




# Network Innovation Allowance Annual Summary

## Progress and results from 2020/21

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UK Power Networks
Delivering your electricity

# Contents

# Foreword

Innovation is part of who we are at UK Power Networks. We are continually ambitious to trial, test, prove and implement real change in our business. That is because we know innovation has a central role in delivering a safe, reliable, cost efficient and green energy supply for our customers.

Despite the challenges we've all faced in the past year, we have seen innovation continue to deliver real benefits to the customers we serve. That is true across all the areas of our business – whether in our core responsibilities of safety, reliability, sustainable cost-efficiency and customer service or in the future energy landscape of facilitating Net Zero carbon emissions and building a smart network.

This report covers the regulatory year from 1 April 2020 to 31 March 2021. Throughout this period our enthusiastic team of innovators have adapted to remote working without ever losing sight of our goal to deliver industry leading performance. Since the beginning of the RIIO-ED1 regulatory period in 2015, we have now adopted 50 innovative solutions into our everyday business as usual operations delivering a total saving of £283.6m in the process. That is significantly more than any other GB network and it shows just how with the right innovative culture we can achieve great things when we think creatively and collaboratively.

It feels almost impossible to write a foreword for our annual report without mentioning the impact of the pandemic. During this tumultuous time, I have been astounded at the hard work and dedication from our innovation partners and innovation teams. We have re-assessed and re-imagined our projects and ways of working to continue to deliver day-in, day-out and make real benefits a reality.

What has not changed this year is the close relationships we hold with our stakeholders. Now more than ever we are sharing ideas, improving access to our plans and working together to solve the challenges which matter to them most. Digital engagement has opened up a new realm of possibilities – we have hosted ever-growing webinars and used new platforms to co-design our plans and get live feedback from dozens of stakeholders at once.

This engagement has driven our strategic approach to innovation. We have had many in depth sessions with stakeholders this year, helping us to shape our focus areas. We are continually listening, testing and re-testing new ideas with our stakeholders so they can guide our journey. Whether we are reviewing our Innovation Strategy, assessing a new idea, reviewing our portfolio or underway on a project, the people we serve will always be at the front and centre of our decision-making.

> "Despite the challenges we've all faced in the past year, we have seen innovation continue to deliver real benefits to the customers we serve."

In 2020 we released the third version of our **Innovation Strategy** to reflect our stakeholders' priorities. These pillars continue to serve us well, and have been a solid foundation to continue our innovation focus over a tough year. These pillars are:

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

Within this document you will read about projects across the broad range of things we do at UK Power Networks. This ranges from new community-led projects to facilitate low carbon heating, to a major smart substation trial, to building a data-driven visibility tool, to improving network reliability and safety through new hardware. It is a testament to the diverse nature of our team and the passion of the individuals who leave no stone unturned to make a difference.

The Network Innovation Allowance continues to play a major role in enabling us to innovate, find great ideas and work with stakeholders from all areas of society to put customers first.

If you have an idea or want to work with us, we would be delighted to hear from you. Get in touch at **innovation@ukpowernetworks.co.uk**

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

# Innovation at UK Power Networks

# Innovation facts and figures

**50**
Solutions deployed into BAU in RIIO-ED1

**55**
Total number of projects in delivery

**£283.6m**
Benefits delivered from innovation in ED1

**39**
Industry awards
won for innovation in RIIO-ED1

**75%**
NIA funding to third parties

**£71m**
Value of all projects in delivery

**6**
Fast follow projects

**38%**
Collaboration projects in ED1

# Our innovation strategy evolves

Our first innovation strategy was published in 2014, setting out our leading role in respect of innovation for the RIIO-ED1 period. Our vision was clear. We wanted to be the most innovative DNO working on cutting edge projects guided by our stakeholder needs. From the outset we believed that innovation would play a crucial role in providing us with the flexibility to respond better, faster and more cost-efficiently to the changing requirements of our customers.

As we form and grow our innovation culture and capabilities, we looked to continuously evolve our strategy. This ensured that our priorities were ambitious and our approach met the needs of our customers and stakeholders. In 2017, we refreshed our innovation strategy to reflect feedback that we had received from stakeholders trying to engage with us for idea and project development. Alongside this, we challenged ourselves to improve our own processes and procedures and undertook a total refresh of the way we innovate at UK Power Networks. We were driven by our desire to make it easier and more accessible for customers, companies, innovators and general stakeholder to engage and collaborate with us.

Following these changes and our laser sharp focus on outcomes-based innovation, we now have a deep culture of innovation embedded throughout our organisation. This culture is underpinned by our talented, dedicated and highly collaborative innovation team who work as one with teams across our organisation on projects that deliver practical value and outcomes for our customers.

Our most recent innovation strategy was published in January 2020, at a time when the opportunities and challenges facing electricity distribution have never been greater. The strategy focused on our ongoing approach to react to customers' needs and desire to continue to innovate in order to make our services more reliable, more affordable, easier to connect to, cleaner and safer.

As set out above, we have been on a journey of continuous learning and growth since our first innovation strategy in 2014. Throughout this journey, we have developed an industry leading track record of successfully undertaking and delivering innovation projects which deliver savings to our organisation and our customers. We believe that our innovation journey to date, guided by our innovation strategies, has set the foundation and building blocks to foster innovation across our business as part of our business as usual processes.

# What our stakeholders are telling us

We have a range of stakeholders that we continually interact with on innovation. As we move into RIIO-ED2, our range of stakeholders will increase as we innovate in new areas relating to consumer vulnerability, Net Zero and the whole energy system. These stakeholders are helping us to shape our current innovation strategy and our aims forward. This has included the commitments we have made along with other energy networks in the EIC Innovator Charter around collaboration, responsiveness and pace. It has also informed our pillars of innovation.

## Deliver value to customers from proven innovation

Our stakeholders have told us that our innovation should continue to deliver the greatest impact and that includes financial as well as environmental and societal benefits. Our Innovation portfolio has delivered £52m benefits in 2020/21, growing our overall RIIO-ED1 innovation savings to over £284m. We have started to use a social return on investment (SROI) tool to calculate the benefits our projects deliver more widely than our previous CBA tool.

## Collaborate to unlock industry challenges

Consistently, stakeholders told us to continue our efforts to collaborate with regional cross-vector networks. Over this year we have continued to collaborate with other energy networks, with 21 collaborative projects underway. We are working with a wide array of companies from small start-ups to large multi-nationals. We sponsored the Northumbrian Water Limited Innovation Festival to get involved in innovation in other utility sectors and to co-create a digital solution for us with partners. We have also signed up to the EIC Innovator Charter and are continuing to improve our ways of working and communicating to reflect the feedback we have received over the year.

## Target greater societal good through Innovation

There is a unanimous view from our stakeholders that the overall innovation funding should be increased due to the bigger challenges we as a society and electricity network operator will need to address. They told us that we have a strong role to play in scaling-up and tailoring solutions for different customers segments, so that everyone is supported along the road to Net Zero. We are responding by increasing our focus and portfolio of innovation projects to understanding and facilitate Net Zero faster and at a lower whole system cost. We are also growing a portfolio of work on the topic of customer vulnerability to ensure nobody is left behind along the way.

## Embed innovation deeper into our business

Our stakeholders have told us that we should continue to innovate in core business areas such as network reliability, and that we should embed that innovation activity and culture deeper within our business. This includes focus on proactive optimised assets and practice areas and making sure that we bridge the gaps between our innovation team (and activities) and our business as usual operations. We are doing this through using our MyIdea portal to gather ideas and facilitate discussion around innovation across our business.

At grass roots, our operational directorate is deploying a mission directed work teams' methodology to improve efficiency and empower staff at every level to innovate and improve our business. We are also improving communication and transparency around our procurement processes to ensure that anyone getting involved in an innovation project can see the route to deployment should the project prove successful.

# Collaboration is more than words

Our focus has always been on collaborating with our stakeholders, which include other Licensed Network Operators (LNOs) to deliver positive change and benefits for our customers and stakeholders.

We believe collaboration is key to successful innovation, and successful innovation leads to benefits to customers. The challenges we face to reach Net Zero are too big for any one organisation or even sector to manage alone – that's why collaboration is vital for innovation to have an impact and deliver tangible outcomes for our customers.

That belief has formed a key part of our innovation journey in RIIO-ED1. It ensures that we have the right people and the required skill sets in each project, delivering the greatest opportunity to succeed. In 2020/21, we have conducted more than 60 external innovation sessions to connect with the industry. This allowed us to work on a variety of projects with various stakeholders, including traditional technology vendors, software start-ups, energy suppliers, vehicle and fleet operators, local public bodies and the Government's Department for Business, Energy and Industrial Strategy (BEIS) to name but a few.

The rate and scale of change to the energy system anticipated by rapid decarbonisation means we cannot do this alone. That is why this year the Energy Innovation Centre (EIC) member companies took the unprecedented step of formulating a charter to collaborate more with each other and third parties. The Industry and Innovator Operating Charter demonstrates our commitment to continue to improve how we work with innovators. It focuses on a recognition that we need to respect our innovator community and provide them with a great service, as we do our customers. To achieve this, we will change how we do business to make it easier for innovators, particularly SMEs, to work with us. We will improve our processes, make decisions on proposals more quickly, provide better guidance and give clear feedback as required. We are changing our culture in this way, with our commitment to achieve Net Zero together, and promote the contribution innovators make.

> “Collaboration ensures that we have the right people and the required skill sets in each project, delivering the greatest opportunity to succeed and deliver benefits to our customers.”

**Ian Cooper**
Innovation Lead – Opportunities & Bid

## Case Study
### Net Zero Ready – CommuniHeat

To transition a whole community is complex, especially in an efficient and co-ordinated way, so we worked with partners in Barcombe, an off-gas grid village in East Sussex, to develop a repeatable playbook for other off-gas grid communities to follow.

Working with Community Energy South, Buro Happold and Lewes Council, we engaged with over 600 individual households and businesses, including the wider community via digital town-hall meetings, to understand their needs and challenges, identifying customer journey improvements and evaluating the benefits of a locally coordinated transition. We installed energy monitors in 50 homes to assess the customer comfort and associated network impact of transitioning to electrified heat alongside other low carbon technologies such as EVs and solar panels. This approach could now be replicated to benefit our 340,000 off-gas grid and wider GB customers who are yet to transition.

OVESCO

BURO HAPPOLD


*"Decarbonising heating systems is crucial to tackling the UK's greenhouse gas emissions and I'm delighted that Barcombe is leading the way to demonstrate how to make the decarbonisation of heat a reality. It is fantastic to see UK Power Networks passionately collaborating with a range of stakeholders, to ensure they support rural constituents like mine to decarbonise as quickly and efficiently as possible."*

**Maria Caulfield**
MP for Lewes Constituency

## Case Study
## Future Ready – Shift

To deliver Net Zero at the lowest cost to customers, we need to look at options which incentivise customers to shift their energy use to when it is cheaper and greener to do so. We need to better understand consumer behaviour to design attractive flexibility products to maximise participation and value.

We partnered with forward-thinking energy companies to develop and run UK-first trials of a range of smart charging products, with over 2,000 EV owners in control of how they respond to financial incentives.

Through trials, we identified that 7.5% of customers chose to manually charge their car more often than they chose to follow the automated smart charging schedule. This insight validates that a small but significant number of customers want to stay in control of their EV charging and allows us to factor this real-world behaviour into our network planning.

We worked with our partners to survey customers and understand which aspects of behaviour can be influenced through proposition design. The insights will help us develop products that optimise existing network capacity, minimising cost and customer disruption.

Our insights into real-world customer behaviour are now informing policy and flexibility services for domestic consumers in ongoing V2G trials with Octopus EV. A total of 2,000 customers saved 33% on their EV charging bill in our domestic smart charging trial over the course of the last year.

New revenue streams available for EV customers thanks to new commercial products for V2G trials, supporting the business case for electrification of transport.

> *"UK Power Networks' market-led approach is innovative and supports widespread adoption of smart charging, which is a win for customers by reducing energy costs, a win for the network by reducing congestion, and a win for society by supporting a zero-carbon grid."*

**Nick Woolley**
CEO and co-founder of ev.energy


*Figure 1: Relationship between Shift trial participants.*

## Case Study
### Efficient & Effective – Storm Resilience

We developed an artificial intelligence system designed to predict the impact of a storm on the electricity network. 'Storm Resilience' is using a machine learning algorithm to help control room staff decide where to send engineers, so they are ready to respond as storms hit. The project combines sophisticated machine learning techniques with historical power cut data to forecast the impact of gale force winds and storms on overhead power lines. It is helping the network to prepare for such weather, including moving engineers into the optimum places so they are poised to restore power supplies faster. A separate part of the project will trial lightning tracking software that could help restore power supplies caused by lightning strikes up to 90% faster.

Lightning strikes hit the ground about 300,000 times per year in the UK. Protection devices usually prevent the line being damaged so it can be re-energised to restore power supplies. If the location of the strike is within 1km of the faulted circuit (this value is arbitrary and can be made larger or smaller) then the software will assume it has caused the fault. In addition the lighting strike must be recorded within 60 seconds of the fault occurring, this assumes there is delay between the fault and the lightning strike being reported to PowerON.

If successful, the new system will mean when a lightning strike trips a circuit, the control system quickly knows the grid coordinates of the location and can then automatically restore customers' supplies in under three minutes – much faster than the current time of up to 30 minutes.

*"We are excited to partner with UK Power Networks on this innovative and dynamic use of weather data. At DTN, we are committed to empowering our customers with actionable insights that help them manage their operation's weather risks. UK Power Networks application of storm impact analytics is showcasing the future of utilities to mitigate impact and optimise restoration and recovery efforts."*

**Michael Eilts**
DTN senior vice president-weather

### Collaborate to innovate

We also worked with the EIC to gather common innovation ideas and identify better ways to collaborate with other electricity, gas and regional water networks. Our executive team attends regular board meetings with other senior EIC innovation members to discuss innovation and collaboration across the utilities industry. Our Innovation Management team attend DNO forums held by the EIC on a quarterly basis, to discuss strategic focus for innovation with other electricity networks, as well as gas and water utilities. Accordingly, a strong collaborative culture has meant that since the beginning of RIIO-ED1, 75% of our NIA funding has funnelled to third parties, with 38% of projects happening in direct collaboration with other LNOs.

Internally, we have constantly aimed to bring thinking from outside the sector and work collaboratively with our internal teams to deliver innovative solutions. For example, our analytics team took machine learning experience gleaned from technology disruptors like Netflix and Amazon to develop an advanced machine learning tool for customer connections. Our innovation team also worked with the analytics team to combine three years of customer feedback with our own internal performance data in order to create a predictive algorithm to flag potential dissatisfaction in each unique customer's journey before it happens. We demonstrated that the algorithm could achieve a 91% accuracy level and it continues to learn and improve as more data is added to it. We provided this tool to our customer service teams and displays recommendations prioritised each day to support early interventions and avoid dissatisfaction. This not only improved productivity of our customer facing teams but, moreover, helped to shape the conversation our staff have with customers, providing each customer with a more tailored and empathetic service.


*Figure 2: Signatories to the EIC Innovator.*

EIC

Collaborate to innovate

## INDUSTRY AND INNOVATOR OPERATING CHARTER

### As Industry Partners of the EIC, we will:

1. **Conduct our business with Innovators in a way that is supportive and engaging for Innovators, recognising the shared need to deliver increased value to energy customers.**
   - Develop a cross-industry Innovator induction pack which provides clarity of likely processes and timescales when collaborating.
   - Develop a transparent communication channel, where Innovators can easily access support and voice their concerns about a collaboration they are engaged with.
2. **Foster a culture of ambition and innovation with sustainability and value to customers at its heart and an emphasis on what can be achieved through collaboration with Third Party Innovators.**
   - Through the Innovation Measurement Framework, ensure that innovation provides customer benefits.
3. **Work in collaboration with other Industry Partners to provide Innovators with a deeper understanding of the specific needs and priorities of the energy industry, supported by open data initiatives.**
   - Through the EIC, gain a greater understanding of Innovators needs, providing a more responsive service to the Innovator Community.
4. **Operate efficient and effective processes to a common set of standards that will reduce barriers to entry for Innovators, increase consistency, and reduce the costs, time and complexity of engaging with Innovators.**
   - Create industry standards / guidelines that reflect best practice in innovation that has Innovators at its heart.
5. **Make decisions in a timely manner in accordance with good business practice, recognising the needs of Innovators.**
   - Transparency and commitment to making key decisions on innovation within realistic timescales.
   - Agree an escalation process when guidelines or timescales are not met.
6. **Support and promote the contribution made by Innovators to the energy industry in its journey to Net Zero.**



*Figure 3: The EIC Industry and Innovator Operating Charter.*

Net Zero Ready

# Project Highlights

The world has changed this past year but the target to bring all greenhouse gas emissions in the UK to Net Zero by 2050 has not. Climate change remains one of the greatest challenges facing our generation and generations to come. We all have to act now before it is too late.

