Innovation projects live

**40**
Solutions deployed into BAU in RIIO-ED1

**£232m**
savings delivered through innovative solutions in RIIO-ED1

**34**
Industry awards
won for innovation in RIIO-ED1

**75%**
of our NIA allowance contracted to third parties

**£65m**
Value of all projects in delivery

**6**
Fast follow solutions embedded in RIIO-ED1

**38%**
DNO collaboration projects in RIIO-ED1

# Our innovation strategy evolves

In 2015, we published our first Innovation Strategy. In 2017, we refreshed the document to reflect feedback we had received from stakeholders engaging with us for idea and project development. In response, that year, we undertook a complete refresh of the way we operate the Innovation department.

The industry has rapidly evolved since 2017 so in 2020 we produced an updated Innovation Strategy to reflect the changing needs of our customers, and to remind you, our stakeholders, why we innovate and how we do it. For example, in May 2019, the Committee on Climate Change published its 'Net Zero' report detailing the UK's progress so far to reduce greenhouse gas emissions. We have now seen an uptake of more than 87,000 EVs across our network; we have 1.7GW of accepted storage connection offers and over 9GW of distributed generation.

We continue to see first-hand how our customers, motivated by technology efficiencies, clean air and carbon challenges, commercial propositions, new technologies, and government policies can drive radical change in how we operate our networks. Innovation has enabled us to react to our customers' needs as we ensure the network is ready for low carbon technologies. Innovation provides us the flexibility to respond better, faster, or more cost-efficiently to the changing requirements of our customers, both today and tomorrow.

New technologies such as power electronics, modern sensor and control systems and data analytics are revolutionising the way we distribute electricity. We continue our journey from Distribution Network Operator (DNO) to a Distribution System Operator (DSO), providing more active, market-focused services to our evolving customers. Our refreshed Innovation Strategy comes at a time when the opportunities and the challenges facing electricity distribution have never been greater. Our updated strategy sets out why we innovate, how our stakeholders inform our strategy, how we develop and deliver our innovation programme and the challenges and areas of focus moving forward.

## We continue to demonstrate that innovation brings value to the business.

**The reasons we innovate include:**

- **Deliver value for consumers –** by maximising the smart savings we deliver against traditional solutions and ensuring we have a strong conversion rate for transitioning innovative solutions into business as usual
- **Deliver measurable social, environmental and safety benefits –** including CI, CML, carbon emissions and safety performance
- **Facilitate a low carbon system –** by improving network access through reducing time and cost to connect low carbon load, generation, and storage technologies
- **Prepare for the uptake of electric vehicles (EVs) and electric heat –** we must ensure we have the right skills and processes in place, we have the best forecast and data available, we monitor locations where we think issues could appear and we deploy smart solutions before investing. Ultimately, we then strategically identify locations where more capacity will be required for these technologies
- **Be recognised as a collaborative, thought leader in innovation,** evidenced by the number of innovation projects delivered jointly with our peer utilities, external recognition achieved, and our industry working group involvement
- **Be the benchmark for innovation** and best DSO practice nationally and internationally by leading BAU rollout of DSO capabilities to ensure safe, reliable and cost effective networks.


*Innovation aims to deliver our vision while bringing value and having impact across our business and communities*

# Key Collaborations

Innovation is critical to delivering the best service and value for our customers and stakeholders. We know from years of experience that innovation cannot happen in isolation. From creating and assessing new ideas, to idea development, delivery and into business as usual deployment, we're working with organisations large and small, from all sectors and backgrounds, to make sure we are developing the best possible outcomes for our customers.

That collaborative approach is key to everything we do, every day. It ensures we have the right people and the required skillset in each project, delivering the highest value in a cost-effective way. It is a continuously evolving picture and we are always refining our approach, identifying new and better channels to communicate and finding new organisations to work with. It is evident in the numbers, too: since the beginning of RIIO-ED1, 75% of our NIA funding has funnelled to third parties, with 38% of our total projects happening in direct collaboration with other DNOs.

In October 2019 we launched our refreshed EV Strategy, designed as a consultation with questions we are seeking our stakeholders help to answer and direct our focus. We received more than 40 responses from investors through to manufacturers and installers to understand how we can work more closely with the sector. We have attended and presented at dozens of conferences and events to promote engagement around our work on EVs. These range from the Low Carbon Networks Innovation Conference in October 2019 to the Worshipful Company of Fuellers Energy Conference in November 2019 and MOVE 2020 in February, a flagship event for the global electric transport industry.

Elsewhere, our TransPower V2G project portfolio has seen us partner with over 20 organisations including local authorities, suppliers, technology provides and academics to develop a vast cross-sector initiative involving the likes of Nissan and Innovate UK.

Collaboration is also the heart of our cutting edge Shift project. We are working with Octopus Energy, intelligent energy platform Kaluza and EV charging platform provider ev.energy, to offer EV owners across our region the opportunity to take part in the economic, environmental and social benefits of smart charging. The trial is already gathering vital results we will share across the industry, generating further ideas. As a result we have provided feedback to Ofgem to inform their Targeted Charging Review, which has led to new business-as-usual supplier tariffs for consumers, such as Octopus Go Faster.

We continue our work on Optimise Prime, the world's largest commercial EV trial in partnership with household names Hitachi, British Gas, Royal Mail and Uber.

> "By listening to energy retailers and taking a customer-centric approach to smart charging instead of a 'command and control' model, UK Power Networks is demonstrating real innovation and leadership."
>
> **Greg Jackson, CEO of Octopus Energy**

In March 2020 we hosted our first ever Net Zero Networks Forum, attended by more than 70 industry professionals. At the event we launched our industry-first Heat readiness strategy, which outlines our key objectives on decarbonising heat, and like our EV strategy was set out as a consultation to ensure we gather feedback throughout the life time of the strategy, acknowledging this fast changing and dynamic sector. We were joined by eight guest speakers from across government, industry and the charitable sectors. They

included Dr Matthew Aylott, Electrification of Heat Lead at the Department of Business, Energy and Industrial Strategy (BEIS), and Danni Barnes, Director of Operations at fuel poverty charity National Energy Action (NEA). It is this kind of collaboration which is critical to facilitating more innovation. Ultimately, by deepening our knowledge and our evidence base, will help us prepare a robust investment plan to facilitate the uptake of electric heat for our next regulatory price control period commencing in 2023.

Collaboration is evidenced throughout our innovation portfolio. We are working with owners of distributed generation, such as wind and solar farms, on our Energy Exchange and Network Vision projects. On Urban Energy Club we are collaborating with EDF and community energy organisation Repowering London. We are also working with Repowering on our Home Response project alongside the Greater London Authority and home energy storage company Moixa to help London residents access the benefits of the growing flexibility market.

In the last year we have conducted more than 60 external innovation sessions to connect with the industry. We continue to see first-hand how our customers are motivated by technology efficiencies, cleaner air, carbon challenges and commercial propositions.  All whilst government policies and new technologies drive radical changes in how we operate our network.


*Figure 1: Our first ever Net Zero Networks event held at Coin Street Neighbourhood Centre raised more than £600 for fuel poverty charity National Energy Action from the entry fee.*

Net Zero Ready

# Project Highlights

In 2019 the UK set a legally binding target to achieve Net Zero carbon emissions by 2050 to end its contribution to global warming and fight climate change. The transition to a Net Zero future is revolutionising the way we produce, distribute and consume electricity. As of March 2020 there are an estimated 87,000 EVs in UK Power Networks' licence areas, a number projected to rise to up to 3.6m by 2030[1].

As a trusted local 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.

It is clear that no organisation or sector can achieve Net Zero in isolation. The Net Zero Ready strand in our Innovation strategy reflects our commitment to join forces with our stakeholders to tackle the Net Zero challenge together. We will do this by developing innovative solutions to connect, manage and run electric transport, heat, generation and storage at the lowest cost to consumers.

Our key objectives are:

- developing new technical and commercial solutions that address our customers' changing needs and can connect low carbon technologies and EVs cheaper and faster
- maximising network utilisation
- delivering environmental and societal obligations
- playing an active role in addressing the increasing challenge of decarbonisation of heat
- reducing our own carbon footprint[2]

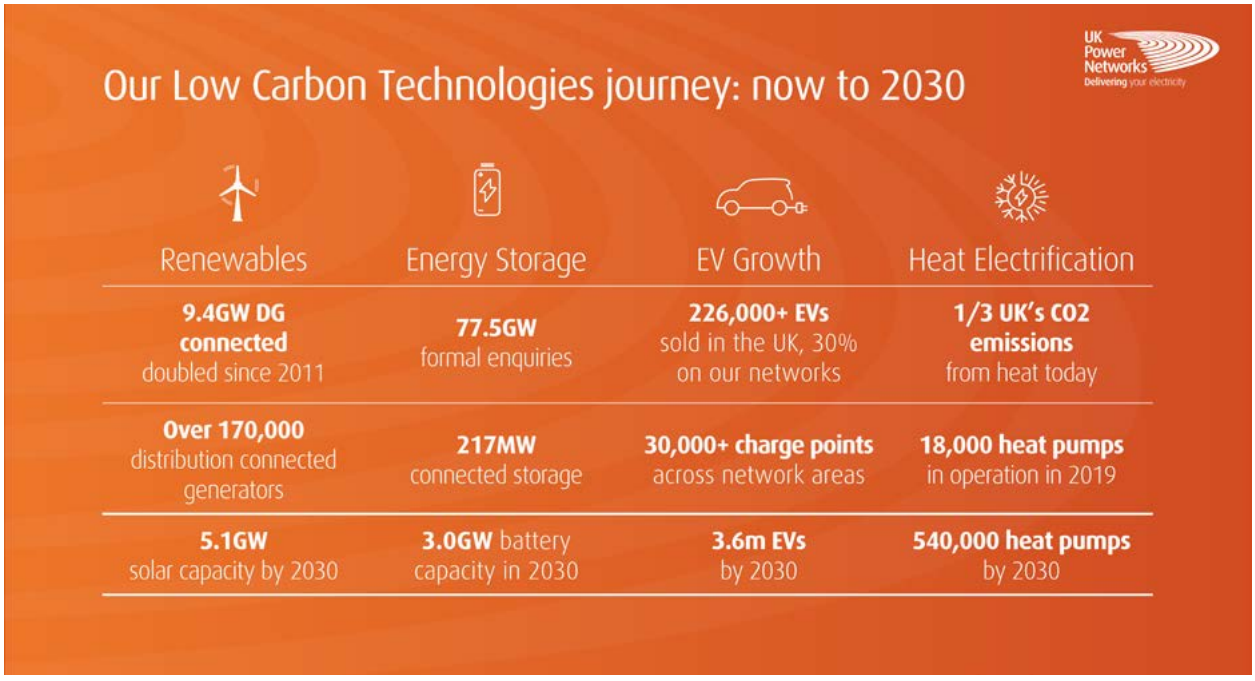


*Figure 2: Our Net Zero journey - LCTs connected to UK Power Networks today and our 2030 Distribution Future Energy Scenarios projections by 2030[1]*

[1] According to the Engaged Society scenario of UK Power Networks' Distribution Future Energy Scenario

[2] We are not only enabling the Net Zero targets by facilitating the connection of low carbon technologies. We are also ensuring sustainability of our operations and we are systematically reducing our own carbon footprint. This is reflected in the 20.5% reduction of our carbon emissions achieved in 2019 (compared to 2014/15 baseline) with UK Power Networks being the first DNO achieving the Carbon Trust Standard for Carbon worldwide.

