Distribution

NIA Annual Report

2021 – 2022

SP ENERGY NETWORKS

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Foreword

At SP Energy Networks we are committed to delivering the Distribution Network of the Future in our two license distribution areas (SP Distribution Plc and SP Manweb Plc), and are at the forefront of the industry across several areas with our wide and varied innovation portfolio. We have the drive, ambition and capability to continue leading growth in these areas, and to provide the best service possible for our customers and communities.

This Network Innovation Allowance (NIA) Annual Distribution Report provides an overview of NIA innovation projects which cover our distribution networks in Scotland, England and Wales that were initiated, worked on and completed during the regulatory year 2021-22.

Despite the challenges of the COVID-19 pandemic, we have continued to provide our customers and communities with value for money, a secure and stable electricity supply, and to support the most vulnerable in society.

We were also proud to welcome the United Nations COP26 Climate Change Conference to our home city of Glasgow last year, where world leaders came together to set targets and agree on action to tackle climate change. As a Principal Partner with our ScottishPower Group colleagues, we were delighted to be able to demonstrate how we are playing a vital role in enabling Net Zero ambitions. Throughout the two-week conference we showcased our diverse innovation portfolio across the decarbonisation of transport and heat; data/digitalisation and network visibility.

The energy landscape is going through a rapid change and therefore providing several challenges, but also lots of opportunities for our network. Innovation is going to continue to be absolutely critical to tackling climate change, and our project portfolio puts us at the forefront of finding smarter, more agile ways to manage our network and to find solutions to challenges like the decarbonisation of heat and transport, and in enhancing network resilience and security of supply. It's also why we've incorporated significant innovation investment and specific deliverables in our ED2 Business Plan. This includes a dedicated Innovation Strategy, focusing on key areas such as the electrification of heat and transport, hydrogen and consumer vulnerability.

We recognise the scale of the challenge faced by our industry, and are committed to ensuring we bring everyone along on that journey as we drive a just transition for all. I'm proud of what we've achieved so far and excited by what I know is yet to come as we build a greener energy future for all.

If you have an idea you would like to discuss with my innovation team or if you'd like more information on a particular project featured in this report, please get in touch via **innovate@spenergynetworks.co.uk**.

Graham Campbell

Director of Processes and Technology

SP Energy Networks

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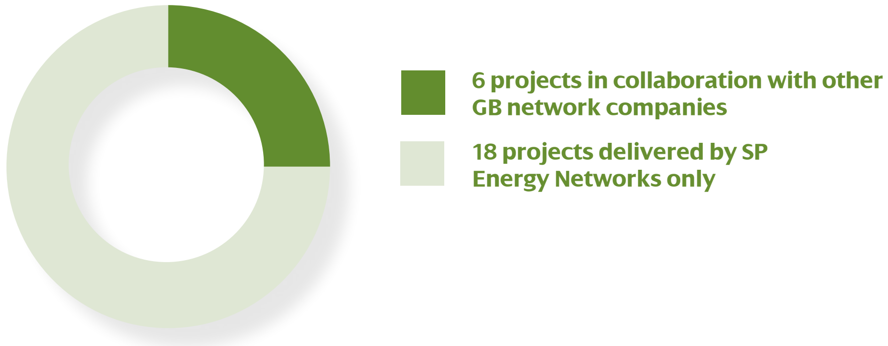
Executive Summary

This Network Innovation Allowance Annual Distribution (NIA D) Report has been compiled in accordance with Ofgem's Electricity Network Innovation Allowance Governance Document which sets out the regulation, governance and administration of the Electricity NIA. This NIA Annual Report presents an overview of the projects we have initiated during the regulatory year 2021/2022 and an update on those projects reported during 2020/2021 which are still active.

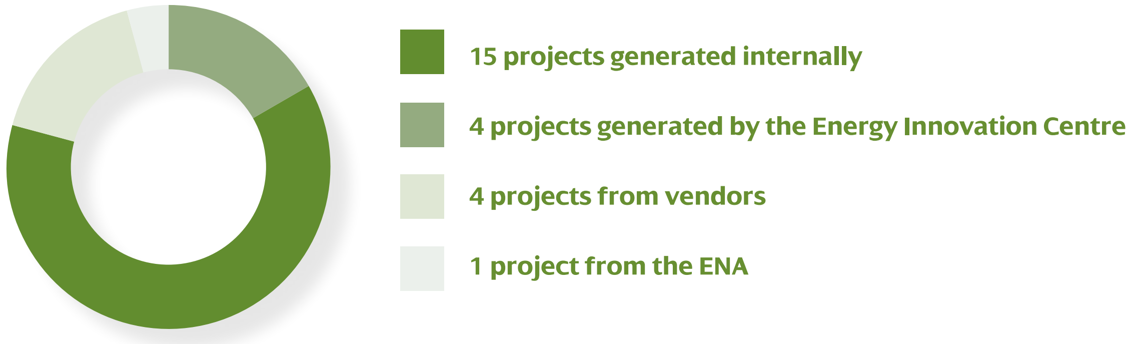
Collaboration

We collaborate with other GB network companies to ensure that all customers benefit from customer funded innovation projects.



Project Origin

As part of the overall strategy for our technology portfolio, SP Energy Networks aims to have a balanced mix of projects that originate from other sources and not just from within SP Energy Networks, as illustrated below.



SP ENERGY
NETWORKS

1 | Introduction

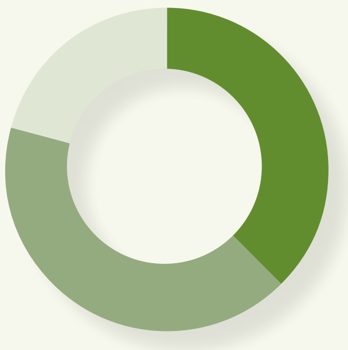
We recognise the need to be innovative in order to get more out of our electricity distribution network and deliver value for money for customers.

SP Energy Networks is committed to identify innovative performance improvements across all aspects of our business.

In ED1 there has been an increased need to ensure that innovation is embedded into all business functions, and as such the role of our Innovation Board is to ensure increased participation from all business functions and to allow innovation projects to be completed and integrated into Business as Usual (BaU). Our Think Big, Start Small, Scale Fast approach to innovation enables us to be at the forefront of innovative practice and is embodied in our guiding values. At SP Energy Networks we believe in the power of innovation to enhance all aspects of our business and improve our service for the benefit of both our internal stakeholders and customers.

SP Energy Networks recognise that consideration needs to be given to not only the RIIO-ED1 period and stakeholder's immediate needs, but also how we address the longer-term issues which the Distribution network may face. This is being addressed through a balanced portfolio of innovation projects where we are considering some of the longer-term issues which may involve technology and techniques at a lower technology readiness level as well as challenges to be faced over the next decade.

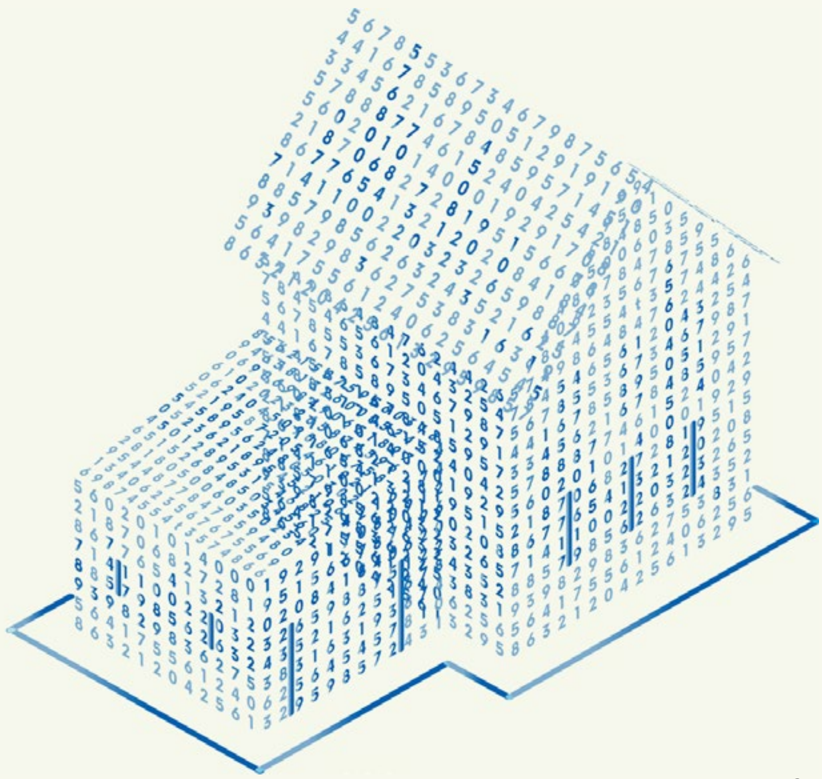
Estimated Timescale to Adoption for delivery within our Project Portfolio



9 projects – Short term (within 12/24 months)

10 projects – Medium term (2-4 years)

5 projects – Long term (4 years +)



2 | Progress Summary

During the reporting year 1st April 21 to 31st March 22 SP Energy Networks registered the following five NIA Distribution projects:

Project No.	Project Name	Project Start Date
NIA SPEN 0060	*ADAPT-DC* *https://smarter.energynetworks.org/projects/nia_spen_0060/*	Sept-21
NIA SPEN 0061	*Innovative Replacement for Underground Substations* *https://smarter.energynetworks.org/projects/nia_spen_0061/*	Sept-21
NIA SPEN 0063	*Virtual OHL Inspections: Combining Statutory Inspection & Condition Based Assessment (CBA)* *https://smarter.energynetworks.org/projects/nia_spen_0063/*	Oct-21
NIA SPEN 0065	*Introduction of Process Mining Enabler into SP Energy Networks* *https://smarter.energynetworks.org/projects/nia_spen_0065/*	Oct-21
NIA SPEN 0066	*Level Up* *https://smarter.energynetworks.org/projects/spen-0066/*	Dec-21

The following sections provide a short overview of each active NIA Distribution project and summarises the progress made on them. Further details on SP Energy Networks Innovation activities can be found on SP Energy Networks' website (www.spenergynetworks.co.uk/pages/innovation.asp) and on the ENA Smarter Networks Portal (www.smarternetworks.org). Key learning associated with these projects is summarised in ***Section 5***.

3 | NIA Projects Led by SP Energy Networks

3.1 | NIA SPEN 0008 Environmentally Acceptable Wood Pole Pre-treatment Alternatives to Creosote (APPEAL)

Project APPEAL was registered in March 2016; it is a collaborative project between SP Energy Networks, UK Power Networks, Northern Powergrid and Scottish & Southern Electricity Networks and managed by the Energy Innovation Centre (EIC). This project aims to assess the performance of environmentally friendly alternatives to creosote for wood pole preservation. It is expected that the outcome of this project will influence UK DNO policies for the replacement of wooden poles.

The project consists of three stages with individual objectives:

Stage 1 – Literature Review: This stage will provide a comprehensive review of candidate replacements for creosote, enabling the DNO partners to select the solutions to take forward for testing.

Stage 2 – Accelerated Testing: This stage involves the creation of a 'fungal cellar facility' to provide a test environment to simulate >20 years of exposure to the elements for wood pole samples. This test bed will then be utilised to test several creosote alternatives side by side as well as wood pole samples treated with creosote

Stage 3 – Final Report: This stage looks to collate and formally report on the key findings on the previous two stages and make recommendations based on the results obtained.

3.1.1 | NIA SPEN 0008 Project Progress

Stage 1 – Literature Review: This stage provided a detailed literature review of existing and novel preservative types, offering at least two candidates (and low creosote alternative) as potential replacements for creosote (offering similar or greater decay prevention for timbers). This stage is now complete and has informed Stage 2 of the project.


Timber stakes located within the fungal cellar

Stage 2 – Accelerated Testing: Successful construction of fungal cellar facility and test bed deterioration results for timber posts/stakes treated with Stage 1 candidate preservatives and creosote (high & low retention). Pole lifetime will be predicted based on three samples of the specimens. The fourth uplift report has now been issued, completing the first 48 months of exposure to the fungal cellar for the timber stakes.

As with each annual assessment, the stake samples recovered from the accelerated decay chamber were visually examined for any obvious decay. The samples were dried and then subjected to breaking tests to assess the impact of any decay on Modulus of Rupture (MOR). The determination of MOR was undertaken via a modification of the standard static bending test for small clear specimens of timber (BS 373 (1957)). Identically treated stakes that had been stored in a dry environment, and therefore not subjected to any decay processes, were included in these tests to give baseline MOR values for each sample type.

After the breaking tests were completed, untreated control stakes that had been encapsulated in the copper lined CAPTURA sleeve type were chemically tested to identify any copper migration to the untreated timber surface. After completion of all tests, all stake samples were treated as hazardous waste and disposed of as appropriate.

Stage 3 – Final Report: This stage will see the provision of final report detailing the outcomes of project Stages 1 and 2 and providing recommendations for further work with regards to any changes to existing treatment protocols and industry adoption.

The final report will be compiled when Stage 2 is fully completed. Annual reports have been issued during the course of Stage 2 with each report informing policy updates and decisions in this area.

3.3 | NIA SPEN 0014 Active Fault Level Management (AFLM)

The management of fault levels can be challenging and problematic. Fault Level Management (FLM) is particularly challenging given the safety criticality implications as they can result in catastrophic equipment failure and represent a serious personnel and public safety risk.

While conventional practice has been to establish system fault level design limits in line with accompanying plant specification, novel approaches that enable full utilisation of the existing headroom must be developed to facilitate a timely decarbonisation of the economy.

Due to unprecedented growth in distributed generation, fault level headroom constraints are becoming increasingly challenging, often requiring major reinforcement schemes. Fault levels can act as a barrier to the connection of renewable generation and have become a decisive factor in determining the financial viability of distributed generation connections.

There are distinct approaches to Fault Level Management, with variation in the means of management and operational characteristics. Each of the following approaches have a role in the proposed AFLM Toolbox:

Model: where power system modelling is used to support Fault Level Management, either as:

- An operational means of FLM;
- An input to FLM; or
- For FLM.

Monitor: where fault-level measurement methods either:

- Enable the verification of network modelling methods and assumptions; or
- Facilitate the online measurement of fault level for operational management purposes.

Mitigate: where various techniques for fault current limitation are taken in real-time through physical fault current limitation or via protection actions.

Manage: where control systems provide preventative avoidance of fault level infeed exceedance through control of demand and renewable generation to reduce fault level and create network headroom.

The project will aim to develop an AFLM Toolbox based upon the Manage approach, using elements of Model and Monitor, with opportunities to work in co-ordination with Mitigate techniques.

3.3.1 | NIA SPEN 0014 Project Progress

The objective of the project is to maximise utilisation of existing fault-level headroom by demonstrating the potential merits of a comprehensive AFLM toolbox combing model + monitor + mitigate +manage approaches.

The AFLM project is tasked with demonstrating an innovative solution to Fault Level Management by automatically controlling network equipment and customers in real time. This constrains network fault levels within equipment limits and will enable acceleration of flexible non-firm connections into fault level constrained areas of the network.

Phase 1 of the project considered a toolbox of solutions for the development of active fault level management systems, including modelling, measurement, mitigation and management techniques. A range of networks were assessed with the toolbox of techniques, and cost benefit analyses were undertaken on the concept designs.

Phase 2 of the project has progressed a solution design with prototyping and laboratory-based testing. This has refined the AFLM concept and use cases, including development of the AFLM specification, requirements, design principles, and high-level commercial principles of access. Development of a prototype AFLM solution has been progressed and has undergone laboratory-based testing.

An area of network (Warrington) has been selected to refine the solution. Long run tests, network and system studies and scalability assessments have been undertaken to provide a foundation for a production grade AFLM network trial in Phase 3 of the project.

Phase 3 has now started with the development of the network architecture and functional specification. The detailed design specification has now been completed, defining all operational requirements for deployment of the trial. Some delays have been encountered, which mostly relate to stringent cybersecurity requirements. The trial is now expected to go live in the summer of 2022.

The proof-of-concept solution has been demonstrated in laboratory-based testing. If the subsequent live deployment is successful, this will meet the key project objective.

3.5 | NIA SPEN 0023 Connected Worker Phase 1 – Field Data Automated Capture

It is widely recognised within the industry, the importance of acquisition of field data to support and impact on decision making. However, due to the manual nature of this job, this can lead to inaccuracies with reporting.

Through this project the business aims to find a new way to improve the quality, accuracy and timelessness of data collected by field staff, whilst simultaneously reducing the burden on those staff. As is the case with many innovation projects, the focus will be placed upon new technologies and applications of existing technology in order to improve data acquisition. Although at present field operatives enter some data via electronic devices, it is not yet widespread and in certain cases much of the manually collected data requires specific action by the field staff, especially when dealing with linear assets such as cables and overhead lines.

However, there are technologies which are widely available- for example Global Positioning Systems, geo-fencing and barcoding – which could be used to improve the quality of data collected by our field staff in a more direct manner.

For this project specifically, the data collected will relate to work on-site regarding underground assets that would be consumed and utilised by the Work Management System (SAP) or the Geospatial Management System (ESRI) to include both installed and decommissioned assets.

The project objectives for the project is to validate and confirm that the technologies are capable of:

1. Providing a significant level of data capture automation
2. Reducing time spent in the field collecting and entering field data
3. Providing that data for consumption directly to corporate systems
4. Reducing the need for secondary (back-office) data entry
5. Providing a cost effective solution that is financially viable

3.5.2 | NIA SPEN 0023 Project Progress

The original project specification has evolved to a point where there are 2 phases.

- The functionality of redlining from the Field has been established through a Functional Specification that was defined and created under the NIA project but will be delivered within a funded project to upgrade the current GEOGRAPHICAL INFORMATION SYSTEM solution to the new ESRI Utilities Network GEOGRAPHICAL INFORMATION SYSTEM platform over the coming years. (Objectives 1, 2, 3 and 4).
- We have undertaken a successful pilot to use Robotic Process Automation techniques to essentially gather information that has been entered onto established asset data collection forms. Robotic Process Automation reads this data, and then create assets within our propriety asset management systems, replacing a manual process. The process can read this data from a common spreadsheet format or can be used within the ESRI Survey123 data gathering mobile application. This has been proven in a pilot phase for 3 asset types, distribution level circuit breakers, transformers and ring main units. This is now implemented in production and is undergoing final post implementation testing. (Objectives 1, 2, 3, 4 and 5).

The intention is to complete testing on the initial three assets above and add a further three during 2022 to reduce the manual effort required in updating these key asset records in our asset management systems.

3.7 | NIA SPEN 0029 Secondary Telecommunications Phase 3 – Trial of Hybrid Telecoms

Transitioning from a DNO (Distribution Network Operator) to a DSO (Distribution System Operator) will require significantly increased real-time monitoring and control of remote electrical assets than is currently in place.

This will be of critical importance in order that the continued adoption of distributed renewable generation and electric vehicle utilisation can be maximised without inadvertently destabilising the UK electricity grid or putting the security of supply at risk. The need for much improved monitoring and control in the future is well documented. There are six main criteria which must be satisfied and the current telecommunications solutions which are available to DNOs do not adequately do so. Furthermore, without a reliable and fit for purpose telecommunications network in place, it is not possible to capitalise on the possibilities that are presented by the 'Smart Grid', and this would also severely delay the DNO to DSO migration.

Previous work in this area (by SPEN, UKPN and WPD) has concluded that a single technology solution (which can cost effectively satisfy all of the technical and commercial criteria) is unlikely to be suitable. It is likely that a hybrid approach to the solution will be most cost effective and will 'future proof' the solution to the greatest extent possible. Similarly, arguments around the pros and cons of self-build vs third party solutions are not straightforward and the optimum is probably an intelligent combination of both.

The objective of this project is to trial a hybrid of innovative communication solutions previously short-listed in the Secondary Communications Phase 2 project and combine them into a holistic architecture which could be deployed by UK DNOs as they transition to DSOs and support full smart grid capability.

3.7.1 | NIA SPEN 0029 Project Progress

To validate and confirm the technologies are capable of supporting smart grids the following objectives have been identified:

Objective 1: Providing wide geographic coverage in a range of environments from dense urban to deep rural.