Across the globe everything from our economies to our way of life has changed because of the pandemic. For those fortunate enough to still be employed, our places of work have changed. Alongside travel restrictions, this has led to changes in transport patterns and behaviour such as new vehicle sales. How, when and where we consume energy has also changed. Meanwhile, the impact of climate change has become increasingly visible. Our customers demand action.

We are responding through our actions. Change breeds uncertainty, which is reflected in our **Distribution Future Energy Scenarios (DFES)** published in December 2020. Our response must remain flexible, agile and innovative. We stand ready to make the most of the opportunities to build back greener as we emerge from the pandemic, whilst ensuring these opportunities are available to all.

The UK Government released their **10 Point Plan** for a Green Industrial Revolution in November 2020, shortly followed by their **Energy White Paper** in December 2020. £12 billion of government investment in renewable electricity, low carbon heating and transport will follow. Schemes like our **Green Recovery programme** launched in February 2021 are seeking to kick start the low carbon economy.

The government has banned sales of petrol and diesel cars by 2030. Regional and local government and communities have set even more ambitious targets. Some, like London, are targeting Net Zero by 2030. Car manufacturers are committing to stop sales and manufacture of petrol and diesel cars sooner than 2030. Rapid divestment in fossil fuels mirrors increasing investment in renewables.

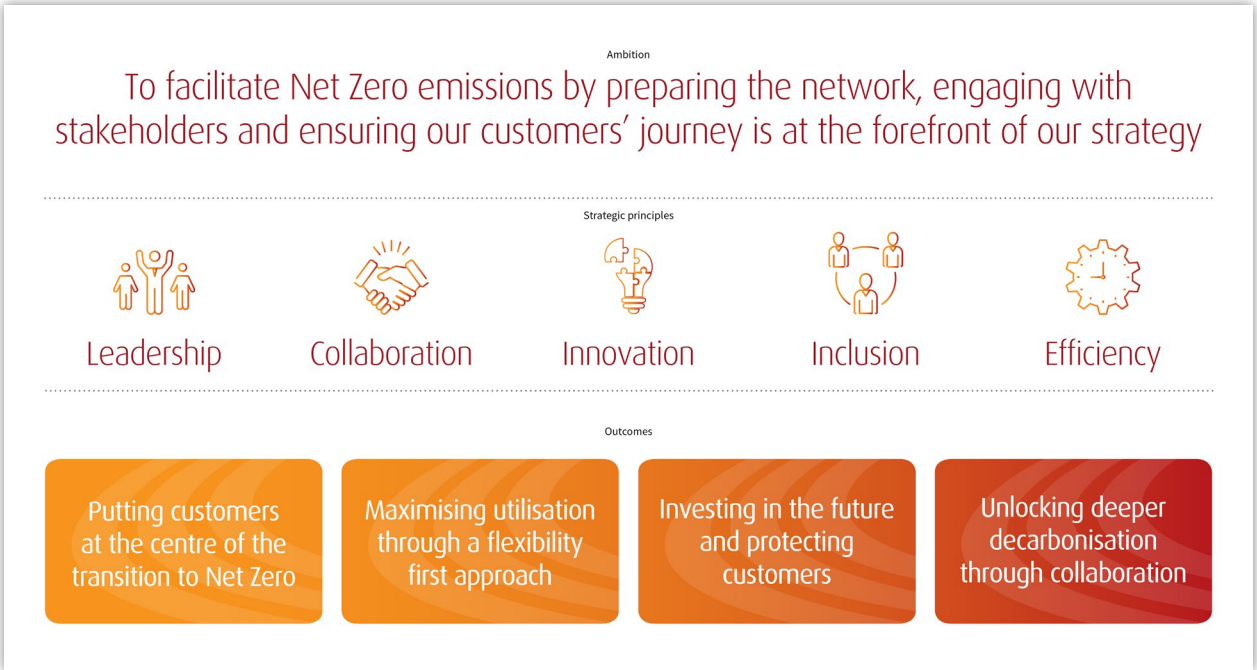


*Figure 4: Leadership, collaboration, innovation, inclusion and efficiency are integral to helping us facilitate Net Zero.*

Our innovation strategy aims to address the challenges whilst ensuring we respond at the pace of the fastest of our stakeholders. Technologies, such as renewable energy, Electric Vehicles (EV) and low carbon heating are all at different levels of maturity and evolving at different speeds. We must keep pace if we are to continue to be an enabler of change. Neither must we leave anyone behind in the transition.

Our innovation portfolio is as diverse as the challenges we collectively face, demonstrated by the breadth and depth of our highlights selected below:

**CommuniHeat**

Fossil-fuel based heating accounts for around a third of UK carbon emissions. For the CommuniHeat project we're working with the community of Barcombe, East Sussex, to understand the most efficient, reliable and effective way rural communities can transition to low-carbon heating. Our ambition is to create a blueprint that ensures comfort, affordability and resilience for the four million off-gas grid properties in the UK. Alongside community groups, local partners, and over 600 households we are researching and comparing approaches to reduce the village's carbon emissions from household heating. Taking a step towards achieving Barcombe's goal of becoming the first Net Zero village in the UK.

**Charge Collective**

The mass adoption of EVs has started to gain pace. As of March 2021 there are an estimated [149,000] EVs registered within our network area our DFES scenarios forecast up to 4.5 million by 2030. However, areas of market failure remain and may prevent this forecast being realised. A lack of on-street, easily accessible charge points is one of the biggest challenges for drivers who do not have a driveway and might want to switch to an EV. Charge Collective is a collaborative project aiming to demonstrate how we can work together with Local Authorities to plan local, public charging networks in areas at risk of being left behind in the transition. We are designing and trialling an intervention to enable investment in this area in a way that is fair to customers and addresses the high connection costs currently faced by charge point developers.

**Voyage**

Engagement with customers and other stakeholders tells us that another critical barrier to EV adoption in the UK is a lack of confidence in accessible en-route rapid charge points. Motorway and major A-road service areas are key strategic locations for the wide scale roll-out of high powered EV charging infrastructure. The Voyage project plans to design and install a compact scalable supply solution that addresses the high cost of conventional solutions as well as reduces the time to install and the space required for the solution. We are working with charge point developers to ensure they only pay for the capacity they require in line with the different stages of EV uptake and charge point utilisation. At the same time minimising the on-site disruption to service area owners and operators. Ultimately working towards the goal of giving existing and future owners of EVs the confidence of ubiquitous access to high powered en-route charge points.

**Socially Green**

Consumer behaviours are changing. New technologies – such as renewable energy, battery storage, EVs and heat pumps – are evolving. New energy markets are appearing and the energy system is digitalising. Socially Green aims to understand how we can continue to serve the needs of customers from all backgrounds and include those in vulnerable circumstances in this changing energy world. For the project, we are looking ahead to analyse and understand what the future might look like for customers who may be disadvantaged. Working with consumer groups and stakeholders we are conducting both qualitative and quantitative research as well as trialling new methods of supporting customers to test their effectiveness and create a fair, accessible energy system for all.

**Constellation – NIC**

Our DFES scenarios forecast that up to 8.6 GW of distributed electricity generation is expected to connect to our networks by 2030. Whilst this increase is necessary to achieve Net Zero, it will have a significant impact on the stability of network operation. The Constellation project will demonstrate a novel approach to protection and control by introducing local intelligence in DNO substations. We expect this to reduce the risk of system wide frequency events and the cost of system balancing, protecting our customers and the smart flexibility services we will rely on to operate the network. It supports achieving Net Zero through unlocking network capacity for Distributed Energy Resources (DERs) to connect and provides an environment for quick and scalable deployment of smart network functionality as software.

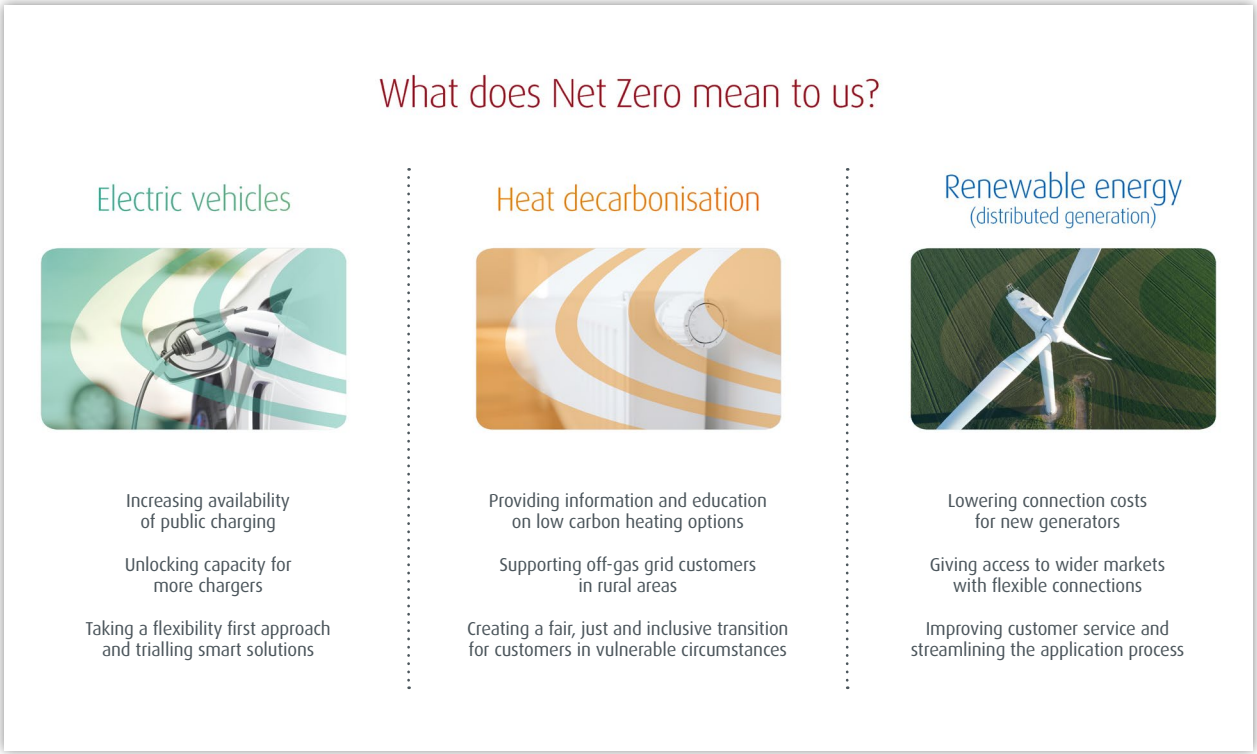


*Figure 5: Our key objectives to facilitate a Net Zero future.*

# CommuniHeat

**Background**

Residents in Barcombe, East Sussex, are helping UK Power Networks to create a model roadmap for 'greener' home heating that will in time show the way for other communities to follow suit.

Fossil-fuel based heating accounts for around a third of UK carbon emissions, making decarbonising heat a vital part of the UK's legally-binding commitment to reaching net zero carbon emissions by 2050. Across the UK, there are four million properties like those in Barcombe which are 'off-gas grid', meaning residents burn fossil fuels such as oil for cooking and heating. This produces significant carbon emissions and is expensive.

The CommuniHeat research aims to best understand how Barcombe and similar communities could switch to low-carbon heating using electricity. It will explore the potential value of a coordinated local area energy planning approach in delivering value to both the customer and DNO as compared to an uncoordinated or piecemeal approach. We are working with local community group Ovesco to host digital community events and engagement to understand residents' needs and opinions from over 600 households that are involved in the project. Our other project partner, Buro Happold, will create a digital twin for the village and other simulation models to forecast the impact of electrifying heat. We expect this to create a sustainable, replicable model for Barcombe that could be applied in other parts of the country.

Through the coordinated approach to electrify off-gas grid rural communities, CommuniHeat expects to deliver £200,000 savings to decarbonise Barcombe village, and an estimated £114 million to decarbonise off-gas grid customers in the UK Power Networks area.


*Figure 6: Heat pump in a Barcombe home.*

**Experience To Date**

The project has reached over 600 Barcombe households through our various local communications and project website. This has drawn many of the residents to interactive webinar sessions to learn more about CommuniHeat and what it could mean for them.

To forecast the impact of electrifying heat, 50 home energy monitors have been installed in the village, enabling the development of simulation models. Furthermore, we are completing home surveys in up to 200 households to inform the varying heat demands of different types of properties based on factors such as size and occupancy. This will further contribute to developing an accurate picture of household heat demand, by feeding into the creation of a digital twin. This will enable residents and the local authority to graphically see and interact with a system that shows factors such as the heat load, EV loads, renewables in the area, and carbon usage.

**Future Developments**

Data from the newly-installed meters will offer new insights into how residents currently use their energy. With this new information, we will run advanced simulations for different approaches to installing low carbon electrical heating. The simulations will investigate the costs, efficiency, and electricity network impact of multiple different approaches and technology options. This includes shared district heating and medium sized heat pumps serving a few properties, or individual heat pumps installed at each property.

The project will then look at potential community finance models for making the switch and analyse how other low carbon technologies like electric vehicles and solar power could play a role. With a clear plan in place, residents will understand what a zero carbon future could look like, and it will enable UK Power Networks to plan effectively for coordinated decarbonisation of off-gas grid communities.

**Project Lead: Ashita.Anand@ukpowernetworks.co.uk**


*Figure 7: Dashboard photo of Barcombe Interactive Digital Twin.*

# Charge Collective

**Background**

Our projections forecast up to 4.5 million EVs within our licence areas by 2030 and around half of those will be parked on street. Customers will require public chargepoints to serve their home charging needs, and providing these will need close coordination between distribution networks, local authorities and chargepoint operators.

Low provision of public charging infrastructure in the UK has been identified as a significant barrier to growth of the EV market. Investors in chargepoints face high capital costs (driven by network reinforcement and sole use asset costs) and policy and regulatory barriers that exacerbate market failures. These failures reduce investment in chargepoints to below levels required to meet UK carbon budgets and the Net Zero target of 2050.

Stakeholders have said that DNOs should go further in addressing the cost barriers: 74% of respondents to UK Power Networks' 2019 EV strategy consultation expressed this view. However, a network solution that could help tackle upfront connection costs and cut through market, co-ordination, social challenges does not exist for the on-street charging segment. In addition to this, once these chargepoints are connected to the network, it is unclear how much flexibility EVs charging on-street can provide to the distribution network. This limits the opportunity to rely on the EV flexibility market to optimise network capacity utilisation.

Charge Collective is designing and trialling an intervention to enable investment in this area in a way that is fair to customers and addresses the high connection costs currently faced by chargepoint developers. The aim is to ensure that drivers have the confidence to switch to EVs, regardless of where they live or park. By sharing data and expertise, the local authorities will help UK Power Networks to identify charge point blackspots. The project will also assess the potential for smart charging solutions in an on-street context to manage network load.

*Figure 8: An EV charging.*

**Experience To Date**

We have partnered with Cambridge City Council, Cambridgeshire County Council, Norwich City Council, Norfolk County Council and the London Borough of Redbridge to help ensure that nobody is left behind in the transition to EVs.

We have developed a robust and replicable methodology for identifying charging blackspots that would benefit from the provision of public chargepoints. This methodology combines quantitative data and qualitative local insights to allow us to work with local authorities to help build a truly local plan for public residential charging. We have then looked at these sites from a network perspective to see what network reinforcement is necessary to facilitate the chargepoints.

