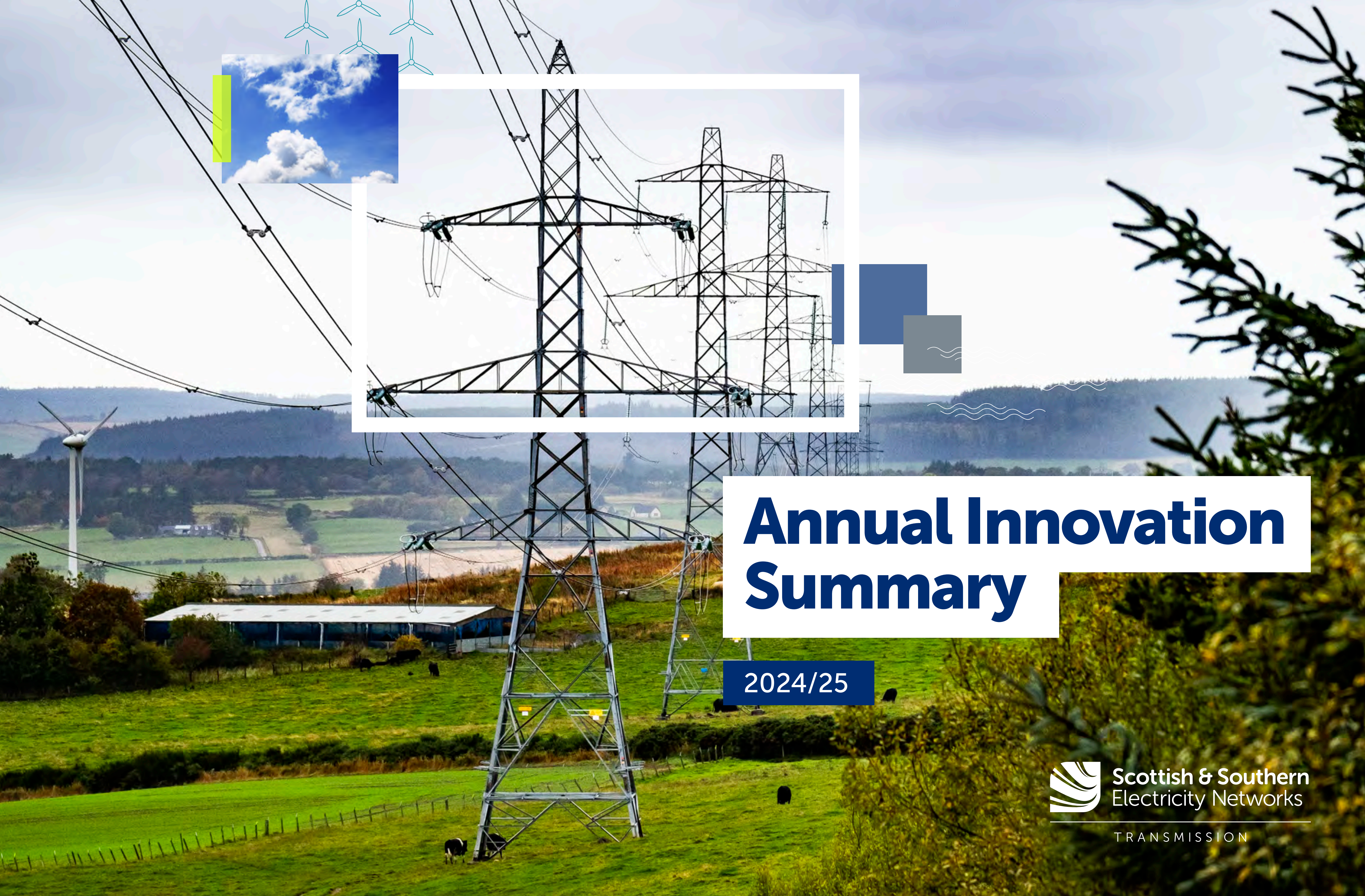


Annual Innovation Summary

2024/25

Scottish & Southern Electricity Networks

TRANSMISSION

Contents

"Our innovation initiatives are expected to generate over £190 million in benefits by the end of RIIO-T3, demonstrating our commitment to building a smarter, more resilient, and more sustainable electricity network."