To ensure that we continue to focus on the right areas and our priorities are aligned to those of our customers, in November 2019 we revised our industry-leading **EV Readiness Strategy**.

Building on our experience in facilitating electrification of transport, we have now launched our **Heat Readiness Strategy**, the first of its kind amongst DNOs, which aims to deliver three core objectives:

1 Inform heat decarbonisation policy through provision of data and evidence
2 Deliver a great service experience to customers wishing to connect low carbon heating solutions
3 Undertake least regret actions to ensure network readiness

The Network Innovation Allowance continues to play a crucial role in allowing us to explore the enablers and smart solutions required to facilitate the Net Zero transition at the lowest costs to consumers. In 2019/20 we have focused on technical solutions such as Phase Switch System, which addresses the imbalance caused at feeder level by high penetration of LCTs ranging from EVs to photovoltaic.

**Phase Switch System** aims to demonstrate how a pavement switching device combined with substation monitoring can switch customers from one phase to another whilst maintaining phase rotation. It will automatically rebalance LV networks and increase capacity utilisation.

Collaboration continues to play an essential role to explore how EVs can support the network at certain times by shifting EV demand away from peak times (smart charging) or releasing the electricity stored in their batteries (through vehicle to grid technology, V2G). In our project **Shift** we partnered with customer-centric energy companies to test the effectiveness of a market-led approach to smart charging as opposed to DNO controlling charging. In **TransPower** we worked with 20+ organisations including suppliers, technology providers and academics to accelerate the development and deployment of the V2G technology. Overall across our three licence areas, ~100 V2G charge points have been installed to date.

With over 900 EV drivers recruited onto its trials, **Shift** is exploring a market-led approach to smart charging by testing the effectiveness of three different market mechanisms to incentivise EV flexibility: Capacity Based Pricing; Time of Use DUoS; and Flexibility Procurement.

**TransPower** is exploring the opportunities associated with the V2G technology in four areas: buses; fleets; on street; and domestic. In partnership with Innovate UK, everoze and EVConsult we also promoted knowledge sharing of V2G innovation projects through the development of the V2G Hub, showcasing 67 pioneering V2G projects across 17 countries worldwide.

Improving our connection offerings to better accommodate our evolving customer needs is at the centre of our EV Readiness Strategy. In March 2020 we finalised a tool that

allows us to assess a Timed Connection offer in a timelier manner, getting customers such as bus garages connected faster and at considerably lower cost.

With the number of timed connection referrals expected to increase in the future, the **Timed Connection SW Development** tool will support planning engineers deliver a greater service to our connecting customers by reducing the amount of time required to assess a timed connection offer.

The Network Innovation Competition (NIC) has been crucial to design Profiled Connections, another innovative connection agreement where the maximum power requirement varies according to the time of day and the season. Profiled Connections are part of the suite of technical and commercial solutions explored in our NIC project **Optimise Prime** to accelerate the transition to electric for commercial fleets and Private Hire Vehicle (PHV) operators. In **Active Response** we are also preparing our networks to support the future mass uptake of EVs by trialling new power electronic devices (Soft Open Points and Soft Power Bridges) and advanced automation. By connecting networks together and moving spare capacity around to where it is needed, these technical solutions will help DNOs manage the uncertainty associated to the growth of LCTs.

**Optimise Prime** is the world's biggest EV trial involving up to 3,000 commercial EVs 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.

**Active Response** is testing a responsive, automated electricity network that re-configures itself in real-time. It will demonstrate new ways to maximise the capacity of existing assets to respond quickly to the clustering of LCTs, particularly EVs.


*Figure 3: At our Net Zero Networks Forum in March 2020 we presented the results of our EV Consultation and we launched the first DNO Heat Strategy setting out the clear actions we need to take to support decarbonisation of heat*

# Phase Switch System (PSS)

**Background**

UK Power Networks have collaborated with a small & medium enterprise, Low Carbon Electric (LCE), to demonstrate the application of their novel unproven solution called 'Phase Switch System'. The solution automatically rebalances low voltage (LV) networks and makes voltage, current and losses more linear and predictable whilst increasing network visibility.

National Grid's Future Energy Scenarios forecast the increase of electricity demand by up to 25% between now and 2038, with most new demand including low carbon technologies (LCTs) connected to LV networks. An impact on the LV distribution network of this proliferation will be feeder imbalances that shift as and when customers decide to adopt and use LCTs that range from EVs to photovoltaics (PVs). These adoption patterns will make current, voltage and losses more non-linear than they already are, and will prevent the LV network being used to its full capacity.

The PSS consists of two parts: a substation monitor; and a pavement switching device installed halfway along a feeder. Both parts monitor the voltage and current on each phase of the feeder, and a controller decides whether moving customers from one phase to another could improve the imbalance measured at the substation. If proven to successfully operate, the project is expected to deliver benefits of deferring up to 14 transformer replacements and 140 cable overlays each year for 11 years saving nearly £2.0 million.

**Experience To Date**

Before a new device can be connected to the distribution network, it needs to be approved. LCE have developed their PSS prototype to the stage where it is ready for network trials. Initial testing at Power Networks Demonstration Centre (PNDC) has been completed, which reassures engineers that the PSS is safe to install on the LV network. The PSS has been subjected to events that are unlikely to occur on a real LV network with connected customers.

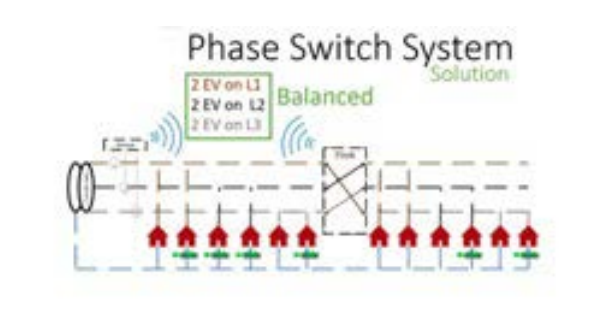


*Figure 4: The Phase Switch System is a pavement-mounted cabinet designed to improve the balance of demand caused by LCT connected by our customers. It is able to move downstream customers from one phase to another without causing an interruption.*

Identifying clusters of EV chargers has proved challenging as the only information we have received from the Office of Low Emission Vehicles is the postcode of the installation. An LV feeder from ground mounted substations may cover many postcodes. Spotting an EV charger mounted on an external wall is easy, however one installed within a customer's garage is almost impossible to identify. Other clusters of LCT, e.g. PVs, are easier to identify as the installation regulations require the installer to register the PV installation with the DNO and can be confirmed from aerial photographs.

**Future Developments**

We have selected 16 LV feeders and these will be studied to shortlist them down to seven trial locations. Studies involve checking that there is a problem needing to be solved and predicting how much benefit is likely to be realised.
The seven trial locations will have a PSS system installed to demonstrate that the imbalance caused by LCTs can be improved and capacity headroom can be created. This in turn will confirm the predicted benefits of the earlier studies.

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# Timed Connection Software Development

**Background**

The uptake of EVs is expected to increase demand on our networks which may require network reinforcement that can be costly and time consuming. The shift of commercial and fleet vehicle operators to electric transport brings with it the requirement for significant upgrade to the power supply to the location where the EVs will be charged. UK Power Networks has identified that these heavy-duty users of commercial EVs have a characteristic charging demand because of their vehicle duty-cycles. This presents an opportunity to explore alternative flexible connection arrangements that can result in cheaper and faster connection offerings to our customers. In 2017, UK Power Networks introduced the Timed Connections offering which is a type of flexible connection that allows customers to import/export different levels of power during certain times of the day (up to four time slots per 24 hour period) based upon availability of the network or known network constraints (see Figure 5).

The Timed Connection Software Development project focuses on developing and delivering a long-term enduring solution to analysing the network for opportunities for timed connections. The software solution will identify the discrete periods in a 24 hour timescale when the typical peak demand on network is for a specific connecting customer and how much additional load can be accommodated within and outside these periods.

The specific software solutions are:

- A new distribution network visibility (DNV) tool with capabilities for data cleansing and data preparation for timed connection assessments; and
- Two add-ons to existing software planning tools which will allow the assessment of potential timed connections offerings to specific parts of the network that the customer is intending to connect to.

These new suite of tools and add-ons will help to reduce the amount of time required to assess a timed connection offer, allowing UK Power Networks to assess such timed connections in a much more timely manner and customers to get their new loads, such as EV loads, connected much faster and at considerably lower cost.