Progress on Objective 1: Dual Sim 4G (public cloud) has been demonstrated in practice to provide coverage in rural and urban environment for the SPEN estate. Desktop propagation studies of VHF scanning telemetry indicate effective rural coverage. Private LTE utilising 1800MHz available spectrum would not provide economic coverage. Broadband powerline technologies remain to be trialled.

Objective 2: Providing reliable performance generally (>99.99%) and during a black start event.

Progress on Objective 2: Limited progress has been made in assessing the reliability of the trial technologies. Public cloud solutions have been contracted at a target performance level of 99.9% although real-world performance is subject to factors separate to the technology deployed.

Objective 3: Providing communication with sufficiently low latency to support real time control of distributed assets as part of the smart grid. Designs for deployment of a private network utilising the trial spectrum acquired from Ofcom in 2020 for rural locations are being reassessed. Backhaul infrastructure has been installed to support field deployment once this is completed.

Progress on Objective 3: Public cloud solutions shown to provide sufficient latency to support switching of pole mounted assets.

Objective 4: A high degree of interoperability between connectivity technology and equipment vendors.

Progress on Objective 4: Field router integration into pole and ground mounted installations has been completed.

Objective 5: To demonstrate to what extent third party solutions from mobile operators can be relied upon in terms of coverage and performance.

Progress on Objective 5: Further Field deployments on the mobile network operator's infrastructure has provided additional data on data usage, response times and reliability. Research into the practicalities of failover between public and private networks using the available frequency options is ongoing.

Objective 6: To build upon output of previous innovation projects such as WPD's Falcon & Nexus and UKPN's 'Flexible plug and play'.

Progress on Objective 6: The trial has explored issues raised in the Nexus project gathering experience of Build vs Buy, applying for segments of UK spectrum and applying standard end to end encryption to the 4g trial solution.

3.11 | NIA SPEN 0031 Radiometric Arc Fault Location RAFL 2

Transient faults on the overhead line distribution network can be difficult to locate costly to repair and can have an adverse impact on customer service and quality of supply. Certain transient, intermittent faults are not easily detected through a line patrol and can be onerous to narrow down using fault passage indicators on a network with numerous branches. When the circuit repeatedly trips, field staff manually reset and re-energise, but this does not address the root cause. These faults are frustrating to customers and staff and are time consuming and costly to locate.

This project builds on an earlier proof of concept project (NIA_SPEN005) which SP Energy Networks undertook to investigate the feasibility of a Radiometric Arc Fault Locator (RAFL) based on fixed hardware to detect transient faults.

This project culminated in a field trial of the RAFL system which was permanently mounted to wooden poles supporting transformers on an 11 kV overhead line circuit.

Despite this circuit being chosen due to its historical poor performance, no faults were recorded during the trial period. Nevertheless, the trial demonstrated that the hardware was reliable and suited to the purpose of detecting impulsive radio frequency emissions from power system arcing.

The project will develop RAFL system hardware and software and expand on the NIA_SPEN005 project learning to develop a low cost, portable, battery powered version of the RAFL system field deployable unit that can be rapidly redeployed in service.

3.11.1 | NIA SPEN 0031 Project Progress

Work commenced on the RAFL 2 project in July 2018. The project closed in January 2022.

In the reporting period the following tasks have been successfully completed:

Network Field Trials

The RAFL devices were deployed to the 11kV network across both SP Energy Networks and UKPN's regions from the summer of 2021 to December 2021. The units were deployed on circuits where faults had been experienced or those which had been experiencing poor performance.

Within the duration of the trial the units did not detect any faults in the areas deployed. However, the devices detected activity which was correlated with lightning and 400kV switching at a nearby National Grid substation.

It was noted that the battery life of the devices meant that operational staff were required to attend site weekly. This was an area of the unit which may be able to be improved in future should battery energy density improve.

In general, the project has met the objective to design, develop and test a portable radiometric arc fault device. The key objectives for the systems design, development and evaluation phases have all been met which are:

Initial system design: Identify the electronic specification for the recording hardware of the FDU based on current understanding of the (radio frequency) RF receiving constraints for arcing faults, GPS receiver accuracy and latest battery technology. Similarly, identify the housing for the FDUs considering DNO field practices.

Development phase: Convert the initial system design specification into hardware suitable for field use; develop software to fulfil the system software specification.

Evaluation phase: Validate location accuracy. Review design and establish fitness for purpose. Success will be measured by the device's location accuracy, and the field teams' feedback on its fitness for purpose.

The RAFL project has developed a device which is easily used by staff, and it has been shown in test conditions that the device can locate faults accurately. There are, however, issues with the battery life that have affected the usability of the device when in field conditions therefore the device will not be integrated into DNO BAU operations. This means that the project success criteria relating to reliability and BAU integration have not been met by the project.

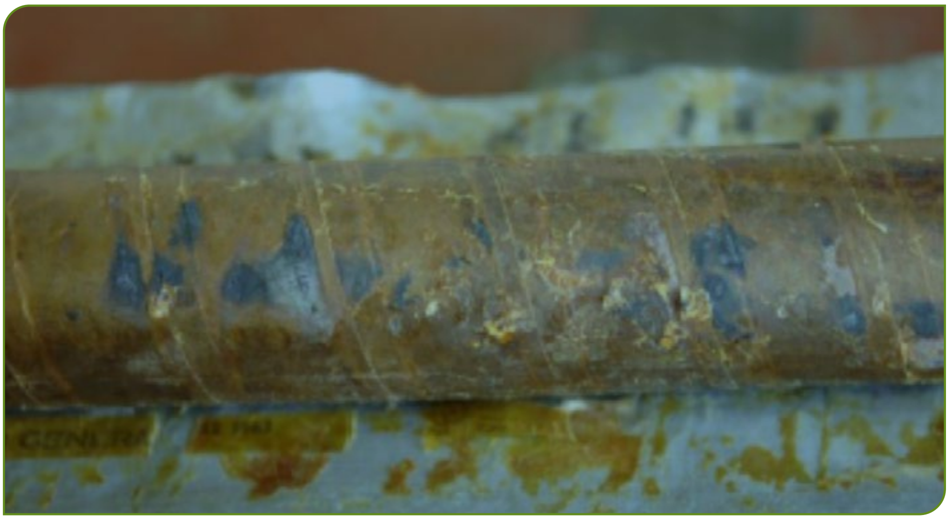
PNDC Test Result

3.12 | NIA SPEN 0033 CALISTA

CALISTA (Cable Asset Life by Integrating STAtistical failure models) is a three-strand project being run in partnership with Glasgow Caledonian University.

The first work package of CALISTA was to develop an analytic model to predict cable asset lifespan through analysis of the cable parameters. This has allowed the remaining lifespan of cable assets to be forecast and developed an asset management tool for asset managers to make informed decisions on the replacement of cable assets. This work has been carried out as a PhD study. The second project strand has supported this study through monitoring the partial discharge in 33kV cables, particularly across trifurcating joints. This will also support work to monitor and manage failures in these joints.

The final strand of this project will look at using the techniques behind wireless charging to facilitate the location of cable faults. This will also be carried out as a PhD project.



PILC cable with signs of wear and degradation

3.12.1 | NIA SPEN 0033 Project Progress

A large amount of work has been carried out on the classification and understanding of failure modes for cables, and the modelling of this to allow predictive analytics to be carried out. This includes the development of new analytical and statistical models.

Glasgow Caledonian University have completed the following:

- An analytical model of cable insulation lifespan and aging mechanisms, with statistical approach to the failure mechanisms;
- An asset management model which can assess a circuit's remaining lifespan based on its present operating condition; and
- A software package which incorporates both of these models to enable asset managers to evaluate individual circuits remaining lifespan.

The project is now in its closing stages, with work being carried out to manage the use of the developed software package, and applying its outputs to inform the cable management and replacement strategy for our districts.

3.13 | NIA SPEN 0034 NCEWS 2

Management of network access for the expected volumes of new and resultant increases in customer energy requirements continues to be the key theme for the Network Constraint Early Warning System phase 2 (NCEWS2) project. Continuing from the original NCEWS project, key goals for the next phase are;

1. Develop data analytical support for key business process use cases:

- **a.** Provision of a new IT supported innovation test platform called Network Analysis and View (NAVI);
- **b.** Ongoing development of improved data visualisation, data gathering and Application Program Interface (API) data export functionality;
- **c.** Identification, training and logging of feedback on the platform from key business stakeholders;
- **d.** Prioritisation and delivery of functionality identified through stakeholder engagement; and
- **e.** Explore existing gaps in data analytical capability with initial investigation of HV network requirements.

2. Data science investigation of network constraint risk from the growing volumes of observable energy data supplied through Smart Meters (SM's) and LV network monitoring:

- **a.** Initial use of SM data for constraint analysis through the use of underlying network impedance understanding and extrapolation of SM Voltage.
- **b.** Connection constraint risk modelling through the combination of applied After Diversity Maximum Demand (ADMD) modelling data, improved through background property analysis along with the growing input of real observation data.
- **c.** Use of observable energy data and underlying network asset data (impedance) to investigate data analytical techniques for network running and phase identification connectivity improvement.

Platform Evolution	EV and DER Management	Business Engagement	HV Analysis
• Platform Enhancements • Data Analytics • Data Improvement • SM Enablement • BAU Management	• LV/EV/DG Modelling • EV API Development • Data Analytics	• Stakeholder Engagement • BAU Implementation	• HV Development • Data Analytics • Leverage other Project Funding

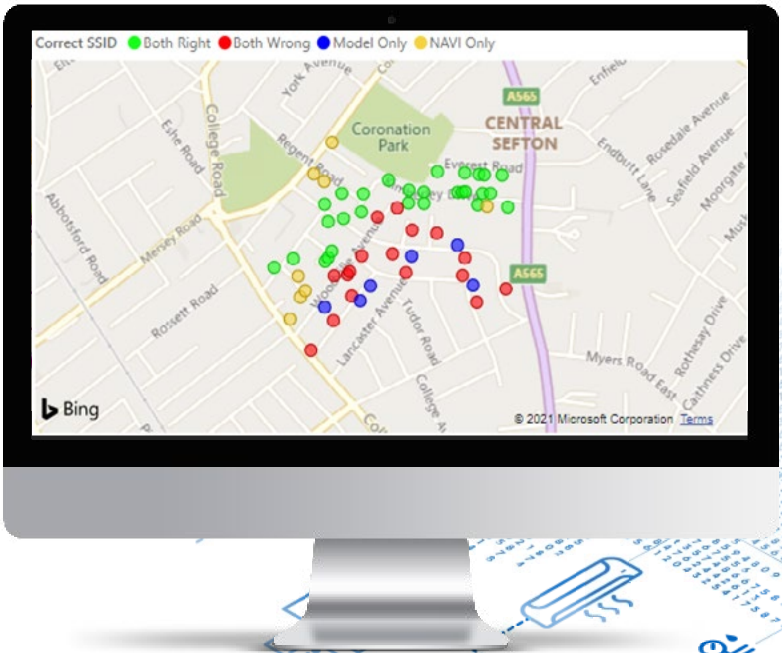
NCEWS2 Revised Project Structure

3.13.1 | NIA SPEN 0034 Project Progress

The focus within the NCEWS2 project has been to develop a fully connected LV network model that was suitable for supporting detailed analytics and data extracts to identify network issues. To achieve this the following objectives were identified:

1. **Automated verification of network connectivity**

   The methodology used for phase identification will also be used to verify the network connectivity. Customers' voltages that share the same source (from the same transformer) share the same voltage profiles. For those that were indicated to share the same transformer but with different profiles, there are high likelihood that they are not connected to the same source. Initial analysis has been made and further refinement is needed to ensure accuracy of the output.



Result of initial analysis of network connectivity verification, which compares the algorithm (model) and what was indicated in NAVI against what is reported in ESRI, assuming ESRI is the source of truth

2. **Near real-time network connectivity understanding**

   Scheduled jobs are setup to extract voltage data from smart meters. Risk reporting is provided by identifying networks with the largest voltage variations and high number of smart meter alarms.

   Within NAVI we have recently developed several network traces and heatmaps to help with network analysis and visualisation. This includes impedance traces to fault locations, as well as traces to allow users to manipulate the network for analysis relating to faults and new points of connection.

Smart meter voltage profiles used to identify faults on the network

3. **Improved LV Network modelling capability**

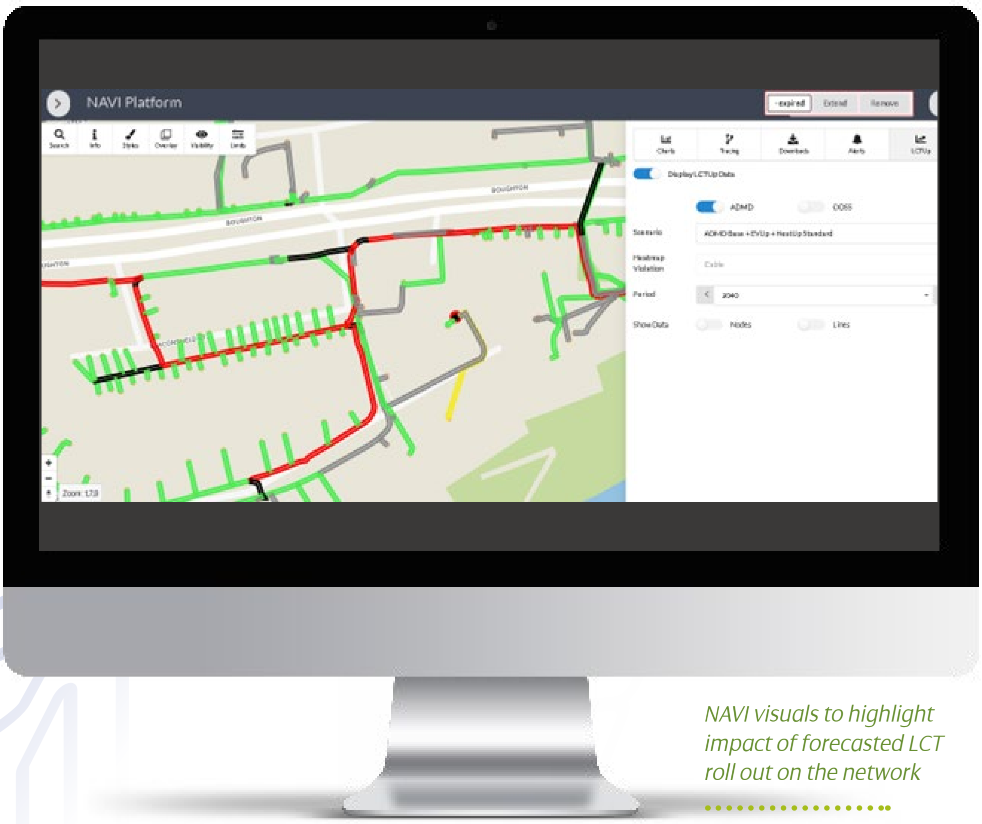
   NAVI has formed a key part of many projects including LV connection and scenario analysis, HV tracing to assist earthing studies and has acted as the main feed of pre-analysed GIS data to several other internal projects.

   One key feature of NAVI is the way in which we have rationalised and backfilled asset data within the network model. The rules have been created for LV and HV assets up to 33kV. A fully rationalised network model has a multitude of benefits including identification of potential risks on the network and the need for reinforcement and faster identification of suitable points of connection.

   We have now developed several exports from the platform to various PSSE tools including WinDebut, DIgSILENT and IPSA, which is allowing trial users to model fully annotated circuits and LV substations within minutes.

4. **Scenario analysis of investment requirements for EV penetration**

   NAVI is also processing and visualising the results of other innovation projects EV-UP and Heat-UP where it analyses the impact to our network of predicted LCT penetrations from now until 2050. This work is being used around the business to help prioritise and plan reinforcement of our assets.



NAVI visuals to highlight impact of forecasted LCT roll out on the network

3.14 | NIA SPEN 0036 A Holistic Intelligent Control System for Flexible Technologies

This project will investigate the potential use of a Holistic Intelligent Control System for the power network. There is a strong drive for DNOs to facilitate the ambitious UK Government and Scottish Government target to ban all new petrol and diesel cars and vans by 2040 and 2032 respectively, and also relying on renewable energy resources for heat and transport. The way energy is consumed and generated are changing and customers are becoming an active player in the energy electricity system. Distribution networks are increasingly important to facilitate these changes in a most cost-effective manner and provide the best value for money to customers. Providing active network operation and transition to a distribution system operator (DSO) arrangement are in the road maps of all the UK DNOs to accommodate the changes in electricity customers behaviour in line with the UK Government Carbon Plan. There has been growing integration of flexible and smart solutions in electricity distribution networks to enhance the utilisation of network assets. In addition, the growing controllable nodes and visibility in the distribution networks are the enablers for transition to DSO where network flexibility offers an adaptive system to customers' needs and facilitating the competition in the energy market.

UK DNOs have been trialling different technologies that allow controlling network parameters such as voltages, power flow and network topologies in real-time e.g. Fun-LV, Active Response, LV Engine, Angle-DC and Equilibrium. Usually each flexible solution/technology requires its own controller which in principle aggregate the local and/or remote monitored data and uses an optimisation algorithm to determine the set points for the controllable devices. The control system architecture often consists of a Master and a number of slave controllers. Typically, the master controller uses regional input data, whereas slave controllers use data available locally.

There are similarities between these controller units in terms of their function, i.e. the control algorithms and the communication requirements. However, due to lack of a holistic smart control system, each flexible solution is currently independently designed, tested and taken through performance check for a period before it can be trusted for Business as Usual (BaU) adoption.

This can result in the following technical and commercial issues:

- Incurring additional and unnecessary costs for a duplicate effort in designing the control systems for every solution;
- Delaying the BaU adaption of the solution as the control system should go through a period of tests and refinement;
- Incurring additional maintenance and training cost for operation staff as they must deal with multiple systems provided by different vendors; and
- Isolated network operation as each solution only limited to specific objectives, network area or voltage levels.

A Flexible Holistic Intelligent Control System, is a proposed solution that sets out the control signal hierarchy and overall network operation optimisation by considering the controllability and impact envelopes of controllable nodes and the customers flexibility offers through aggregators.

HICS can be flexibly adapted to coordinate different optimisation objectives, of controllable devices, to enhance network performance, reliability and provide commercial signals to other network flexibility providers (e.g. aggregators). Some of the high-level network operation objectives can be network losses, wide area voltage optimisations, maximum network headroom capacity etc. Machine learning or artificial intelligence can also be used so the system can be adaptive to network design changes, robust against missing or real time data loss, through loss of network communications, and function independently.

A key characteristic of HICS, is a core control module, which can flexibly and securely integrate the new technologies and interact with other DNO systems (data historian, Network Management System, Data integration platform etc.) The core modules provides a level of interoperability, allowing communication and integration with various network monitoring equipment offering a vendor agnostic solution.