The three areas identified for the trial are densely populated urban centres, where network capacity will be stretched by the future large-scale adoption of low carbon technologies (LCTs). The addition of numerous chargepoints to the network, especially rapid chargepoints, will require network reinforcement in the form of secondary substation upgrades and LV mains extensions. By undertaking a coordinated approach to planning chargepoints in the trial areas, the aim is to 'dig once' by future-proofing these network reinforcements, to allow these areas to connect not only the planned EV chargepoints but additional LCTs in the future.

We have also undertaken customer engagement through a large scale survey focused on drivers within our licence area who park on-street, alongside focus groups within two of our trial areas. This engagement has strengthened the evidence base for our approach, as well as guiding our work with the local authorities to plan the local charging networks.

We have engaged extensively with chargepoint developers, Ofgem and procurement colleagues to design a new commercial model for incentivising investments in these areas of market failure. Cambridgeshire County Council has begun the procurement process for chargepoint installation, and an application has been submitted for the network reinforcements to be fully funded under our Green Recovery programme. We are working with Ofgem on an approach to refine this funding model later in the year.

**Future Developments**

We will continue to work with our local authority partners to design and trial the new commercial model for incentivising investments, through a competitive tender to determine the level of connection costs chargepoint investors are willing to incur. We aim to complete the network reinforcements this year and next, with the chargepoint installations to follow shortly afterwards.

We will then evaluate the outcome of the competitive tenders and what this means for future areas. We will develop a thorough cost-benefit analysis of the approach that will include measuring the wider environmental and social benefits of better air quality and reduced emissions that come with increased uptake of EVs.



We will research the barriers and opportunities to smart charging in an on-street context, including the development of a selection of use cases and commercial models for on-street flexibility services. We have the opportunity to assess these through a real world trial later in the year.

We also plan to share these learnings with other DNOs and local authorities, to increase collaboration in this space and to help local authorities meet their Net Zero targets.

**Project Lead: Shira.Lappin@ukpowernetworks.co.uk**

# Voyage

**Background**

The wide scale roll-out of high powered EV charging infrastructure is seen as a key enabler for accelerating the electrification of the transportation sector. Giving existing and future owners of EVs confidence that they will have access to high powered chargepoints (150 – 350 kW) ubiquitously in a similar manner to fuel station access for conventional vehicles.

Motorway service areas (MSAs) and service areas in major A-roads have been identified as a specific area in which the roll-out of high powered EV charging infrastructure will be important to build range confidence in consumers. In their Energy White Paper published in December 2020 the UK Government expects around 2,500 high powered chargepoints across England's Strategic Road Network and has committed £950 million to achieving this target.

Most of the small/medium sized sites are currently connected to the 11kV or LV network with typically no 33kV network near-by. Extensive network reinforcements are required to bring additional capacity to the site to power the high powered chargepoints. The conventional solution to providing the increased capacity is typically high in cost, time consuming and has a large footprint when space in these areas is limited.

Project Voyage focuses on developing and trialling a standardised substation that can be delivered in kit form which is compact, lower in cost and faster in delivery to support the nation-wide mass roll-out at small/medium sized MSA sites and service areas on major A-roads. The scalable design allows locations to add capacity in 1.5 MVA blocks to match growing demand or to accommodate multiple CPOs (Charge Point Operators). Lowering upfront investment whilst providing flexibility to expand. If proven successful, the compact kit form substation will be made available to the market for rapid deployment.

**Experience To Date**

Engagement with stakeholders (BP, Energy Management Ltd, Ecotricity) has taken place to test our assumptions and gather the key requirements from a customer's perspective. These are mainly:

- 1 – 2 MVA capacity meets short/mid-term requirements
- 7 – 8 MVA capacity meets long-term requirements
- Space at all locations is at a premium
- Scalability is welcomed as customers only want to pay for capacity they require in line with the different uptake stages of EV and utilisation of charge points.

This has led to the co-creation of two new substation designs:

- LV supply solution: A compact unit substation consisting of a Ring Main Unit (RMU), 1.5 MVA or 850 kVA transformer and a distribution board
- HV supply solution: A compact substation consisting of 2 x RMUs and a metering unit with a supply capacity of 7.6 MVA at 11kV

Both substations have been designed to fit within a standard parking space reducing their footprint by 20-50% compared to a traditional solution thus maximising the use of space for charging requirements. We have undertaken extensive internal engagement to ensure the solution is compliant with industry standards and it can be delivered in a kit form for rapid deployment. The main components are the pre-cast concrete base, electrical equipment (RMU, transformer, metering unit, etc.) and the Glass Reinforced Plastic (GRP) enclosure. The pre-cast concrete base will be delivered and installed first, then the electrical equipment installed and finally the GRP enclosure landed on top. The use of the pre-cast concrete base will allow on-site work to be reduced by at least two weeks compared to a conventional cast-in-situ concrete method thus minimising on-site disruption and cost.

In addition, the scalable design allows the two solutions to be utilised in a scalable configuration. Bulk network capacity (7-8 MVA) can be provided to the site using the HV supply solution initially. As the uptake of EVs, utilisation of charge points and number of charge point operators increases the LV supply solution can be rolled out in 1.5 MVA blocks.

The project team has agreed to trial a prototype HV substation with a charge point operator, supplying 11kV power to the Thurrock motorway service area. The offsite build of the prototype pre-cast concrete base and GRP enclosure is currently underway. Consultation with the charge point operator, their appointed Independent Connection Provider (ICP), the motorway service operator and the landlord was necessary to finalise the on-site design and gain the installation consents required.

**Future Developments**

The project team will carry out site preparation work at the Thurrock motorway service area and complete the installation and commissioning of the prototype HV substation. In parallel, the network extension works to bring capacity to the site will be carried out in preparation for the trial which is expected to commence in May 2021. The operational performance will be monitored and the results disseminated over the six-month trial period. If proven successful, the compact substation design will be published in UK Power Networks' G81 Technical Library making it widely available to the market. The project team will also finalise the design of the LV solution and explore opportunities to trial a prototype unit.

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*Figure 9: 3D rendered image of prototype substation at a MSA.*

# Socially Green

**Background**

As we transition to a distribution system operator (DSO) and customers choose to interact with the network for services beyond traditional touchpoints, it is important that we review our services to address the needs of all customers in order to avoid exclusion. Socially Green aims to understand inclusivity and fairness in the changing energy sector through research, stakeholder feedback, data analysis and trials.

The project is focussed on reviewing the needs of all customers including those in vulnerable circumstances, beyond the traditional definition of vulnerability, to inform the services that electricity network operators can offer in the transition to Net Zero by leaving no one behind. We expect this analysis to re-define the service provided to customers, open opportunities for partners to support communities, and improve access to low carbon technology for those who may be hard to reach.

Sia Partners was commissioned by UK Power Networks to support with delivering the Socially Green project in both the qualitative (phase 1) and quantitative (phase 2) analyses.

**Experience To Date**

The first phase of the project carried out an extensive literature review on consumer vulnerability based on both public documentation and previous work by UK Power Networks and Sia Partners. Based on these themes and market trends, a customer segmentation approach was proposed and then presented to key internal and external stakeholders, including charities, Citizen Advice, utilities and other organisations operating in the sector, for validation and feedback.

Three themes emerged from the research and engagement:

1. the importance of social infrastructure – defined as 'The range of activities, organisations and facilities supporting the formation, development and maintenance of social relationships in a community';
2. the importance of early action delivered through key partnerships – moving from acute spending/tertiary prevention to primary prevention in ensuring a successful and inclusive energy sector for all consumers; and
3. the need to move away from the terminology that focuses on customer qualities and into definitions around system failings in inclusion and access.

Further analysis was undertaken to explore these themes further. The reasons limiting customer inclusivity were identified as capacity, opportunity and willingness. These are intrinsically connected to key inadequacies from the energy system perspective that includes: lack of education, accessibility and trust.

Knowledge of the areas and type of access issues our customers face will help us target services tailored to the communities we serve.

**Future Developments**

Phase 2 of this project will develop tailored strategies and services – combining innovation, partnerships and internal business change.

The first step to enable this will be through the creation of an interactive map based on several public and internal data sets and can be used by other organisations that form the social infrastructure that can support all consumers in UK Power Networks' areas. The project will focus on mapping current services and partnerships to identify any gaps in service provision based on customer needs and predict future needs by area. This information will be used to inform our business as usual strategies but will also be used to identify new trial opportunities in communities that would benefit most from it in terms of social return on investment.

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# Constellation – NIC

**Background**
Constellation is UK Power Networks' newest flagship innovation project which will revolutionise the existing management and control models of traditional electricity distribution. It will introduce a first of its kind local intelligence and local intelligent operation at the substation level that complements existing functionality, in a sustainably cost-efficient manner for our customers. The project is delivered between 2021 and 2025 in partnership with ABB, GE, Siemens, the Power Network Demonstration Centre and Vodafone and was awarded funding in 2020 by Ofgem as part of the Network Innovation Competition (NIC).

**The problems it is exploring:** As part of our Net Zero aspirations, more of our customers may rely on electricity to travel and to keep warm, in addition to keeping the lights on. Therefore, it is essential to increase the whole system's resilience and reduce the risk of leaving our customers vulnerable and without electricity. We are keenly aware that we must do this cost effectively to avoid negatively impacting those already in vulnerable or fuel poor circumstances. To enable the transition to Net Zero at the lowest cost to customers, network operators need to employ smart services such as flexibility to allow quick and efficient connection of more Low Carbon Technologies to the distribution network. This means we are now seeking to procure flexible energy services and will employ this approach whenever it is the most cost-effective option for our customers.

**Network resilience:** As we increase our reliance on smart services provided by DER, there is a significant future risk to the network resilience. Previously the loss of distribution generation was of little consequence to the network operation, as it did not provide services in significant volumes to the distribution network. However, as we increase our reliance on DER to provide smart services, the loss of a high proportion of generation at the distribution level will reduce system stability and lead to an increase in disconnection events and potentially blackouts. More specifically, smart services are at risk of being impacted by loss of communication with our central systems or by unnecessary disconnection of DER.

**Network capacity:** The expected increase in DER required to achieve Net Zero will require significant amount of network capacity to be available in specific areas. However, our existing protection systems can limit the available capacity in some instances. Specifically, the directional overcurrent (DOC) protection, designed to protect the network from back-feeding faults, limits the amount of DG that can be connected. Our traditional solution is load blinding. This allows the protection to use a pre-calculated power factor to differentiate between network faults and generation/load. In the future, this will result in parts of the network having spare capacity which is not utilised to connect more DER to support our transition to Net Zero due to static protection settings.

**Digitalisation:** Current protection, control and communication functionality within substations come as dedicated hardware and require lengthy installation, commissioning and maintenance processes. The existing solutions are also hard to integrate and have limited flexibility to adapt their functionality. The Energy Data Taskforce recommend maximising the value of smart digital solutions, rather than solely relying on the mass deployment of equipment. As such, there is a growing need for single hardware containers hosting a number of flexible and easy to implement virtual (software) solutions.

**The solutions to solve the problems:** In order to overcome the limitations of our existing capabilities and facilitate Net Zero we need to enhance our local substations by making them more intelligent, digital, interoperable and enable secure, scalable communication between them. Constellation achieves this through a flexible and future proofed system for local intelligence working in partnership with central systems, which in turn, enables two distinct Methods.

**Method 1:** Local ANM – Local network optimisation at the substation level to provide resilience to DER operation against loss of communication with the central ANM system.

- Whenever the central system is unable to communicate with our local network assets, the local intelligence will take over optimisation for that specific DER, substation or area. This will enable the network to be operated more optimally, controlled locally, compared to using static set curtailment points of operation.

**Method 2:** Wide area and adaptive protection – Provide resilience to DG operation against transient instability events triggering the conventional generator protection. Dynamically assessed protection settings and enhanced wide area control to enable more capacity for DER connections.

- Sophisticated protection algorithms (potentially using R-GOOSE analogues) will be developed to identify when the DER should disconnect, if events have caused islanded operation. This will rely on economic, low latency communications via 5G slicing.
- We will develop the ability to provide real time protection settings information from the substation to validate and modify them. This will allow the load blinding application to adapt to the power flows on the network and correctly discriminate between genuine faults and generation/load.

**The benefits of the solutions**: We estimate that by 2030, the Constellation solutions could save customers in GB £132m in cost efficiencies. The project Methods also enable Carbon Savings of 1.9m tCO2 and will release an additional 1.98GVA of network capacity by 2030.

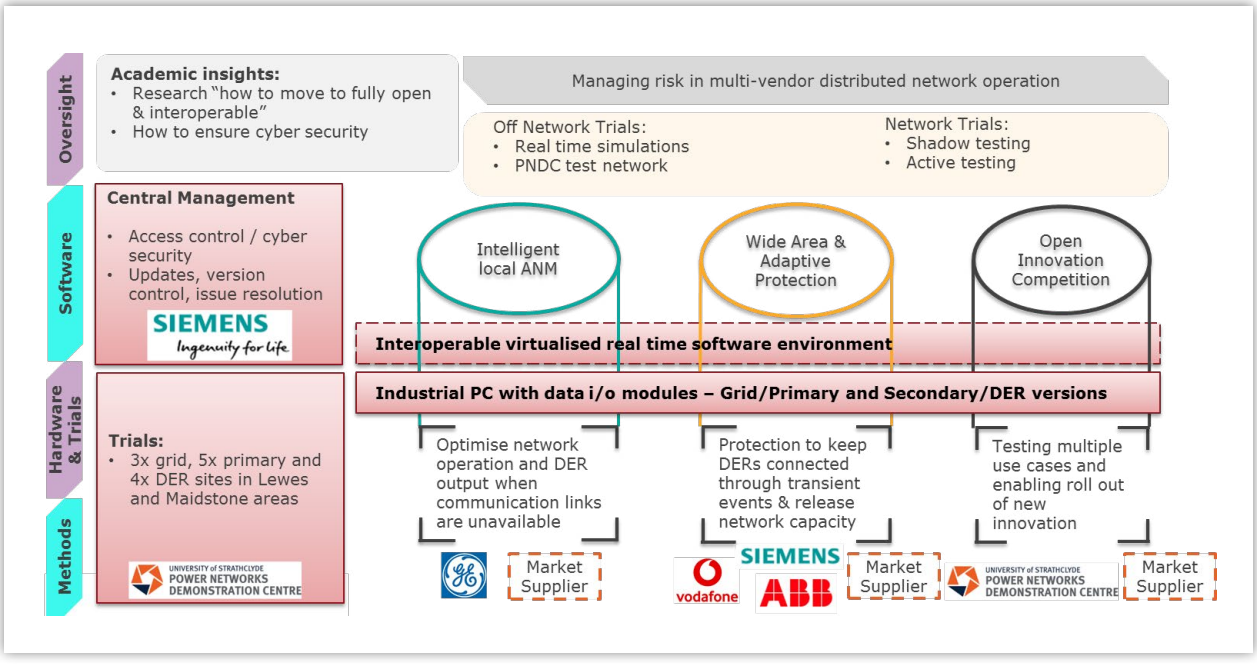


*Figure 10: Constellation summary diagram (with key partners for each Project element).*

### Experience to Date

Since the project has been awarded funding in December 2020, we worked closely with our project partners to ensure we were ready for kick-off in May 2021:

- Mobilisation – We have set up project teams which will lead the day-to-day progress within each partner organisation. Additionally, we have established access to the required technical expertise to successfully design and deliver the solutions.
- Legal agreements – We have identified and discussed the necessary funding requirements and expect to agree those in time for the project kick-off.
- Planning – We have set out the overall plan for the entire project, as well as the plan for the first year of delivery.
- Structure – We have defined clear scope and responsibilities across each partner organisation to ensure the project delivery is aligned.

Furthermore, UK Power Networks carried out the Unified Protection NIA project which will provide a starting point for the specification and design of the Constellation solutions.