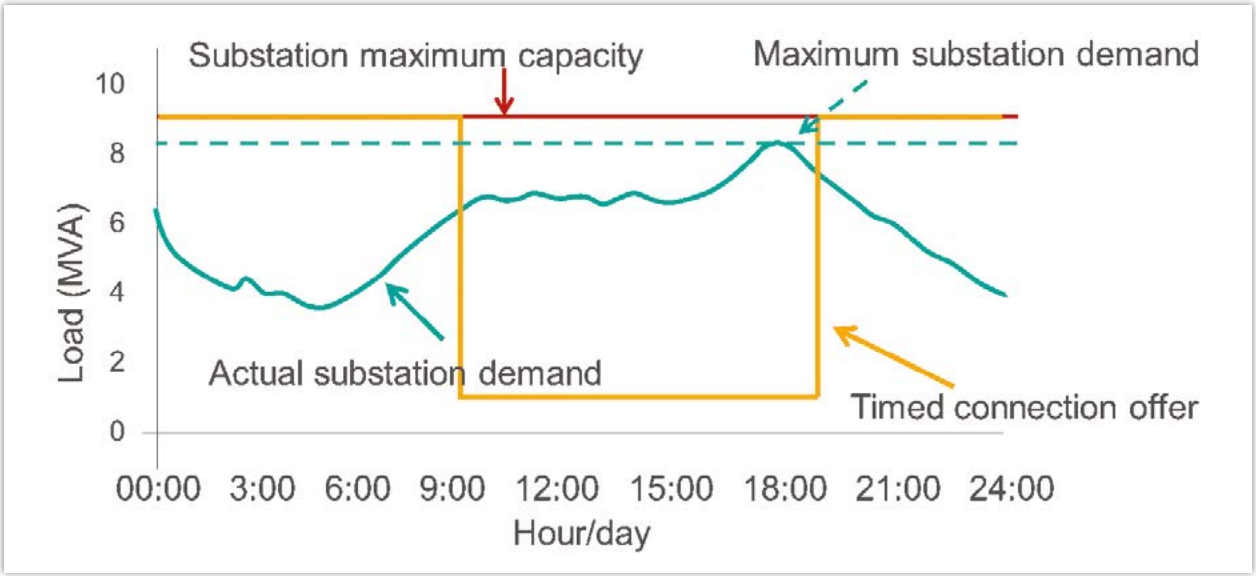


*Figure 5: A Timed Connection offer gives connecting customers, such as EV charging hubs, a power boost outside of network peak time*

**Experience To Date**

The development of the new DNV tool with enhanced functionalities and the add-ons to the existing network analysis software packages DPlan and DigSilent PowerFactory have for the first time provided the Planning Engineers with a suite of tools to support them in assessing timed connections at scale. The developed software solutions will lead to greater consistency and accuracy as well as reduction in assessment time.

A timed connection offering relies on the analysis of historical data. By understanding the conditions which would adversely affect the network and limiting the consumption during certain time periods such as the peak demand period, the connection can be accommodated without the need for significant network reinforcement. The new DNV tool has two key enhanced functionalities that will assist the preparation and cleansing of historical data for analysis. The two new functionalities are:

- **Data cleansing functionalities**, which automatically identify each data quality profile rule and apply the required handling of the occurrence; and
- **Timed connections tab**. This allow the summation of 48 half-hourly demand values, either maximum or minimum, of selected network assets and during a specified period in time (see example in Figure 6).

**Future Developments**

The project is now complete. The add-ons to the existing network analysis software packages DPlan and DigSilent PowerFactory as well as the new DNV tool have passed the User Acceptance Testing and are being deployed into BaU.

The main benefit of the suite of tools developed as part of this project is the reduced labour cost to assess a timed connection referral. With the number of timed connection referrals expected to increase in the future, the Timed Connection Software Development tool will support Planning Engineers to deliver greater service to our connecting customers.

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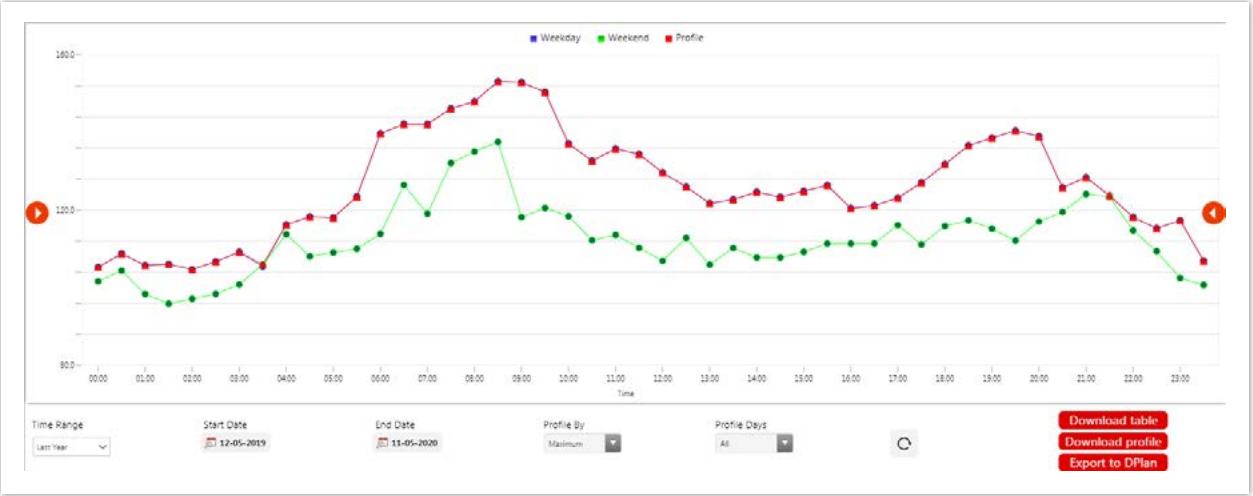


*Figure 6: Example profile generated by the new DNV tool showing maximum demand at 48 half-hourly time slots over a one year period.*

# Shift

**Background**

Shift is exploring a market-led approach to smart-charging to shift EV demand away from peak times and facilitate the electrification of transport at the lowest cost to customers. In collaboration with supplier Octopus Energy, intelligent energy platform Kaluza and EV charging platform provider ev.energy, we are trialling different market mechanisms such as price signals and flexibility markets to incentivise smart-charging.

**Experience To Date**

Engagement with more than 800 motorists during the research phase of Shift revealed that the majority of customers would be happy to charge their EV outside of peak times in return for lower bills. The research provided valuable insight into customers' attitudes towards smart charging and indicated a market-led smart charging approach was the customers' preferred method of managing the increased electrical load due to EV uptake.

The level of reward expected by customers for smart charging formed a part of the survey. It found more than two-thirds of participants would allow smart charging to occur for £4 or less per month, under the condition that their mobility is not impacted. The need to provide customers with 'peace of mind' when it comes to meeting their mobility needs was reinforced by nine out of ten participants rating the ability to override the smart charging process as important.

While setting up the trials, we developed new flexibility products to explore Time of Use Distribution Use of System (ToU DUoS) charges, capacity-based charges and LV flexibility markets as smart charging incentives as shown in Figure 7.

Working with the project partners, these incentives have been packaged into various smart-charging propositions which are being trialled with over 900 EV customers. As well as creating value for EV customers, the mechanisms incentivise more efficient use of existing network capacity to facilitate the decarbonisation of transport at the lowest cost to customers.

**Future Developments**

With the trials now up and running, we will continue to collect charging session data and assess the effectiveness of different mechanisms in shifting EV demand from peak times. By working with the project partners to evaluate customer behaviour throughout the trials, we will build an understanding of the factors which impact the level of response to market-led smart-charging. In parallel, we will work with the project partners to find out more about the customer experience and the scalability of the mechanisms based on their ability to meet customers' needs while reducing the impact of EV charging on the network.

Throughout the trials, we will collect the data required to assess the network impact of market-led smart charging for residential customers and inform enhancements to forecasting tools. This will allow us to facilitate the electrification of transport at the lowest cost to customers by making the best use of existing network capacity before investing strategically to meet customers' needs; that is what our 'flexibility first' approach means. Early insights from the trials will continue to be shared with Ofgem to inform the Access and Forward-Looking Charges reform of the Significant Code Review.

**Project Lead:** Evie.Trolove@ukpowernetworks.co.uk

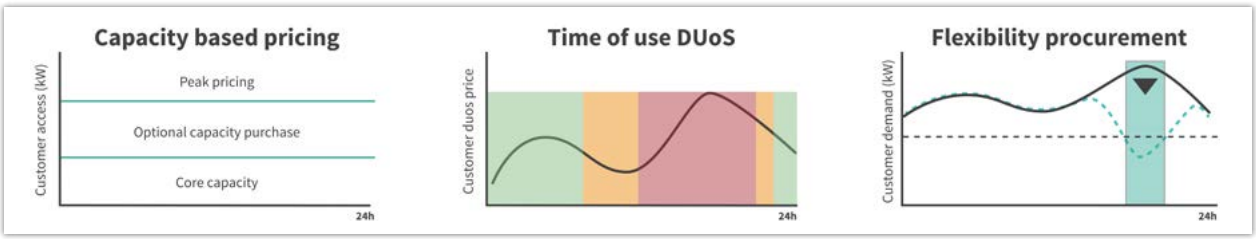


*Figure 7: Mechanisms for incentivising smart-changing as trialled in Shift*

# Optimise Prime – NIC

**Background**

With businesses buying 58% of all new vehicles in the UK, commercial vehicles may determine the speed of the transition to low carbon transport once a large variety of commercial EV models become available. Compared to vehicles used for domestic purposes, commercial EVs are expected to have a much greater impact on the electricity network due to higher energy requirements resulting from higher daily mileage and payloads as well as co-location of multiple EVs at a single site such as a depot. 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 largest 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 four year project will involve up to 3,000 EVs from Royal Mail, British Gas (a subsidiary of Centrica) and Uber, supported by the distribution network operator Scottish and Southern Electricity Networks (SSEN), Hitachi Europe and Hitachi Capital Vehicle Solutions. It will be split into three trials, reflecting the three partner fleet use cases (Figure 8):

- 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

**Experience To Date**

Overall, the project has made good progress in the design and build phase of the programme whilst addressing the significant challenges in ensuring that there are sufficient EV volumes available to meet the requirements across the three trials.

The project team have completed the initial designs of the three trials. These designs set out the objectives for each of the trials which are then further broken down in to a series of sub-objectives and activities. The high-level design and specification of the three trials which forms the first Deliverable1 was delivered in August 2019.

The IT hardware platform which captures and manages all data from the project as well as hosting applications used by the project has been commissioned. Work has also begun on detailed design and implementation of the Trial Operational Applications, Trials Management System, Depot Planning Model and the Depot Optimisation system. A prototype version of the Depot Planning Model has been developed.

In addition, the project team have developed a methodology and the design of profiled connections, an innovative connection agreement where the applicable maximum power requirement varies according to the time of day and the season, up to 48 half-hourly time slots per day, with adherence to the profile actively managed through smart systems by the customer and monitored by the DNO (Figure 9). An add-on functionality to UK Power Networks' existing network planning tool which will allow the assessment of profiled connections is also under development.


*Figure 8: Optimise Prime Trials and project partners*

The very limited availability in the market of electric light commercial vehicles has been an ongoing challenge to the fleet partners due to a series of factors:

- suitable vehicles are not available within the required timeframes
- the total cost of ownership have changed from the previous year making the business change less viable due to a general shortfall in supply of electric vans in UK at present, increased vehicle prices and Transport for London's announcement that the congestion charge discount for EVs will cease in December 2025.