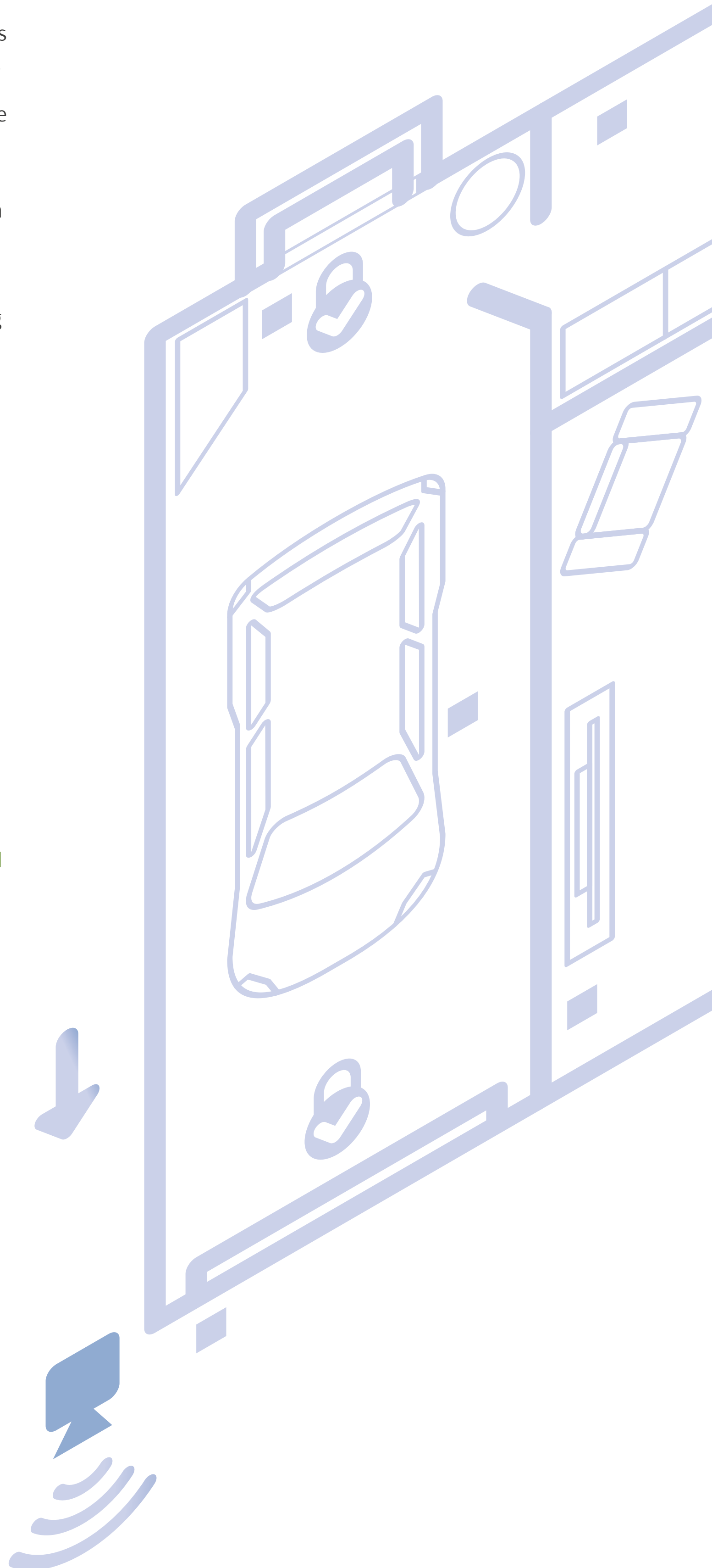
HICS technology is a DSO enabler and capable of providing market commercial signals and technical requirements associated with the DSO transition.

Through the Project, the corresponding international standards and forums, including but not limited to CIGRE B4, C4 studying committee, IEC and SQSS, will be identified to inform and influence the ongoing discussion and standardisation when the TRL level is sufficient to allow a trial.

It is envisaged that the HICS consists of the main (master) controllers providing overall coordinated network optimisation and local (slave) control units providing fail-safe function and set point adjustments based on local data. This project aims to identify the system architecture, optimisation algorithms HCIS and trial of HICS within the distribution network demonstrating its performance at different voltage levels.

The objectives of the project are to:

1. Identify the features required for a Holistic Intelligent Control system owned by a DNO (DSO) Technology Readiness Level at Start TRL 6 Technology Readiness Level at Completion TRL 8;
2. Using existing trial project and proposed control systems to assess the feasibility of incorporating these systems into a HICS scheme;
3. Analyse the evolving characteristic of distribution network with uptake of renewable generation, energy storage and EVs;
4. Define the existing and future control technical requirements to future proof the controller functional design;
5. Scoping and specifying the control interfaces depending on the engineering and/or commercial relationships;
6. Review and Identify present common control algorithms used to optimise flexible and smart solutions; and
7. Propose an open source protocol for the development of future HICS devices.



3.14.1 | NIA SPEN 0036 Project Progress

This project aims to carry out a feasibility study, technical requirements, and implementation of a Holistic Intelligent Control System (HICS). There are several control systems being developed for controllable devices but there are similarities between these control units in terms of their control algorithms, hardware, and the communication requirements.
As reported previously LV Engine and Angle-DC were selected as two pilot projects where similarities between them can contribute directly to the HICS developments with focus on distribution networks covering both LV and HV networks.
Since the last reporting period, the following progress has been made against the project objectives:

1. We progressed on the feasibility study and technical specification of the HICS document. This document is in a stakeholder review stage and is due to be finalised before July 2022;

2 & 4. The server which has been used for Angle-DC central control system (CCS) is a component of HICS. The CCS server has now been built and passed factory acceptance tests. To align this development with other BaU solutions, which are under development in IT and OT system, we are planning to commission the CCS in Q1 2022. However, network architecture delivery has been suspended, due to heightened global cybersecurity risk due to recent geopolitical events. The commissioning will continue once the suspension has been lifted. The system architecture embracing all the communication requirements, third party access, remote control through PowerOn have now been designed and in the final stage of delivery;

2 &3. All necessary telecommunications are now in place providing the two-way monitoring and control communication with SCADA, and an additional telecommunications link has been established between North and South licence areas to meet cybersecurity requirements;

1, 5 & 6. The control philosophy of LV Engine in line with requirements in HICS has also been developed and finalised; and

7. This activity has yet to start.

3.17 | NIA SPEN 0039 THOR Hammer

Over the last ten years in partnership with Industry and Academia, Groundline Engineering has developed a seismic pole tester, "THOR", capable of non-destructively evaluating the in-situ health of timber poles. The real value of this device is its simplicity of use – being as close as possible to the traditional hammer test that the linesmen are used to performing, while still providing the following potential outputs:

- Presence and extent of any internal decay, including below ground level without excavation;
- GPS-tagged measurement results provide confirmation of measurement location for auditing purposes;
- Predicted end of life for refurbishment investment planning;
- Accurate pole condition assessment, making pole climbing activities safer; and
- Pole embedment depth and foundation stiffness.

At present, all results obtained are assessed using both qualitative and quantitative assessments. Qualitative assessment includes a review of the pole hammer input trace and its velocity (output) response in the time domain. The Quantitative assessment of the pole is undertaken using parameters directly obtained from the THOR unit, and once real engineering units are applied, then mechanical impedance parameters such as hammer force input, duration, mobility and dynamic stiffness can be compared against similar pole populations to identify poles requiring further attention or identifying that poles are indeed healthy and sit within a normal admittance range.

Poles tested to date have allowed for the building of a large database of poles and the establishment of health indices for the various parameters in determining if the pole is an "outlier" or outside of the norm.

Barriers to BaU application for the device, to be overcome during the project, include:

- Output given as a reduction of diameter requires modification to an output reduction of strength to allow asset management decisions to be made;
- Detailed analysis is manual, time-consuming and reliant on a small number of people. The feature that enables embedment depth to be measured can only be obtained with detailed waveform analysis at a later date following the test. In addition, the on-site indication currently provided cannot be 100% relied upon so post-test analysis is recommended;
- The instrument was developed in Australia where a different type of wood is used for the pole (hardwood vs softwood) and different issues are encountered (e.g. termites). The technique and analysis parameters need measuring and confirming for GB standard wood poles, and the effectiveness of the technique needs to be proven; and
- The measured output then needs to be turned into something meaningful, i.e. integrated with existing asset management methodologies such as Common Network Asset Indicies Methodology (CNAIM).

Currently, the device provides the condition of the pole in terms of a reduction in diameter. In order for this to be integrated into the GB electricity industries' current policy, this needs to be taken a step further and used to calculate a remaining RSV for the pole. Further works are currently undertaken for the automation of pole analysis – preferably at the time of test, which could be achieved through a machine learning approach. The machine learning technology will convert the conventional way of analysing or processing pole data in, to a faster and potentially accurate output in a timely manner for the industry. The deliverable will be a self-contained unit that provides all of the above analysis, automatically and at the time of test.

Alongside the above, some consultancy work is required to review existing processes and the definition for an end-of-life pole, i.e. 80% remaining residual strength. The deliverable will be an agreed policy to use going forwards.

3.17.1 | NIA SPEN 0039 Project Progress

THOR Testing of a SP Energy Networks pole

Objective 1: Convert the existing output from the instrument (reduction in residual diameter) to reduction of residual strength value (RSV), as assumptions. Output from the THOR device has been altered from reduction in residual diameter to RSV. A proprietary residual strength value evaluation was developed during the project, which accounted for nominal age reduction factor, timber immaturity factor, characteristic fibre strength and THOR field diameter evaluation.

During the project, the DNO partners tested a total of 6,085 poles with a total of 17,298 THOR tests. The data from these tests was fed into the algorithm for RSV.

Objective 2: Utilise machine learning to automate the detailed wavefrom analysis and provide the required outputs at the time of test.

Before the project began, the detailed analysis of the THOR waveforms was completed manually. Throughout the project, Groundline have analysed the waveforms of the THOR tests completed by the DNOs and used machine learning to automate the waveform analysis. The results from the destructive testing completed during the 2nd stage of the project were used to validate the automated waveform analysis.

This waveform analysis now provides Residual Strength Value and embedment depth calculation as outputs from the THOR device at the time of test.

Objective 3: Use real data and destructive examinations to prove the accuracy of the technology on pole types common to the GB electricity industry.

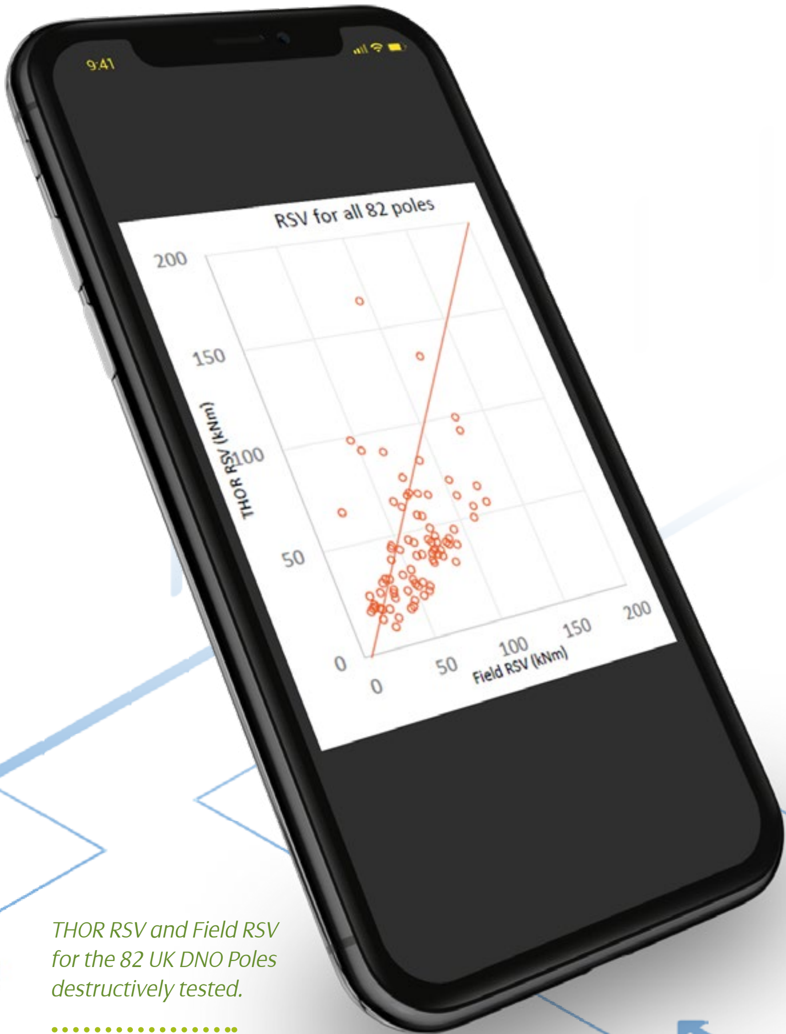
A destructive test rig was set up by NG Construction, in April 2021 with a view to perform destructive pole testing to validate the Thor device tests on UK wood poles. The testing rig set-up followed the standard ASTM D1036 – Standard Testing Method of Static Tests of Wood Poles.

Setup of destructive testing rig in line with ASTM D1036 standard

A total of 83 poles were tested using the THOR device, subsequently removed from service, and destructively tested within the test rig. The load applied, deflection and final breaking load of the poles were recorded.

Destructive testing of a SP Energy Networks pole, showing breaking point at ground level

The destructive RSV was compared with the THOR calculated RSV for each pole. The results for the 82 poles showed good correlation between the field RSV and the THOR RSV. 52 poles were also used to test the automated embedment depth calculation. The embedment depth prediction for 90% of the poles were within 3.5% of the measured embedment depth value.



THOR RSV and Field RSV for the 82 UK DNO Poles destructively tested.

3.19 | NIA SPEN 0041 Proof of Concept Tarmac Reinstatement Tester

Currently, when the quality of asphalt reinstatement is investigated, no non-destructive on-site analysis is used. Instead, core samples of 100mm diameter are extracted from the site and sent for laboratory analysis. The core sample analysis will give an indication of the depth of surface and binder layers but also whether the air void density falls in between the acceptable minimum and maximum tolerances; depending on the material, in the range of 2 to 13% respectively. This method is destructive, intrusive, labour intensive and limited in coverage. Hence, a method that is non-destructive, non-intrusive, and enables accurate measurement of the air void density and layer thickness of the pavement, would be of great interest for the industry.

The Project will look to develop a technique based on combining ground penetrating radar (GPR) technology with a survey technology that has been successfully used in seismology, i.e. the multi-offset antenna array method. This development work will initially be limited to proof of concept. If successful further development will be required to deliver a BaU device.

The Project initially will be limited to laboratory work to develop the proof of concept. This research and development work will be split into four work stages.

Stage 1 – A list of specifications regarding the system requirements and the samples specifications will be established. Theoretical and simulation work will be carried out to determine the conditions under which the tests will be performed, such as signal power, frequencies, number and shape of bespoke antennas and the offset distances.

Stage 2 – When the main parameters relating to the tests have been established the laboratory tests will be undertaken. Signal generators-receivers and bespoke antennas will be used to perform tests on air gaps, gypsum and concrete plates to optimise the antennas characteristics.

Stage 3 – After the optimal characteristics of antennas have been determined, the next step will be to test real pavement samples. Possible field tests may also be carried out.

Stage 4 – The results of the project will be incorporated into a final report which will inform on whether any technique developed within the project could be taken further.

3.19.1 | NIA SPEN 0041 Project Progress

The objective of this project is to develop a technique that will determine the depth of surface and binder layers but also whether the air void density falls in between the acceptable minimum and maximum tolerances; depending on the material. The technique developed should be non-intrusive and such that It could be incorporated into a device that could be conveniently used on site to determine the quality of the reinstated tarmac.

During the reporting year the project progress was as following:

- The project has seen stage 1 successfully completed with the specification for the system requirements defined as well as identifying the various reinstatements that the system will have to detect in terms of air void densities and thicknesses.
- Stage 2 of the project involved reinstatement core samples provided to NDT consultants for further development of the prototype equipment. The core samples were a mixture of internal SP Energy Networks samples and laboratory samples supplied by third party. The samples were used to successfully further develop the equipment. During the laboratory tests impedance analysis was used to measure air void density in the surface layer and GPR to measure the layer thickness. Concrete slabs, printed plastic samples and asphalt samples were all studied.
- Stage 3 has been successfully completed with several field test of the equipment carried out in July 2021. The prototype equipment was used to measure areas of pavement and carriageway reinstatements, for both thickness and air void densities. The measured values were compared with laboratory tests of core samples removed from the reinstated areas. The prototype equipment showed promise in the measurement of thickness and air void density of reinstatements when compared to laboratory test values. Following submission of the final report in Stage 4 of the project, further development of the equipment is planned.
- The device developed is non-intrusive and provides thickness and air-void density measurements to allow the user to determine whether surface and binder layers of reinstatements fall within acceptable limits or not which is in line with the project objective.

SP ENERGY
NETWORKS

3.20 | NIA SPEN 0043 Bethesda Home Hub

This project is exploring a method to look to customers to shift their electricity usage to times of the day or night when demand on the network is traditionally lower. This involves changing people's routines and habits until they feel they are getting all of the electricity they need, for minimal inconvenience, while also avoiding peak usage times when possible. This project will explore this specific problem and trial a novel commercial arrangement as part of a potential solution.

The objectives for this project are:

1. Demonstrate the impact of DSR for local balancing and its ability to manage constraints ahead of safety critical active network management schemes at LV. Demonstrate how flexible solutions and business models benefit the network and deferment of reinforcement. Model of the impact at scale.
2. Demonstration of how readings from meters at remote points of the network and forecasts of demand and generation can be used for network management or planning and provide more accurate planning and lower cost connections.
3. Development of new parameters to quantify the impact of DSR for planning purposes and how these can be used in network planning in future. This can defer reinforcement via flexible solutions.
4. Test a practical framework (a penalty and reward scheme) to encourage efficient behaviour on the network and demonstration of how it can be implemented within dataflows. Evidence for the impact of reward and penalty scheme for Ofgem. This will encourage more efficient behaviour to reduce network reinforcement.
5. Demonstration of how DSR and flexible solution can help tackle fuel poverty and transport poverty.
6. Better interaction and understanding of the network by communities.

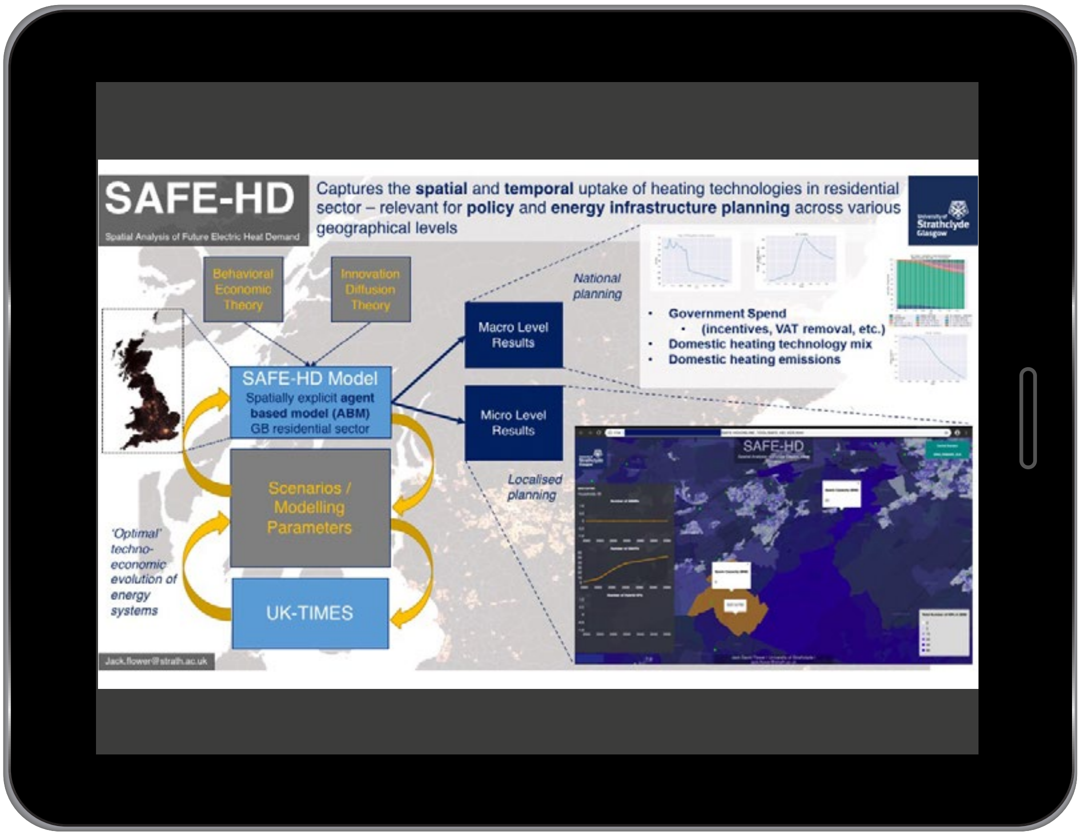
3.20.1 | NIA SPEN 0043 Project Progress

Energy Local have been developing a domestic home hub to allow households to schedule appliances to run at the optimum times. Progress has been made, however, installation of these home hubs in the selected trial areas has been less than expected due to COVID-19 restricting access to properties. That said, all customers have access to the same information provided by the Hub via an online dashboard. Each customer can have a probability signal sent out to them each 24 hours with 48 values to indicate 'how good or bad' each half hour during the day is to use power. This is based on a forecast of the community's demand, the forecast of local renewable generation and a Time of Use Tariff. However, other parameters could be considered. The household can schedule appliances according to when they need an appliance to be finished, how long it takes and whether it can be interrupted.