### Future Developments

The project kicked-off in May 2021 following the formal approval of the collaboration agreement across all project partners. In 2021 the project team will work to specify the requirements for each solution, identify suitable trial sites and design each project Method. In 2022 the project team will develop all of the Constellation elements and in parallel prepare the trial locations. The trials are planned to begin towards the end of 2022 with the first testing in the Power Networks Demonstration Centre. Following that, the project will transition to testing on the electricity network until 2025.

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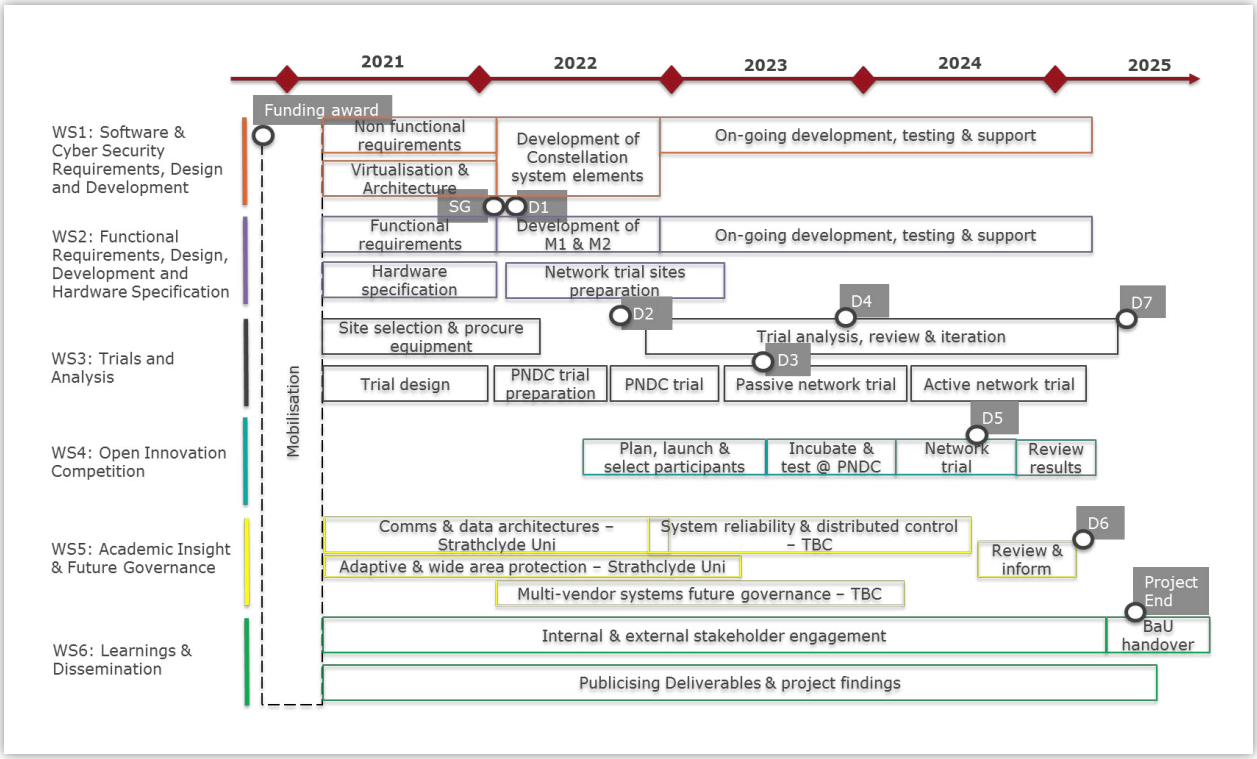


*Figure 11: High-level project plan for Constellation (D1 to D7 represent the Ofgem Deliverables).*

Future Ready

# Project Highlights

The second strategic focus area for our innovation portfolio is to create a future-ready distribution system. We must do this while continuing to recognise the financial, social and security of supply impacts of that change. This means meeting the needs of tomorrow's customers as they and their needs evolve. Future Ready is also about ensuring that no one is left behind in the energy transition towards Net Zero and covering the provision of new services involving DERs.

Within this innovation summary report, we highlight two NIC projects and three NIA projects in our Future Ready portfolio.

**Envision** (NIA) is exploring ways in which our own data can be used to model demand and enhance the visibility of our Low Voltage (LV) network. Using external data to enhance what we already know will allow us to build an even more detailed picture of what is happening on our network now and improve our service for customers. As more renewable energy sources connect to the network and more people switch to electric vehicles and heating, having exact data means we can plan targeted investment in infrastructure across our network at the right time and in the right places.

**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 generator in areas with limited network capacity. These generators have been able to connect more quickly and cheaply than would have been possible using traditional techniques. However, this project will manage curtailment cost-effectively and help us understand how we offer a better service for flexible connections as well as identify new customer revenue opportunities. This can be based on generation cost, creating price signals for future reinforcement needs to reduce curtailment and helping establish new solutions to curtailment from demand-response and storage operators. This year the project developed the detailed commercial design, presented the Energy Exchange concept to our stakeholders including individual DER, other DNOs, Ofgem, BEIS, National Grid ESO and market platform providers and finally developed a detailed market-simulation of the potential value of Energy Exchange going forward.

**Unified Protection** (NIA) is trialling 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 and will enable the use of a central system within a substation, instead of having local protection relays on each bay. If successfully demonstrated, the project has the potential to be scaled across all GB networks.

**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. The device allows much more generation to connect before the network needs to be upgraded due to fault level constraints. The design of the device also reduces the footprint compared to the existing fault level mitigation technologies. The project developed and energised the device in August 2020 and is currently under trial at a primary substation under a number of different running arrangements. 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 help keep down electricity connection costs for CHP customers.

**Power Potential** (NIC) is creating a world-first regional reactive power market to manage transmission voltage. 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. 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. 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. This year the project successfully delivered a series of live trials of the end-end services, developed new approaches to continue testing the Distributed Energy Resources Management System upgrades and delivered individual live technical trials of the automated services with each DER, National Grid ESO and UK Power Networks' Control Engineers.

However being Future Ready goes beyond our innovation portfolio:

- UK Power Networks has been recognised as having the smartest grid in the world and leading among UK DNOs in the international Smart Grid Index study by the Singapore Power Group. A smart grid is at the heart of the future sustainable energy landscape, enabling the transition to the net zero carbon economy for all at lowest cost
- We were the first DNO globally to offer flexibility at street level, enabling a wider range of organisations to take part in flexibility services by pooling residential flexibility such as EV chargers. To support growing participation, we provided simplified procurement information via our online Flexibility Hub, providing a one stop-shop for interested stakeholders. We proactively educated potential participants such as community energy stakeholders through tailored engagement sessions
- We launched our 2021 Distribution Future Energy Scenarios, featuring 1.6m forecast data points to analyse how low carbon technologies could be taken up in future. This included extensive stakeholder engagement with London Councils, Essex County Council and the Great South East Energy Hub. We also created an interactive data visualisation map with the Open Data Institute Leeds
- Building on the foundations of the Energy Data Taskforce, we launched our new DSO Dashboard. The portal unlocks unprecedented live insights into how power is flowing through our electricity networks to help a broad range of stakeholders. We launched the new platform in a 'beta' trial mode for now, with new regions such as London and more granular data to be added throughout 2021
- Since accelerating the launch of Flexible Connection services in 2019 thanks to our Active Network Management (ANM) capability, we have seen huge interest from customers who have rushed to secure flexibility capacity. We developed a digital Application Programming Interface (API) platform with leading smart battery company Moixa to automate flexibility activation, replacing traditional email dispatch and enabling flexibility services to be introduced and called upon more easily, supporting a resilient and efficient grid. Flexibility providers can now integrate to our systems 50% faster.

# Envision

**Background**

With the rise of renewables, decentralisation and the millions of connected devices on our network, it will take more than human intelligence to decarbonise the grid. To harness the benefits of the fourth industrial revolution, which centres on digital advancements, it is important we collaborate and experiment with stakeholders to solve emerging challenges using the latest technology.

Detailed 'visibility' of our network is critical as we plan ahead to facilitate a low carbon, Net Zero future. In simple terms, 'visibility' means collecting data about what is happening on our network at any given time. The data can include anything from how power is flowing through the network to where demand for electricity is high and at what times of the day.

As more renewable energy sources connect to the network and more people switch to EVs and heating, having exact data means we can plan targeted investment in infrastructure across our network at the right time and in the right places.

We are exploring ways in which our data can be used to model demand and enhance the visibility of our Low Voltage (LV) network. In partnership with CK Delta, Envision is developing a software based machine learning tool that will generate greater LV network insights faster and cheaper compared to traditional methods of physical monitoring. The project is a key step to widening the flexibility market and building a smart grid that enables cleaner, greener energy resources to connect quicker and at lower cost.

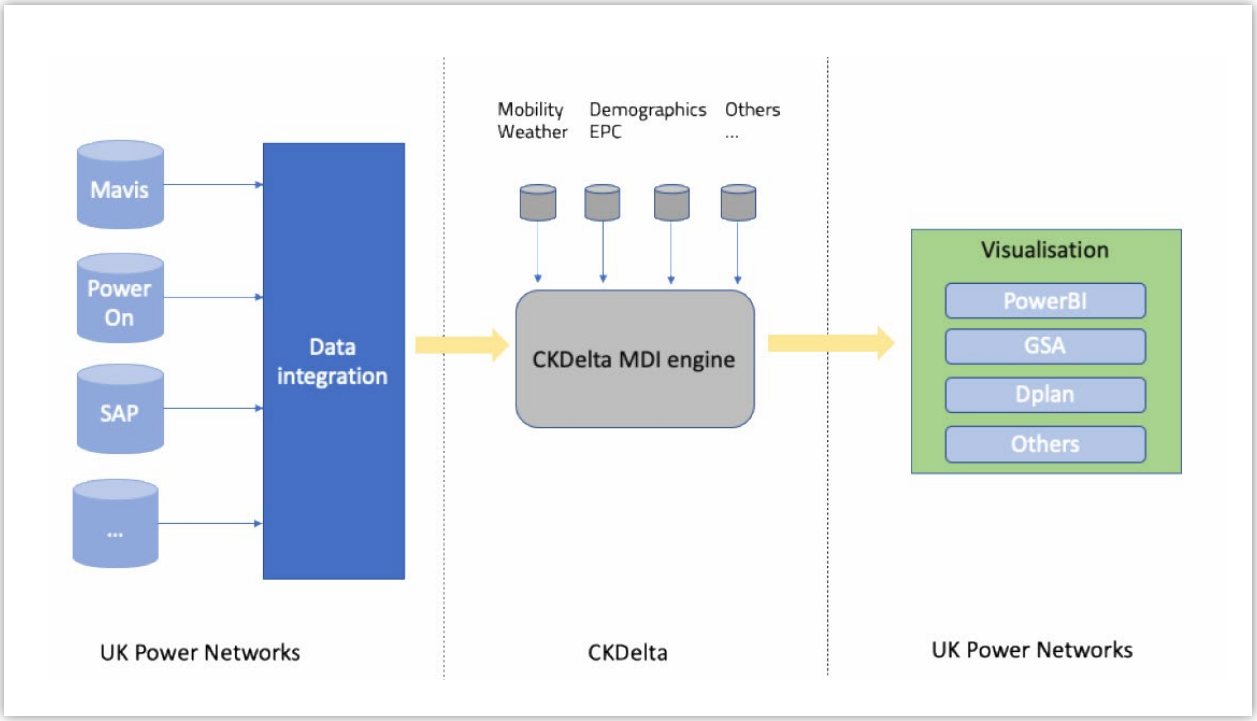


*Figure 12: A high level overview of how the machine learning ingests data from UK Power Networks, is analysed by CK Delta's engine, before a visualisation is produced. One such visualisation is seen in Figure 13.*

**Experience To Date**

Of the circa 117,000 substations UK Power Networks operates, only 10% have remote terminal units (RTUs) which help monitor load information and relay information back to us. The remaining 90%, require in-person visits to record data whenever this information is needed for network upgrades. Thus, there is a need to gain this insight into LV visibility in a more efficient and scalable manner.

We have proven that a machine learning model can be applied to gain estimates on maximum loads on substations, as seen in Figure 12. This was done by using 596 substations, of which 356 were used to train the model, another 90 were used to validate it, before the model estimated loads on 150 of the remaining. The results indicate which substations have a certain degree of available headroom remaining, as seen in Figure 13. Headroom is a term to describe the difference between present Maximum Demand Indicator and Maximum load. As maximum demand indicator tends towards maximum load, there is a need to reinforce the network.

Through extensive internal stakeholder engagement, we are currently assessing our existing systems and their respective data sets and further developing the data models necessary to allow us to monitor the remaining substations, automate data handling and improve the accuracy of predictions.

We are also exploring how much UK Power Networks would value visibility of connected DER from owners and operators of those resources. In simple terms, how much are we willing to pay third parties for the information they have on DERs connected to our network and associated electricity flows? This external data could form part of the data models for our software based LV visibility tool, but we are not ruling out other possible use cases. Thus far, we have concluded interviews with internal stakeholders, conducting 21 interviews with over 40 participants. Interviews with external stakeholders to determine available data and commercial models are ongoing.

**Future Development**

Once we have completed our assessment of existing systems and the data models are finalised we will adopt cloud based infrastructure to build our data lab. Allowing for the secure exchange of data between our systems and the machine learning tool. We will commence a wide scale trial of a comprehensive LV transformer estimation model providing a user interface to visualise and use the data and outputs. We will also explore whether we can offer Data as a Service commercially or share the data with the public as part of our open data initiative.

Meanwhile, we will wrap up our external data assessment with a report that sets out:

1. What data would be of use – in a practical sense – to UK Power Networks; why we may want it; what the counterfactuals are; what benefits it would bring; and what it may be worth.
2. What data DER manufacturers and aggregators have/could make available; what condition it is in; how they could convey it to UK Power Networks; and what it might cost to be able to do so.

If the data identified is available and the benefits can be proven a real-world commercial software demonstration will follow. A common cloud based "DER Data Gateway" will be developed loading data streams from multiple sources. Analysis tools and techniques will then be used to turn data into useful products for UK Power Networks' teams.

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*Figure 13: A map illustrating the maximum demand of various areas within London. The colouration of the legend indicates the amount of available headroom is available.*

# Energy Exchange: Market-Based Curtailment Management

**Background**

UK Power Networks' 'flexible connections' enable cheaper and faster connections for generators in areas with limited network capacity. Generally, a 'last in, first out' (LIFO) rule applies to restrict (curtail) generator output when there is a constraint on capacity. The rule is based on when different generators connected, not on minimising customers' lost revenue due to curtailment.

The Energy Exchange project has developed a commercial design for a more efficient and cost-effective approach - market-based curtailment management (MBCM). The scale of benefits depends on the participant mix, but our core simulation of generator trading shows a 43% reduction in total curtailment costs.

As well as reducing total costs due to curtailment, MBCM creates new market and revenue opportunities for the additional participants in constraint management – generators on conventional firm connections who are not normally curtailed, and demand customers including batteries willing to increase demand to prevent curtailment. A MBCM could signal where there should be future distribution network reinforcement to reduce curtailment, and encourage battery storage providers to locations where they can absorb and avoid curtailment for renewable generators.

Developing a market-based curtailment approach may become particularly important if there is a regulatory change to a 'shallow' connection boundary i.e. only pay for new sole-use rather than new shared assets at the time of connection, with the costs of reinforcement of the network to reduce curtailment as part of the ongoing network charges.

**Experience to Date**

Early stakeholder engagement in the project informed the choice of commercial market design, in which a market platform would enable flexible trading of MWh curtailment by settlement period. Stakeholders preferred this approach over trading of capacity access rights or peer-peer. Therefore, the project developed this into a detailed commercial design, including bid, dispatch and settlement approach.