Nevertheless, the fleet partners have continued to work on the procurement and roll-out of their vehicles, with 220 EVs currently on the road for Royal Mail, five EVs for Centrica and 732 EVs for Uber as of 6 March 2020. The project team with support from Royal Mail have identified seven depots to take part in the trial. The installation of charge points and charge point controllers (CPCs) have been completed in all seven sites. The Uber EV trip data are being ingested into the IT hardware platform as well as the distribution network utilisation data of secondary substations.

**Future Developments**

In the coming year, the project will focus on:

- completing the installation and commissioning of equipment at the seven Royal Mail depot sites
- testing the depot optimisation system
- finalising the development of the profiled connections tool and of UK Power Networks' Active Network Management (ANM) system to interface with the project IT platform
- developing the end-to-end flexibility architecture and the definition of the flexibility products (specifically, building on UK Power Networks' Flexibility Programme and the products designed in our innovation EV projects Shift and TransPower).

In addition, the Mixed Charging Trial is expected to formally start and analysis of Uber journey data combined with the secondary substation utilisation network data from both UK Power Networks and SSEN will be used to model the impact of future demand of Private Hire Vehicles (PHVs) on the electricity network.

The project trial partners will either continue to procure EVs or support the recruitment of additional trial participants to meet the EV volume requirements.

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.

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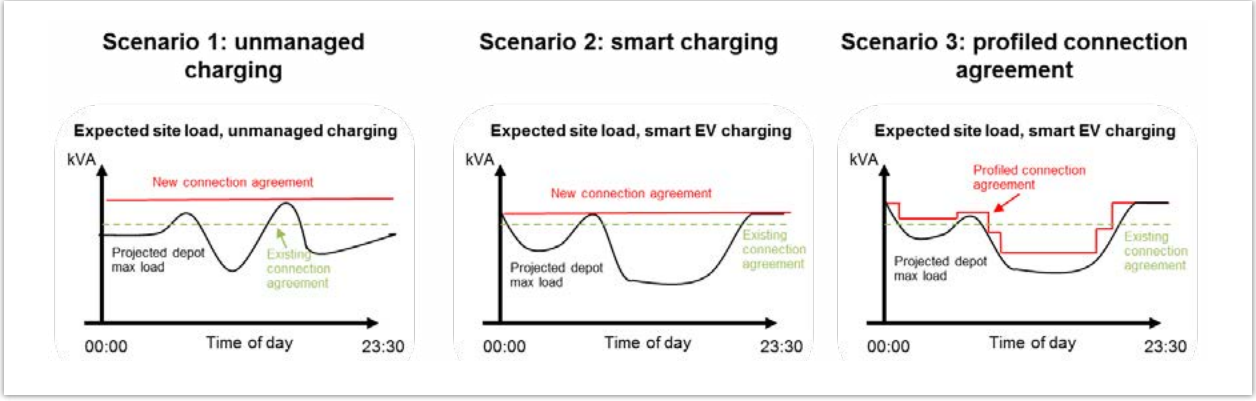


*Figure 9: Comparison of different load scenarios for unmanaged and smart charging under a standard connection agreement versus smart charging under a profiled connection agreement*

# Active Response – NIC

**Background**

By 2030 it is anticipated there will be up to 3.6m[3] EVs in use across London, the East and South East of England where UK Power Networks delivers electricity. 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. 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 started 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)
2 Primary Connect – controlled transfers between primary substations using a Soft Power Bridge (SPB) to share loads and optimise capacity

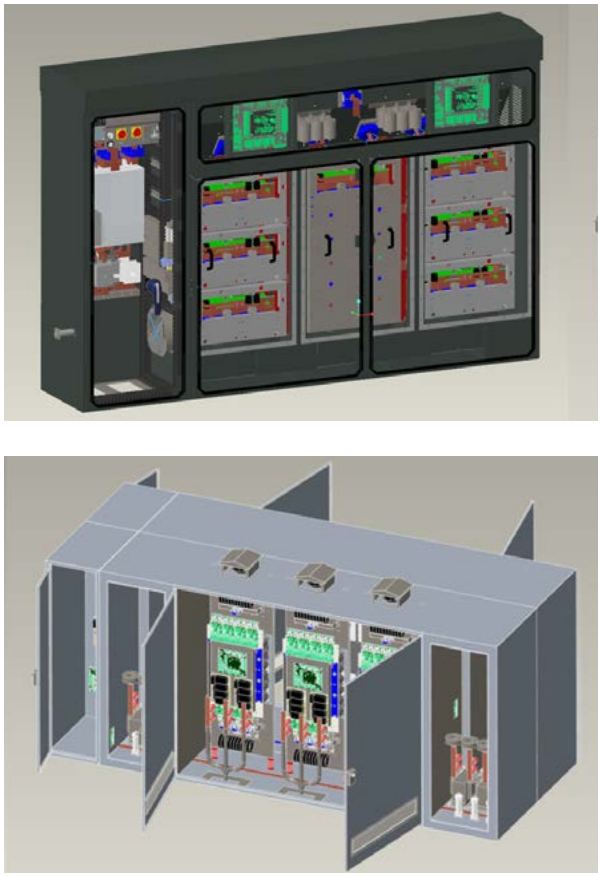

*Figure 10: SOP (top) and SPB (bottom) 3D models*

**Experience To Date**

To date, the project has made great progress and developed excellent learning that has been, and continues to be shared with industry stakeholders. Significant progress has been made in the development of power electronic devices, with a robust testing process devised and followed to ensure that all components, individually and collectively, perform as per design.

In parallel, the core platform of the advanced automation solution has progressed from conceptual phase to offline trials. The trials play an instrumental role in iterative performance testing and enhancement of the Active Network Management system, which supports the Active Response software engine.

[3] https://innovation.ukpowernetworks.co.uk/wp-content/uploads/2020/03/UKPN_Distribution_Future_Energy_Scenarios_10_March_2020.pdf

The learnings associated with these activities have been shared through external forums, 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 are:

- Inductors, filters, DC busbars, and water cooling and control system are the key components that are critical for the correct operation of power electronic devices for electricity network applications. As such these components must be carefully designed, modelled and tested to achieve an efficient and stable performance;
- The success of an advanced automation solution, such as Active Network Management, heavily relies on a seamless interaction between different existing and developing systems. The availability of good network data such as transformer capacity, cable types and equivalent impedances improves confidence to generate high quality optimisation results; and
- The preparation for the installation of novel technologies, such as power electronic devices, requires a holistic approach to delivery and planning. This requires coordination of experts across different engineering disciplines and logistical planning with local authorities.

**Future Developments**

The project is completing the build and test phase for the advanced automation solution. SOPs and SPBs and will move into the installation and commissioning phase. This will be followed by the commencement of live network trials for Network Optimise and Primary Connect.

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 DNOs.

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*Figure 11: Sharing progress updates at Project Partner Meeting*

Future Ready

# Project Highlights

The second area of strategic focus for UK Power Networks' innovation portfolio is to execute projects that help enable a future-ready distribution system that meets the needs of tomorrow's customers.

Future Ready means meeting our customers' evolving needs, including ensuring that no one is left behind from the benefits of the energy transition towards Net Zero. It also covers the provision of new services involving Distributed Energy Resources (DERs), often renewable energy providers. Our projects in this area include whole-system optimisation across the transmission-distribution interface, and increasing resilience of the low voltage (LV) network with greater visibility, monitoring and control.

Within this innovation summary report, we highlight five key projects in our Future Ready portfolio.

**Urban Energy Club (NIA)** is preparing for the **future social challenges that might be associated with the transition to a flexible energy system**, understanding what our role should be and informing future vulnerability strategies through its insights into how different consumer groups can participate in flexibility). The project has started recruitment of domestic customers for a trial of demand-side-response with a battery installation on a small block of flats.

**Unified Protection (NIA)** will enable the **use of a centralised protection system within a substation to facilitate future changes in substation requirements**. It will enable us to move away from having to provide new hardware every time substation requirements change, instead providing a centralised system which can be modified via a software upgrade. Such a shift will not only assist in the transition to delivering a DSO (Distribution System Operator) model, but will also reduce the overall operational costs, delivering benefits for the networks and our customers.

**Energy Exchange Market-Based Curtailment Management (NIA)** is developing a more efficient approach to managing the curtailment of generation customers connected via a flexible connection. These generators have been able to connect more quickly and cheaply than would have been possible using traditional techniques, but this project will help us **understand how we offer a better service for flexible connections and new customer revenue streams, by managing curtailment cost-effectively**. This can be based on generation cost, creating price signals for future reinforcement needs and helping establish new solutions to curtailment from demand-response and storage operators.

**Power Potential (NIC)** is creating a world-first regional reactive power market to manage transmission voltage. A complex system integration and customer trial, **this is an example of how a DSO system can open up a new service and market**. The project has implemented a Distributed Energy Resources Management System to enable generation connected to our network in the South East to offer reactive and active power services to the transmission network. The first generator has now been commissioned for the service. Power Potential will create a new revenue stream for connected generators and make it cheaper and quicker for new resources wanting to connect to the network, by enabling a new flexible source of voltage control.

**Powerful-CB (NIC)** is using 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, allowing much more generation to connect** before the network needs to be upgraded due to fault level constraints. The first unit was commissioned this year, ready for trials.

However being Future Ready goes beyond our innovation portfolio:

- In the past year, we have developed an **Open Data Portal** which shares data outputs from many of our projects.
- **Our Distribution Future Energy Scenarios**, which are driven by stakeholder input and insight from our innovation projects, give us localised insight into how we should plan our investment and services.

- **Active Network Management** is enabling the Smart Grid of the future, building on past innovation projects and our flagship Power Potential partnership with National Grid Electricity System Operator. This will enable us to deliver the next generation of flexible connections and flexibility services across our three network areas.
- We committed to market-test our load-related investment and have now completed our second tender for **flexibility services** this year.

# Urban Energy Club

**Background**

Living in multiple occupancy premises like blocks of flats is common in urban centres, and as social housing where people who are financially underprivileged may live, but it can often limit customers' energy options and the uptake of low carbon technologies (LCTs) such as rooftop solar panels and batteries. This is because of the nature of shared properties and limited space on individual sites. This can be a barrier for certain customers who would be unable to own distributed energy resources, actively participate in the energy market, and offer flexibility services.

Future categories of exclusion and potential future vulnerability are key areas of focus for us to ensure we can provide services that deliver the best value to our customers and address their changing customer needs, while ensuring no one is left behind in the Net Zero transition. Shared ownership and virtual allocation of energy assets can open energy saving opportunities, choices and new revenue streams for customers who would otherwise not be able to participate in the flexibility market.