Alongside this, De Montfort university have begun modelling to develop 'what if scenarios'. This is developing the concept of parameters to give:

- **Flexibility –** a measure of people's willingness to be flexible at different times of day and for different demographics.
- **Stay-ability –** a measure of people's ability to maintain new habits over time for different demographics.
- These parameters will then provide a method for tracking the success of any trial method to change peoples' habits and maintain them. In addition, the communications use will enable remote voltage measurements on LV feeders via the meters in real time.

3.21 | NIA SPEN 0045 SAFE-HD (Spatial Analysis of Future Electric Heat Demand)



This project explores the heterogeneity of residential heat demand, and assesses how this diversity, along with social demographic and dwelling characteristic diversity relates to the suitability and cost effectiveness of heating technologies. This knowledge will be used to better understand how, against a backdrop of demand, policy and cost uncertainty, likely uptake of electrical heating technologies will impact future network infrastructure requirements

The Committee for Climate Change (CCC) has, in its 2018 review of UK progress towards meeting carbon targets, continued to highlight the ongoing difficulties and lack of progress in decarbonising the heat sector. Decarbonisation of heat within domestic buildings provides one of the greatest challenges to overcome the 'lock in' barrier of natural gas-fired heating. The CCC strongly promotes the uptake of heat pumps as part of the solution and has recommended that no new homes be connected to the gas network by 2025 at the latest.

Electrifying large amount of heat demand is expected to impact future network infrastructure due to the scale and seasonal nature of heat demand.

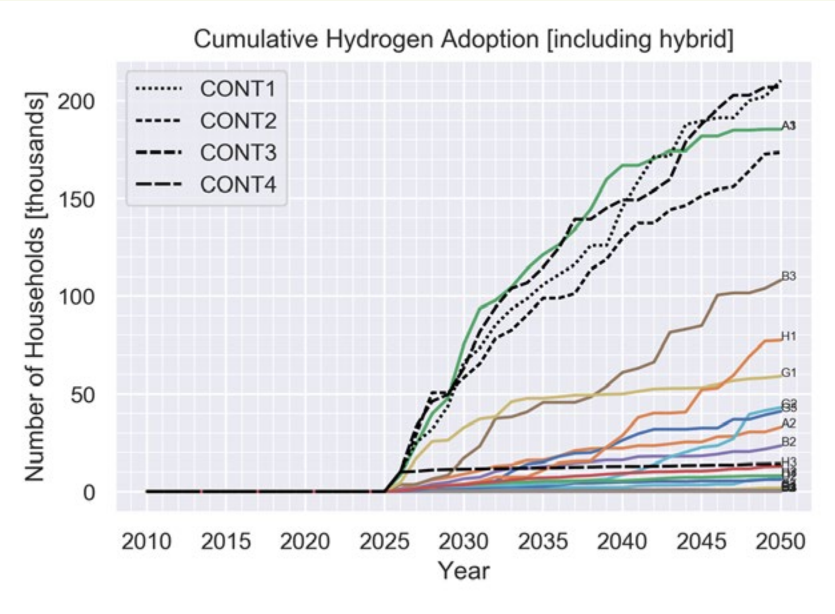
This project is developing and applying methods to explore optimal decarbonisation pathways to determine likely future heating technology mixes against a backdrop of policy, cost and demand uncertainties.

It is being delivered in several stages including:

- **Geospatial Analysis:** An examination of the heterogeneity of UK heat demand, dwelling characteristics, social demographics and how these relate to existing heat pump uptake. Analysis will be performed using geospatial analysis software.
- **SAFE HD Model:** Building on the Geospatial analysis, a spatially explicit agent-based model (ABM) of the GB housing stock model will be developed to explore future electric heat demand. The model will be soft linked with the whole energy systems model called UK-TIMES (UKTM) in order to account for wider energy system interaction.

3.21.1 | NIA SPEN 0045 Project Progress

Progress was made on model development, with useful learnings having been successfully generated, and the SAFE-HD project is now complete. Construction of the SAFE-HD model is now complete and it has been calibrated and validated. The SAFE-HD project will be packaged for external use as an interactive mapping tool (the aim is to host this on the University of Strathclyde website).



Interim SAFE-HD modelling results showing cumulative hydrogen adoption by scenario for GB owner occupied households. Note, it is assumed that there is only one gas conversion programme in GB (that is blue hydrogen) starting in the same location with a fixed conversion rate for all scenarios modelled (as per Leeds City Gate study).

The project has met the specific objectives to:

- Generate high spatial resolution heat energy demand estimates based on actual energy consumption data and investigate how these heat demands relate to type of heating system, dwelling characteristics and social demographics;
- Characterise households by their behaviour and attitudes towards alternative heating technology uptake; and
- Develop the SAFE-HD agent based model and explore the spatial distributions of future electric heat demand under uncertainty.

During the project the third phase was not able to be completed.

- Conduct network impact assessments with the aim of identifying least regret network investment options required. Recommend how the tools and methods developed for the SAFE-HD project can be used by all DNOs.

It was felt that the network modelling aspects could be carried out better by existing tools within the DNO organisations.

3.22 | NIA SPEN 0047 A Transition to LVDC – Phase 2

LVDC Phase 1 explored the potential benefits that lie in converting Low Voltage AC circuits to LVDC. The advantages being releasing extra power transfer capacity in the cables, allowing Low Carbon Technologies to connect more readily, reducing/negating conversion losses and facilitating longer LV feeders in rural areas. Huge cost, time and environmental benefits can be realised through conversion to LVDC as opposed to conventional network reinforcement. Furthermore, the considerable expected increase in LCT uptake in the coming years can be more easily facilitated with the aid of a LVDC network.

LVDC phase 2 will conduct laboratory tests on the cables and network apparatus most prevalent on SP Energy Network's network to gain an understanding of how SP Energy Network's LVAC cables and network apparatus behave when energised with LVDC. The outcome of the tests will then inform which areas of the network would be suitable for conversion to LVDC.

LVDC Phase 2 – Deliverable 1

"To compile a testing specification which covers the predominant AC assets within the LV network."

This involves understanding the most populous LV Cables, joints and link boxes found on the LV Network as well as understanding what value they present to potential conversion to LVDC from LVAC.

LVDC Phase 2 – Deliverable 2

"Conduct a tender exercise for a testing facility to complete the testing specification created."

This involves searching the UK and beyond for specialised facilities that can provide the equipment, expertise and availability to complete the rigorous testing regime required. As these tests are UK (if not world first) then there is a very limited number of facilities around the UK that meet the necessary criteria.

LVDC Phase 2 – Deliverable 3

"To complete the testing programme as per the testing specification and compile a report on the findings from the laboratory testing."

After the testing facility has been procured the detailed testing programme on the LV cables, joints and link boxes will be completed in order to gain a deep understanding of how they will perform when energised with LVDC.

3.22.1 | NIA SPEN 0047 Project Progress

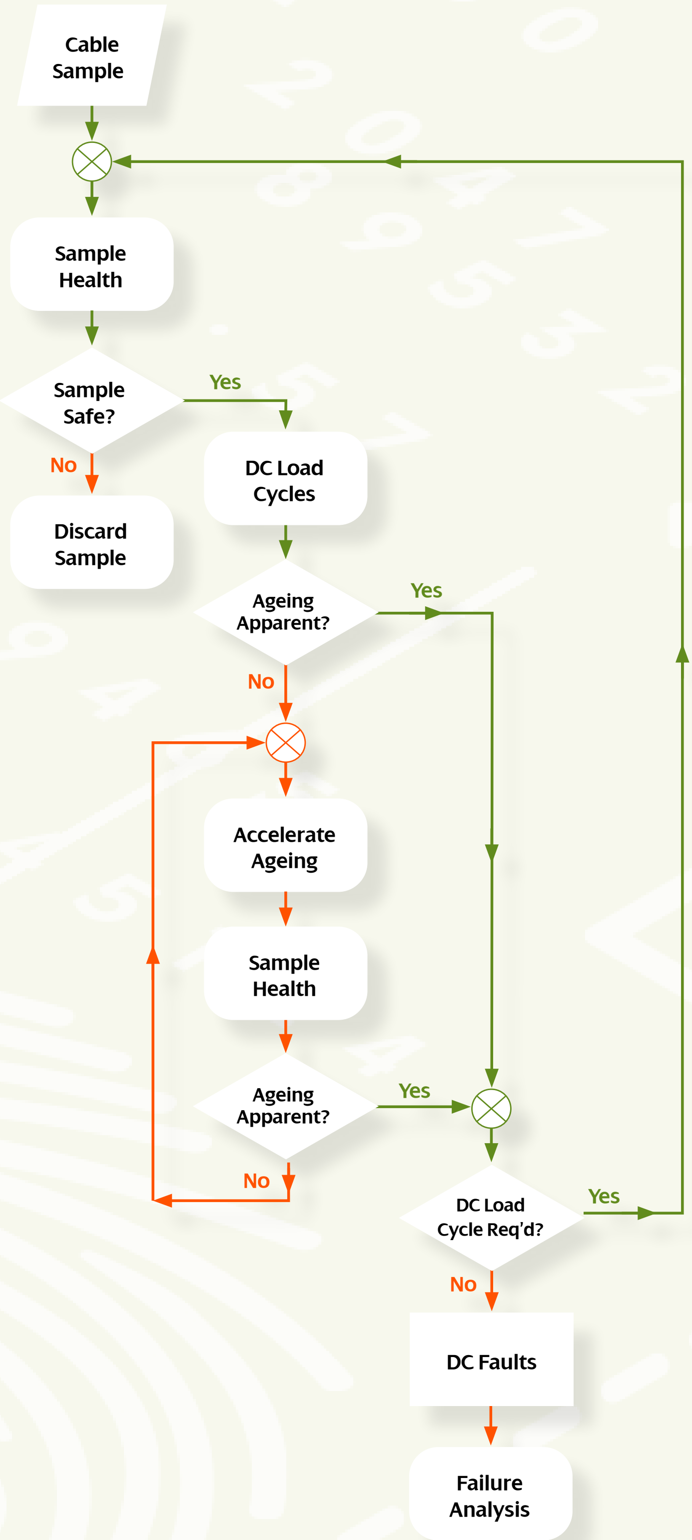
At the end of the reporting period this project was nearing completion with the following progress being made against the project objectives:

1. To compile a testing specification which covers the predominant AC assets within the LV Network.

   A robust scope and testing specification was completed for the purposes of the project. This document outlined what assets were to be tested, what tests they needed to be subjected to, and detailed technical information to assist with test rig construction and testing outcomes.

DC energisation in a lab based environment

The figure below shows a flow chart of the testing programme employed on each cable type:



2. **Conduct a tender exercise for a testing facility to complete the testing specification created.**

   A comprehensive tender exercise took place to ensure the best testing facility was selected for the project against the tender criteria. Facilities from the UK and North Europe were contacted to complete a pre-qualification questionnaire (PQQ) for the project. Following completion of the PQQ, a shortlist of capable facilities were invited to formally tender for the project. Following completion of the tender exercise, the Power Networks Demonstration Centre (PNDC) was selected as they performed highest against the project / tender criteria.

3. **To complete the testing specification and compile a report on the findings from the laboratory testing.**

   A detailed report from the testing was produced by SP Energy Network and PNDC. The tests were completed, and primary outcomes were:

   Tests employed:

   - Routine sample health assessment (Insulation Resistance, Capacitance, Tan Delta and Conductor Resistance);
   - Representative DC load cycles (+500 and +707 Vdc) with 8 hours of loading and 16 hours offload;
   - DC accelerated aging based on CIGRE TB496 at 1.85 times the rated DC voltage; and
   - The application of DC forced faults using a bespoke fault rig simulating a number of EV rapid chargers.

Outcomes:

- All samples completed the programme and only one partial failure was observed, due to mechanical damage rather than the DC test regime.
- The testing confirmed that no adverse behaviour was evident whilst the LVAC cables were energised under representative DC load cycles.
- No samples failed during the accelerated aging programme and there was no significant degradation in insulation performance on the range of samples.
- All samples withstood the applied fault current and were deemed safe in the post fault health assessment.
- One sample group completed the prescribed 40 years of service and projections suggest that groups which experienced 10 years of aging would also complete the 40 years of service.
- The availability of cable/accessory health assessment data would enable more effective run to failure trends to be developed for the different cables/joints/linkboxes.

4. To create a series of case studies and a cost-benefit analysis which will conclude where converting existing assets to LVDC would be technically and economically viable.

A comprehensive Cost Benefit Analysis (CBA) methodology has been derived and utilised for real world CBA examples. A formula for ascertaining the estimated cost of the LVDC solution has been developed which is then used against the traditional LVAC costing to ascertain where LVDC is financially viable.

3.24 | NIA SPEN 0049 iDentify

iDentify will address issues with reporting of faults in customer's cut-outs. The following issues are common when considering this:

1. **Asset data collection –** There are unknown quantities of customer devices with no straightforward method of data collection. Cut-out types and quantities are also unknown without major expenditure to gather information manually.
2. **Aborted calls –** SP Energy Networks staff are often sent to site for "check for safety" when the issue is a non-SP Energy Networks asset or pole, or where the customer has tripped switches.
3. **Ageing assets and younger workforce –** there are some situations where switchgear won't operate as it takes some more experience than our operating manual offers, particularly for old equipment which is no longer installed but has not been replaced.

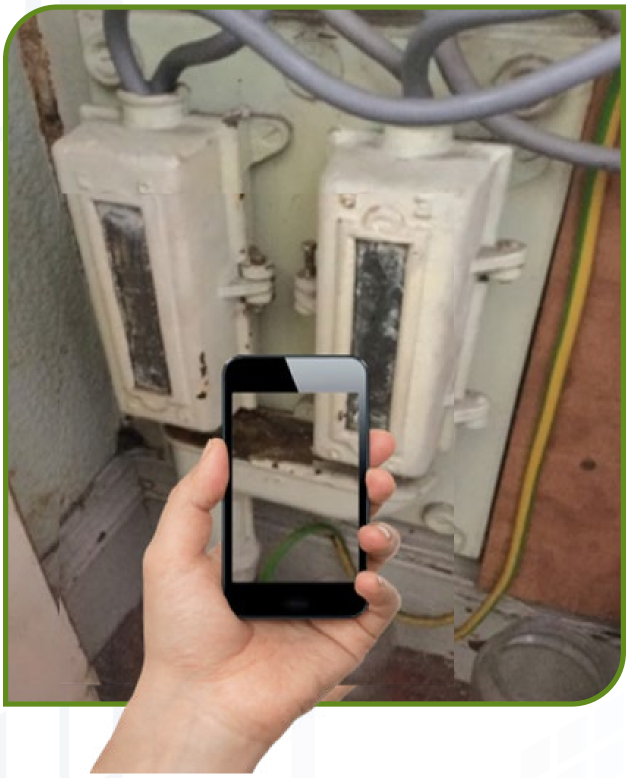
This project will exploit artificial intelligence (AI) Recognition technology and augmented reality to:

1. Crowdsource data on SP Energy Networks assets and customer devices to aid in updating the SP Energy Networks asset records;
2. Identify 3rd party assets to reduce aborted calls; and
3. Offer training, support and guidance to field staff on SP Energy Networks assets.

It will do this through the development of an app which will identify the asset it is trained on and will provide either useful asset data or problem-solving guidance to the user.

3.24.1 | NIA SPEN 0049 Project Progress

Objectives: there are 3 use cases (UC) for the AI recognition iDentify project



1. **Replace the ENA Electric vehicle charge point (EVCP), Heat pump (HP) and small generation (G98) paper forms to enable installers to provide information digitally.**

   Description: The iDentify system will also include a fuse size calculator, visual AI check on the cut-out and rules-based decision making to instantly inform the installer whether they can continue with the installation (Connect and Notify) or if SP Energy Networks need to intervene (Apply to Connect). Additional benefits to the return of installation information are; this app will also transfer all existing household data collected by the installer, complete a proximity check to confirm the cut-out was surveyed in the vicinity of the address, and enable installers to register on the app and send information reducing their effort. Benefits to SP Energy Networks is a much-reduced full time equivalent (FTE) headcount currently forecasted to deal with the increase in LCT installations. There are further enhancements to be considered following the minimum viable product (MVP) rollout, such as creating a version for local authorities to survey their housing stock rather than a visit from SP Energy Networks to survey our on-site equipment; improving the ease of use incorporating customer directly; and to add functionality to replace the G99 fast track and G100 forms (larger generation and batteries).

Progress: The app and system are working and available for test and demo. Rollout is now due mid-September 2022 following a decision from the ENA not to take the opportunity to roll out UK wide as was expected. Extra time added to the project to bring outstanding ENA actions inhouse, and carry out a rebranding exercise.

2. **Identify 3rd party assets to reduce aborted calls.**

   Description: Create a system to provide a customer with an AI recognition weblink when they call to inform of either; a single premise off supply. They will point their smartphone camera at their fuse box to look for switches in the off position, and; when a customer finds a street furniture cabinet door open. The customer will follow a weblink to AI software and point their smartphone camera at the cabinet which will inform them if it is a SP Energy Networks cabinet or some other such as telecoms.

   Progress: This is not yet started and will follow on from UC1 if it fits into the business roadmap.

3. **Offer training, support, and guidance to field staff on SP Energy Networks assets – the ability to recognise and measure.**

   Description: with many of our experienced staff retiring from the company leaving a knowledge vacuum, this app would bring the intelligence of the human into the app to be shared company wide and inform field staff of known issues and solutions, such as tips on problematic switch gear, measurement of stripped cable prior to joining measuring conductor exposure.

Progress: This is not yet started and will follow on from UC1 if it fits into the business roadmap.

SP ENERGY NETWORKS

3.25 NIA SPEN 0050 Real Time Fault Level Monitoring Stage 2

This project is a follow on from the Stage 1 project (NIA_SPEN0015). The main outcome of the Stage 1 project was a proof-of-concept design to measure network Fault Level in real time. This has been clearly demonstrated. One of the prototype devices is illustrated.

To maximise the benefits of this innovation and achieve widescale BaU rollout and move to TRL9, the scope of Stage 2 (NIA_SPEN0050) is to:

- Expand the network trial locations, to assess the performance of the devices and compare measured fault level values to existing practices for multiple network configurations.
- It is known that there are approximations in the existing practices (modelling) for determining Fault Level. Controlled tests at a suitable test network at which real fault current can also be measured would enable calibration / approval of measured results to be used as the primary information source when managing the network.

Real Time Fault level monitoring prototype

3.25.1 | NIA SPEN 0050 Project Progress

This project has continued to progress well. A key milestone was completed in July 2021 as planned – full scale live tests at the VEIKI laboratories in Budapest, Hungary. These tests were designed to examine the ability of the Real Time Fault Level Monitor to correctly predict the network fault level under different conditions, representative of normal electricity network operation. The actual fault current present was measured following full bolted faults at the target busbar.

The target bus voltage was energised, and then the Real Time Fault Level Monitor operated for a short time period to predict the fault level for both half cycle Peak (Make) and 90ms RMS (Break). A bolted fault was then applied on the target bus under the same conditions, and the fault current measured using the laboratory instrumentation. Steps were taken to ensure that the results were consistent and repeatable.

The test results corroborated the results previously seen (obtained from the tests at the Power Networks Demonstration Centre, as reported previously). The average difference in magnitude between prediction and measurement for RMS fault level at 90ms was less than 1%, with a worst case of 1.6%. This is well within the original project aims of <5%.