The bid mechanism operates by ranking curtailment offers by their effective price in addressing a network constraint. Dispatch identifies how the ranking is implemented in how

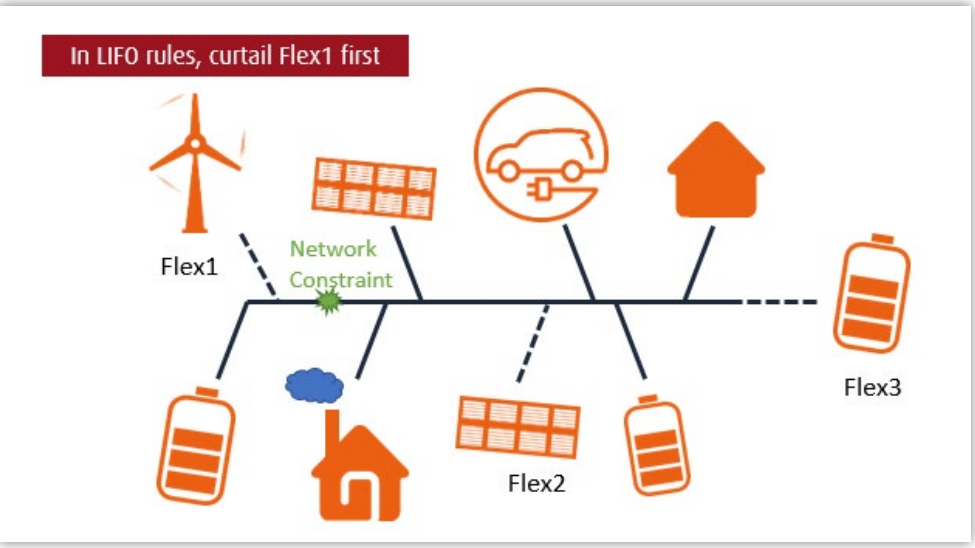


*Figure 14: Diagram explaining how MBCM could benefit connectees. In this figure, Flex1 would be the first generator curtailed due to a constraint as it was the most recent to connect, followed by Flex2 and Flex3. The other assets connected with solid lines are on firm connections. If MBCM was used, Flex1 could pay to avoid curtailment, which could then be taken by any other connectees on the circuit, taking account of both price and the effect of each customer's output at the constraint point.*

a constraint is managed. Settlement determines how participants are paid relative to not participating in managing a constraint (the baseline).

While noting the additional potential value of the market signals noted above, we set out to quantify how MBCM could reduce generators' total lost revenue due to curtailment. The project has identified three sources of enabled value:

1. Generators trade distribution curtailment to an efficient total cost and volume.
2. Demand customers, including batteries, increase demand to prevent distribution curtailment.
3. Generation and demand customers on the distribution network participate in managing curtailment on the transmission network.

Notably customers in our flexible connection zones are excluded from participating in managing transmission constraints via the 'Optional Downward Flexibility Management' service introduced in 2020 due to potential conflict in managing distribution and transmission constraints. Thus an open co-ordinated market-based approach could reduce transmission costs by expanding the participant pool with more distributed energy resources.

We used our Distribution Future Energy Scenarios, together with historic data on curtailment of flexible connections, to inform the potential value of Energy Exchange by developing a detailed market-simulation. Through this we identified that half of planned future generation connection capacity is earmarked for flexible connections, so the total curtailment is expected to increase. For such a case, the annual benefits from MBCM as opposed to LIFO range from £6,500-£27,000/MW of flexible connection capacity, with individual benefits highly dependent on the heterogeneity of the local generation mix.

The commercial design has been subject to an academic review by University of Cambridge, including an international comparison to confirm it was novel. This highlighted how generation curtailment and demand increase are separate but related products for constraint management. Academic analysis also demonstrated a new statistical approach to improve baseline estimates of curtailed energy.

We presented the Energy Exchange concept and our early insights to flexible connection customers at our regular customer forum, and to other key stakeholders including electricity network operators, Ofgem, BEIS, DER and market platform providers. The feedback received was generally positive with some suggestions that have been incorporated into our plans. These include ensuring that bids can be made for partial capacity, that an API approach rather than hardware approach will be developed to enable participation, and estimating carbon impacts.

We are currently working on long and short-term considerations for implementing MBCM in all flexible connection zones. This work has featured in our scoping activity for a proof-of-concept trial of Energy Exchange, which is based on enabling market-based curtailment in our South Eastern Power Networks licence area to more efficiently manage more than £1m of curtailment due to planned outages in the late summer. It will demonstrate the principles and market appetite, in advance of full technical and commercial system development. We have already developed the potential Heads of Terms and Market Procedures, and are now assessing how to implement this.

**Future Developments**

95% of DER attendees at our Winter Flexibility Forum said that we should build Energy Exchange into our RIIO-ED2 plans, or that they would like to participate in a trial in the next year. In Q2 2021, we will decide whether to run a curtailment trading trial in 2021, and then engage with prospective participants.

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# Unified Protection

**Background**

The network is becoming increasingly complex and increased certainty is needed around protection function requirements and what will be available in the future to meet changing network topologies.

DNOs are often required to extend busbars and modify protection schemes for new connections and load growth projects. However, current relay replacement programmes miss opportunities for the implementation of advanced protection functions due to like-for-like replacement strategies. When replacement programs are undertaken, existing equipment is replaced with similar relays to avoid additional work. There are also physical limitations, such as the number of bays that a single device can support, and the system cannot be expanded indefinitely. As such, hardware modifications associated with protection functionality enhancements are rarely introduced.

*Figure 15: Panel holding the CPC units and ethernet switches.*

At the same time, multiple Intelligent Electronic Devices (IEDs) are being installed across the network. These include protection relays, Remote Terminal Units (RTUs), power quality meters and disturbance recorders. This introduces a large training and familiarisation overhead to ensure field staff can support and maintain multiple tools from multiple vendors.

Unified Protection is trialling a new substation centralised protection system. Our project method will verify and validate the use of this system for the protection of future substations. Additionally, the future requirements of distribution substations will be developed and aligned with the wider DSO strategy as part of this project.

Instead of using local protection relays on each substation bay as the main source of protection, a central system is being used within a substation. This system can be modified and upgraded via software and does not require new plant or the introduction of new functions or bays. For the purpose of the trial demonstration, the system has been installed in parallel with the existing protection scheme. It will receive measurements but the trip signals have not been connected to the switchgear.

This is the first full IEC 61850 substation solution with centralised protection and control implemented by a DNO in GB and among the first three in the world.

**Experience to Date**

The majority of the project activities have been completed.

- Design specifications were created for the protection and communications
- The equipment was purchased and factory tested
- The equipment was installed on site and commissioned

The process of completing the initial engineering specifications in accordance to IEC 61850 was a considerable learning experience. A large suite of engineering documents was produced and they will form the main template for the project replication. One of the main advantages of the solution is the replicability without a need for customisation.

One of the big differentiators of the solution is the use of digital communications to carry measurements and control signals. This is a concept that the engineers of UK Power Networks had limited experience with and the learning process was crucial to future implementation. The engineers had to use new tools to complete the design, testing and commissioning. The experience has shown us that protection engineers will need to be proficient in communication systems in the future.

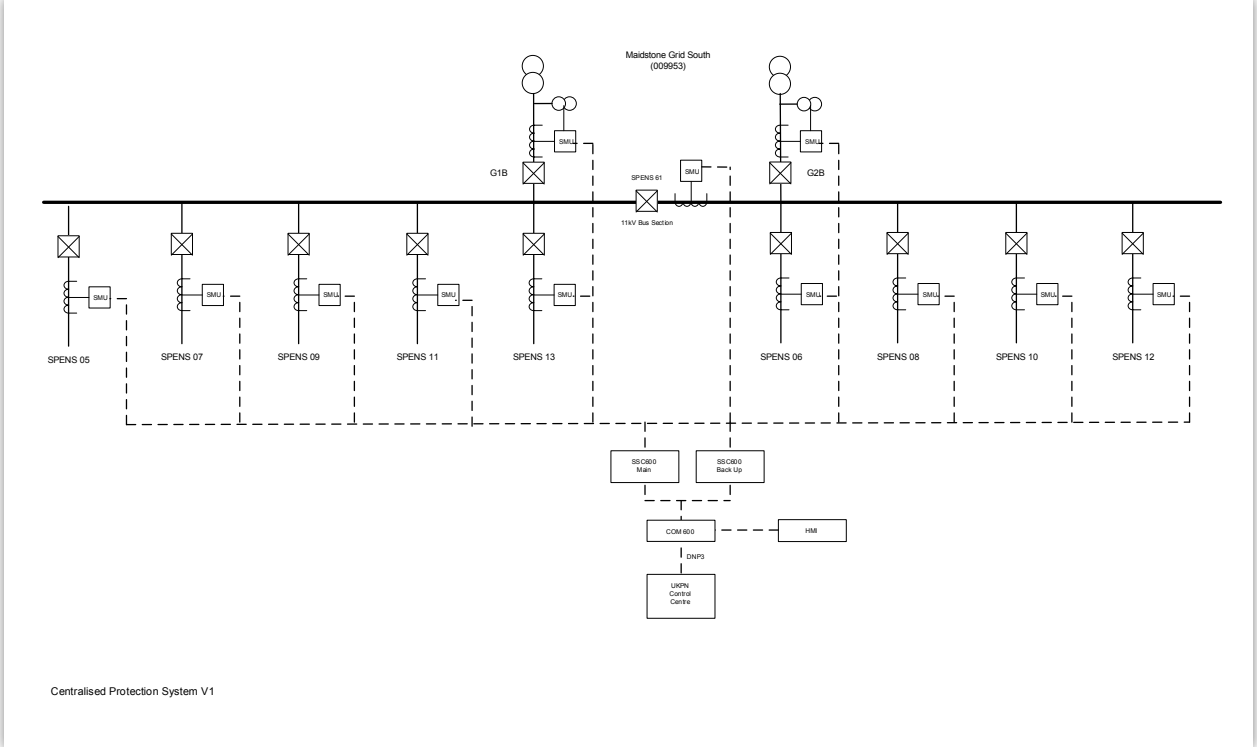


*Figure 16: Single line diagram of the substation and protection units.*

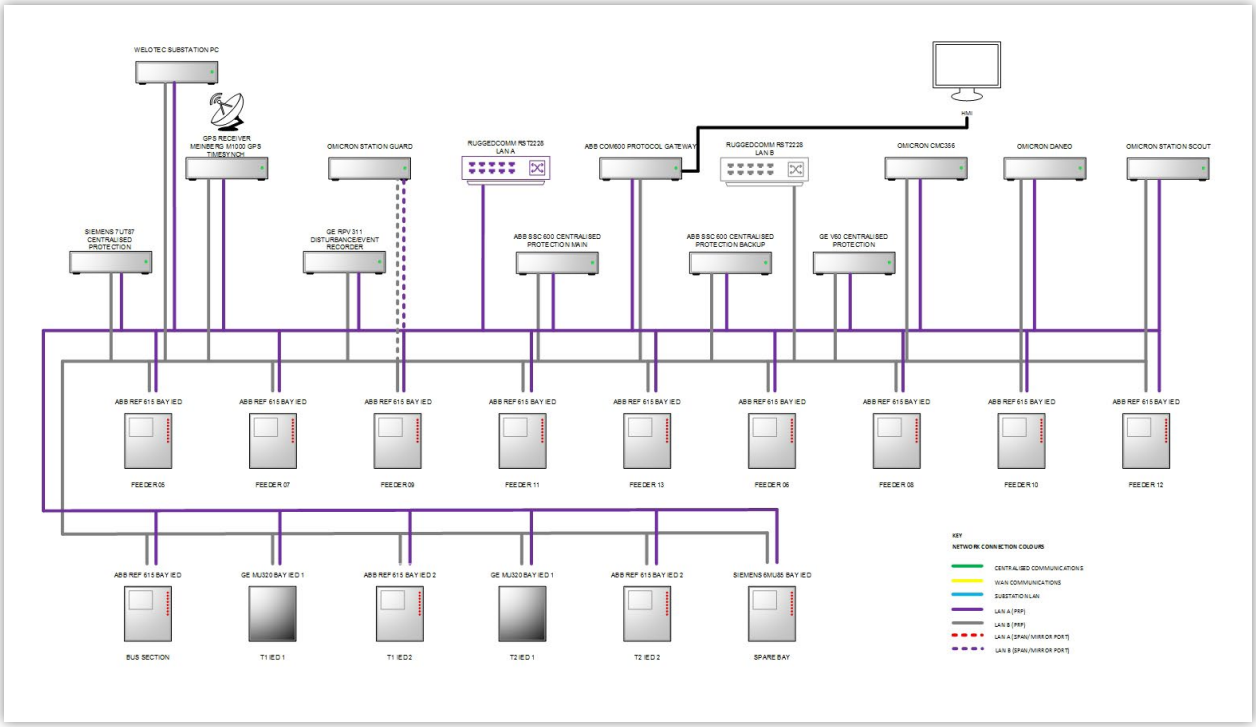


*Figure 17: Substation operational communications design.*

**Future Developments**

The system is live and operational but there have been no faults in the area since the commissioning of the system. In order to maximise the learning and achieve the originally set success criteria, the decision was made by the team to extend the trial for another 12 months to allow for faults.

Once faults have been experienced the system's performance will be compared with existing protection systems by protection experts from the technical standards team. The costs for installation and commissioning will also be a key input for making the financial case for wider device adoption.

Additionally, modern standard designs adhering to IEC 61850 have been produced in order transfer the learnings from the project and will be used to facilitate a wider supplier procurement event to achieve better prices.

**Project Lead: Boris.Yazadzhiyan@ukpowernetworks.co.uk**

# Powerful CB: Power Electronic Fault Limiting Circuit Breaker – NIC

**Background**

The challenge for Powerful-CB includes the Government's plan for the transition to Net Zero by 2050, which highlights the importance of 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.

London Power Networks (LPN) 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 other 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. In the future, installing the device will help deliver a long-term solution for multiple DG connections to substations that have fault level and physical space constraints.

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

**Experience to date**

During 2020/21 the project completed a major milestone which was the energisation of the FLCB. Initially this was planned for March 2020 however restrictions due to COVID-19 meant this work was successfully completed in August 2020. Working closely with our project partner, ABB, they were able complete modifications to the high voltage (HV) door interlock to rectify a fault identified previously during commissioning. Following this our commissioning engineers completed the final tests and energising the device.

All of our learnings and experience from the installation, commissioning and energisation of the FLCB as well the operation to date was published in our **learning report SDRC 9.2.1** which was made available in November 2020.

Since starting the trial phase of the project, we have trialled the FLCB in a number of running arrangements. The first month after energisation saw Running Arrangement 1 trialled where the FLCB underwent a 'soak' test to ensure there are no problems. There is no requirement for the FLCB to trip for a network fault under this running arrangement as it was connected in parallel with other equipment. A 'soak' test' is typical for all new equipment in order to avoid early failures.

Working closely with our Outage Planning Team and following the successful 'soak' test of the FLCB we transitioned to Running Arrangement 2 in September 2020. This arrangement simulates the scenario where the FLCB would be used as a circuit breaker for a specific transformer, also known as a transformer incomer. As seen in Figure 20 by switching over to this running arrangement, the current flowing through the FLCB increased when compared to Running Arrangement 1 as there was no longer a parallel path for the current to flow.

We transitioned to the final trial, Running Arrangement 3, in December 2020. This arrangement sees the FLCB operated as a bus coupler and will require the FLCB to break the short circuit current fed from two transformers for certain faults. Due to this, Running Arrangement 3 is considered the most onerous for the FLCB as the potential fault current is highest however this is the arrangement where most benefits can be realised from the device in the future.

*Figure 18: Commissioning of the FLCB complete.*

The FLCB continues to report with no issues including when confidence switching takes place on a monthly basis or when outages of transformers and circuit breakers were taken to complete wiring of the auto-close scheme and external fault recorders.

**Future Developments**

In 2021/22 the project is continuing with the trial phase where the project team continue to monitor and analyse the performance of the FLCB while waiting for any possible network faults to occur.

During 2020/21 we will publish learning report SDRC 9.2.3 which will include results and analysis of the data captured by the FLCB as well as experience from operating the device. In parallel, the project will also continue to update the project Safety Case, incorporating any new learnings from the trials.