In collaboration with EDF Energy and Repowering London, Urban Energy Club is supporting customers living in small flats with limited space and financial capabilities to participate in the flexibility market. The project will create flexibility service opportunities for customers living in high density urban areas through virtual ownership of shared energy storage asset and 'club-type' commercial models. Ultimately, the insights from this project will help inform DNOs' future vulnerability strategies on the role local networks can play in facilitating the participation of potentially excluded communities in a smart flexible energy system.

**Experience To Date**

Urban Energy Club has successfully started the recruitment process for participants, with four residents joining the scheme to date. Early insights from the project have revealed that domestic customers may have further obstacles in the ability to access similar LCT technology if they are on billing solutions such as prepayment and cheque. Currently the trial is restricted to residents that are already on a contract with our supplier partner (EDF) for bills and payments to be processed correctly. This project has highlighted how important it is to overcome the limitations from these policies to enhance penetration of future community shared low carbon assets.

The flexibility that will be offered has been based on the profile of the local substation, obtained through LV monitoring. This shows an unusual local peak in midday caused by a local school's energy needs, which opens up opportunity for use of solar power at the highest generation time. This is different from the most common LV peaks, which are found in the evening and network impact mitigation would therefore rely mostly on storage. The project has so far designed the network flexibility offer for trial participants and has integrated the network preferences in the platform used to manage the virtual allocation of the energy asset.

*Figure 12: The flats involved in the trials*

The site surveys required to be carried out at the property to assess the installation process and get relevant permits had to be paused due to the lockdown measures recently put in place due to COVID-19. In addition, virtual modelling, simulation and off-site testing of the communications between battery and the platform have been also put in place.

**Future Development**

The next phase of the project will focus on the installation of the battery on site and on data collection from the live trial. Repowering will continue to engage with the local residents to offer them the opportunity to join the trial. We will be also working with an academic partner to further investigate the data collected and the wider impact and opportunities associated with the scale-up of this type of solutions. The academic partner will also compare this approach with other DSR models and will provide insights into flexibility integration opportunities and future developments. This will be carried out through several collaborative workshops and through the analysis of both societal and technical data collected during the trial.

We will continue to work with key stakeholders across the industry to ensure we provide our domestic customers with the best opportunity to participate in the evolving flexibility market. The models explored in Urban Energy Club and in our wider domestic DSR portfolio will improve inclusiveness of marginalised communities, including those from disadvantaged backgrounds or living in apartment blocks, who may also experience fuel poverty. These models have the potential to enable more people to participate in the net zero transition and bring new revenues for individuals and communities otherwise unable to participate in the flexibility market.

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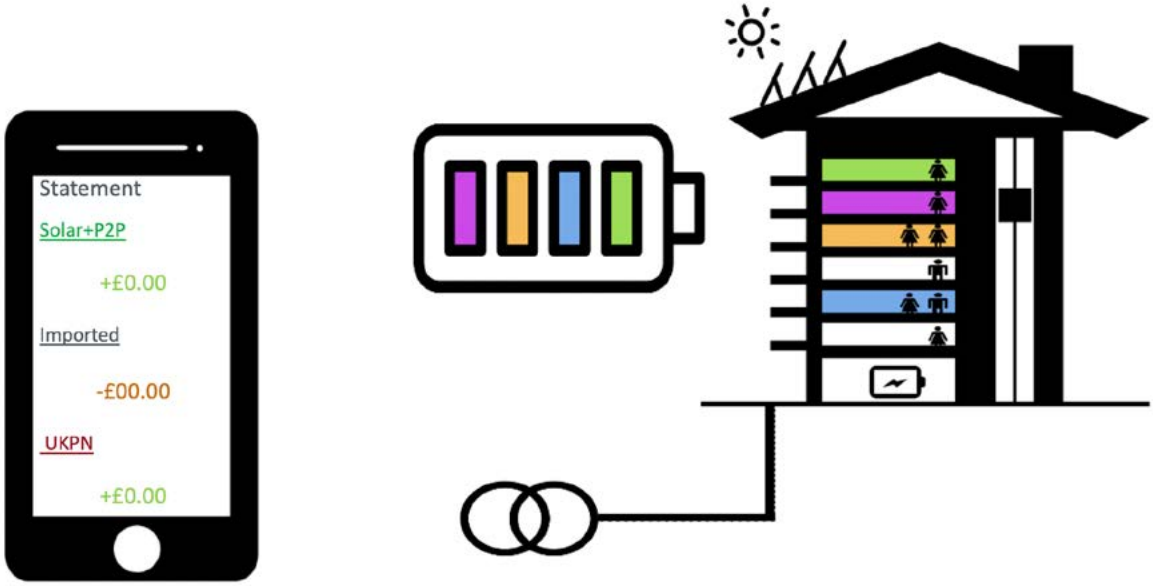


*Figure 13: Illustration of shared storage and virtual allocation*

# Unified Protection

**Background**

The network is becoming increasingly complex and there is uncertainty of what functions may be required, or even available, in the future for protection to meet changing network topologies.

DNOs are often required to extend busbars and modify protection schemes for new connections and load growth projects. However existing relay replacement programmes are often implemented on a like-for-like basis to avoid additional work at an extra cost for hardware modification associated with functionality enhancement. At the same time, multiple Intelligent Electronic Devices are being installed on the network such as protection relays, RTUs (Remote Terminal Units), power quality meters and disturbance recorders, which means different tools from multiple vendors need to be maintained by the field staff. This introduces inefficiencies in the use of time, cost and resource for DNOs.

To alleviate this challenge, Unified Protection will trial a new substation centralised protection system to verify and validate the use of this system and its compatibility with future substations. The project will also seek to develop and align the future requirements of distribution substations with the wider DSO (Distribution System Operator).

Unified Protection will enable the use of a central system within a substation, instead of having local protection relays on each bay. This system's firmware can be modified and upgraded remotely and does not require additional plant for the introduction of new functions or bays. If successfully demonstrated, the project has a potential to be scaled across all GB networks adhering to modern industry standards such as IEC 61850. Such a shift will not only facilitate the transition to a DSO model, but will also reduce the overall operational costs; delivering benefits of up to £100k per applicable substation for the networks and our customers.

**Experience To Date**

In 2019/20, all major activities to design, specify, procure, test and install the equipment were completed. The target was to have installed equipment from two manufacturers, however only one manufacturer's equipment was installed because the second had not released the product yet.

*Figure 14: Conventional solution*

*Figure 15: Method solution*

Once available, the plan is to install the second manufacturer's equipment, resolve any minor technical issues and monitor and compare the performance of the method to the conventional solution.

The project is proving that this technology works and can be used in the future as BaU by the DNOs. The technology enables seamless standardisation and interoperability of the equipment, which is essential for the network of the future, which is expected to overcome complex challenges. Therefore it is no surprise that there has been a global expression of interest to earn more about this project. The project team facilitated several visits to the trial site for such interested stakeholders.

To date, the project has gained key learnings that continue to be disseminated across the sector. These include:

- The project learned that DNOs must prepare for a change in engineering skillset; in the future it is likely that protection engineers will need more telecoms knowledge to setup such equipment;
- The demonstration method adopted by the project provides the possibility of remote work which increases safety and efficiency of employees. Additionally, it reduces the amount of equipment and wiring needed so considerably less labour is needed for installation;
- Another lesson from the application of the system is that it gathers a large dataset, which can be used by analysts and engineers. There is a possibility to manipulate this data for wider applications to generate greater value. For instance by helping to improve asset use and maintenance; and
- It has also been identified that cyber security is critical for such applications and can be achieved with different options. First, firewalls are required to prevent malevolent access. Secondly, the system can have a watchdog functionality or strange behaviour (threat) detection. Finally segregation systems can be used to limit the impact of cyber security threats.

**Future Development**

The next steps in the project are to install equipment from other manufacturers and test interoperability. Some of the communications issues needs to be resolved and the equipment requirements and specification finalised. It is envisaged that the training and procedural documents preparation will be commenced once installations are complete and performance tests successful.

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# Energy Exchange: Market-Based Curtailment Management

**Background**

UK Power Networks is leading the way in developing flexible connections, which will help us provide excellent service for new distributed generation customers connecting to our network. Flexible connections were first trialled through our Flexible Plug and Play project, which paved the way for 120MW of distributed generation (DG), which is often renewable energy, to connect more quickly and cheaply than would have been possible using traditional techniques. Flexible Distribution Generation (FDG) connections have, to date, saved customers over £75m. Overall, UK Power Networks and other DNOs are increasingly connecting DG through flexible connections.

However, FDG connections have some limitations: inefficient curtailment, failure to accommodate alternatives to curtailment (such as demand turn-up) and limited signalling to trigger future reinforcement. The development of appropriate market-based solutions may address these limitations. Therefore, in order to improve our service to DG customers, we started the project 'Energy Exchange: Market-Based Curtailment Management'. If successful, the market-based curtailment approach is expected to benefit network participants in the following ways:

- Cost effective curtailment: Curtailment will be based on the cost of generation of the respective FDG
- Helping establish new solutions to curtailment: The market-based curtailment will facilitate other parties such as demand-side response and storage operators to alleviate constraints. This will help create revenue streams for DERs, reduce the cost of curtailment and reduce losses, as energy will be consumed closer to the point of generation
- Establish price signals: Curtailment trading will help the discovery of prices regarding the scarcity of capacity in the constrained areas. For example, consistent and repeated high constraint prices will indicate where future reinforcement should be triggered to manage constraints effectively.

The key output of this project to is to understand how we can offer a better service to our customers. This will facilitate and incentivise additional DG by reducing curtailment levels and create new revenue opportunities for existing customers through curtailment trading.

**Experience To Date**

The project completed initial market design and research into several different market options in the 2019/20 regulatory year. As well as developing market designs, the project engaged with a broad range of stakeholders to understand what customers think are the most important areas to focus on. The 16 targeted stakeholders engaged included DER designers, developers, financers, owners, operators, flexibility providers, storage developers, an aggregator, a supplier and another DNO. We found stakeholders agree that a market-based curtailment management solution is worth pursuing, particularly if it can be designed in a way that will reduce complexity and offer certainty to market participants. Of the five market designs considered, the DSO Curtailment Mechanism was the preferred option to pursue into detailed design. More detail on the options considered is available on the UK Power Networks Innovation website.