The strong performance gives us confidence in the device and supports our ambition to roll out this technology across the network over the coming years. The work has also provided the opportunity to undertake detailed analysis on the laboratory data, to fully understand the behaviour of circuit breakers and how this affects fault current, and what should be taken into account in network design.

Further to the above, design and build on further devices for test and deployment on both SP Energy Networks and UK Power Networks distribution networks has continued to progress, albeit with some small delays due to supplier issues, the Covid pandemic being the key influencing factor. Development of supporting documentation has also commenced.

Progress against objectives:

1. **To progress the device from a working prototype design to a fully tested and ratified device for use on the GB electricity networks.** Project is on course to meet Objective 1. Laboratory testing has so far been successful and the appropriate documentation is under development.
2. **Complete trials on various network configurations and demonstrate potential benefits.** Project is on course to meet Objective 2. Different network topologies have been trialled with more scheduled in the project plan.
3. **Develop and produce a system for measuring fault level in real time across split busbar configurations.** Project is on course to meet Objective 3. Focus has been on other areas to date, however background work on this part of the solution has started.
4. **Develop and produce a portable ‘traveller’ version of the device.** Project is on course to meet Objective 4. Focus has been on other areas to date, however background work on this part of the solution has started.
5. **Undertake a live trial combining with Active Fault Level Management (SP Energy Networks only)** Project is on course to meet Objective 5. Formal commissioning has started at the trial site, with deployment scheduled for Summer 2022.
6. **Disseminate results to the industry.** Project is on course to meet Objective 6, with several dissemination exercises already completed (including CIRED 2019, Cigre 2021, CIRED 2022, and press releases in trade media).

3.26 NIA SPEN 0052 A Substation of the Future

The Substation of the Future project will purchase and install alternative non-SF6 Stand Alone Panels, as part of the re-design of a secondary substation to account for the non-SF6 Panel & low carbon TX and other standard components. The project will investigate the Life Cycle Analysis of the non-SF6 unit and novel substation arrangement and develop learning of commercially available options to enable the solution to be optimised for rollout.

Current expectations are for SF6 to be banned for new installations come 2025. A review of current legislation is due to take place prior to June 2020. As this EU review incorporates up to 52kV it will have a large impact on DNOs as this is where SF6 alternatives are scarce and they will need to act fast to propose new solutions to the alternative installation of gas insulated equipment. From the RIIO-T2 submissions there has been an incentive to UK TNOs from the regulator, OFGEM, to install alternative gas insulated technologies. It is expected that the same will happen when RIIO-ED2 takes effect and the same principles in consideration of CO2 emissions will be applied. Non-SF6 alternatives exist but their integration into BaU has not yet been seen. Doing nothing now means potentially having to rapidly rollout an unfamiliar solution when the issue becomes imminent.

The project scope of work includes:

- **Procurement:** The procurement process will include engagement with supplier to obtain the novel equipment required for the S/S;
- **Identification:** To identify and specify the optimal demonstration site for trial;
- **Design:** To design and approve the novel arrangement for the S/S; this will also include analysis of the offset carbon from the approach;
- **Deploy:** To deliver, install and commission at the selected site; and
- **Review:** To review the project learning to inform future rollout.

3.26.1 | NIA SPEN 0052 Project Progress

The substation of the future project is now complete. The substation has been successfully installed and put into operation serving in the south of Glasgow.

Significant tasks during the past year have included:

- Procurement, manufacture and delivery of all substation components in line with the detailed design and specifications created for the project;
- Installation, commissioning and operation of the substation during the second half of 2022; and
- Carbon reduction optioneering assessment against a baseline of our standard secondary substation.

The substation has a prominent position just south of the CoP 26 conference venue and was displayed as part of this event. A short YouTube video https://www.youtube.com/watch?v=L5Om-OeTv9M provides further information.

The project has met the key objectives including the purchase and installation of non-SF6 standalone panels and low carbon transformer, within the novel secondary substation.

A further objective was to conduct an investigation into the Life Cycle Analysis (LCA) of the non-SF6 unit and novel substation arrangement. In meeting this objective we discovered that the LCA of the novel substation emits circa 15% less CO2 than a typical substation.

Finally the objective to develop learning of commercially available options to enable solution to be optimised for rollout has been met and learnings will inform our strategic net zero and sustainability plans for ED2 and beyond.

3.28 NIA SPEN 0055 On-Site Non-Intrusive Polychlorinated Biphenyls (PCB)

The European Union has issued a directive for the elimination of all HV equipment containing polychlorinated biphenyls (PCB) contaminated oils that have a concentration of above 2 parts per million; the UK deadline is 2025.

GB DNOs have large fleets of oil filled Pole Mounted Transformers (PMTs). To meet their legal responsibilities, they need to confirm the levels of PCB contamination to enable appropriate asset management including the required asset replacement planning and appropriate disposal. Chlorinated hydrocarbons are only present if PCBs are present in the oil. The project will target chlorine concentration measurement remotely based on radionuclide decay using gamma ray detection.

The proposed solution is intended to be a non-intrusive method of determining the PCB levels in the field without the need to return samples to the laboratory

The method does not require obtaining an oil sample from the asset or any interference with the fabric of the asset.

The project will enable EA Technology to present a service to the UK DNOs that if adopted will enable UK DNOs to manage their fleet of pole mounted transformers and meet the requirements of Environmental legislation.

The project comprises of four stages:

Stage 1: Sourcing of and purchase of suitable detector instrument and associated consumables: The output will be the delivery of equipment to EA Technology (the ownership is retained by the Energy Innovation Centre (EIC) partners and a functional specification of the detector instrument will be documented).

Stage 2: Theoretical Undertakings and Equipment Calibration: Investigation of theoretical aspects of establishing the algorithm for converting the gamma ray activity into PCB Aroclor concentration will be investigated. The output will be a report detailing the findings of the stage to establishing a theoretical algorithm. The necessary information will be available to decide on the likely success of the project, at which time the project could be terminated or continued with the agreement the partners.

Stage 3: Completion of Algorithm Verification and Laboratory Trails: Testing of the theoretical algorithm against experimental data and identify any correction required and verify the model. The output will be a written report detailing the findings of the stage and producing the working algorithm.

Stage 4: Completion of Field Trials and Training: Adaptation of the equipment for field testing, field trials will be performed to assess the methodology, accuracy of detection and logistics of completing the tests in the field, documentation of the procedure and future service offering and training of SP Energy Networks staff. The output will be a report including documented working methodology for the onsite procedure.

Pole Mounted Transformer

Benefits

The partners will own the detector instrument and a functional specification of the detector instrument will be produced. The project will enable the partner DNOs to collect the required data from the field for EA Technology to process using the algorithm determining the PCB concentration. This will enable the partner DNOs to manage their fleet of pole mounted transformers and meet the requirements of environmental legislation. In addition, the methodology will aid reducing the number of interruptions to customers, while ensuring network companies maintain a sustainable and resilient electrical network. The cost savings associated with this method compared to obtaining an oil sample from the asset is estimated to be millions of pounds for the UK DNOs. Furthermore, there is very little safety impact of utilising the non-intrusive method compared to obtaining an oil sample from the field.

The project will commence at Technology Readiness Level (TRL) 2 and complete at TRL 8.

3.28.1 | NIA SPEN 0055 Project Progress

The project objective was to develop an on-site non-intrusive PCB tester based on radionuclide decay using gamma ray detection.

The project objective was explored but not met due to the prohibitive cost of development and inherent health and safety risks that became apparent over the course of the project. It was mutually agreed that this project would close and SP Energy Networks would continue to look at other means of addressing this problem.

The initial proposal was to achieve determination of PCB through naturally existing gamma rays from Chlorine-36, while acknowledging that the challenge is to find a detector that is sensitive enough for the gamma ray detection.

EIC Partners (SP Energy Networks, Scottish and Southern Energy Networks, Northern Power Grid and UK Power Networks) were formally informed that potential suppliers could only provide deuterium- tritium neutron generator, which has health and safety concerns arising from the additional radioactivity introduced. Besides that, there is a need for understanding and addressing all possible radioisotopes that are to be generated from such an activity.

Citing health and safety risks for the whole lifecycle of such a detector, together with consideration of the tight timescale needed to not just understand but also address incremental radioactivity, EIC Partners decided to close the project.

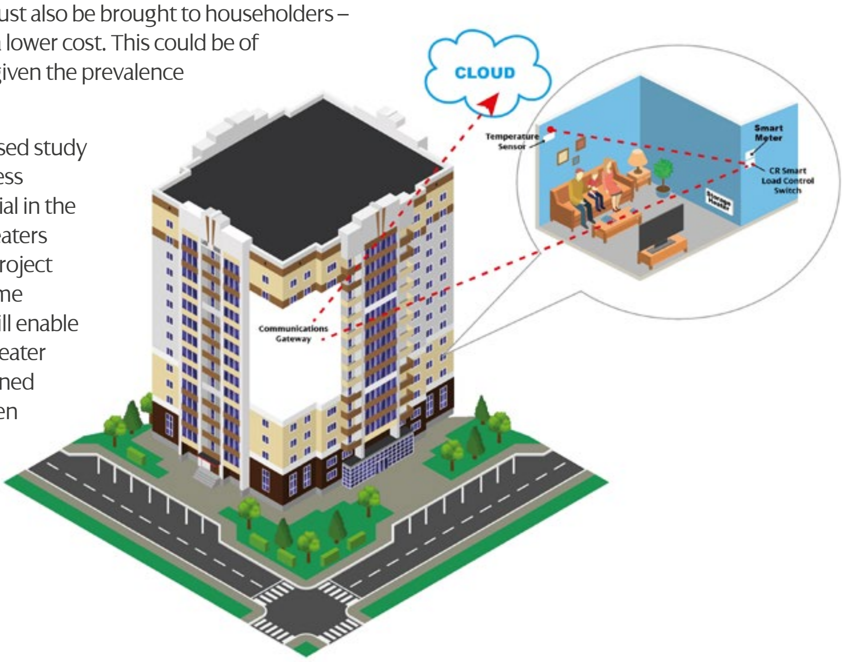
3.29 NIA SPEN 0056 Flexible Tower Block

The Flexible Tower project will investigate how SP Energy Networks can support and benefit from smart controls to influence the timing of storage heater charging. The project will benefit the customer through ability to lower bills and the network by opening up a largely untapped resource to the flexibility market. We have partnered with Glasgow Housing Association (GHA), Scotland's largest social landlord, to deliver the Flexible Tower project. GHA are currently investing in smart heating control across their properties across the city of Glasgow and one of these properties, Cartcraigs Tower in the south of Glasgow, has been selected to form the basis of study and trial.

Presently storage heating is seen as a non-flexible load and vulnerable customers are suffering as a consequence of night-time-only charging; heating performance is poor and expensive; On Peak supplementary heating is often required at the daily evening peak. The experience for customers can be improved by introducing flexible storage heater charging in conjunction with tariffs to achieve better heating profiles and costs. Around 260,000 households in Scotland have electric storage heaters installed and a significant proportion are likely 'here to stay' in the long term.

Smart storage heating controls offer wider whole system benefits to the ESO and to electricity suppliers. In doing so, benefits must also be brought to householders – through improved provision of comfort at a lower cost. This could be of considerable value to these householders given the prevalence of fuel poverty in Scotland.

The scope of the project includes a desk-based study focusing on commercial, market and business issues which will be complimented with a trial in the Cartcraigs tower block which has storage heaters fitted with smart in home controllers. The project will develop an API interface between in home controller and SP Energy Networks which will enable trials to be run on the tower block storage heater use against typical EV charging and constrained wind data sets. Monitoring will be undertaken within a percentage of the tower block properties and at Feeder level in order to evaluate the performance of the in home smart controller.



3.29.1 | NIA SPEN 0056 Project Progress

In the reporting year we have concluded work on the desk-based study and made significant progress with the work toward the tower block trial.

The initial work comprised a desktop study into the tariffs available to the residents and their ability to access the flexibility market. This desktop study into existing tariff structure and its suitability for networks and customer investigated how benefits for customers and network can be captured.

Connected response have been engaged by the Glasgow Housing Association (GHA) to supply in-home smart controllers. The smart controllers and monitoring is now installed in the Cartcraigs tower block.

The project has delivered its first set of objectives relating to the opportunities that smart control of storage heaters can bring to customer and network.

Project progress has realised the following findings :

- There would be benefits from a flexible smart storage tariff
- Dual-rate tariff most appropriate in next 5-7 years (rather than half-hourly time of use)
- Could enable value from flex market to be shared with customers
- Retailers, Aggregators and control providers all with role to play.
- A number of options available to networks to enable storage heater flexibility
- Revised red band DUoS wrapped into tariff as present situation
- Continue Flex tenders within Constraint Managed Zone (CMZ)
- Arrangement with retailer/aggregator to avoid red band
- Direct overriding signals (ANM)
- Working with local energy market using price signals
- Combination of these approaches
- There is potential for a trial
- Multiple groups of storage heaters across Glasgow
- Each group provided with simulated constraint
- 2-3 retailers per trial
- Electricity Supply Operator (ESO) involvement
- Under a sandbox arrangement
- SP Energy Networks needs to better understand future flexibility at LV level and develop better visibility of future constraints
- Electric vehicles and heat pumps down to street level
- Implement greater monitoring of these assets

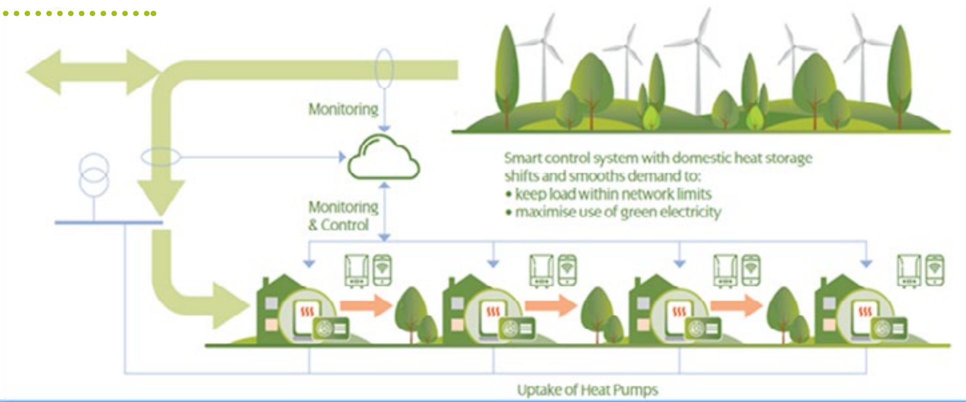
In addition to the tariff study a trial will take place at the Cartcraigs tower block in the southside of Glasgow. The objectives of the trial are listed below, these will be completed during the next reporting period.

- Demonstrate the shifting of demand using thermal storage heaters whilst maintaining customer warmth and comfort in the tower block.
- Show that the storage heating demand shift in the tower block can support local electric vehicle charging requirements.
- Show that the storage heating demand shift can be randomised to support cold load pick up and support use of constrained wind.

3.30 NIA SPEN 0058 ReHeat

Re-Heat is the first DNO-led large-scale trial of electrified heat which will develop combined technical and commercial solutions to make heat demand flexible, reducing the peak demand on the electricity network. Re-Heat is a strategically significant project being a first of its kind to investigate the impact of full electrification using technology such as Air Source Heat Pumps (ASHPs) and thermal storage to maximise the usage of existing assets by deferring and optimising the conventional network reinforcement needs. Re-Heat will demonstrate tools to enable an accelerated deployment of low carbon electrified heating at an efficient cost to customers, and release the whole-system benefits of flexible heat, providing timely evidence to inform national policy and electricity networks' investment strategy.

The RE-Heat Solution



The solution includes smart grid controls and smart heating management with domestic heat storage to reduce peak electricity demand as a customer friendly and cost effective alternative to network upgrades

The primary technical method that will be trialled in Re-Heat is the deployment of domestic thermal storage in conjunction with smart control as an alternative to conventional network reinforcement. A high temperature ASHP and Phase Change Material (PCM) thermal storage will be supplied to around 150 off-gas households across Scotland as part of the live demonstration. Each property will be provided with an in-home controller to co-ordinate the ASHP and PCM thermal storage to meet customer heating needs whilst ensuring the Distribution network is not overloaded. The project will demonstrate how cost optimal solutions can be put in place to enable the transition to renewable heat. The tools developed by the project will enable DNOs working in conjunction with Scottish Government and other stakeholders to make better informed, quicker decisions on the best options to facilitate the uptake of electrification of heat.

3.30.1 | NIA SPEN 0058 Project Progress

We commenced pre-delivery work in the latter part of 2020 undertaking contractual discussions with our suppliers and initial engagement with the Local Authorities in which trials will be run. During 2021 we progressed the contractual discussions and the agreement with our Collaborators (SSEN and E.On) was signed in April 2022. Delivery of the main work packages has now commenced with three of the four main work packages having made good progress. Through our Collaborator, E.On, we have agreements in place with three Local Authorities for the in-home trial, these being: East Ayrshire, East Dunbartonshire and Highland. Complementary funding from the Scottish Government's LCITP programme has been agreed. This will contribute to the behind the meter assets required for the trial including heat pumps and thermal stores. Further funding sources for these assets and in-home insulation will come from either ECO or HEEPS:ABS funding which will be sourced from our collaborator and the Local Authorities.

The specific progress for each work package is outlined below:

WP1 - Network Planning and Operational Tools

Derryherk have been appointed to carry out work on this package. Half hourly profiles have been applied to the end points within the NAVI platform and trial runs with dummy external loads have been trialled prior to input with the project data. Work has been done to create diversification algorithms using ACE49 methodology. The next step will be to develop the API interface with E.On.

WP2 - Direct Load Controller (DLC) Architecture and Deployment

The DLC concept specification has been developed by E.On. Alignment with the network tools has been agreed between E.On and Derryherk. Procurement of the DLC supplier has been undertaken and a hazard identification and mitigation workshop has been completed.

WP3 - The large-scale trial

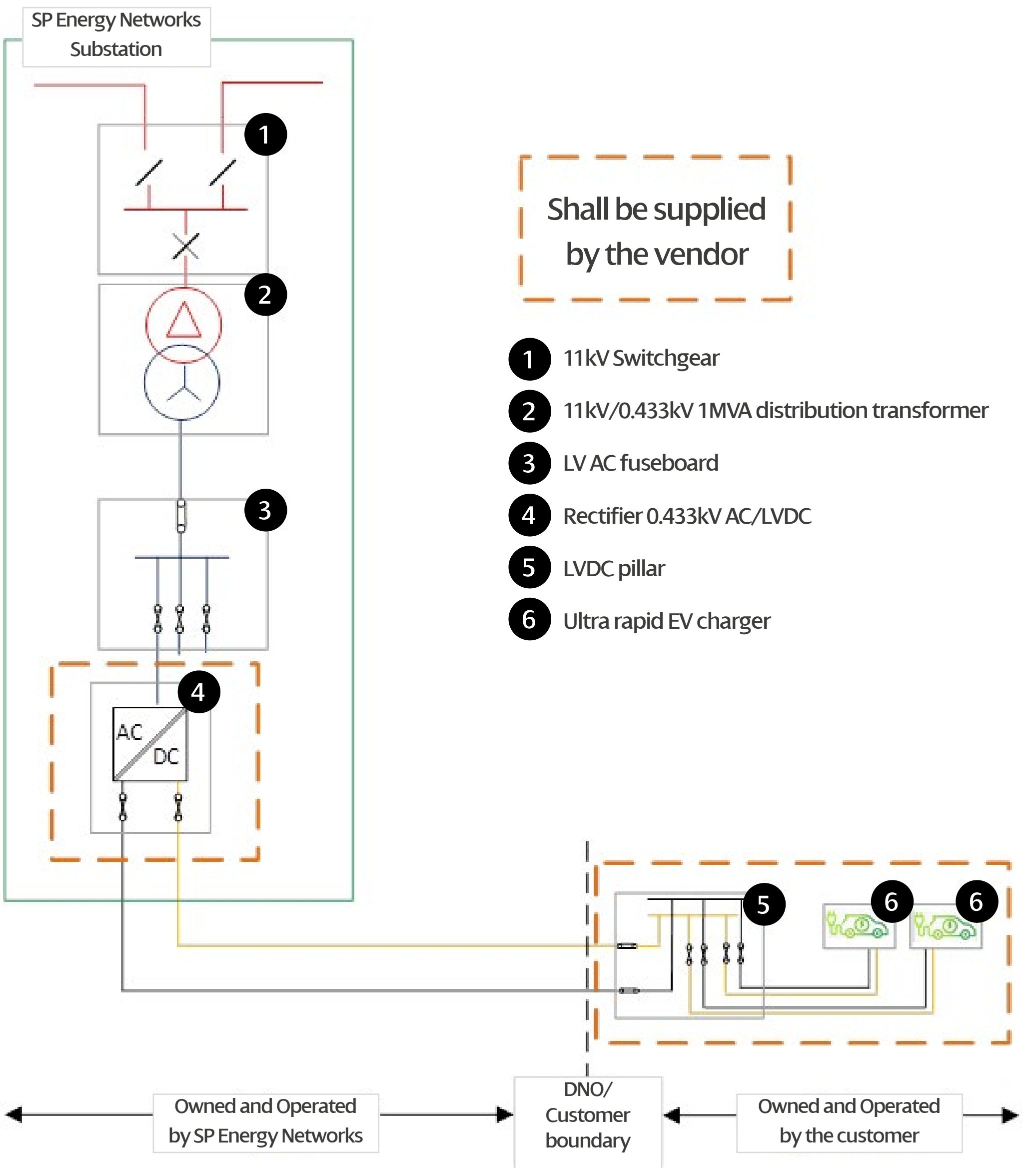
The process to recruit trial participants has commenced across the three participating Local Authorities. E.On are leading this part of the work and to date have engaged with just under 100 customers. The customer journey includes initial discussion by phone to assess suitability followed up by a detailed site survey to address the detailed technical requirements.