Scottish & Southern Electricity Networks
TRANSMISSION

Welcome to our Annual Innovation Summary 2024-25

As we approach RIIO-T3 and reflect on the RIIO-T2 price control period to date, it's evident that innovation has come a long way at SSEN Transmission. From a modest starting point, our innovation portfolio has grown into a powerful driver of progress, addressing some of the most complex challenges facing the UK's transmission networks.

Our network challenges are unique compared to those faced elsewhere, demanding tailored, forward-thinking solutions and that's exactly what we've been delivering. Our innovation initiatives are expected to generate over £190 million in benefits by the end of RIIO-T3, demonstrating our commitment to building a smarter, more resilient, and more sustainable electricity network.

Our Pathway to 2030 programme sets a clear and ambitious direction, and the window to act is narrow. We must continue to build momentum, working closely with our supply chain to deliver the large-scale capital projects that will underpin the energy transition. The work we do now will not only shape the next five years but will prepare us for the decades beyond.

Our recently published RIIO-T3 business plan outlines an investment of £22bn between 2026 and 2031, with the potential for over £9bn more. It is built around our shared long-term strategic objective to deliver a network for net zero, and three core goals: ensuring a safe and resilient supply, delivering the capability to meet 20% of GB demand for clean power, and delivering transformative lasting benefits for local communities, our economy and nature. Innovation is central to achieving all three.

To deliver on this ambition, we will continue to maximise funding through mechanisms such as the Network Innovation Allowance (NIA) and Strategic Innovation Fund (SIF), alongside our own business-funded activities that support ongoing operational improvements. We are committed to tackling the challenges that matter most to our network and our customers by refining our processes, increasing efficiencies, and exploring new opportunities to collaborate with innovators, stakeholders, and academic partners.

One standout example is our deployment of Dynamic Line Rating (DLR) technology. Our pilot project on a 153km double overhead line circuit (306km coverage in total) has created the UK's largest DLR network, enabling near real-time monitoring and unlocking additional capacity without the need for new infrastructure. This is innovation in action - delivering more renewable energy to the grid, maximising our existing infrastructure and reducing costs for consumers.

In preparation for RIIO-T3, our annual innovation strategy action plan is built on three key priorities: growing our innovation culture, establishing a clear roadmap, and building a robust pipeline of future projects that deliver real value to communities and the network. These steps will ensure we remain agile, ambitious, and aligned with our long-term vision.

We are proud of the progress we've made but recognise there is much more to explore. Innovation will continue to be the driving force behind our efforts to deliver a network for net zero, and we are excited to lead the way. This report provides a transparent overview of our innovation activities and achievements over the past year.

If you have an idea to help us deliver a reliable and resilient network in a safer, smarter, greener, and faster way, I invite you to get in touch at transmissioninnovation@sse.com.

Alan Ritchie
Senior Manager – Innovation
SSEN Transmission

About SSEN Transmission

We are SSEN Transmission (the trading name for Scottish Hydro Electric Transmission), part of the SSE plc Group. Our responsibilities include maintenance and investment in the high voltage 132kV, 220kV, 275kV and 400kV AC electricity transmission network along with High Voltage Direct Current (HVDC) cables, overhead lines (OHLs) and convertor stations. Our operational area extends over a quarter of the UK's landmass, navigating some of the most challenging terrain and powering our communities by providing a safe and reliable supply of electricity.

The north of Scotland transmission network has a strategic role to play in supporting the delivery of the national net zero targets. We currently have over 9GW of renewable generation connected to the network, however, by 2050, the network is expected to need upwards of 40GW of low-carbon energy capacity to support net zero delivery.

As part of the network's ambitious £22bn RIIO-T3 plan, the construction of additional infrastructure consisting of new overhead lines, substations, convertor stations, and subsea links will be vital to unlocking Scotland's potential to be a clean energy powerhouse. Innovation will play a critical role in supporting the energy transition, continuing to make our network safe, secure and resilient for future generations.