**Project Lead: Jack.McKellar@ukpowernetworks.co.uk**

*Figure 19: Training from ABB for our staff following commissioning of the FLCB.*

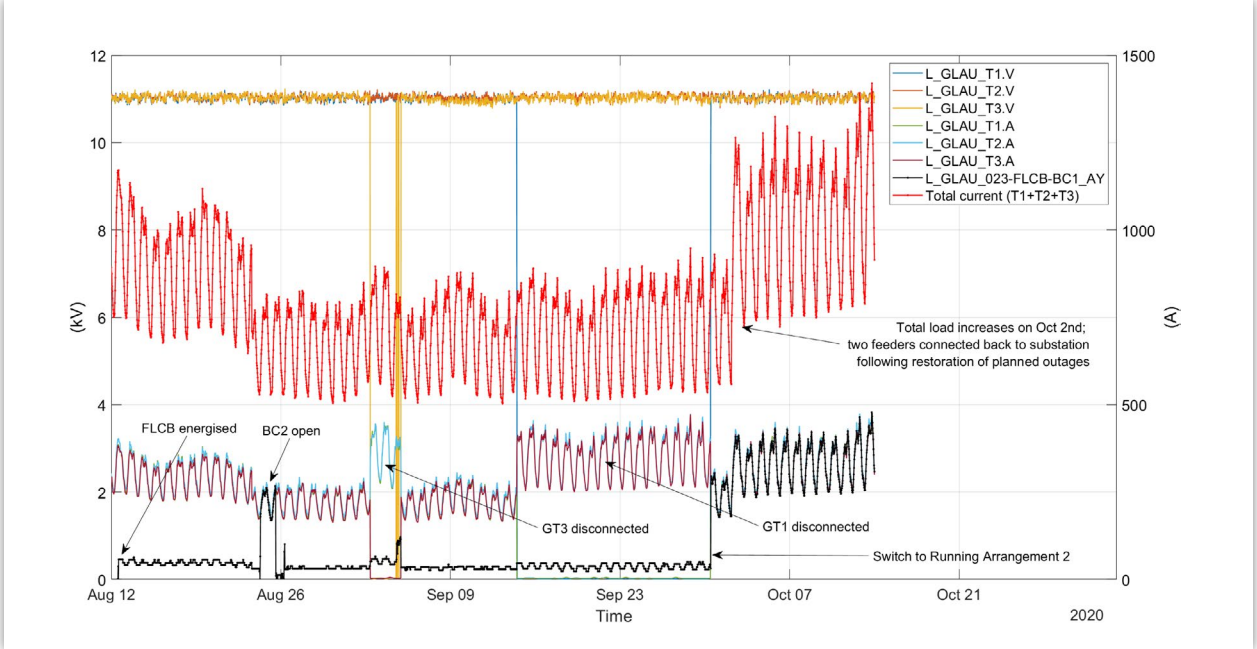


*Figure 20: Glaucus St PI Data - Energisation to 14 Oct 2020.*

# Power Potential – NIC

**Background**

Power Potential is a Network Innovation Competition project, in which UK Power Networks has enabled generators on the distribution network to provide reactive and active power services to the electricity transmission system. It is a world-first demonstration of enabling automatic voltage control from DERs and a regional reactive power market. It unlocks a new source of voltage and constraint management services for the Transmission System Operator which should unblock future generator connections and facilitate a new revenue stream for participating DER. As such, this project demonstrates UK Power Networks' development as a DSO. The trial area covers the network served by four Grid Supply Points (GSPs) in the South Eastern Power Networks licence area (Canterbury North, Bolney, Sellindge, Ninfield). The project is being delivered with National Grid ESO, and ZIV Automation is the supplier of the Distributed Energy Resources Management System (DERMS) created for the project, integrated with UK Power Networks' network management system.

**Experience to Date**

In 2020/21, despite COVID-19 related challenges, we have successfully delivered a series of live trials with five customers. The trial included solar PV, battery and wind participants. At the end of the previous regulatory year, we had already:

- Recruited customers and signed contracts;
- Completed laboratory tests of the integration of their power plant controllers with UK Power Networks' systems, according to the interface schedule developed for the project;
- Taken the initial DERMS system live; and
- Commissioned one of the customers for the reactive power service, prior to the first COVID-19 lockdown.

Following a pause of several months due to COVID-19 restrictions, site preparation and commissioning of the remaining four customers occurred over the rest of 2020, using the test procedures developed in the previous year. The commissioning process identified and resolved numerous site-specific issues.

In parallel to commissioning, we developed new approaches to continue testing the DERMS upgrades, trained DER on the DERMS web interface, and delivered individual live technical trials of the automated services with each DER, National Grid ESO and UK Power Networks' control engineers. These trials demonstrated that the services could be delivered based on declared day-ahead availability, instructions at the Grid Supply Point, and respecting safe operating limits on the distribution network e.g. the defined 'PQ' operational envelope for each DER, and the statutory voltage limits on the distribution network.

Once three customers had completed their individual trials, and the remaining system testing and live integration with National Grid's Platform for Ancillary Services (PAS) system was complete, we entered the collective technical trials in October 2020. This was an eight week phase of 24/7 trials of the reactive power service, demonstrating continuous end-end service delivery. National Grid ESO's control engineers could request response from the service, based on the GSP voltage.

This trial stage successfully demonstrated 3,747 hours of DER service availability, but the system was slowed as a precaution to address risks associated with the volume of data traffic between DERMS and the DER via our network management system. There were also issues with DER dropping out of voltage control and with mismatches between DER and DERMS interpretation of voltage set-points sent to the DER. As a result, changes were implemented to the DERMS-DER integration design in December, ready for the start of the commercial trials in January. This returned the system to its expected operation. The upgraded DERMS systems also highlighted issues with loss of connectivity between the PAS and DERMS systems, to be addressed in a BAU implementation.

The commercial reactive power trials lasted for nearly 1,800 hours. DERMS presented expected volumes and costs as a 'Virtual Power Plant' to PAS (based on calculated effectiveness at the Grid Supply Point). Following which, the National Grid ESO team did a daily commercial assessment and nomination of DER volumes. This was based on an utilisation assumption, and relative to a daily budget cap. It highlighted future benefits of including their assessment and market reporting within end-end testing of any post-trial solution.

The UK Power Networks' team continued to support the trials delivering technical improvements and liaising with customers. DER have been paid for their participation, with the settlement approach developed and delivered by UK Power Networks. We also demonstrated simultaneous active and reactive power service delivery from DERMS in March 2021, and helped National Grid ESO identify potential changes in the DERMS design for BAU i.e. to hold more reactive range in reserve for post-fault response and change the utilisation of the service for comparability with transmission alternatives.

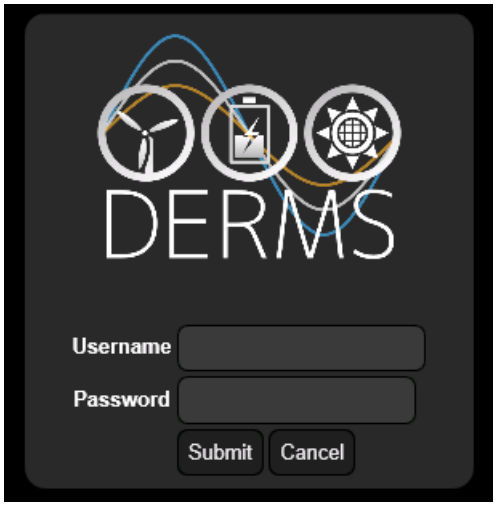


*Figure 21: Secure web interface to the DERMS system.*

**Future Developments**

As trials finished at the end of March 2021, the remaining activity was project reporting – covering trials and BAU transition, cost-benefit analysis and DSO risk-reward framework.

The trials have shown that a DSO can enable automated reactive power services from DER for voltage control for transmission, integrated with the existing UK Power Networks network management system. The project has highlighted how the services could be further developed for a BAU solution. The additional trial stage involving direct comparison of DER with transmission alternatives did not proceed, but DER participants recognised UK Power Networks' commitment to delivering and learning from the trials, as a template for the future.

System functionality and processes from trials will now be assessed to determine which elements to take forward with National Grid ESO as an extension to the scope of the joint Regional Development Programme in the trial region. National Grid ESO will use Power Potential to inform developments introducing competition in wider reactive power and voltage control markets, currently being progressed under their "Future of Reactive" work.

**Project Lead: Rita.Shaw@ukpowernetworks.co.uk**

Efficient & Effective

# Project Highlights

Electricity generation and consumption is changing at an unprecedented pace due to the accelerated drive to decarbonise, digitalise and decentralise energy, transport and heat. This means our customers are becoming more aware of their energy use, adapting their behaviour, generating electricity and accessing the benefits of low carbon solutions. These changes have introduced a mix of technical and commercial challenges to electricity distribution. It is our job to ensure our network is ready for the future uptake of the low carbon technologies required to reach Net Zero.

We believe one of our core strategic focus areas for innovation 'Efficient & Effective' responds to that challenge. It aims to deliver a network ready for Net Zero at the lowest possible cost by enhancing the reliability, availability and performance.

Underpinning this focus area is the commitment to deliver great business value by maximising smart savings for customers. Being efficient and effective is not just about successfully demonstrating new ideas or solutions. The true value of the portfolio is only delivered when we embed each solution into business as usual.

One of our core corporate values 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:

- **Radio Teleprotection** – this project is testing and trialling a VHF (Very High Frequency) and UHF (Ultra High Frequency) radio equipment in a live substation environment as an alternative cost-efficient solution for fibre-optic teleprotection systems;
- **Storm Resilience** – this project is developing a solution to integrate real-time weather and operational resource data with our central control system to improve network performance; and
- **HV Feeder monitoring to pre-empt faults** – the project aims to trial a data-driven and machine learning based predictive monitoring solution to detect and locate abnormal disturbances before they materialise into faults.

> "It is our job to ensure our network is ready for the future uptake of the low carbon technologies required to reach Net Zero."

**Zain Habib**
Innovation Programme Delivery Manager

Stakeholders are central to our journey. Despite this year's COVID restrictions, we continue to engage and use remote communication channels to disseminate learnings with the wider industry on a regular basis. The platforms used include technology specific forums and webinars we hosted ourselves or by other stakeholders, including, the Power Networks Demonstration Centre (PNDC) knowledge forums.

Our engineers and project partners also showcased our innovation portfolio at the remote and re-branded Electricity Networks Innovation Conference, providing detailed insights to share our project findings, share best practice and encourage collaboration for the benefit of our customers and environment.

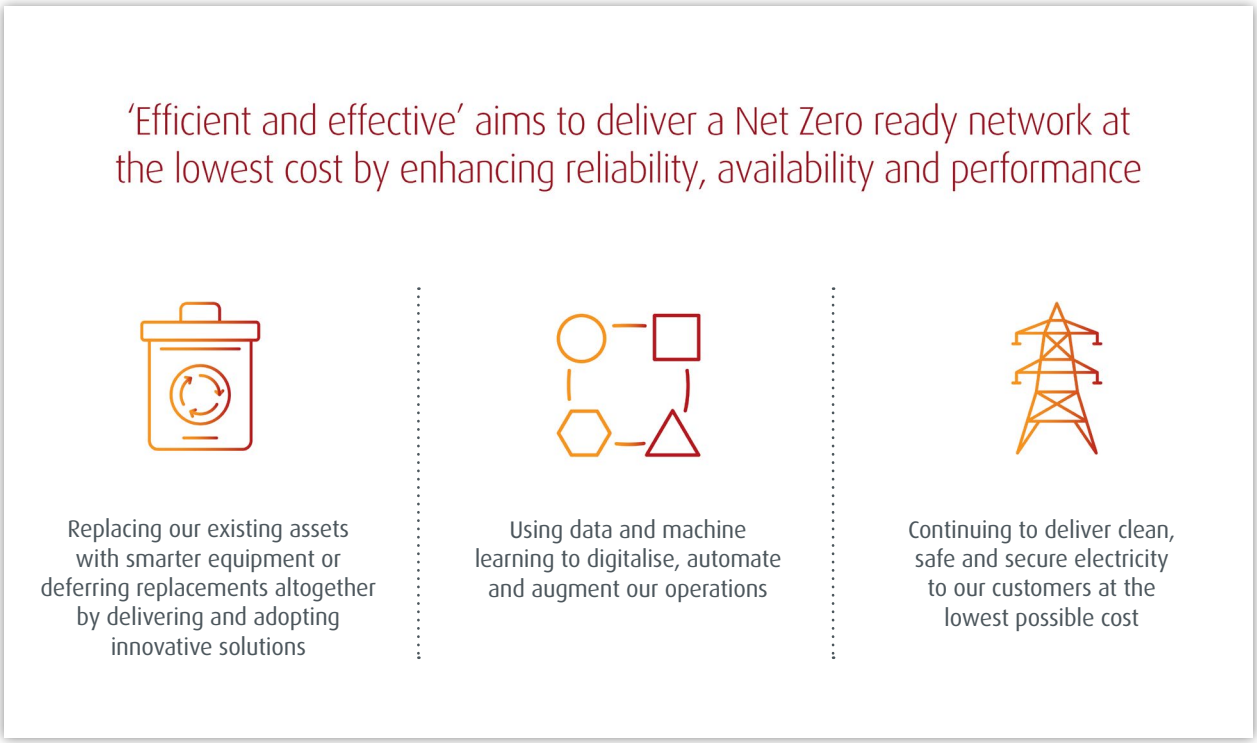


*Figure 22: Our efficient and effective portfolio means Innovating to make our network safer, more reliable or more cost-effective for our customers. Through new technology we can deliver tangible benefits in performance including on customer interruptions (CIs), customer minutes lost (CML), lower emissions or safety.*

# Radio Teleprotection

**Background**

The cost of fibre-optic teleprotection can often prohibit customer connections. Microwave radio is an alternative low-cost option, but limited to line-of-sight (LoS) applications only (no hills, buildings, or tall trees), whereas non-LoS radios have not previously met requirements for modern teleprotection services.

Recent developments in VHF (very high frequency) radio equipment and spectrum plans may allow radio to be used over partially obstructed paths for modern teleprotection. The key is to identify and assess radio solutions technically compatible with requirements for teleprotection circuits, including onerous latency requirements and available licenced spectrum plans.

Thus this project, being carried jointly by UK Power Networks and the Joint Radio Company (JRC), will identify, investigate and report back on the overall performance of available solutions. It will bring together existing components in a new way to meet this specific need.

The project expects that non-LoS VHF radio will provide a cost-effective radio system for teleprotection, in scenarios where other solutions (optical fibre and microwave radio) are expensive or impractical.

**Experience to Date**

The technical work, which is being led by JRC, is organised into multiple stages as follows, with a review gate at each stage:

**Stage 1** Desktop Study
**Stage 2** FAT (Bench Tests)
**Stage 3** SAT (Field Trials)

**Stage 1** carried out spectrum and radio equipment research. It confirmed that using modern VHF radios to operate on non-LoS paths while remaining compliant with modern protection service requirements was possible, but challenging due to bandwidth requirements and available frequency spectrum.

**Stage 2** is currently in progress and has identified a single radio supplier, Mimomax (based in New Zealand) offering a solution in VHF which meets the stated requirement. Antenna systems, as shown in Figure 23, have been installed at UK Power Networks' Maidstone Grid site, and testing is in progress to validate the performance of the radios under laboratory and live network conditions.

**Future Developments**

After 12 months of trials, assuming the performance is acceptable to meet protection requirements, Mimomax radio may be offered for teleprotection service as an approved alternative to fibre optic, microwave and line of sight microwave communications.

In addition, as a result of activities carried out thus far, work is now underway to assess the possibility of using radio for anti-islanding protection with less onerous requirements than teleprotection.

**Project Lead: Peter.Lang@ukpowernetworks.co.uk**


*Figure 23: Examples of Antenna systems being trialled.*

# MILES Better Fault Location

**Background**

To minimise the impact of power cuts on our customers we must find the cause and fix them quickly. One way of measuring this impact is by measuring Customer Interruptions (CI) and Customer Minutes Lost (CML).