The final Work Package relates to analysis and dissemination and will commence in 2023.

3.31 NIA SPEN 0060 ADAPT-DC

Following on from the learning garnered from SP Energy Networks NIA project "A Transition to LVDC Networks – Phase 2" SP Energy Networks are looking to investigate and demonstrate a viable alternative to traditional LVAC EV connections. At present the best means of facilitating Rapid EV Hubs (500kW+) is to provide a connection to the existing mains (where there is sufficient capacity) or to build a purpose-built secondary substation and connect the EV charging hub to the network via a dedicated LV Mains feed. This can be costly and very disruptive to the local environment as substantial roadworks/digging is required to facilitate this. Coupled with this is the requirement for an AC to DC conversion either within the charger or on the EV itself, this is costly and a complexity that can be removed with an LVDC solution.

ADAPT-DC approaches this problem differently by switching the network from LVAC to LVDC unlocking much greater power transfer capability meaning the Rapid EV Charging hub of 500kW+ can be met with the infrastructure that is already in the ground. In many examples the cost of the two solutions is comparable however with ADAPT-DC the requirement for digging (and as such disruption to the local area) is all but removed. ADAPT-DC will be an important piece of the puzzle in reaching Net-Zero and a great addition to the suite of options available to network designers. Thus, the scope of the project is to demonstrate this in practice. Diagram of expected solution is below.



3.31.1 | NIA SPEN 0060 Project Progress

Project progress against the project objectives is as follows:

1. **Build, operate and demonstrate a viable commercial alternative to traditional LVAC EV connections**

   The project design and collaboration agreements are in the process of being completed. To date a detailed Request for information (RFI) and separate Expression of Interest (EoI) have been completed to understand what products are available in the open market. Several potential suppliers have completed the invitations and once a council customer partner has been secured then the project will move to formal tender. Following the tender process and design completion, the build, operation and demonstration of a viable commercial alternative to traditional LVAC EV connection will be completed.

Engagement with suitable councils has been difficult as our needs have to align with their plans. However, the project team are working to finalise a collaboration partner and push the project to delivery.

2. **Implement safe working practises for LVDC Networks**

   This objective is dependent on Objective 1.

3. **Expand the capability of our existing assets; particularly the LV Mains cable infrastructure as well as secondary substations**

   This objective is dependent on Objectives 1 and 2.

3.32 NIA SPEN 0061 Innovative Replacement for Underground Substations

The aim of the project is to investigate the feasibility of new and/or existing overground solutions to existing underground secondary substations. The current methodology of removing and replacing on an alternative overground site has a number of problems, including; high capital costs, problematic land ownership issues, the need to install a large amount of HV cable in urban environments and the impact of voltage levels when moving LV substations further away from the point of demand. The key aims of this project are to:

- Investigate and find alternatives to the above mentioned current methodology;
- Compare the current methodology against solutions with both high and low Technology Readiness Level (TRL), providing feasibility studies and comparative supporting Cost Benefit Analysis (CBA); and
- Also undertake the studies to understand the potential benefits of using Power Electronic Devices (PED) on the LV Distribution network.

To this end, the project is being undertaken in multiple phases:

Phase 1 – Simulation studies to understand the benefits of using a PED in conjunction with a transformer at the same site, i.e. the new substation will comprise of both a transformer and a PED. This phase also undertakes the development of a Technical Specification of the PED and the development of a plan to develop and deploy these PEDs potentially further.

Phase 2 – This phase will compare the current methodology against solutions with both high and low Technology Readiness Level (TRL), providing feasibility studies and provide a comparative supporting Cost Benefit Analysis (CBA).

Phase 3 – This phase if undertaken will look at simulation studies and the benefits of deploying PEDs on the network but not in conjunction with a transformer i.e. the site of the PED would be different to the site of the underground substation.

3.32.1 | NIA SPEN 0061 Project Progress

Project Progress against the project objectives is as follows:

Objective - Identify a solution which can be installed in the existing location of the underground substation.

Progress - A PED that can work in conjunction with a transformer has been identified and the various transformer options are currently under research.

Objective - Highlight the full range of PED solutions and assess the feasibility of each.

Progress - The topology of a PED solution has been identified. Furthermore, the detail for its practical development and deployment has also been developed. The feasibility studies are due to finish by the end of 2022.

Objective – Outline the technical and practical requirements for deployment of innovative PED.

Progress – This has been completed.

Objective - Produce a CBA of proposed PED.

Progress – A study to this end is being undertaken by WSP and due to finish by end of 2022.

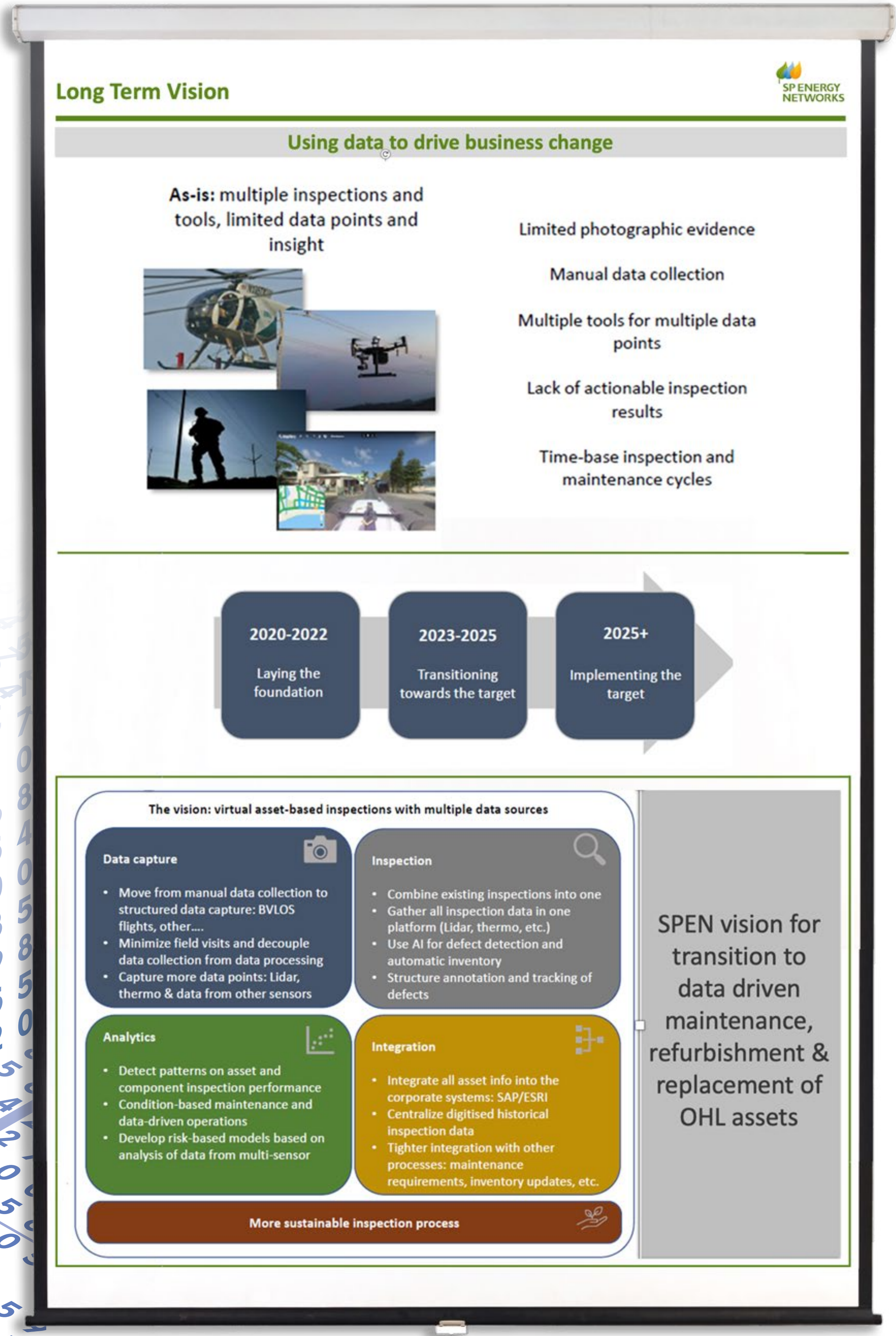
Objective- Develop a decision-making procedure to select an optimum solution.

Progress – This part of the above study being undertaken by WSP.

3.34 NIA SPEN 0063 Virtual OHL Inspections: Combining Statutory Inspection & Condition Based Assessment (CBA)

The overarching goal of the pilot project is to determine the viability of a virtual Overhead Line (OHL) inspection process supported by Artificial Intelligence (AI). To assess this viability we require the following:

- To determine if AI can successfully recognise OHL distribution assets;
- To determine if AI can successfully differentiate between different asset types, models and materials;
- To determine if AI can successfully identify defects present on OHL assets;
- To determine how many poles per day can be flown by drone and images taken;
- To determine how many poles per day can be inspected virtually from a desktop; and
- To determine if an automated drone/AI model is more cost effective than the current manual overhead line inspection process.


Long Term Vision
SP ENERGY NETWORKS
Using data to drive business change
As-is: multiple inspections and tools, limited data points and insight
Limited photographic evidence
Manual data collection
Multiple tools for multiple data points
Lack of actionable inspection results
Time-base inspection and maintenance cycles
2020-2022
Laying the foundation
2023-2025
Transitioning towards the target
2025+
Implementing the target
The vision: virtual asset-based inspections with multiple data sources
Data capture
Move from manual data collection to structured data capture: BVLOS flights, other....
Minimize field visits and decouple data collection from data processing
Capture more data points: Lidar, thermo & data from other sensors
Inspection
Combine existing inspections into one
Gather all inspection data in one platform (Lidar, thermo, etc.)
Use AI for defect detection and automatic inventory
Structure annotation and tracking of defects
Analytics
Detect patterns on asset and component inspection performance
Condition-based maintenance and data-driven operations
Develop risk-based models based on analysis of data from multi-sensor
Integration
Integrate all asset info into the corporate systems: SAP/ESRI
Centralize digitised historical inspection data
Tighter integration with other processes: maintenance requirements, inventory updates, etc.
More sustainable inspection process
SPEN vision for transition to data driven maintenance, refurbishment & replacement of OHL assets

eSmart Systems chosen due to maturity of their platform (Grid Vison) and distribution AI models.

The project consists of two main deliverables:

1. Conducting a trial for how to capture images of distribution wooden poles using drones
   - **a.** Approximately 400 poles in scope across Scotland (SPD) and Wales (SPM)

2. Testing how an inspector can use the software Grid Vision to conduct a statutory inspection in a virtual setting instead of out in the field
   - **a.** Ability to cover requirements in a statutory inspection
   - **b.** Evaluation of user experience
   - **c.** Support from the 6 AI models in scope
     - **i.** Broken insulator
     - **ii.** Cracked insulator
     - **iii.** Flashed insulator
     - **iv.** Woodpecker damage
     - **v.** Cracks in poles
     - **vi.** Missing danger plate (custom development during the project)

3.34.1 | NIA SPEN 0063 Project Progress

The overarching goal of this pilot project is to determine the viability of a virtual Overhead Line (OHL) inspection process supported by Artificial Intelligence (AI). Individual objectives were determined at the outset of the project, and these are as follows:

1. **To determine if AI can successfully recognise Overhead Line distribution assets**

   The inspection software Grid Vision uses AI to assess images of Overhead Lines captured by the drone. The software successfully recognises each OHL distribution asset in the image and displays a detailed suggestion on any defects/faults it recognises in each, specifying the exact asset.

2. **To determine if AI can successfully differentiate between different asset types, models, and materials**

   As discussed in Objective 1., Grid Vision assesses images captured by the drone using AI and has an "Inventory Functionality" which can successfully recognise each asset and give a detailed breakdown of the asset and its components when selected.

3. **To determine if AI can successfully identify defects present on Overhead Line assets**

   Grid Vision, the AI-powered inspection software, can successfully identify defects present on Overhead Line assets – all defects except for a small number of woodpecker damages and broken insulators were identified. Process is underway to retrain Artificial Intelligence for improved performance in detecting woodpecker damage. 712 defects were confirmed on the 205 poles inspected – an average of 3.5 defects per pole.

4. **To determine how many poles per day can be flown by drone and images taken**

   The drone was able to inspect 93 out of 243 (35%) poles on the low-voltage & high-voltage circuits and 160 out of 162 (98%) poles on the extreme high-voltage circuit. Due to factors such as weather conditions and drone battery life, and in compliance with UK Drone Aviation Laws, the number of poles flown by drone was decreased, however, in ideal conditions and in finding solutions to the challenges faced, this reach could be significantly extended.

5. **To determine how many poles per day can be inspected virtually from a desktop**

   208 desk based virtual inspections were completed over a 6-day period during testing, at an average of 35 poles per day. Again, in advancing the technology used, the efficiency of the system, and the number of poles that can be inspected virtually from a desktop can be significantly increased.

6. **To determine if an automated drone/AI model is more cost effective than the current manual Overhead Line inspections process**

   Within the initial scope and costs of the project, the AI model is less cost effective than the current manual Overhead Line inspections process. Throughout this project, several factors contributing to why it would not be cost effective to replace manual inspections with this process today were considered, however, there is potential for it to become cost effective if explored further, alongside gaining many other benefits that do not come with the traditional methods.

This project has now been completed.

Grid Vision

Aerial Inspection

3.35 NIA SPEN 0065 Introduction of Process Mining Enabler into SP Energy Networks

The aim of the project is to create a proof of value/pilot for the use of Celonis Process Mining at SP Energy Networks. Working with our service partners and using the Celonis Process Mining Tool, we aim to feed in to Systems Applications and Products (SAP platform) data relating to our Faults Process, allowing us to map out the process in full and identify the 'happy path' for this process. Analysis can be carried out for deviations from the 'happy path' to identify where enhancements can be made to processes or behaviours.

Following on from the results of the Faults Process, we aim to move the mining tool to review other end to end process such as new connections (design and quote, acceptance and payment), conceptual, technical and financial planning, fault management and recording, inspection and maintenance planning, delivery planning and execution. The initial project will see colleagues across SP Energy Networks being trained on the use of the Celonis software by our service partners to ensure that future processes can be mined using only internal resources with no additional cost to the business.

The goal for the project will be to push as many processes through the solution as possible to identify as many potential improvements as possible along with the potential impact of each process/behavioural change. Benefits will be expected to be delivered in the short and medium term, with behavioural improvements identified being potential quick wins, and process/system improvements potentially moving into the mid-term.

3.35.1 | NIA SPEN 0065 Project Progress

This project objective is to trial the effectiveness of an innovative process mining product. Fact based, data driven process analysis linked to performance indicators is needed to make valuable improvements to our processes, systems and ultimately our people. An update on progress is as follows:

- Data connections to Systems Applications and Product application (SAP platform) completed
- Initial dashboards created and continual refinement
- Data validation completed
- Additional data sources being added to allow additional views (storm faults etc)
- Rework data identified and added to the model
- Steering group reviewing progress of dashboards and providing additional Key Performance Indicators to be tracked/measured
- Knowledge transfer sessions mostly completed with end user session scheduled
- Director demonstration arranged
- Solution documentation in progress

3.36 NIA SPEN 0066 Level Up

To achieve the Scottish and UK Government's Net Zero Targets, all citizens and communities will need access to low carbon heat, power and transport services. The transition towards new service models and architectures will require multiple mediation models to be developed to encourage a more engaged public and greater participation. There are significant barriers to engaged participation in the current energy market which are expected to amplify as prices increase and fuel poverty goes up. Ofgem's recent review into the competitive market in domestic supply concluded that the market is not sufficiently competitive and customer satisfaction rates remain low. Innovative models of engagement are required to tackle these barriers and promote the adoption of new services. In addition, technical barriers will occur. e.g. Linmill substation, serving Carluke and the wider area, has thermal constraint and fault level issues which consequently constrains generation connection above 200kW. The scale of community energy schemes could be affected by these constraints, leading to a barrier to LCT deployment.

Level Up will develop and use a digital platform of LCT assets (Solar, PV, EV etc) installed by members of the ONECarluke Community Energy Club (OCCEC). The platform will take real data from the LCT assets and monitoring from our substations into a model, developed by consultants (ZUoS) and integrating with our NAVI platform. Simulations will be run to show how the LCT assets can be modified to minimise peak demand in the area helping to lower the risk to Linmill substation which presently has thermal and fault level concerns.

The energy balancing platform provided by ZUoS will be trialled within the project. The platform enables demand shifting through cloud-based communications with 'in home' energy management systems. This will allow the Solar PV and Distributed Energy Resource (DER) assets within the OCCEC to be optimised against a set of external signals e.g. Weather Forecasts, Grid Carbon Intensity, Standard and Time of Use (ToU) Tariffs, and Network Signals.

3.36.1 | NIA SPEN 0066 Project Progress

The project commenced in December 2021 and initial progress has been made on the following tasks:

- **Industry and Regulatory Engagement** – a review of the present regulatory environment surrounding community energy and its relationship with the networks.
- **Local Energy Network Simulation** – Power system simulations which will integrate the community energy club assets with SP Energy Networks network data.
- **Pilot monitoring and communications** – Monitoring and communication set up for community energy assets and data from secondary substations in Carluke.

The high-level objective of Level-Up is to facilitate the deployment of low carbon technologies by avoiding delays and costs created by the need for reinforcement. Key project objectives are:

- We will enhance our knowledge and develop our existing DSO toolkit to assist with the assessment of the impact of the deployment of LCTs on the LV Network;
- Evaluate the technical and commercial models used in the trial to understand their effectiveness and costs/ benefits of using the consultant's (ZUoS) method in comparison with conventional reinforcement; and
- Assess the potential for energy clubs to galvanise local support and engagement in the energy transition, and ensuring it is socially just.

During the reporting period we made progress towards meeting these objectives however the project is at an early stage and we expect these objectives to be met in the upcoming year.

SP Energy Networks Innovation Strategy

PRINCIPAL PARTNER
UN CLIMATE CHANGE CONFERENCE UK 2021
IN PARTNERSHIP WITH ITALY

SP ENERGY NETWORKS

4 | NIA Activities Linked to SP Energy Networks Innovation Strategy

SP Energy Networks has been actively working with the ENA and contributed to the collective innovation strategy for the GB energy sector.