Pathway to 2030 & T3 Projects

Existing Network

LOTI INVESTMENTS

New Infrastructure (routes show here are illustrative)

Upgrade/Replacement of Existing Infrastructure

ASTI INVESTMENTS

New Infrastructure (routes show here are illustrative)

Upgrade/Replacement of Existing Infrastructure

TCSNP2 INVESTMENTS

New Infrastructure (routes show here are illustrative)

Upgrade/Replacement of Existing Infrastructure

T3 INVESTMENTS

Load

Non-load core

New OHL

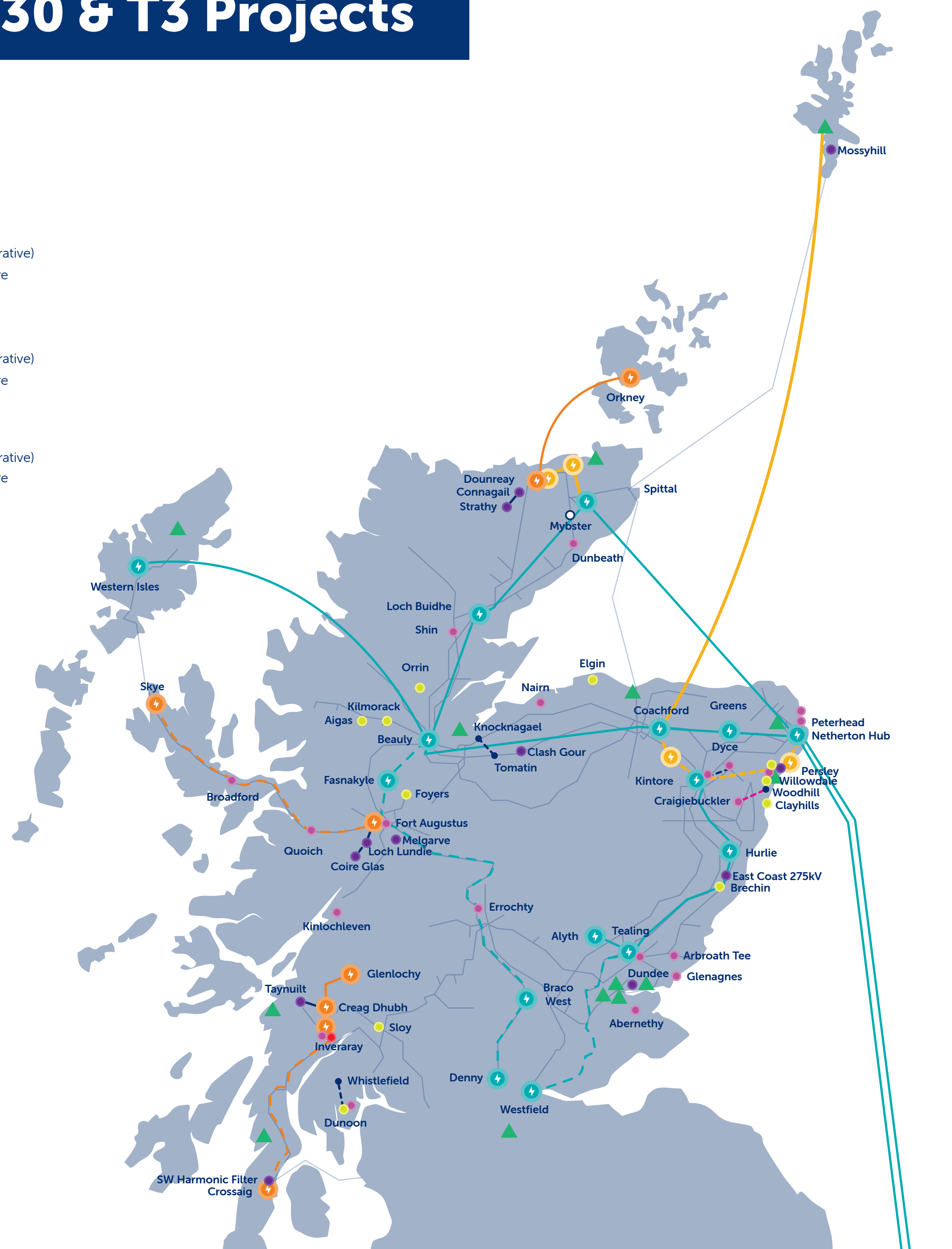
Upgrade/replacement OHL

Underground cables

Asset upgrades

Disposal

Resilience



Innovation Strategy & Action Plan

In March 2024, we launched our new SSEN Transmission Innovation Strategy which sets out our strategic innovation purpose, vision and focus areas, and has clear alignment with the ENA's Innovation Strategy and our RIIO-T3 Business Plan.