MILES[3] has two primary objectives. To find the causes of:

- Permanent power cuts when they happen
- Transient power cuts before they become permanent

The underlying premise of MILES is shown in Figure 24, where voltage sensors on the low voltage (LV) network measure and detect voltage wave forms as a fault occurs. The voltage waveforms are then uploaded to a server where they are analysed by the MILES algorithm, which combined with prior knowledge of the upstream high voltage (HV) feeders, is able to estimate a probable location of the fault. This technology was successfully developed and rolled out by Hydro-Quebec in Canada, and is now being industrialised in the UK, (which has a different network configuration to Canada), in partnership with CGI. The technology may detect faults which occur which get resolved within the 3 minutes of APRS activating, which then don't contribute to CI in the first instance. Knowing where they are can help in preventing them from recurring again in subsequent instances (which may occur for more than
three minutes thus counting towards CI). If proven successful from a technical and commercial perspective, we seek to deploy this on our network at scale so as to reduce the CI and CML impact, and improve the service to our customers.

**Experience to Date**

Thus far, we have worked together with CGI to model six feeders in our network, and completed a desk study of our network trial sites. The potential levels of accuracy demonstrated by the desk study are promising, with about 87% of faults found within 200m. Sensitivity analysis has been performed to assess the impact of erroneous voltage measurements, as well as impedance values. CGI has also deployed their software based platform within UK Power Networks' technology infrastructure.

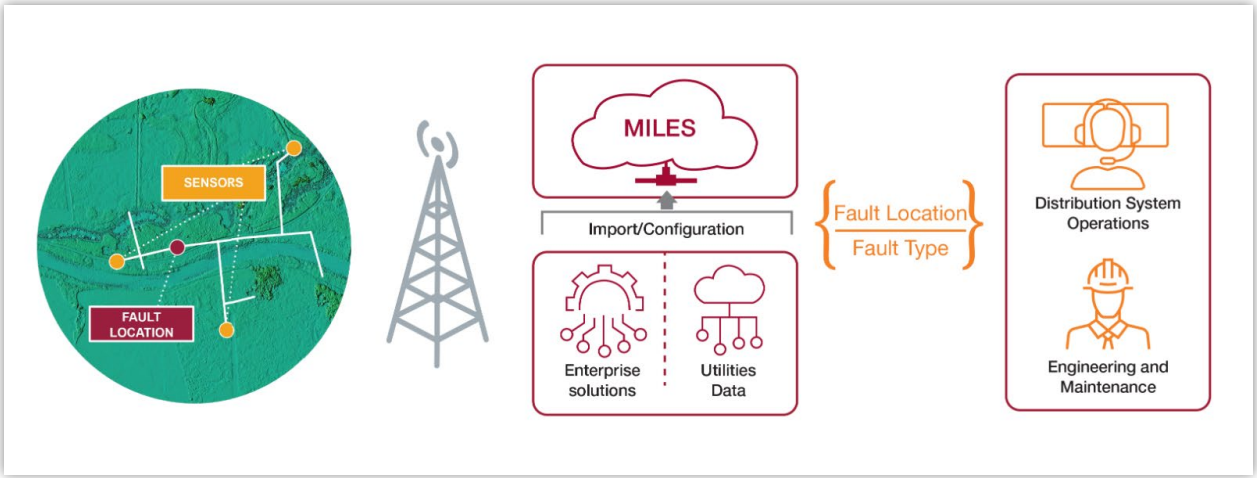


*Figure 24: A diagrammatic view of the system. In the field, voltage sensors are deployed on LV networks. These send the captured waveform data of voltage drops back to the MILES platform © CGI. Inc, which then provide an estimate of where the fault may be located.*

[3] A French acronym, when translated to English, it reads 'Intelligent Maintenance of Electric Lines'.

**Future Developments**

Our next step is to install and integrate sensors onto our network, and perform a system acceptance test. With a positive result, we would then have the greenlight to commence the six-month trial. Following which, the results will be analysed and compared with real fault information and feedback from engineers. With the conclusion of the trial UK Power Networks will better understand the efficacy of this system, and understand the best method of deployment, so as to reduce CMLs for our customers.

**Project Lead: Kelvin.Lee@ukpowernetworks.co.uk**

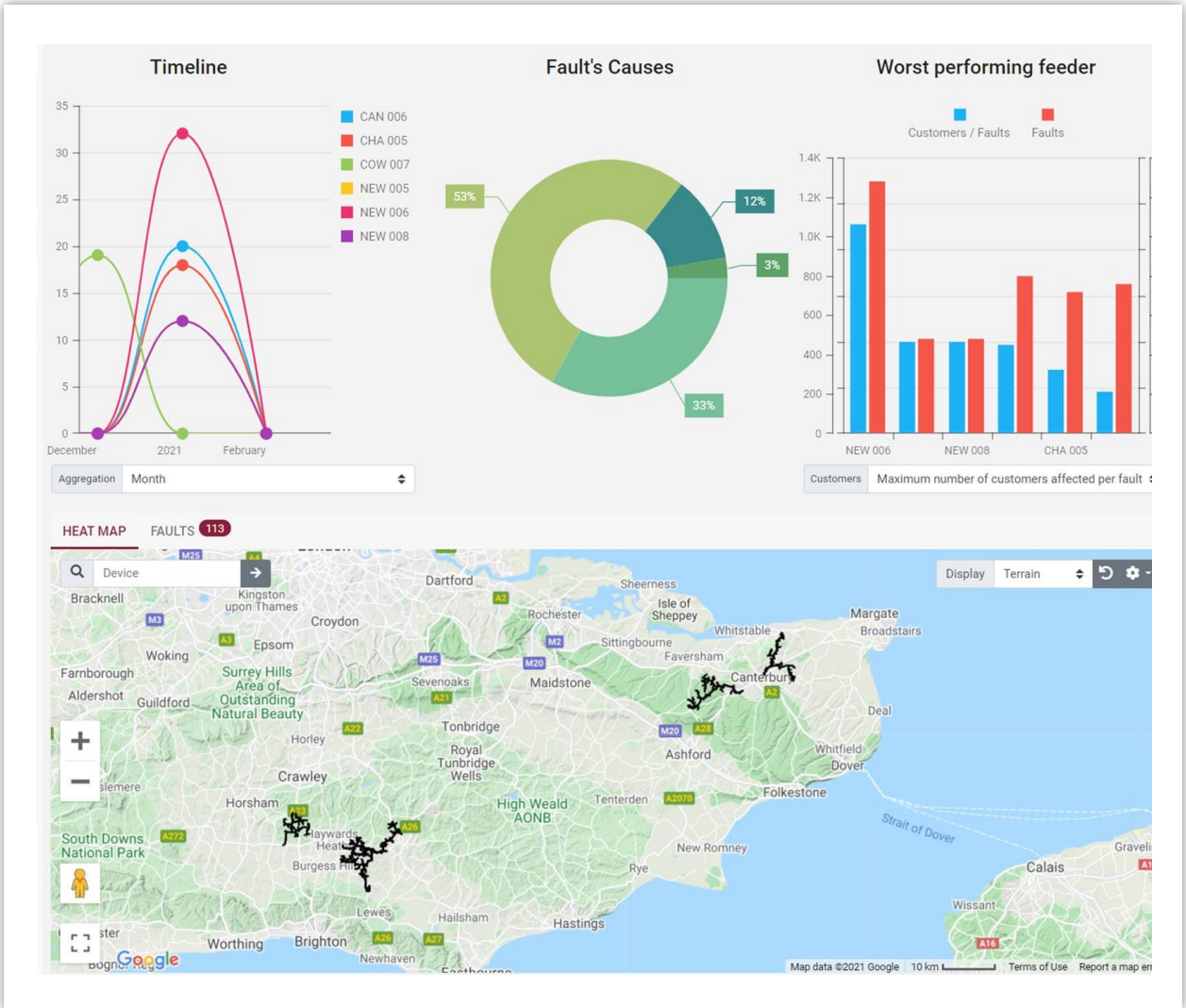


*Figure 25: A view of the platform (currently still under testing), and the how it may display faults on set of HV feeders.*

# Storm Resilience

**Background**

UK Power Networks experience over 20 severe weather events per year which require an emergency response. These events are categorised by a high volume of unplanned power outages or faults, especially on the overhead network. This means our customers can be off supply for up to 24 hours and we need extra engineers, often working through the night, to fix the many faults that can occur simultaneously during weather events. Such events, particularly those with significant lightning strikes, can result in a number of transient faults on the network that can cause considerable disruption to UK Power Networks and our customers.

When severe weather is forecast, UK Power Networks invokes an emergency escalation process led by the emergency planning team. Currently, the information available to the emergency planning team is limited and not well mapped to the electricity network. This makes estimating resource requirements complex and often suboptimal. In addition to this, during a lightning storm, network control engineers do not have sufficient information to determine whether a fault is transient or permanent. Therefore, as per the current standards, they wait 30 minutes to allow time for safety issues to be reported before attempting to re-energise the circuit.

The Storm Resilience project, in partnership with MeteoGroup and GE, aims to develop two distinct solutions which reduce CMLs during a storm. The project is developing and trialling a proof of concept to integrate the Advanced Distribution Management Solution (ADMS) with an Application Programming Interface (API) to import lightning data from meteorological stations around the south east of England. The location of lightning strikes will be mapped to network assets using time and distance parameters. The mapping will verify if lightning has caused a transient fault and, if so, instruct the ADMS to reconnect customers immediately, reducing CMLs by up to 90%.

For the second solution, the project is trialling machine learning to predict the number of faults on the network. Based on historical and real-time fault and weather data, the tool will predict the number of weather related faults in each sub region of our network. The algorithm will provide a probabilistic forecast of the storm impact and quantify the expected level of risk each weather event presents. As part of the project, the optimum number and location of resources required to manage the severe weather will be estimated using UK Power Networks look up tables. Accurate forecasting will help UK Power Networks reduce the time customers are off supply during a storm by ensuring we have the right number of engineers in the right place.

**Experience to Date**

To gather data on lightning strikes, Storm Resilience has developed a software function within the network management system (PowerOn) that is able to call the weather application programming interface (API) when there is a fault on the network.

Testing of the software has been successfully completed to ensure it does not impact the operation of the distribution network, in particular work has focused on how the new software will integrate with the existing automated power restoration system (APRS) without affecting its performance. The software has been deployed to the live environment working in a passive state to see how the scripts would react to lightning events. Figure 26 presents the graphic and text that the network control engineers see, they can use this live information to test if the scripts can identify transient faults caused by lightning strikes with enough accuracy that the reliability of the network is improved.

To improve resource allocation, the Storm Resilience team have developed a machine learning algorithm to forecast the number of HV and LV faults within UK Power Networks. The analysis from the algorithm is visualised in a web based resource estimation tool as presented in Figure 27.

MeteoGroup have trained the algorithm using 10 years of UK Power Networks' historical fault and weather data, and the project developed an API to provide the resource estimation tool with real-time fault data along with the real-time weather data from MeteoGroup. The tool is now being trialed with the UK Power Networks Emergency Planning team.

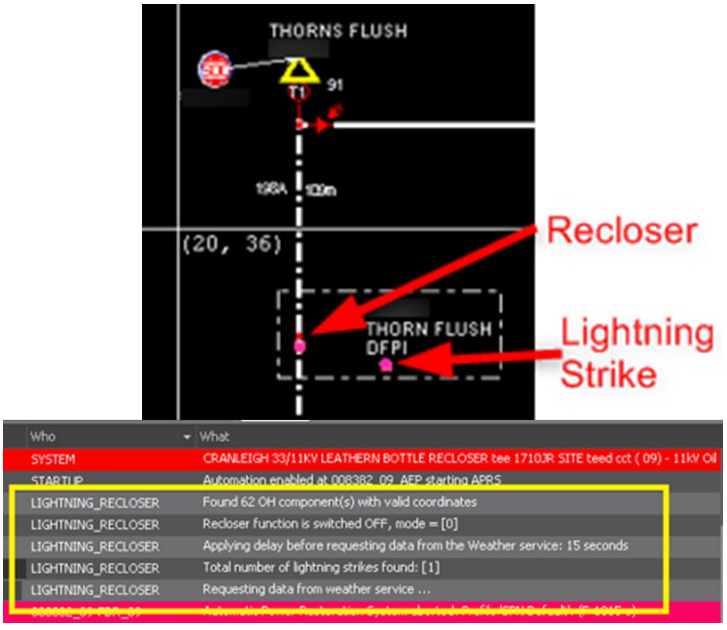


*Figure 26: Visualisation of the lightning strike and affected recloser on the network management system with the text output shown to the control engineer.*

## Future Developments

Storm Resilience will run trials until December 2021. If the project is successfully able to identify transient faults due to lightning, the next stage will be to operate it together with the UK Power Networks APRS. If successful, automation of the solution would enable further reduction in CMLs and could reduce the duration of lightning power cuts for our customers to under three minutes.

The Emergency Planning team have provided positive feedback to the project team and have started to use the resource estimation tool as part of the suite of tools used when the business goes into a severe weather event escalation. Storm Resilience will continue to trial the resource estimation tool to prove it is capable of forecasting, planning and responding to severe weather events effectively. Using the data and operational experience from UK Power Networks emergency planning team we will work with MeteoGroup to suggest potential improvements and make a decision if the tool, with these improvements, could be used as part of our emergency planning going forward.

**Project Lead: Joe.Colebrook@ukpowernetworks.co.uk**

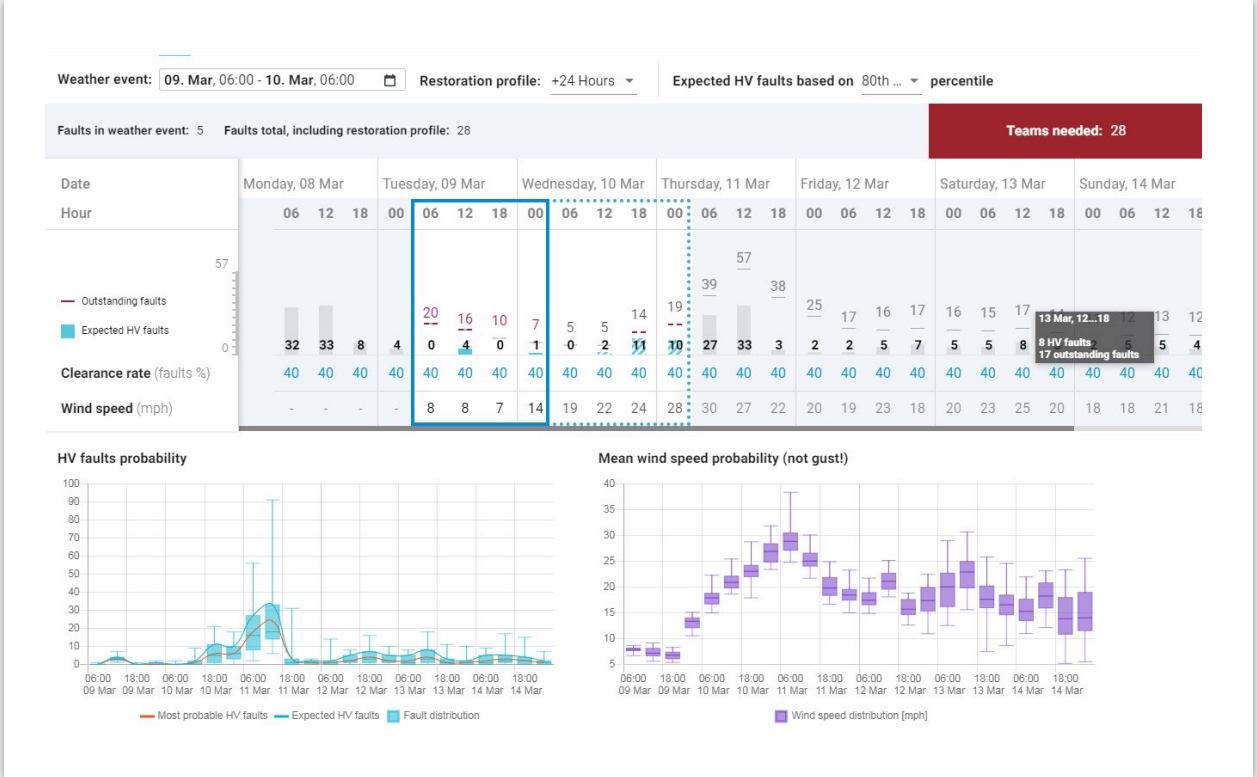


*Figure 27: Snapshot of the Storm Resilience resource estimation tool used by the emergency planning team.*

# Arc Aid

**Background**

This project is trialling a new type of fault indicator (MetrySense MS-5000) to improve the efficiency, reliability and resilience through better detection of faults. The device will be demonstrated in certain parts of UK Power Networks' and Western Power Distributions' regions where arc suppression coil (ASC) earthing configurations allow overhead lines to remain energised in the event of a fault on a single phase conductor for up to two hours.