While this report links our NIA activities to SP Energy Networks Innovation Strategy with regards to the ENA Innovation Strategy, we are looking to ensure that our existing and new projects can contribute directly to the five focus areas in the near-term:

- Facilitate the adoption of flexibility and smart systems;
- Facilitate and enable the electrification of heat and transport;
- Facilitate the efficient connection of low and zero carbon electricity generation;
- Understand the operational impact of long duration reserve services on the network; and
- Contribute to a UK-wide methodology for calculating the cost of carbon.

4.1 | From Inspiration to Solution

*Our approach to innovation development (From Inspiration to Solution) is summarised in **Figure 1** below which contains five steps:*

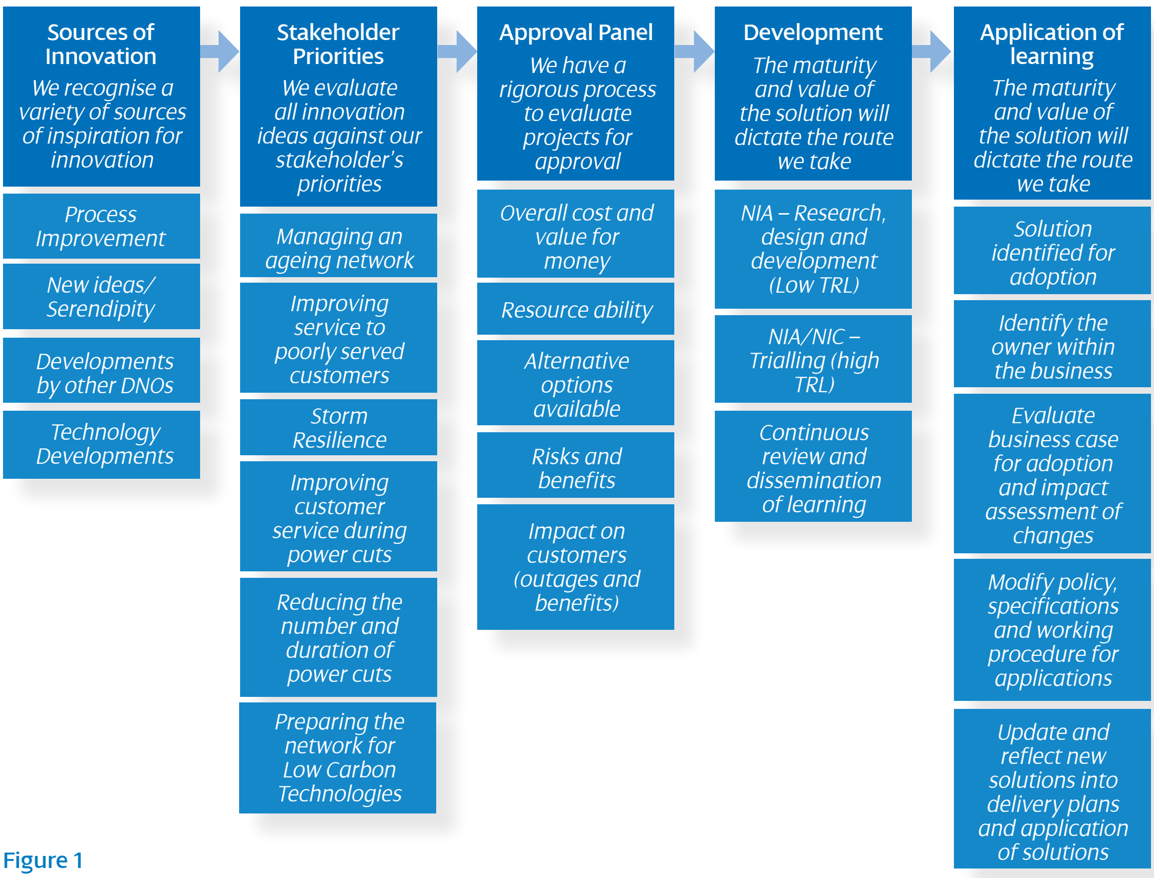


Figure 1

Approach to Innovation Development

The five key steps of our innovation process are:

1. **Idea Generation:** Ideas can come from a variety of sources. These sources can include technology developments by suppliers or academia and developments by other network companies and wider industry.
2. **Evaluation:** We use the priorities of our stakeholders as the main evaluation criteria for new projects. We will ensure that all new projects align with at least one of the areas listed in Figure 4 under stakeholder priorities. Operating our network safely, providing value for money and delivering excellent customer service are all implicit requirements in what we do.
3. **Approval:** Our Innovation Board reviews all technology innovation projects before they progress with innovation funding. This is to ensure that the project aligns with our strategy, offers value for money, and is expected to deliver benefits that will justify the cost and risk. We also use the approval process to identify any other activity which has synergies to avoid any duplication, and identify resources from the wider business that may need to be involved.
4. **Development and Delivery:** A project manager and project team are identified for each project to deliver the day-to-day project activities. Business Sponsors help to facilitate the integration of proposed, existing and completed project into BaU. Projects are monitored through their life cycle and, in the event that anticipated benefits do.
5. **Application of Learning:** Appropriate channels both internal and external will be used to disseminate learning from both successful and unsuccessful projects to a wider audience. We will also seek opportunities to learn from and collaborate, as appropriate, with other DNOs. There is a need to ensure that innovation is embedded into all business function as such the role of the innovation board is to ensure increased participation from all business functions and to allow innovation projects to be completed and integrated into BaU.

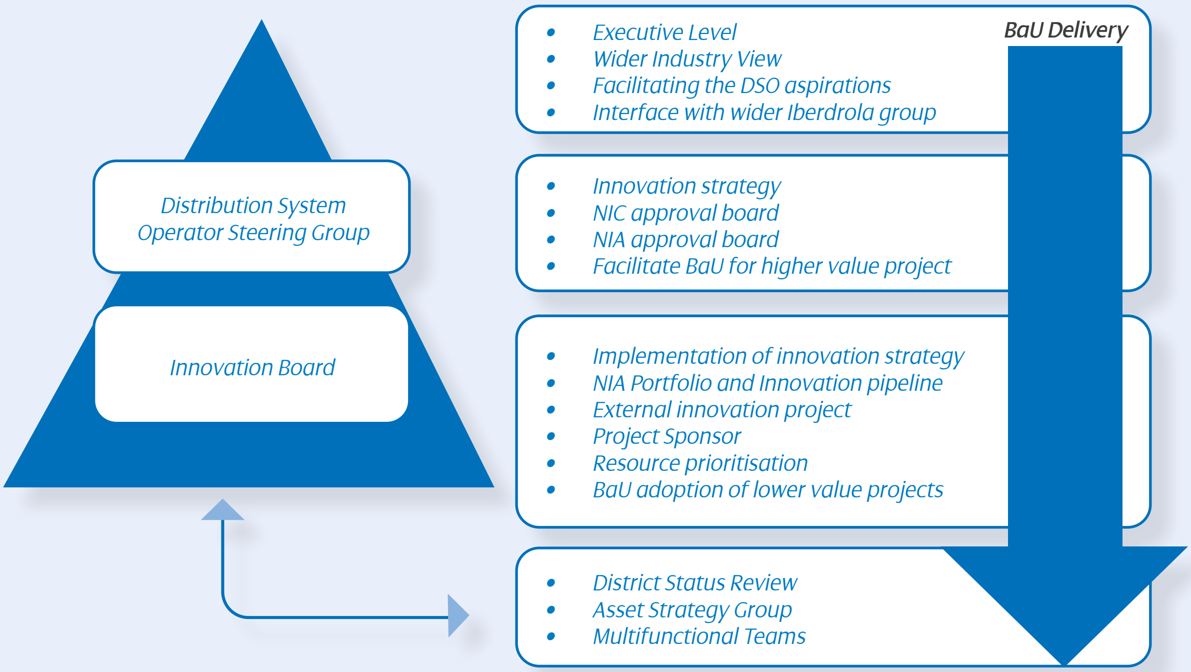


Figure 2

Innovation Governance Structure

Our innovation governance structure and project approvals process, Figures 2 and 3 respectively, helps to ensure the following:

Projects involve the Research, Development, or Demonstration of at least one of the following:

- A specific piece of new equipment.
- A specific novel arrangement or application of existing equipment.
- A specific novel operational practice directly related to the operation of the network.
- A specific novel commercial arrangement.

A Project must also meet all of the requirements

- Has the potential to develop learning that can be applied by all Relevant Network Licensees.
- Has the potential to deliver net financial benefits to electricity Customers.
- Does not lead to unnecessary duplication.

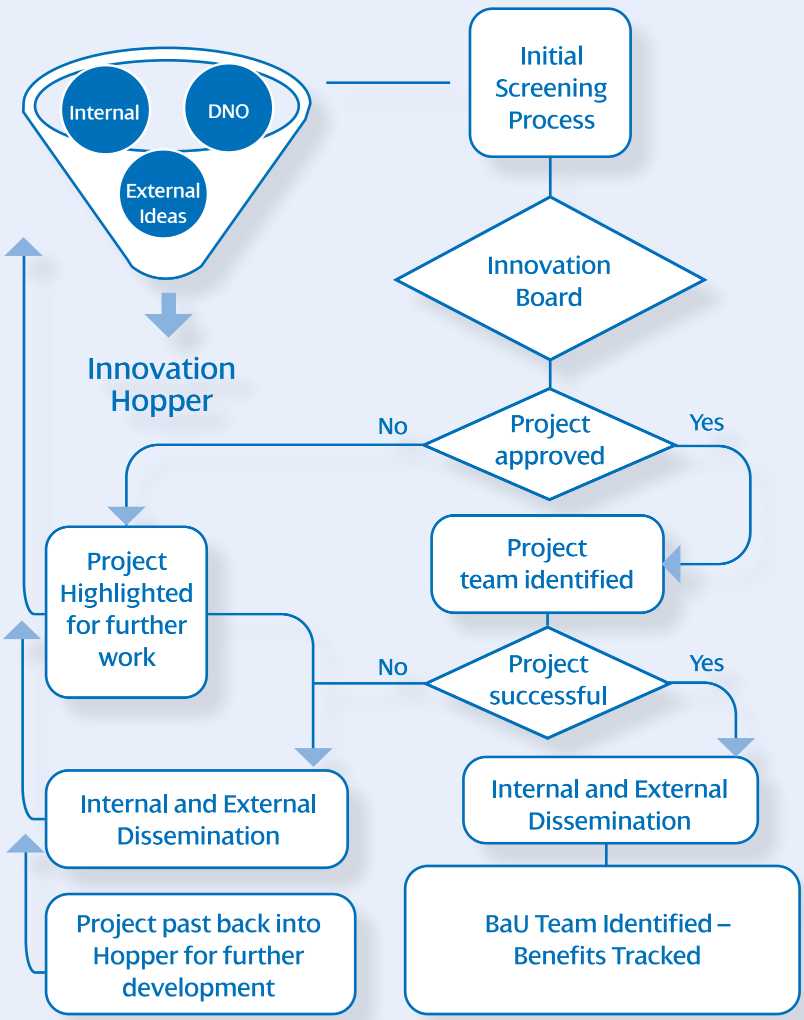


Figure 3

Ideas Generated

4.2 | SP Energy Networks NIA Project Mapping with Innovation Strategy

4.2.1 | Informed by Our Stakeholders

We are acutely aware that the funding we access through the various innovation mechanisms is sourced from our customers. In developing our Electricity Distribution Network Innovation Strategy 2018 we have not only ensured that our innovation activity is focused on areas which customers most value, but also that customers are willing to invest more in these particular areas in the short term, to allow the longer term benefits of innovation to be realised. Our Innovation Strategy uses the priorities identified through our stakeholder engagement process.

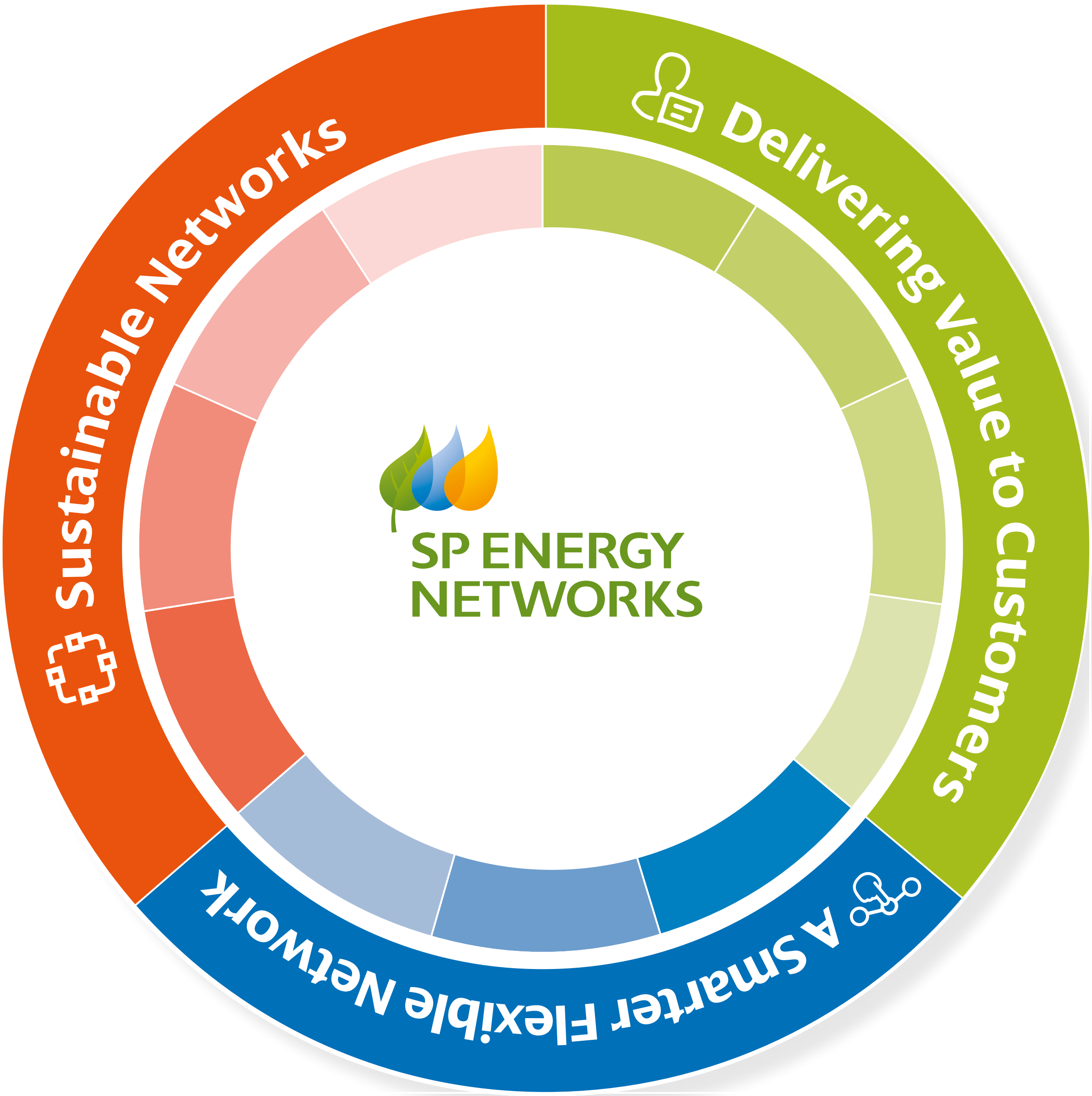
Of all the areas identified, stakeholder feedback identified the following specific priorities:

1.	Managing an ageing network
2.	Reducing the number and length of power cuts
3.	Investing for storm resilience
4.	Improving customer service during power cuts
5.	Improving service to poorly served customers
6.	Preparing the network for low carbon technologies

We have aligned our innovation strategy to these areas and will use this as a key feature of the selection process for new projects. These areas will be addressed within the context of a continued focus on health, safety and the environment.

In mapping our innovation projects onto the priority areas identified with our stakeholders, we took into account the following factors:

- Many of our innovation initiatives will fulfil more than one priority at a time.
- Individual projects will be assessed relative to others in terms of the overall cost, effort, risk and benefit to customers and the network.
- The learning from innovation projects will be an important input to the ongoing strategy.
- What we learn from our innovation initiatives will have an impact on the overall innovation priorities. Where we have addressed a problem, the priority may become less relevant, or if an initiative is unsuccessful that priority may require greater focus.



- **Delivering Value to Customers**
  - Managing an Ageing Network
  - Maximising the Benefit of Data
  - Network Control and Management
  - Reducing the Number and Length of Power Cuts

- **A Smarter Flexible Network**
  - Faster, Easier, Accurate Connections
  - Network, Flexibility and Communications
  - Preparing the Network for Low Carbon Technologies (LCTs)

- **Sustainable Networks**
  - Minimising the Environmental Impact of Assets and Activities
  - Modernisation of Work Practices and Business Systems
  - Our People - Skills and Resources
  - Socially Responsible Member of the Local Communities We Serve

4.3 | SP Energy Networks NIA Project Mapping with Innovation Strategy

No.	Project
01	NIA SPEN 0008 APPEAL
02	NIA_SPEN_0014 Active Fault Level Management
03	NIA SPEN 0023 Connected Worker Phase 1 – Field Data Automated Capture
04	NIA SPEN 0029 Secondary Telecommunications Phase 3 – Trial of Hybrid Telecoms
05	NIA SPEN 0031 Radiometric Arc Fault Location RAFL 2
06	NIA SPEN 0033 CALISTA
07	NIA SPEN 0034 Network Constraint Early Warning Systems (NCEWS 2)
08	NIA SPEN 0036 A Holistic Intelligent Control System for Flexible Technogies
09	NIA SPEN 0039 THOR Hammer
10	NIA SPEN 0041 Proof of Concept Tarmac Reinstatement Tester
11	NIA SPEN 0043 Bethesda Home Hub
12	NIA SPEN 0045 SAFE-HD (Spatial Analysis of Future Electric Heat Demand)
13	NIA SPEN 0047 A Transition to LVDC – Phase 2
14	NIA SPEN 0049 iDentify
15	NIA SPEN 0050 Real Time Fault Level Monitoring Stage 2
16	NIA SPEN 0052 A Substation of the Future
17	NIA SPEN 0055 On-Site Non-Intrusive Polychlorinated Biphenyls (PCB)
18	NIA SPEN 0056 Flexible Tower Block
19	NIA SPEN 0058 ReHeat
20	NIA SPEN 0060 Adapt DC
21	NIA SPEN 0061 Innovative Replacement for Underground Substations
22	NIA SPEN 0063 Virtual OHL Inspections: Combining Statutory Inspection & Condition Based Assessment (CBA)
23	NIA SPEN 0065 Introduction of Process Mining Enabler into SP Energy Networks
24	NIA SPEN 0066 Level-Up

Delivering Value to Customers				A Smarter Flexible Network			Sustainable Networks			
Managing an Ageing Network	Maximising the Benefit of Data	Network Control and Management	Reducing the Number and Length of Power Cuts	Faster, Easier, Accurate Connections	Network Flexibility and Communications	Preparing the network for Low Carbon Technologies (LCTs)	Minimising the Environmental Impact of Assets and Activities	Modernisation of Work Practices and Business Systems	Our People – Skills and Resources	Socially Responsible Member of the Local Communities We Serve
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5 | Areas of Significant New Learning

The following identifies areas of learning on a project-by-project basis.

5.1 | Project Learning: NIA SPEN 0008 APPEAL

After four years of operation, it can now be said with certainty that the soil bed and environmental conditions within the fungal cellar are providing a very severe decay test for timbers. This is highlighted not only by the very poor disintegrating condition of the untreated stakes but also now by the fact that the preservative types are starting to lose their effectiveness.

In terms of equivalence with field conditions, the project has run for 48 months, and this was planned to be equivalent to 40 years in the field. Having overcome problems over the first 24 months of the trial and based on the condition of the control (untreated) timbers, the current assessment concludes the effect is now equivalent to between 25-35 years in the field. Future changes to the soil bed enrichment policy will accelerate this further.