**Future Developments**

Throughout the rest of 2020, the project will complete detailed market design and data analysis from existing FDG data to understand the potential benefits of a market-based curtailment mechanism (MBCM). Once these are complete, we will conduct market simulation to test whether or not this type of market design can deliver value for money to participants whilst conforming to the criteria we set out for designing the marketplace, which are:

- Cost borne by beneficiaries: cost of curtailment needs to be borne by those DERs opting for flexible connections, rather than being socialised across the wider DNO customer base – this might change in the future
- Technology agnostic: the design option allows for a broad range of technologies to take part

- Improvement for participants: market design needs to present an opportunity for all potential market participants to improve their situation
- Efficient curtailment: the market should incentivise the participation of low cost and optimally sited generators allowing constraints to be relieved in the most efficient manner
- Fair: it should discourage behaviour that would be seen as "gaming" the system, particularly if it results in some network users paying more than they would under current arrangements

Most importantly, we will continue to engage with network, industry and customer stakeholders where necessary in order to understand their views and to ensure that the market design is informed by their needs.

Following these detailed design and simulation stages, we will review the outcomes of this feasibility project in order to determine whether to explore this further through a live trial. Ultimately, if successful, Energy Exchange will benefit customers and the network by further optimising network capacity.

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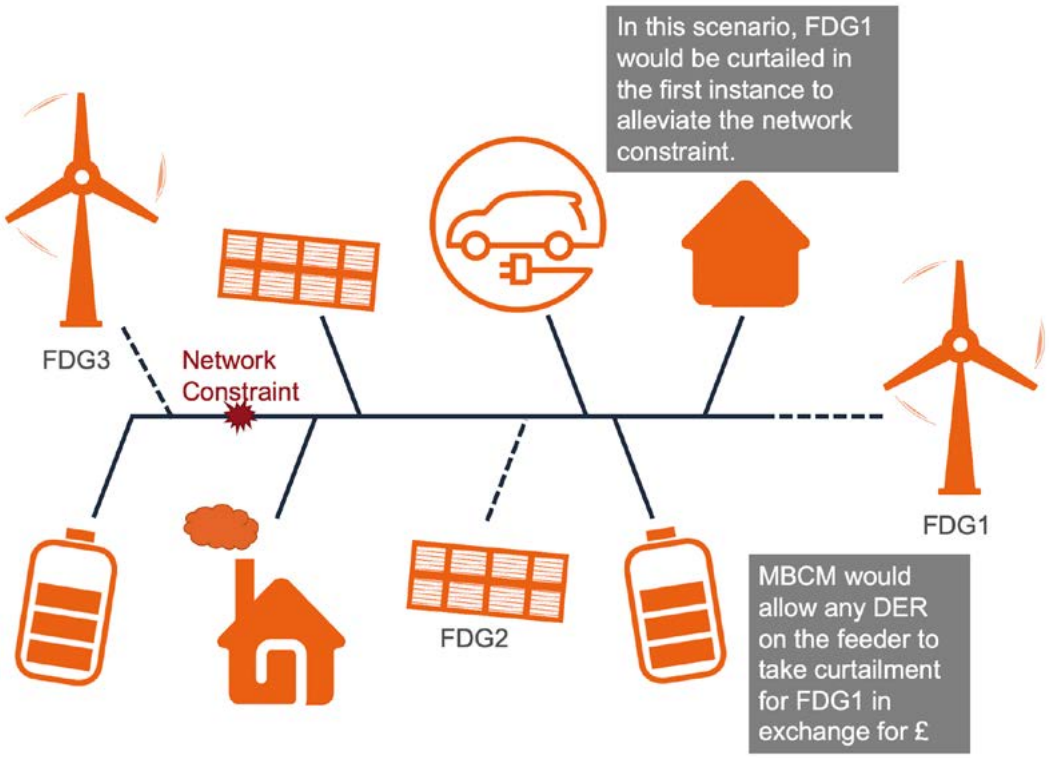


*Figure 16: Diagram explaining how MBCM could benefit connectees. In this figure, FDG1 would be the first generator curtailed due to a constraint, followed by FDG2 and FDG3. The other assets connected with solid lines are on firm connections. If MBCM was used, FDG1 could pay to avoid curtailment, which could then be taken by any other connectees on the circuit. As FDG3 is closest to the constraint, there would be reduced total curtailment if they were curtailed first.*

# Powerful-CB – NIC

**Background**

The challenge for Powerful-CB includes the Government's plan for the transition to Net Zero by 2050, which highlights the importance renewable distributed generation (DG) 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.

As we transition to Net Zero, the network has seen a growth in using combined heat and power (CHP) generation, district heating using CHPs and a general increase in renewable DG 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. Traditional reinforcement as a connection solution is time consuming and costly which can make new DG unattractive to customers.

The LPN (London Power Networks) network 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 physically large smart solutions that would work in other types of network are unsuitable or of limited use in LPN and GB networks with comparable density where space is constrained.

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.


*Figure 17: Powerful-CB being presented at LCNI Conference 2019*

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 road for one year.

**Experience to date**

One of the primary focus areas of the project for 2019/20 was finalising the design, validation and type testing for the FLCB. These activities were completed in July 2019. Working closely with our project partner, ABB, we identified and implemented further safety additions such

as time delay relays restricting access to high voltage (HV) compartments and modification of the panel structure during the development of the FLCB to further ensure the safety of personnel and equipment. All our learnings from the development and testing process were published in our **learning report SDRC 9.1.1** which was published in October 2019.

UK Power Networks completed site preparation works and the delivery of the FLCB in November 2019. Following the installation of the FLCB, other equipment installation took place including protection panels, high voltage (HV) cabling and extending the existing switchgear.

During commissioning two key lessons learned include:

- The addition of uninterruptable power supplies (UPS) for the FLCB control system to mitigate the inadvertent loss of substation supplies. Even a momentary loss of supply would require the FLCB to be powered down and powered up again so adding the UPS increases the FLCB robustness and reliability; and
- The speed of the FLCB trip signal was not picked up by our supervisory control and data acquisition (SCADA) system until software updates were made. This will be important when rolling the FLCB out on a wider scale.

**Future Developments**

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.

During 2020/21 we will publish learning report SDRC 9.2.1 which will include results and learning from installation, commissioning, and operation to date of a FLCB at a substation. The project will also continue to update the project Safety Case, incorporating any new learnings from the trials.

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*Figure 18: Delivery of the FLCB to the trial site*

*Figure 19: FLCB positioned into place and installation*

# Power Potential – NIC

**Background**

Power Potential is a project which UK Power Networks is delivering with National Grid Electricity System Operator (ESO). We are setting up a Distributed Energy Resources Management System (DERMS), integrated with UK Power Networks' network management system. This enables DER to deliver reactive and active power services to National Grid ESO, using generators connected to the distribution system to help manage voltage constraints on the transmission system, a world first. As such, this project is a demonstrator of UK Power Networks' development as a DSO. It unlocks a new source of voltage and constraint management services for the transmission system which should unblock future generator connections, and facilitate a new revenue stream for participating DER. The trial area covers the network served by four Grid Supply Points (GSPs) in UK Power Networks' South Eastern licence area (Canterbury North, Bolney, Sellindge and Ninfield) (SPN).

**Experience To Date**

In 2019/20, the minimum level of DER participation (participating sites and Mvar) was achieved, with five DER signing the project contracts (framework agreement and variation to the connection agreement) to provide up to +/-75 Mvar of reactive response. Customers brought their DER controllers to the UK Power Networks' laboratory for integration testing with a Remote Terminal Unit (RTU), the PowerOn network management system and the DERMS, against a defined interface schedule. In November 2019, one field RTU was upgraded and limited integration was achieved; however, learning from this led to a switch in analogue signal exchange from integer to float values, simplifying the commissioning and support activities for both UK Power Networks and the DER. The RTU software logic and interface schedule were amended as a result.

From a technical perspective, software development, testing and integration of the DERMS software has been carried out during this year on a pre-production system (similar specification to live). Integration, functional, user-acceptance, penetration and non-functional testing were undertaken to prove capability for DER commissioning and the initial Mandatory Technical Trials stage, and make progress towards the capabilities required later in the trials e.g. proving integration with National Grid ESO's 'Platform for Ancillary Services' (PAS) via an enterprise service bus and web services link, generating settlement statements from a PowerBI system, and defining the detailed commercial functionality. Purchase orders were raised so DER can be paid during the trial via a self-billing approach.

The Successful Delivery Reward Criteria report on **Customer Readiness and Performance of the Technical Solution in a Controlled Environment** was published at the end of November 2019. The project team also published the **Power Potential Reactive Power Commercial Procedure Wave 2 &**


*Figure 20: Power Potential achieves complex integration between DERMS, a DER and UK Power Networks' live network management system – verified during commissioning via displaying internal values on the Remote Terminal Unit's mimic .*

**Wave 3** to outline to participants the commercial approach and potential revenue from the trial. Detailed trial preparations continued within both partners to ensure that operational teams, systems and processes are ready, including internal and **external** guidance. Stakeholders were kept informed via the project's Regional Market Advisory Panel, and a fortnightly email newsletter was introduced at the end of 2019.

The initial DERMS system go-live took place in December 2019, proving that DERMS could be installed, supported and if necessary recovered on live, and that crucial SCADA data for the four GSPs could be sent in real-time from National Grid ESO to DERMS.

One of the DER (LightsourceBP, a solar PV customer) achieved national press recognition for their own reactive dispatch tests facilitated by UK Power Networks at the end of 2019, showing they could deliver a reactive power service at night from their inverters. The combination of the customer and system works then led to end-to-end testing with this DER on the live system in early 2020, successfully commissioning to deliver the reactive power service with the DERMS on 16 March 2020. This covered capability, failsafe and integration testing to deliver a reactive power service. Enhanced data logging was set up from a Power Quality Monitor reconfigured at site.


*Figure 21: Power Potential was the winner of IoT project of the year at the 2019 National Technology Awards.*

**Future Developments**

Further commissioning activity for the remaining trial participants requires site works, so was put on hold due to COVID-19 restrictions, but site works restarted in June 2020. However, the project is progressing remote testing where possible, including switching to remote delivery of the mandatory trial for the commissioned customer. Subject to COVID-19 restrictions, the project aims to deliver the remaining commissioning and mandatory trials over summer 2020, the main technical trial phase for the reactive power service from September 2020 and the commercial trials in November 2020 – March 2021.

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Efficient & Effective

# Project Highlights

The nature of electricity generation 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 improve network performance and reduce carbon emissions.