This device for ASC arrangements could help field engineers locate faults more efficiently by saving time and effort taken to undertake a full line patrol, reducing operational costs, improving safety and ultimately providing a better service to our customers. It could reduce up to an average of 3,000 customer minutes lost per site per year.

**Experience to date**

Two sets of the devices were tested on a simulated model of one of our three-feeder substations. The tests were conducted at the University of Strathclyde's Power Networks Demonstration Centre (PNDC), using its real-time digital simulation test laboratory. Voltage and current measurements from the model were amplified through Omicron amplifiers and then fed simultaneously to the two sets of MS-5000 sensors and three protection relays. The tests simulated several fault types, including Phase to Earth and Phase to Phase, in different locations with respect to the sensor. This was complemented by additional tests to further assess the functionality of the units. The outcome of these tests and simulation determined that the sensors could successfully detect 100% of the faults, including high impedance faults, which were tested under different scenarios and had secure and reliable communication and connection.

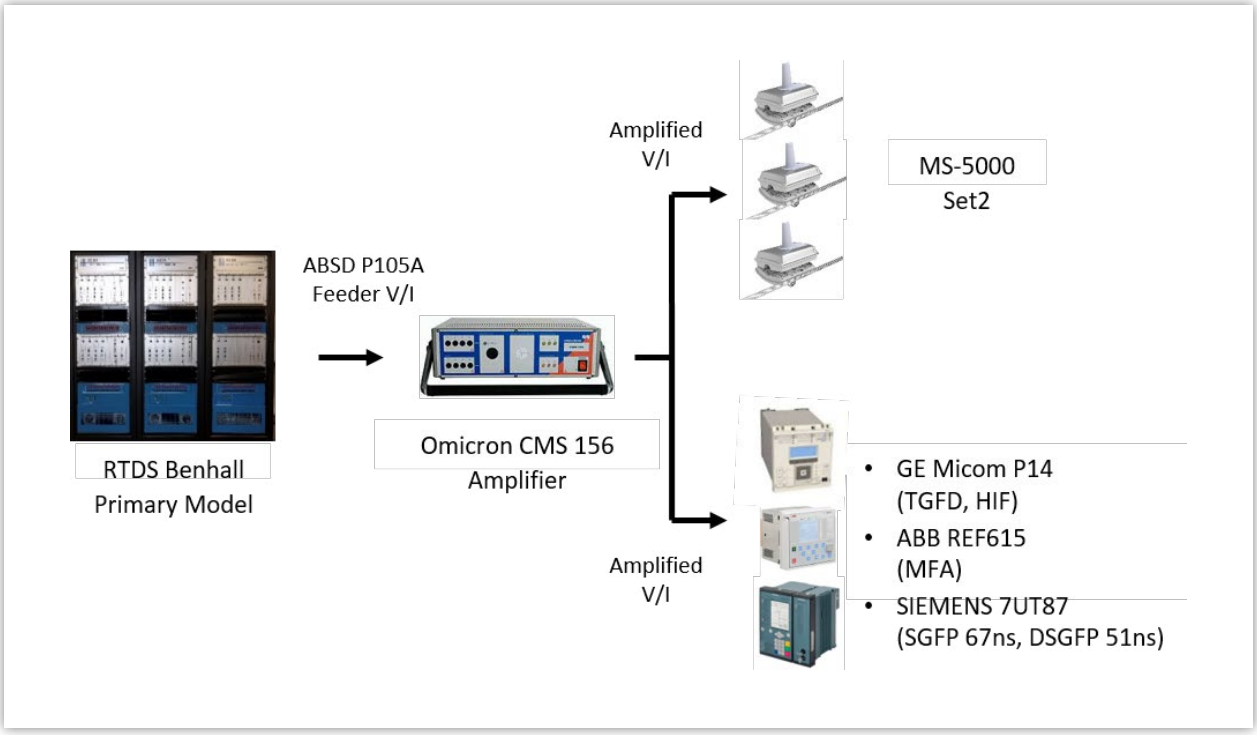


*Figure 28: Schematic of testing configuration.*

*Figure 29: Engineer installing units in training centre.*

Following the successful testing UK Power Networks carried out familiarisation training with the teams required for the installations. This highlighted the ease of the installation: each sensor was installed with a short stick or a hot glove procedure, and approximately 10 minutes installation time was required for each gateway in accordance with distribution safety regulations and HV live manual.

**Future work**

The next step of the project will focus on finishing the installation of the 20 sets and monitoring six months of data received from the sensors. It will be particularly useful to detect several fault events during the project timescale and to see the units practically used during this scenario.

This will be followed by integration into UK Power Networks' network management system to allow control engineers to easily access to the data retrieved from the sensors. The data will also be used to better understand the performance of the networks where it is trialled in order to make more informed decisions for the management of assets.

Depending on the quality of the data it could be potentially used to better understand cross-country faults in the network and the implications for network operation and maintenance.

**Project Lead: Romina.Arefin@ukpowernetworks.co.uk**

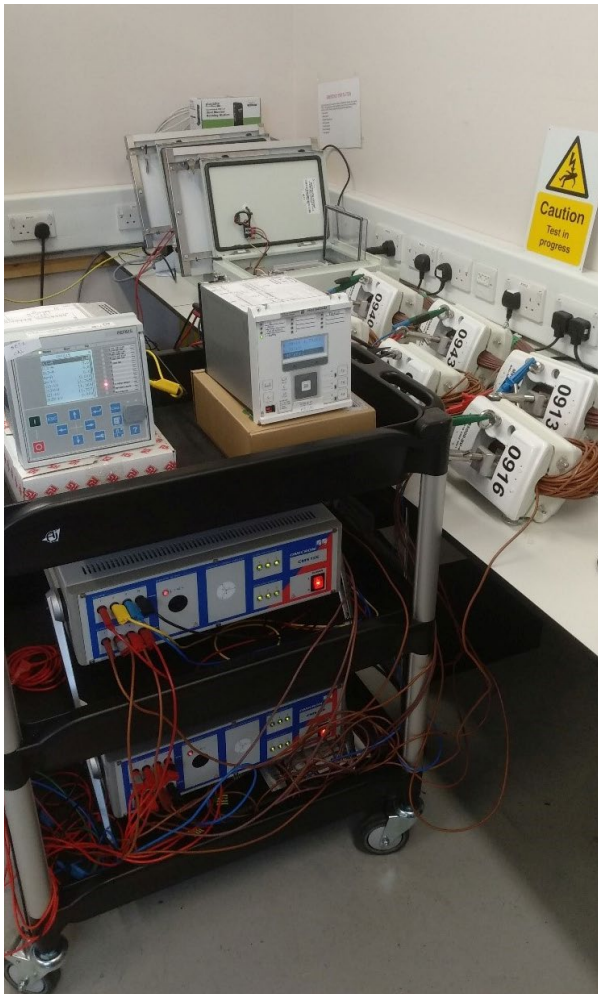


*Figure 30: Testing configuration at PNDC.*

# HV Feeder monitoring to pre-empt faults

**Background**

DNOs experience faults on their electricity distribution networks which result in CIs and CMLs. Most CIs and CMLs are incurred on the HV network. DNOs implement a number of measures to reduce the amount of CIs and CMLs incurred, for example through switching using remote control, use of protection relays to identify faults and minimise impact.

However, most of these measures only address scenarios where the fault has already materialised. Further improvements in network performance and reduction in operating costs could be achieved if DNOs are able to monitor key network characteristics including voltage and current in real-time, and carry out interventions e.g. asset or component repairs before a fault materialises. Monitoring network characteristics in real-time presents some practical challenges and considerations. For example: "what are the typical network characteristics that are identifiable before different types of faults occur?", "how would the location of the emerging fault be identified?", "what are the operational processes and steps that would need to be followed to successfully pre-empt an emerging fault?"

This project aims to test a solution, "Distribution Fault Anticipation" (DFA), to monitor feeders to pre-empt faults. The DFA solution consists of a disturbance recorder (Figure 31) and a "Master station" that displays the waveforms and is the main data repository. This will be trialled alongside a network analysis tool (ASPEN Distriview) and Fault Passage Indicators (FPIs) to monitor a selection of HV and 33kV feeders and expectantly identify the location of network issues before they materialise into faults.


*Figure 31: DFA disturbance recorder.*

**Experience to Date**

UK Power Networks has installed 11 DFA units monitoring ten 11kV circuits and one 33kV circuit supplying a generator. The units have detected many events and the waveforms collected have been analysed by the "Master station" identifying likely defect types, e.g. tree branches touching the overhead line, a bird or squirrel coming into contact with a transformer, a porcelain insulator beginning to fail. The waveform data has been input into the ASPEN Distriview application which has been able to predict likely defect locations.

We started monitoring 11kV circuits in July 2020. Since then, events have been detected and waveforms have been collected. Some events build up over time before they result in a supply interruption. These events have been analysed in detail allowing the project to predict the area where the fault may occur. The build up to a recent underground cable fault was causing operational staff and control engineers concern as different circuit breaker reclosers were operating. Analysis of the waveforms was able to confirm that the events were caused by the same fault and identified a protection grading issue between two network reclosers, which has now been resolved.

To date, we have waited for the defect to become a permanent fault to confirm the predictions. However, there have been several instances where early indications suggest that the project can deliver warnings and potential locations before or immediately after an event occurs. For example, the waveform characteristic of a confirmed cable termination failure was compared with a different event which predicted that the cause of the fault was likely to be a cable termination. Figure 32 shows a faulty cable termination.

*Figure 32: Faulty cable pole termination.*

**Future Developments**

A further five DFA units will be installed to increase the total number of feeders being monitored to 16. The trails will continue to December 2021 when a cost benefit analysis will be carried out to determine whether the solution should be rolled out across selected feeders. Over the next six months the project will consider whether we can be proactive and identify an incipient fault and repair the defect before it causes many repeat interruptions. For example, can we identify a failing cable pole termination before it causes a supply interruption, by planning a pre-arranged outage.

This information will need to packaged and presented to internal stakeholders including Network Control, Asset Management and Network Operations, to facilitate the transition to business as usual. The project will engage with external stakeholders and other DNOs for the dissemination of these learnings.

**Project Lead: Peter.Lang@ukpowernetworks.co.uk**


*Figure 33: John, lead field engineer, inspecting an installation of a DFA monitor at Broad Oak primary substation.*

# 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_UKPN0032 | Mobile Field Control | Customer and stakeholder focus<br>Safety and health and environment | 03/18 - 02/21 | £1,539,960 |
| NIA_UKPN0049 | Phase Switch System | Transition to low carbon future Network improvements and system operability | 06/19 - 03/23 | £959,000 |
| NIA_UKPN0045 | Shift | Transition to low carbon future<br>New technologies and commercial evolution | 01/19 - 05/21 | £1,295,500 |
| NIA_UKPN0033 | TransPower | Transition to low carbon future | 04/18 - 07/22 | £2,143,717 |
| NIA_UKPN0056 | Cold Start | Transition to low carbon future | 02/20 - 02/21 | £184,349 |
| NIA_UKPN0066 | CommuniHeat | Transition to low carbon future | 10/20 - 06/22 | £919,688.00 |
| NIA_UKPN0072 | Voyage (MSA) | Transition to low carbon future | 02/21 - 02/22 | £248,930.00 |
| NIA_UKPN0067 | GIS temperature monitoring | Network improvements and system operability | 10/20 - 06/22 | £327,000.00 |
| NIA_UKPN0065 | Cleaner Engines | Customer and stakeholder focus | 10/20 - 10/22 | £433,000.00 |
| NIA_UKPN0063 | Charge Collective | Transition to low carbon future | 08/20 - 04/22 | £843,640.00 |
| NIA_UKPN0060 | White Van Plan | Customer and stakeholder focus | 07/20 - 10/22 | £604,000.00 |
| NIA_UKPN0073 | Enable | Transition to low carbon future | 03/21 - 03/22 | £254,000.00 |
| NIA_UKPN0061 | Heat Street: Local System Planning | Transition to low carbon future | 07/20 - 05/21 | £318,652.00 |
| NIA_UKPN0069 | Socially Green | Customer and stakeholder focus | 11/20 - 05/22 | £925,000.00 |

## Future Ready

| Project Reference | Project Name | Research Areas | Duration | Budget |
|---|---|---|---|---|
| NIA_UKPN0052 | Energy Exchange: Market-Based Curtailment Management | Network improvements and system operability | 09/19 - 05/21 | £985,800.00 |
| NIA_UKPN0039 | Engineered Poles Products | Network improvements and system operability | 07/18 - 01/21 | £249,815.00 |
| NIA_UKPN0035 | Network Vision | Network improvements and system operability<br>Customer and stakeholder focus | 05/18 - 09/20 | £975,800.00 |
| NIA_UKPN0048 | Unified Protection | Network improvements and system operability<br>New technologies and commercial evolution | 04/19 - 03/21 | £765,254.00 |
| NIA_UKPN0058 | Line Search | Safety and health and environment | 05/20 - 07/21 | £209,000.00 |
| NIA_UKPN0050 | Urban Energy Club | Customer and stakeholder focus | 05/19 - 11/21 | £195,238.00 |
| NIA_UKPN0070 | Envision | Network improvements and system operability | 12/20 - 09/22 | £1,971,000.00 |

## Efficient & Effective

| Project Reference | Project Name | Research Areas | Duration | Budget |
|---|---|---|---|---|
| NIA_UKPN0055 | Arc Aid | Safety and health and environment | 02/20 - 11/21 | £446,000.00 |
| NIA_UKPN0054 | EPRI Research Collaboration on Overhead Transmission (P35) and Substations (P37) | Network improvements and system operability<br>New technologies and commercial evolution | 01/20 - 07/23 | £924,000.00 |
| NIA_UKPN0047 | HV Feeder monitoring to pre-empt faults | Network improvements and system operability | 02/19 - 02/22 | £1,769,311.00 |
| NIA_UKPN0044 | HV OHL Assessment | Network improvements and system operability | 01/19 - 09/20 | £408,378.00 |
| NIA_UKPN0031 | Link Alert | Network improvements and system operability<br>Safety and health and environment | 02/18 - 02/21 | £275,600.00 |
| NIA_UKPN0040 | Transformer Care | Network improvements and system operability<br>New technologies and commercial evolution<br>Safety and health and environment | 08/18 - 09/21 | £218,393.00 |
| NIA_UKPN0046 | Underground fault predictive model and earthing assessments | Network improvements and system operability | 02/19 - 08/21 | £692,887.00 |
| NIA_UKPN0057 | Circuit See | Network improvements and system operability | 02/20 - 04/22 | £957,000.00 |
| NIA_UKPN0053 | Storm Resilience | Network improvements and system operability | 12/19 - 12/21 | £664,943.00 |
| NIA_UKPN0042 | Storm Joint | Network improvements and system operability | 10/18 - 09/21 | £188,586.00 |
| NIA_UKPN0038 | Real Time Thermal Ratings – Cables | Network improvements and system operability | 06/18 - 12/20 | £284,625.00 |
| NIA_UKPN0071 | Smart Cable Guard | New technologies and commercial evolution | 02/21 - 02/23 | £435,281.00 |
| NIA_UKPN0068 | FutureLink | Network improvements and system operability | 11/20 - 09/22 | £288,000.00 |
| NIA_UKPN0059 | Miles better fault location | Network improvements and system operability | 05/20 - 05/23 | £1,838,000.00 |
| NIA_UKPN0064 | 3D Printing of Network Assets | Safety and health and environment | 09/20 - 12/21 | £307,000.00 |
| NIA_UKPN0062 | Radio Teleprotection | ED - New technologies and commercial evolution | 08/20 – 08/23 | £438,000.00 |

# CONTINUING TO raise the bar

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

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