The primary objective of the project was to evaluate whether the alternatives to Creosote (RVP and/or Tanasote) provide a preservative as effective as Creosote for the treatment of overhead line wood poles. At this stage of the project, this outcome is looking very positive. Although the preserved timbers are now beginning to lose effectiveness after 48 months exposure, this is almost identical across all the preservative types, including Creosote. No preservative type is outperforming any other at this stage of the project.

A second objective was to evaluate whether the use of ground-line barrier products provide an additional protective effect. At this stage this appears to be a positive result for untreated timbers, or timbers treated with Creosote, but not for the other preservatives.

Following the success of the preservative treatments to date, the project has now been extended by a further 30 months. This will allow the existing timber stakes to remain exposed for a longer time period, to hopefully provide a comparison with the typical in-field service life of a Creosote pole of 55 years. In addition, some round timber samples have now been added to the fungal cellar (to make use of the space now made available by removal of previous samples) to provide further comparisons for assessment.

5.4 | Project Learning: NIA SPEN 0014 Active Fault Level Management (AFLM)

Phase 2 of the project has refined the concept design for an AFLM system. The project has developed the specification, requirements, design principles and highlevel commercial principles of access for the AFLM system. These provide key learning and insights on the AFLM design and how it can be applied.

Phase 3 is now exploring the technical requirements surrounding deployment of a live trial. This will provide valuable learning for wider deployment of the solution in future if successful.

5.6 | Project Learning: NIA SPEN 0023 Connected Worker Phase 1– Field Data Automated Capture

Field Data Automated Capture

Initial learnings conclude that while the Robotic Process Automation (RPA) can be applied effectively to these tasks, the requirement of setting the process steps up can be time consuming in the short term. As such, the project is focussing on the high-volume asset categories in terms of number of asset changes per annum. It is understood that trying to apply RPA across all processes affected is now unlikely, given the cost/benefit case is not sufficient to do so.

5.9 | Project Learning: NIA SPEN 0029 Secondary Telecommunications Phase 3 – Trial of Hybrid Telecoms

A number of valuable insights have been made during this reporting period:

- End to end security required development by suppliers in the marketplace;
- Site survey information can be used to optimise which public carrier is best suited to a given site – the strongest signal is not necessarily the best;
- Skillsets within the business need to migrate to incorporate network/internet work skills to support deployment of smart grids;
- The complexity of integrating public networks into existing network designs whilst maintaining security and operability; and
- Direct Failover between Public and Private Technologies requires risk/benefits analysis.

5.11 | Project Learning: NIA SPEN 0031 Radiometric Arc Fault Location RAFL 2

The main learning points are:

- The project has demonstrated when in test conditions that arcs generated by utility switching can be located with good accuracy when the RALF Device is located up to 5 km from the arcing source;
- In field trials the tests were not as successful as desired. This was, however, due to lack of fault events occurring on the network; and
- Operational issues arose due to the battery lifetime. Constant replacement of the batteries became an issue for field staff. Ultimately this has concluded that taking the unit forward into BaU is not possible at this stage.

5.12 | Project Learning: NIA SPEN 0033 CALISTA

Numerous Academic papers have been presented through the CALISTA project. These include:

- "A Method for Cable Failure Analysis based on Ageing Model and with Consideration of Daily Temperatures", presented at the CMD 2020 conference;
- "An Improved Weibull Model with Consideration of Thermal Stress for Analysis of Cable Joint Failures", presented at the 2020 IEEE 3rd International Conference on Dielectrics; and
- "Replacement of PILC/PICAS Joints Using Dynamic Programming for Optimization and Weibull Model for Reliability Assessment", presented at the 2021 IEEE Conference on Electrical Insulation and Dielectric Phenomena (CEIDP).

5.13 | Project Learning: NIA SPEN 0034 Network Constraint Early Warning Systems (NCEWS 2)

Due to the slower than anticipated rollout of smart meters in the UK, and comms issues in SPD, some of the connectivity improvement Data Analytical techniques that the project seeked to explore have not been able to be fully analysed. By working with other SP Energy Networks innovation projects, we are utilising available data sets, including that from substation monitors, to try and create a more complete picture of the network.

This will assist with the growing requirement for verification and near real time connectivity understanding, including phase identification, which continues to be a major requirement within this project to maximise the benefit of LV data analytics going forward.

Adopting an agile approach to development also ensures we remain on track and focused on the key business requirements, but also provides the ability to adapt to ever changing priorities. Involving key users in the testing of functionality enabled a smooth transition from project to BaU as the wider business has been part of the journey.

5.14 | Project Learning: NIA SPEN 0036 A Holistic Intelligent Control System for Flexible Technologies

Project Learning: NIA SPEN0036 A Holistic Intelligent Control System for Flexible Technologies:

- A year worth of network data within the Angle-DC sensitivity boundaries has been used to stress test the central control philosophy to demonstrate the optimisation objective for the scheme while the statutory network requirements are satisfied. This off-line method is recommended in any similar project to ensure the robustness of the control algorithm and any adjustment require prior to commissioning and for subsequent network changes e.g. new connections.

A Flexible Holistic Intelligent Control System, is a proposed solution that sets out the control signal hierarchy and overall network operation optimisation by considering the controllability and impact envelopes of controllable nodes and the customers flexibility offers through aggregators.

HICS can be flexibly adapted to coordinate different optimisation objectives, of controllable devices, to enhance network performance, reliability and provide commercial signals to other network flexibility providers (e.g. aggregators). Some of the high-level network operation objectives can be network losses, wide area voltage optimisations, maximum network headroom capacity etc. Machine learning or artificial intelligence can also be used so the system can be adaptive to network design changes, robust against missing or real time data loss, through loss of network communications, and function independently.

A key characteristic of HICS, is a core control module, which can flexibly and securely integrate the new technologies and interact with other DNO systems (data historian, Network Management System, Data integration platform etc.) The core modules provides a level of interoperability, allowing communication and integration with various network monitoring equipment offering a vendor agnostic solution.

HICS technology is a DSO enabler and capable of providing market commercial signals and technical requirements associated with the DSO transition

Through the Project, the corresponding international standards and forums, including but not limited to CIGRE B4, C4 studying committee, IEC and SQSS, will be identified to inform and influence the ongoing discussion and standardisation when the TRL level is sufficient to allow a trial.

It is envisaged that the HICS consists of the main (master) controllers providing overall coordinated network optimisation and local (slave) control units providing fail-safe function and set point adjustments based on local data. This project aims to identify the system architecture, optimisation algorithms HCIS and trial of HICS within the distribution network demonstrating its performance at different voltage levels.

The objectives of the project are to:

- Identify the features required for a Holistic Intelligent Control system owned by a DNO (DSO) Technology Readiness Level at Start TRL 6 Technology Readiness Level at Completion TRL 8;
- Using existing trial project and proposed control systems to assess the feasibility of incorporating these systems into a HICS scheme;
- Analyse the evolving characteristic of distribution network with uptake of renewable generation, energy storage and EVs;
- Define the existing and future control technical requirements to future proof the controller functional design;
- Scoping and specifying the control interfaces depending on the engineering and/or commercial relationships;
- Review and Identify present common control algorithms used to optimise flexible and smart solutions; and
- Propose an open source protocol for the development of future HICS devices.

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5.17 | Project Learning: NIA SPEN0039 THOR Hammer

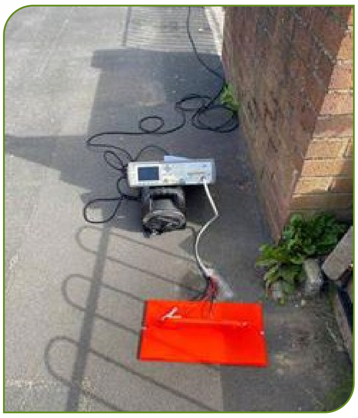
The project has shown that the THOR device, is an accurate non-destructive method in determining the Residual strength value of UK wood poles which will aid in prediction of end of life for refurbishment investment planning. In addition, embedment depth of the pole can be accurately determined using the device.

Through feedback from users during the project, Groundline engineering have made significant improvements to the THOR device to improve end-user experience.

5.18 | Project Learning: NIA SPEN 0041 Proof of Concept Tarmac Reinstatement Tester

During the laboratory tests impedance analysis was used to measure air void density in the surface layer and GPR to measure the layer thickness. The GPR measurements of the layer thickness showed good correlation. The objective of the impedance analysis measurements was to determine the material dielectric constant (permittivity) and correlate it to the air void density in the samples. Two methods were used to determine the material permittivity: capacitance measurement and measuring complex reflection coefficients that were made by using a Vector Network Analyser. The capacitive method showed good correlation between the measured permittivity and the air void densities of the asphalt samples. Using the vector network analyser showed some good correlation but further work would be required to refine the method and improve results.

Field testing of non-intrusive device measuring thickness and air-void density of tarmac reinstatements."



Further details of these analyses, including the field trial results, can be found in the project closedown report. The findings from this project suggest that there is promise in the techniques analysed but further work is needed to develop equipment that will be accurate and easy to use in the field.

5.20 | Project Learning: NIA SPEN 0043 Bethesda Home Hub

Initial data from Bethesda has been used to set up a model using De Montford University's powerful Cascade System that can model from appliance to system level. Interestingly, the data showed the impact of lockdown, during the global pandemic, with less seasonal shift in usage noted in comparison to pre-lockdown levels.

Different scenarios were modelled to evaluate the impact of EV charger and Heat Pump penetration, and potential for LV shifting. An interesting impact on peak loading was noted when Heat Pump penetration reached 60% due to sudden changes in weather. This is likely to become more common and controls need to take this into account.

This work is still ongoing.

5.21 | Project Learning: NIA SPEN 0045 SAFE-HD (Spatial Analysis of Future Electric Heat Demand)

The uptake of electrified heat is a complex matter and will be subject to developments in policy, technical and economic factors varying across different demographics. The high spacial resolution of the agent-based model allows the intricacies of future energy scenarios to be addressed on a street level. The project enables sensitivities within projected uptake to be modelled and assessed by network planners when considering the implications that the electrification of heat will have on future demand growth.

The SAFE-HD model will notably be used as part of work package 3 for the CREDS Flex Fund research programme that is broadly concerned with assessing post coronavirus pandemic impacts on demand, flexibility and infrastructure.

5.22 | Project Learning: NIA SPEN 0047 A Transition to LVDC – Phase 2

Outcomes:

- All samples completed the programme and only one partial failure was observed, due to mechanical damage rather than the DC test regime.
- The testing confirmed that no adverse behaviour was evident whilst the LVAC cables were energised under representative DC load cycles.
- No samples failed during the accelerated aging programme and there was no significant degradation in insulation performance on the range of samples.
- All samples withstood the applied fault current and were deemed safe in the post fault health assessment. One sample group completed the prescribed 40 years of service and projections suggest that groups which experienced 10 years of aging would also complete the 40 years of service.
- The availability of cable/accessory health assessment data would enable more effective run to failure trends to be developed for the different cables/joints/linkboxes.

Next steps:

- Trials of LVDC feeders in a controlled environment. LVDC feeders could consider; hardware trials, power transfer studies, protection requirements, health assessment investigations, studies around DC power quality measurements and control opportunities.
- Overload testing to explore the thermal response of the DC feeder under extreme scenarios.
- Explore withstand testing on insulation samples to determine operational limits for the applied DC voltage.
- Lab based testing such as dielectric spectroscopy (DS) or Fourier Transform Infrared spectroscopy (FTIR) to assess the dielectric properties of the insulation and the chemical composition of the insulation.
- Explore mechanical testing on aged cables samples (Elongation at Break (EAB) or tensile testing) which could inform handling guidance of aged assets.
- Investigate further fault testing on samples with known or manufactured defects to assess typical responses.

5.24 | Project Learning: NIA SPEN 0049 iDentify

While the major learning from this project has been on the use of Artificial Intelligence (AI) and image recognition to identify what an asset is, engagement with installers has also helped understand their issues and the complexity around completing paper forms. The app brings consistency to the process, regardless of the installer, which currently doesn't exist.

5.25 | Project Learning: NIA SPEN 0050 Real Time Fault Level Monitoring Stage 2

All research, development and technology demonstrations undertaken as part of this project thus far have been effective in meeting the aims of the project. Inherent algorithm accuracy has been independently verified as being within ~1% of actual fault level, and various deployment options are being explored.

5.26 | Project Learning: NIA SPEN 0052 A Substation of the Future

The project has generated significant experience in the specification, design, procurement and installation of low carbon alternatives to existing switchgear components including transformers, switchgear and civil components.

We have demonstrated the use of a non-SF6 ring main units (RMUs) which will be valuable to the wider industry as we look to reduce reliance on SF6 technologies and integrate new switchgear with our existing designs and policies.

We conducted a carbon optioneering assessment to estimate the capitol carbon (embodied carbon) and operational carbon (associated with losses e.g. SF6) for the novel substation design against a typical substation.

Our assessment was carried out using our in-house tools which have been developed using accepted carbon emission databases. In addition, the assessment process was validated by a third party.

The optioneering process considered the key components of the substation including major plant and civil aspects.

The 'typical' substation included:

- Substation Enclosure - GRP design
- Substation Substructure – typical concrete foundation with steel beams
- Ring Main Unit – typical SF6 filled RMU
- Transformer – mineral oil transformer

The novel low carbon substation included:

- Substation Enclosure - GRP design (i.e the baseline design)
- Substation Substructure – low carbon concrete foundation with steel beams
- Ring Main Unit – SF6 free RMU
- Transformer – Transformer with bio-based oil replacing mineral oil

Through this carbon optioneering process – which allowed our design teams to identify and select the lowest carbon options, the sustainable substation resulted in a c.15% carbon reduction relative to the baseline design. This was primarily achieved using low carbon concrete in the foundations, the use of bio-based oil in the transformer and the use of an SF6 alternative insulating gas within the RMU.

5.28 | Project Learning: NIA SPEN 0055 On-Site Non-Intrusive Polychlorinated Biphenyls (PCB)

Gamma ray detection was and still is deemed to be the most feasible way of non-intrusively detecting PCB in pole mounted transformers.

However, work concluded by the EIC Partners and EA Technology highlighted that such method of detection is currently not achievable without introducing additional radioactivity, which has health and safety concerns throughout the manufacture, operation and disposal of such a device and associated consumables.

SP Energy Networks and the Energy Networks Association (ENA) will monitor any further developments (such as WPD's trial of a swab-based tester). In addition, SP Energy Networks will continue to manage the ENA statistical model for PCB risk classification and targeted interventions across the GB network.

5.29 | Project Learning: NIA SPEN 0056 Flexible Tower Block

Post-trial, the learnings from the Flexible Tower Block project will be shared with network licensees which will help in developing common approaches to assist stakeholder deployment of electrification of heat at scale. The learnings provided by the project will be directly transferrable to similar households across GB and therefore all network license areas.

Findings to date from the desktop study work include:

- There is an appetite for a flexible smart tariff for storage heaters;
- This would most likely be a dual-rate type tariff;
- This would work for customer bringing improved comfort and financial benefits; and
- The next steps would be a trial of the tariff.

5.31 | Project Learning: NIA SPEN 0058 ReHeat

The project is at an early stage therefore no learnings have been generated to date. However, as the project progresses Re-Heat will deliver significant new learning which will reduce the costs of network upgrades for both customers and network operators and accelerate the deployment of electrified heat.

Re-Heat will generate new learning in the following areas:

- Improved understanding of load profiles and after diversity maximum demand (ADMD) for heat pumps, considering; geographical location, housing archetype, customer demographic;
- Proven techniques as alternatives to conventional reinforcement that can support the wide scale deployment of electrified heat in areas of network constraint, refined and improved thanks to extensive trials;
- Solutions that work for customers. Through learning derived from the significant amount of customer engagement and research that will be undertaken around the different technical and commercial approached trialled; and
- Recommendations for GB-wide implementation. Including policy implications, regulatory requirements, and funding considerations.

The project will generate learning for SP Energy Networks, the other distribution network operators, transmission network operators, National Grid in their role as GB System Operator, aggregators, energy retailers, academia, devolved governments, local authorities and other industry stakeholders such as the heat supply chain, Energy Networks Association, Energy Retail Association, the Department for Business Energy and Industrial Strategy (BEIS), consumer bodies and Ofgem. To ensure that learning is captured and effectively disseminated throughout the project, a Stakeholder/ Dissemination Manager will work with the Project Manager, fulfilling a key role within the project delivery team.

5.32 | Project Learning: NIA SPEN 0060 Adapt-DC

As the project has not yet been implemented the outcomes and learning have yet to be confirmed.

5.33 | Project Learning: NIA SPEN 0061 Innovative Replacement for Underground Substations

- A suitable Hybrid Transformer Topology for a power electronic device has been identified which can be found in the project report delivered by Integrated Power Tech (IPT).
- The use of Silicon carbide (SiC) compared to Silicon (Si) while more expensive can help significantly reduce the volume of the PED which is key in this project.
- To avoid lengthy delays, it is recommended to approach multiple potential suppliers for a comparative quote while it is also important to have clear discussions early on regarding the scope of the project with all involved parties.

5.35 | Project Learning: NIA SPEN 0063 Virtual OHL Inspections: Combining Statutory Inspection and Condition Based Assessment (CBA)

There were more defects identified from the air than the ground. There were instances of pole top rot and of broken insulators that would be difficult/impossible to find in a traditional inspection from the ground.

Lessons learnt from image capture are detailed in the table below.

Area	Issue
UK Drone Aviation Laws	Unable to fly within 50m of people, cars etc
	Drone needs to be in pilot's line of sight
	Can't fly drones autonomously
Site Conditions	Drones can't be flown in the rain/high winds
	Image quality effected by weather conditions
	Trees/Vegetation preventing image capture of full overhead line assets
Battery Life	Drone battery only lasts for approximately 60-90 minutes
	Drone Remote Control only lasts for approximately 4 hours
	Charging issues in SP Energy Networks vans
Memory Cards	High volume of images required over a single working day
Pole Hammer Test	Drone process unable to carry out hammer test on poles
Conductor Heights / Proximity Hazards	Unable to determine height of lowest point or how close nearest proximity hazard is
Daily Productivity / Pole Coverage	Very inconsistent daily productivity due to issues outlined above

Lessons learnt from virtual inspection are detailed in the table below:

Area	Issue
GIS Co-ordinates	Images matched to an incorrect pole
	Not enough images to carry out a full inspection
Artificial Intelligence	Limited number of distribution related defects currently fully trained
	AI suggested defects not always correct
Multiple Images of Same Pole	Multiple suggested defects for the same issue
	Potential for inspector to raise multiple defects for same issue
iHazards	Drone pilots not able to spot and report iHazard situations
Pole Heights / Scarf Mark / Pole off Plumb	Unable to determine height and angle of assets in an image
Virtual Inspection Productivity	Only approximately 35 poles per day inspected virtually

In summary, there are a number of reasons why it would not be practical or cost effective to replace current annual overhead line inspections with this process today. There is, however, value in further exploring this application, and there is a potential improvement path over time which would eventually see the costs come down to today's levels plus gaining many other benefits not seen with traditional inspection methods.

5.36 | Project Learning: NIA SPEN 0065 Introduction of Process Mining Enabler into SP Energy Networks

Key learning points during the reporting period are:

- Celonis dashboards are easy to operate and flexible enough to enable Management Information;
- New views to gain additional insight can be added quickly;
- The tool is easy to connect to SAP, enabling additional processes to be mapped following data table connection;
- 'Skills' allow automated reminders to be sent following activities with escalation built in should actions remain outstanding; and
- Processes can be automated from the tool enabling resources to focus on 'value add' activities.

5.37 | Project Learning: NIA SPEN 0066 Level Up

Community Energy Clubs have been identified as key enablers to support the acceleration of public acceptance of the changes required to support the Net Zero Transition. However, there are limited examples of these Clubs operating within the UK. Level Up will generate empirical evidence on the methods available to supportincreased LCT deployments in areas where there are network constraints.

As the project has just commenced no learnings have been established to date. However the project will deliver learnings on:

- Community energy club engagement and interfacing with our systems
- Reduction of peak demand using the energy club model

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