Our strategy acts as a guide to how we develop and implement the right innovations to help enable SSEN Transmission to support the UK's ambition to transition to a low-carbon economy. Our four focus areas – safer, smarter, greener, and faster - serve as the foundation of our Innovation Strategy and were identified through horizon scanning and stakeholder engagement, pinpointing opportunities where innovation can have the greatest impact.

Safer

Using innovation to push to be safer than we are today. We will focus on the security of the network, reducing physical hazards, promoting safe behaviours, and do so by designing out risk and designing in safety from the start.

Smarter

Becoming future ready by learning and adapting to maximise our assets. We will apply logic, data, and the right skills and experience to increase functionality and actively seek new ways of working and collaboration to improve efficiency.

Greener

Applying the test of sustainability to everything we do. We will use innovation to quantify and communicate our contribution to net zero, reducing environmental harm throughout the lifecycle of our assets.

Faster

Keeping pace, increasing productivity, and minimising delays through flexibility, agility, and empowerment. We will apply new tools and assets, focus on the output to remove barriers and champion efficient ways of working.

Following the successful strategy launch in 2024, we remain committed to keeping the strategy alive. We have taken significant steps to further develop an innovation culture in the organisation, as well as develop meaningful engagement with our project partners, innovators, other networks and our supply chain.

One of our key initiatives following the strategy launch has been the introduction of challenge groups. This created cross-functional forums, designed to bring together diverse teams to explore and address challenges within their respective areas. The sessions created a collaborative space for open dialogue, idea sharing, and co-creation, helping to break down silos and spark new thinking.

To continue shaping our future innovation strategies, and build on the momentum of the challenge groups, we are also in the process of developing an innovation roadmap. The intention of the roadmap is to facilitate a proactive approach to the work we do, covering several time horizons (out to the next 10-15 years) as we embark on achieving our net zero objectives.

The roadmap aims to provide guidance on the short, medium, and long-term business priorities, illustrating the routes and opportunities that can be provided to address the emerging challenges arising from meeting these priorities. This could be achieved through multiple routes and directions, such as highlighting existing innovation technologies and approaches or harnessing our strong external partnerships to develop potential solutions where gaps have been identified.

"We're very excited to have been a part of this important [AIM High] project with SSEN Transmission. The deployment of our robot at Blackhillock HVDC converter hall has delivered a new level of monitoring for this type of critical asset and the data captured will support the transition towards predictive maintenance, with all the operational, availability and commercial benefits it brings."

- Dominic Cusk, Managing Director of Ross Robotics

"Working with SSEN Transmission's innovation team has been smooth. The strong collaboration, including with Operations during site visits, means we are on track to deliver a successful project on time and on budget. This has resulted in a successful demonstration of how data can be collected reliably and used to inform future actions, with a working proof of concept in the field."

- David Moore, Commercial Director of i4 Asset Management

Industry Collaboration and Engagement

Our Innovation Strategy empowers everybody to have an opportunity for innovative thinking and action. This goes beyond the boundaries of our Innovation team so that it lives and is embedded within the actions and behaviours of all our employees and stakeholders.

In the RIIO-T2 price control period, we have built strong relationships across the industry – collaborating with innovators, small and medium enterprises (SMEs), academia, our supply chain, other networks and across business functions at SSEN Transmission. We are delighted to have partnered with 37 project partners in RIIO-T2 to date, who have helped to deliver our Innovation vision and a strong portfolio of projects:

The National HVDC Centre, UK Power Networks, IBM, Icebreaker One, XYTECS, Carbon Trust, NESO National Energy System Operator, nationalgrid, GILYTICS, olsights, SuperGrid Institute, Mott MacDonald, SGN, Scottish & Southern Electricity Networks, SP Energy Networks, Met Office, MapStand, PLPC LTD, Manitoba Hydro International, energyline, University of Dundee, Cardiff University, NPL, i4, NORPOWER Overhead Line Services, wsp, Ross Robotics, Palantir, University of Strathclyde Glasgow, The University of Edinburgh, Catapult Digital, LaGranja Insulators, Full Matrix, Imperial College London, N-SIDE, BVM Systems Limited, Allied Insulators

In addition, we have showcased our Innovation portfolio and disseminated our project learnings and breakthroughs at a series of global events. This includes the Energy Innovation Summit, Innovation Zero, All Energy, IET ACDC Conference, and CIGRE.