At UK Power Networks we believe one of our core strategic focus areas for innovation 'Efficient & Effective' responds to the above challenge. It aims to deliver clean 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 focus 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.

A core corporate value for UK Power Networks is to be a respected and trusted corporate citizen. This is reflected in our diverse portfolio of innovation projects that deliver measurable social, environmental and safety benefits through our innovation projects. Some of our highlights include:

- OHL Fault Location Concept and Directional Earth Fault Passage Indication – the project delivered a smart solution to locate faults on feeders, reducing time taken to restore customer supplies;
- Mobile Field Control – developing an innovative solution to reliably and securely delegate greater control and authority to field engineers on their mobile device. The end product will improve customer service and operational efficiency; and
- Transformer Care – trialling a novel asset monitoring system to replace invasive inspection techniques with smart condition-based maintenance programmes.


*Figure 22: We are delivering value through our Efficient and Effective portfolio, enhancing key initiatives which improve network performance and reliability at the lowest possible cost*

Our journey is incomplete without our stakeholders – we cannot continue to innovate in a sustainable and cost effective manner without listening to and engaging with wider industries.

We aspire to be the benchmark for best practice and disseminate our learnings with the wider industry on a regular basis. Last year, at Low Carbon Network Innovation conference in Glasgow, our engineers and project partners engaged with the wider industry through our 'Meet the innovators' initiative. We showcased our innovation portfolio, providing detailed insights to share the learnings, promote collaboration and facilitate benchmarking to create an inclusive innovative fraternity that can together meet the challenges of today for the benefit of our customers and environment.


*Figure 23: This Nortech NX45 fault passage indicator is battery operated and has a modem allowing remote communications to Network Control of other locations along an 11kV feeder, giving clarity of likely fault locations.*


*Figure 24: LCNI 2019 Conference – meet the innovators*

# OHL Fault Location Concept and Directional Earth Fault Passage Indication

**Background**

The overhead line (OHL) fault location project set out to reduce the time it takes to locate a fault on a rural feeder. Once all remote control switches have restored as many customer supplies as possible, operational staff need to patrol the lines to locate the fault, carry out a repair and restore all remaining customers.

The project used a combination of Aclara's Lighthouse power sensors, Nortech's NX44 and NX45 Fault Passage Indicators (FPI) and Bowden Bros' Pathfinder P360 FPI installed at various points along 11kV feeders. The Aclara power sensor is connected directly to the OHL conductor and measures voltage, current and phase angle to calculate power flow and direction, whereas the other devices only sense the passage of fault current.

Many rural feeders have sections of underground cable and ground mounted substations in larger villages where Nortech's NX44 and NX45 FPIs have been installed. Each FPI has a modem allowing it to communicate with the UK Power Networks control system PowerOn whenever it senses the passage of fault current. During site surveys it was recognised that some ground mounted sites may not have a readily available LV supply. Nortech developed the NX45 to run using a battery with an expected life of ten years. As rural 11kV feeders radiate out across an area the Bowden Bros' Pathfinder P360 FPI was used to indicate in which direction the fault was likely to be.

The Aclara power sensors communicate with a central portal providing an alarm list and an archive of measured values. This portal will communicate with PowerOn giving the control engineer an indication and magnitude of fault current. Nortech FPIs have traditionally communicated with Nortech's iHost portal using a bespoke protocol. During the project, Nortech enhanced their FPIs to be able to communicate directly with PowerOn using a DNP3 protocol. Also during the project GE GridSolutions developed a protocol converter to allow PowerOn to display the Pathfinder messages.

*Figure 25: Aclara power sensors*

**Experience To Date**

The magnitude of OHL fault currents can be used to judge how far along a feeder a fault is likely to be. Comparing the measured fault current with a distribution network fault calculation likely fault locations can be determined. This relies on having accurate network impedance data.

Traditionally when a transient fault occurs, all supplies are automatically restored and the fault is archived as an event. The power sensors can capture waveforms of these transient faults allowing staff to investigate the potential problem, e.g. a tree branch only touching the line during strong wind, remove the branch and avoid the possibility of further supply interruptions.

The ability of the pathfinders to report loss of volts following a fault reassures the control engineer that the fault is not beyond that point otherwise it would have reported the passage of fault current.

In combination with the other FPIs the number of likely locations can be reduced further such that the control engineer can guide the operational staff to one, two or three likely locations greatly reducing the time to locate a fault. Typically, where a feeder has two power sensors and six or more FPIs then the location time can be reduced on average by 30 minutes. This increased visibility of fault indications has reduced customer minutes lost by 14% where they have been deployed.

**Future Developments**

This year over 1,000 Pathfinders are in operation on 306 feeders providing information to the control engineer that was previous only available following a site visit.

The adoption of these FPI technologies has demonstrated that they can help reduce the time it takes to locate a fault, allowing linesmen to carry out a repair and restore supplies more quickly.

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*Figure 26: A Pathfinder being installed using magnetic mounts*

# HV Overhead Line (HV OHL) Assessment

**Background**

UK Power Networks has over 24,000 km of HV OHL conductors on its network comprising of over 280,000 spans). There are no completely accurate records for the ages of these overhead lines and there is sometimes limited information on the condition of these conductors. As a result, the HV OHL conductors are often replaced only after they have failed causing a fault and often replaced without following a condition-based plan.

HV OHL Assessment aims to improve the understanding of the deterioration rate of overhead line conductors through testing a representative and statistically significant sample. The conductors will undergo electrical, structural and mechanical tests and the results will be used to develop an algorithm to estimate the expected end-of-life of HV OHL conductors. This will enable UK Power Networks to assess the state of the overhead line network more accurately and inform long-term plans to manage the distribution network.

**Experience To Date**

So far within the project, 300 randomly selected samples of different types of overhead line conductors from different locations underwent a series of electrical, structural and mechanical tests. Though the final results are still being analysed there are some preliminary findings from the initial testing. Of the ones analysed, we found that the Aluminium Conductor Steel Reinforced (ACSR) types show more signs of corrosion compared to the other conductor types and a few All Aluminium Alloy Conductors (AAAC) are more susceptible to breaking. As depicted below, some observations were made during the testing and the final results will be provided in detail in the closedown report.

**Future Developments**

The project has completed the testing of all the conductor samples and the results are being finalised. The next step is to develop the algorithm that can predict the OHL conductor condition and estimate the expected end-of-life of the asset. If successful, the model could significantly increase network reliability by allowing the distribution network to proactively replace HV OHL instead of reactive fault repairs.

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*Figure 27: Degradation of galvanic zinc coating*

*Figure 28: Rust observed on steel core strand*

*Figure 29: Oxide build-up*

# Link Alert

**Background**

A key component of low voltage networks are underground link boxes. These are configurable cable joints, which may be 'switched' by changing the configuration of the solid metal links inside the device. Variations of this very simple technology has been in use across distribution networks since the start of the 20th century. They greatly improve the reconfiguration flexibility of the network by allowing engineers to restore customers who are affected by a network fault.

Very occasionally, link boxes experience failures. Due to the design and location of link boxes, there is significant risk associated with a link box failure. UK Power Networks introduced mitigations to reduce the number and limit the impact of failures.

However, there is no commercially available solution to proactively identify developing faults on link boxes. In-situ monitoring of link boxes has not previously been conducted for a number of reasons, primarily because cost-effective remote communication from link boxes has not been possible. This cost barrier is compounded by the harsh environment where link boxes are installed, with a lack of auxiliary supply and extremely poor radio reception.
The Link Alert project is about working with technology providers to develop and trial a device to monitor link box temperature. The prototype device is being tested across 45 link boxes in Central London. If successful, this project could lead to reduction in link boxes failures and therefore an improvement in cost and safety performance.

**Experience To Date**

Through the initial project stages, it was established that there are multiple use cases for a link box sensor, depending on whether the aim is to protect the link box or to get information about the surrounding connected network. This project attempted to rationalise these use cases and combine


*Figure 30: Link Alert Installation*

features. However, from working closely with stakeholders, it was concluded that the use cases and the technology readiness level (TRL) of the solution able to provide each feature are very disparate.

Therefore, the lesson learnt is that individual functionalities should be focused on and perfected before they are combined. This is particularly the case with current monitoring, as it requires invasive placement within the link box. This needs to be further researched and developed, so that a user-friendly device can be produced.

The project completed testing of a prototype link box sensor in February 2019. This device was able to detect moisture, current and temperature. We then received sensors later in 2019 and completed network installations by the end of January 2020.

The project also learnt that in areas with reasonable mobile coverage, a 3G/4G communication is sufficient to get information from a link box, provided it is not underneath the bell cover. As such, we are now able to remotely monitor link boxes through Eneida (supplier) DeepGrid software platform. We were able to set static alert and alarm thresholds per sensor. We are now measuring temperatures every 15 minutes across the day and are building up a database of actual temperatures experienced at the bell cover of link boxes. Although in the early stages of trial, we are observing daily sinusoidal temperature variations which we believe are due to network loading.

We look forward to developing our understanding of the link box thermal behavior throughout the rest of the project. We will develop learning on what appropriate temperature settings are and how this type of solution can deliver benefits to DNOs and their customers.

**Future Developments**

Early trial data indicates that link boxes tend to exhibit a daily load-related sinusoidal temperature variation. In order for this technology to be reliably useful in the long term, we need to develop an appropriate system for setting alarm limits. The project will gather evidence and propose recommendations later in 2020. To maximise the long term benefit of the project, we extended the trial to continue through the summer. This will produce a much richer trial data set, with winter, summer and iinter seasonal  weather variation. As we progress through the summer months, we believe that thresholds will need changing to keep up with changing seasonal temperature.

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*Figure 31: An old two-way link box*

# Transformer Care

**Background**

UK Power Networks is faced with managing a highly utilised asset base, as we run the network more dynamically and optimally. We estimate more than half of all grid and primary transformers are close to their expected design life. To ensure our transformers are healthy, along with our maintenance regime we typically employ a combination of active monitoring of asset health and timely refurbishment. Currently, there are a number of methods to monitor transformer health, such as: taking oil samples, carrying out periodic external inspections, and using sophisticated condition monitoring systems. However, they mostly rely on invasive probes, which need to be submerged in the transformer oil to be able to function. This requires the oil in the transformer to be extracted/drained, which disturbs the core, and requires longer outages for the transformers to complete.

Transformer Care will test a novel asset monitoring system, which inspects a transformer without the need for invasive equipment. It works by applying a machine-learning algorithm to the available measurements from transformers (voltage, current, and tap position) at high sampling rates. This in turn provides detailed understanding of the condition of the transformer and any potential emerging issues.