We are also delighted to have received industry recognition through awards, demonstrating our strong commitment to innovation. This includes individuals who are contributing towards innovation across the business and some of our project successes at Utility Week Awards, Green Energy Awards, and Scottish Renewables Young Professionals Green Energy Awards.

13
new projects

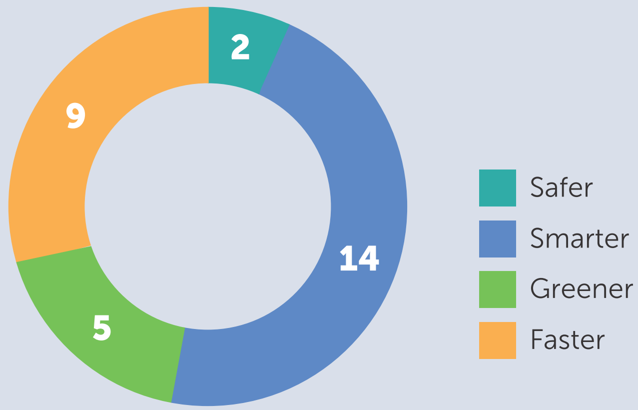
30
live projects

£14.1m
allocated to innovation portfolio

12
projects completed

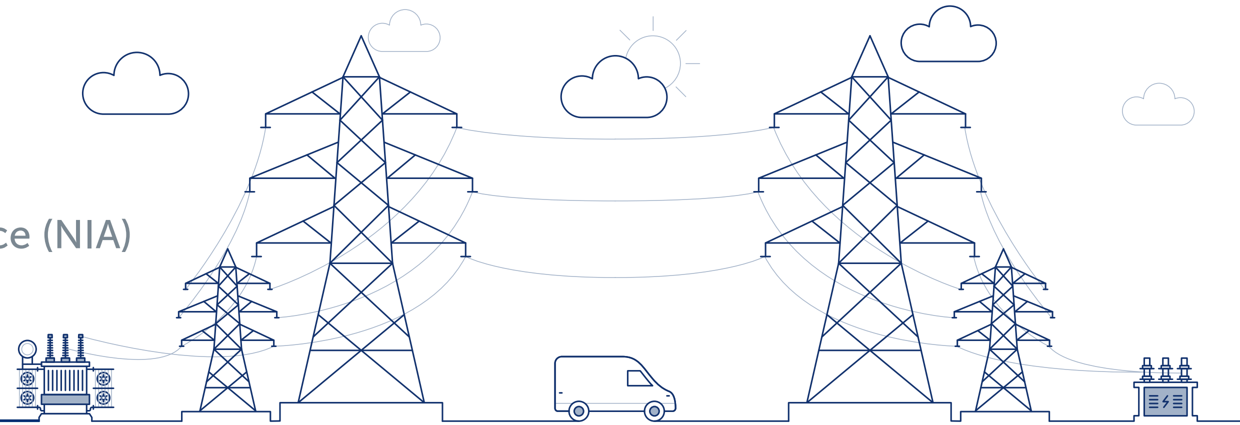
£190m
in benefits by the end of RIIO-T3

Projects allocated to focus areas



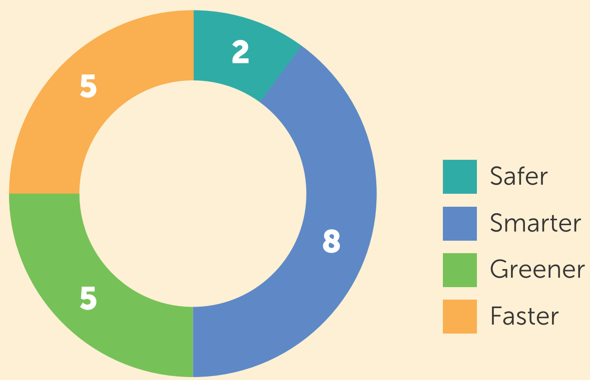
Innovation Dashboard

Key Innovation Metrics for Network Innovation Allowance (NIA) and Strategic Innovation Fund (SIF) in FY24/25



Network Innovation Allowance (NIA) Portfolio Progress

Focus areas



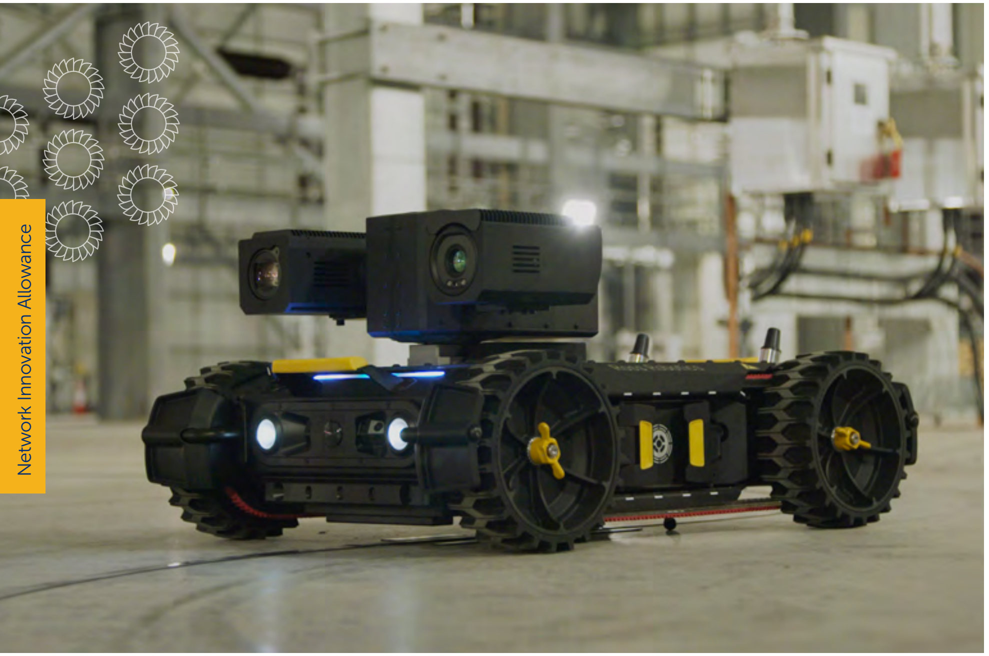
NIA Metrics for FY24/25

Ofgem's Network Innovation Allowance (NIA) is a set amount that we receive as part of our price control settlement. Learn more about NIA here.

The NIA is a valuable mechanism that provides us with the autonomy to innovate by seeking new solutions that address our challenges head-on, guided through the NIA eligibility criteria. Our NIA projects play an essential role within our innovation portfolio by increasing Technology Readiness Levels (TRL) and to support the implementation of innovation into BAU operations.

In FY24/25, we registered 11 new NIA projects on the ENA's Smarter Networks Portal – an increase of 7 projects from the previous year. In addition, 5 NIA projects - Low Profile 132kV Steel Poles, Corrosion Mapping, Autonomous Inspection & Monitoring of High Voltage Assets (AIIM High), TOTEM 2, and High Temperature Low Sag Conductors (HTLS) Non-Destructive Inspection Device - were successfully delivered and are currently in the process of being adopted within the business.

The following pages provide insight into the progress made on NIA projects during the past financial year.



Network Innovation Allowance

Focus areas: Safer | Smarter

AIM High (Autonomous Inspection & Monitoring of High Voltage Assets)

This project installed and tested an autonomous robotic system for conducting continuous monitoring within High Voltage Direct Current (HVDC) valve halls to improve safety and security of the network. These stations operate at an extremely high voltage level of electricity, meaning service personnel cannot access many of the electrical environments when energised and in operation.

Historically, HVDC converter stations were monitored using remote systems and static CCTV cameras to check for any issues, however, they do not provide full visibility of the electrical equipment and its condition. Planned outages are put in place to shut down systems to allow engineers to carry out close inspections of the electrical components. In the instance of a condition-based equipment failure the system would need to be shut down through an unplanned outage. By monitoring the condition of equipment using the robot it is expected that these condition-based unplanned outages can be avoided.

The robot aims to support targeted maintenance complementing current inspections with the potential of an annual £200k cost saving from maintenance per site. An analysis of the scaled benefit was conducted to reflect the implementation of this innovation at 20 applicable sites, generating potential lifetime cost savings of over £22 million.

The project was split into three distinct phases. Phase 1 conducted laboratory testing to define sensor requirements and platform suitability. Phase 2 included a two-week trial at Noss Head Switching Station in Wick at the end of 2023, where the team were able to define the engineering requirements and tested the robot's ability to navigate a similar environment which could be easily accessed by team members. Phase 3 installed the robot at the Blackhillock HVDC converter station.