*Figure 32: Transformer Care solution after commissioning*

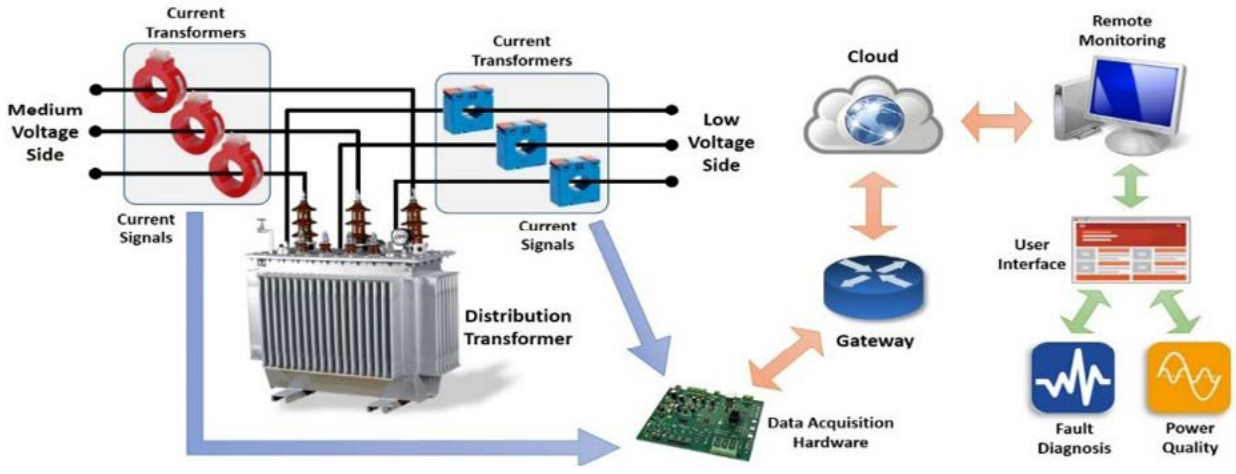


*Figure 33: Transformer Care solution architecture*

If successful, this system can be used to inform UK Power Networks' maintenance and intervention regimes, and future replacement programmes that translate into £350k of annual savings. Additionally, the benefit of less on-site work due to the non-invasive nature of the solution will provide further benefits.

**Experience To Date**

The first part of the project investigated and demonstrated the less intrusive nature of the new monitoring system. This included a detailed system integration design in parallel with the equipment configuration. In early 2020, the equipment was connected to the network and on-site commissioning was successfully carried out. Due to the nature of the selected site, an outage was required to carry out the connection to the transformer voltage input. Nevertheless, the project findings so far confirm that the connection and commissioning were completed quickly and less intrusively. The outages themselves took two days rather than the nine days it would normally take to install monitoring on three transformers.

Throughout the project we have learned about the challenges of international collaboration through the (sometimes) subtle differences in equipment standards and commissioning procedures. An example was a practical difference in the installation of voltage transformers (VTs), as in the UK they are installed in a different location compared to Portugal. While this may seem like a trivial difference, we had to rely on engineering best practice, dedicate more time to the system integration aspects during the detailed design stages and take a short outage on the transformers to mitigate the impact and ensure the system is calibrated correctly.

Another valuable outcome was on the wider coordination with stakeholders. The selected site is in a central part of our London Power Networks area and has an active community which have frequent social events. As such, we worked closely with the local community to ensure the project can be delivered with minimum delays and without affecting the local plans.

**Future Developments**

Currently the system is installed, commissioned and operating on site. The next steps we will take are to remotely commission the system and perform final calibration. Following that we will begin monitoring the transformer health indications and comparing them to the ones from the existing condition monitoring in place. We will study the results to demonstrate the effectiveness of the new solution and share our findings before we proceed with the roll-out plans to ensure the benefits are realised.

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# Mobile Field Control

**Background**

Network stress situations such as load peaks or storms cause inefficiency and delays in restoration due to the extensive number of calls required between Field Engineers and Control Engineers to ensure safe operation and coordination between them. To reduce these delays a methodology defined as "Field Control" provides the Field Engineer with temporary control of a specific area of network. Field Control is currently performed using paper documents and does not allow Control Engineers to have visibility of the delegated network in real-time. As a result, when the network control is handed back to the Control Engineer, confirmation of all switches previously operated by the Field Engineer is required. This introduces delays in the restoration process.

Mobile Field Control will build upon current capabilities in UK Power Networks' mobile solution known as PowerOn Mobile, and will deliver a first of its kind software tool to reliably delegate control to field staff without introducing delays and improving customer service and operational efficiency. In particular, the following innovative functionality not demonstrated or proven elsewhere in GB will be part of the Mobile Field Control solution:

- Ability to delegate control to Field Engineers and return delegation via electronic devices;
- Under Field Control the Control Engineer and Field Control Engineer can see the live running conditions in real time, where communications are available;
- Field Control Engineers to remotely tele-control operations on the network using the electronic device; and
- Safety documents can be issued and cancelled by the Field Control Engineer via the electronic devices.

**Experience To Date**

The project was registered in March 2018 and is progressing in line with the original scope. During the first phase of the project, the requirements and design specifications have been agreed with key stakeholders, including Field Engineers and Control Engineers. Interim releases of the Mobile Field Control software solution were developed and successfully tested on UK Power Networks' infrastructure. This included initial user interface and key functionalities review.

Following the successful completion of the test phase, the project is now in the final phase of deployment and testing of the solution. Live network trials will commence thereafter.

**Future Developments**

In the final phase of the project, the solution is expected to be tested with the current version of UK Power Networks' ADMS (Advance Distribution Management System). To further ascertain future functionality, it will also be tested with the next release of ADMS to ensure the solution integrates well with the control system without affecting the reliability of the critical infrastructure.

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*Figure 34: The UK Power Networks control room*

# Complete NIA Project Portfolio

# Our Network Innovation Allowance Portfolio

## Net Zero Ready

| Project Reference | Project Name | Research Areas | Duration | Budget |
|---|---|---|---|---|
| NIA_UKPN0051 | Firefly | Transition to low carbon future | 06/19 - 06/20 | £99,000 |
| NIA_UKPN0027 | Loadshare | Network improvements and system operability | 05/16 - 05/19 | £2,871,000 |
| NIA_UKPN0032 | Mobile Field Control | Safety and health and environment | 02/18 - 02/21 | £275,600 |
| NIA_UKPN0049 | Phase Switch System | Transition to low carbon future Network improvements and system operability | 06/19 - 03/22 | £959,000 |
| NIA_UKPN0045 | Shift | Transition to low carbon future New technologies and commercial evolution | 01/19 - 05/21 | £1,295,500 |
| NIA_UKPN0036 | Timed Connection Software Development | Network improvements and system operability Customer and stakeholder focus | 05/18 - 09/20 | £975,800 |
| NIA_UKPN0033 | TransPower | Network improvements and system operability | 03/18 - 12/20 | £1,469,960 |
| NIA_UKPN0056 | Cold Start | Transition to low carbon future | 02/20 - 02/21 | £184,349 |

## Future Ready

| Project Reference | Project Name | Research Areas | Duration | Budget |
|---|---|---|---|---|
| NIA_UKPN0030 | Development of Oil-filled Cable Additive- Phase 2 | Transition to low carbon future | 09/17 - 01/20 | £2,418,081 |
| NIA_UKPN0041 | Dual Fuel Transport | Network improvements and system operability | 08/18 - 12/20 | £218,393 |
| NIA_UKPN0052 | Energy Exchange: Market-Based Curtailment Management | Network improvements and system operability | 09/19 - 05/21 | £985,800 |
| NIA_UKPN0039 | Engineered Poles Products | Network improvements and system operability | 06/18 - 12/20 | £284,625 |
| NIA_UKPN0035 | Network Vision | Transition to low carbon future | 04/18 - 10/21 | £1,345,000 |
| NIA_UKPN0037 | SYNAPS Fault Detection, Classification & Location Solution | Transition to low carbon future New technologies and commercial evolution | 05/18 - 03/20 | £475,339 |
| NIA_UKPN0048 | Unified Protection | Network improvements and system operability New technologies and commercial evolution | 04/19 - 03/21 | £765,254 |
| NIA_UKPN0050 | Urban Energy Club | Customer and stakeholder focus | 05/19 - 11/20 | £195,238 |

## Efficient & Effective

| Project Reference | Project Name | Research Areas | Duration | Budget |
|---|---|---|---|---|
| NIA_UKPN0055 | Arc Aid | Safety and health and environment | 02/20 - 08/21 | £391,000 |
| NIA_UKPN0007 | Detection of Broken/Low Hanging Overhead Line Conductors | New technologies and commercial evolution | 10/18 - 10/21 | £534,985 |
| NIA_UKPN0054 | EPRI Research Collaboration on Overhead Transmission (P35) and Substations (P37) | Network improvements and system operability New technologies and commercial evolution | 01/20 - 07/23 | £924,000 |
| NIA_UKPN0047 | HV Feeder monitoring to pre-empt faults | Network improvements and system operability | 02/19 - 02/22 | £2,256,371 |
| NIA_UKPN0044 | HV OHL Assessment | Network improvements and system operability | 01/19 - 09/20 | £408,378 |
| NIA_UKPN0031 | Link Alert | Network improvements and system operability Safety and health and environment | 11/17 - 12/19 | £1,988,128 |
| NIA_UKPN0019 | OHL Fault Location Concept and Directional Earth Fault Passage Indication | Network improvements and system operability Safety and health and environment | 02/14 - 10/19 | £772,900 |
| NIA_UKPN0038 | Real Time Thermal Ratings – Cables | Network improvements and system operability New technologies and commercial evolution | 06/18 - 12/19 | £679,854 |
| NIA_UKPN0053 | Storm Resilience | Network improvements and system operability | 12/19 - 12/21 | £664,943 |
| NIA_UKPN0040 | Transformer Care | Network improvements and system operability New technologies and commercial evolution Safety and health and environment | 07/18 - 01/21 | £249,815 |
| NIA_UKPN0046 | Underground fault predictive model and earthing assessments | Network improvements and system operability | 02/19 - 02/21 | £692,887 |
| NIA_UKPN0057 | Circuit See | Network improvements and system operability | 02/20 - 04/22 | £957,000 |
| NIA_UKPN0042 | Storm Joint | Network improvements and system operability | 09/18 - 01/20 | £165,382 |

# CONTINUING TO raise the bar

If you would like to get in touch or provide feedback, please email us

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