This marked the first deployment of such technology on the electricity transmission network in Scotland. For the first time, thermal & UV images were obtained from within energised HVDC halls, helping to understand operational temperatures and assess live plant from within the hall. Having the ability to see inside the halls using the platform allows quicker fault identification and diagnostics to improve network safety. With the robot successfully deployed at Blackhillock HVDC converter station, we are looking to deploy further robots across future HVDC convertor stations during the RIIO-T3 period.

Ahead of the first deployment at Blackhillock, the project included a successful community engagement initiative. The project team hosted two events at local primary schools, running a competition to name the robot, which was selected as 'Haggis'. The project has also been showcased at several high-profile events, including the Energy Innovation Summit and the 'Pathway to 2030' event in Westminster, hosted by MP Angus MacDonald and attended by Minister Michael Shanks.

Key learnings: One of the key challenges encountered during the trial was communication reliability within the HVDC converter hall, particularly during power changeovers. This issue was addressed through platform updates that enhanced system redundancy and improved overall resilience.

Project Partners: Ross Robotics

Funded: £454,556

Project Timeline: June 2023 – October 2024

Website: https://smarter.energynetworks.org/projects/nia_shet_0041/

Focus areas: Safer | Smarter

High Temperature Low Sag Conductors (HTLS) Non-Destructive Inspection Device

High Temperature Low Sag (HTLS) conductors have gained popularity as they offer significant advantages over conventional conductors in power transmission networks. The higher current-carrying capacity allows for increased power transfer without requiring additional infrastructure, making them a cost-effective solution for upgrading existing lines due to their advanced materials, such as composite cores and specialised aluminum alloys. However, traditional inspection methods used for conventional conductors are not suitable for the advanced materials, requiring new approaches to ensure the condition and performance can be properly assessed.

This project explores the feasibility of using electromagnetic acoustic transducers (EMATs) for non-destructive inspection of Aluminium Conductor Composite Core (ACCC) HTLS conductors in high-voltage transmission networks.

With ACCC conductors gaining traction due to their superior capacity and reduced thermal sag, reliable condition assessment techniques are critical to ensuring grid resilience. The project could provide benefits including offering a non-intrusive means of assessing the condition of the existing carbon cored, HTLS conductor on the Transmission network – a capability that is not known to exist within the UK or globally.

In addition, it could improve estimates on the end-of-life of conductors and the ability to assess the level of damage to the conductor following incidents, such as tree strikes. This could reduce repair time and avoid unnecessary repair work. Fewer conductor replacements could also reduce their environmental impact by minimising manufacturing and procurement of new conductors, as well as mobilisation of equipment and staff required for their replacement.

If further development is undertaken, the new method will reduce lengthy outages following unplanned disruptive events and full section replacement costs as conductors will be non-destructively inspected and repaired, if needed, rather than replaced.

Key learnings: Field demonstrations validated the system's performance under real-world conditions. While defect detection in the composite core proved challenging due to signal noise, condition monitoring techniques, where sensors remain in place for continuous assessment, show promise for improved sensitivity. The study highlights key considerations for future development, including optimising wave modes, mitigating external signal interference, and transitioning toward a deployable, field-ready monitoring system.

Project Partners: Full Matrix

Funded: £65,000

Project Timeline: June 2024 – February 2025

Website: https://smarter.energynetworks.org/projects/nia_shet_0046/

Focus areas: Smarter | Greener

PSL-FC (Protection Solutions to perform for Lower Levels of Fault Current on AC networks)

The transition from traditional fossil fuels to renewable sources of energy is changing the characteristics of the transmission network. This is because fossil fuel power stations use large spinning machines (such as turbines and generators) that help stabilise the system. As these are replaced by renewables, which operate differently, the network's ability to respond to faults is reduced.

Protection & Control (P&C) systems are presently designed to monitor and react to a very large and sudden current event. A Synchronous Condenser can replicate a traditional fossil fuel power source and in the event of a fault it will respond with a very large, sudden, single burst of current.

Our PSL-FC project is studying the effectiveness and reliability of new P&C equipment in a future electricity network that has increased renewable generation and power electronic devices.

The study will investigate network simulations and trials of open-loop devices, as well as seeking to develop new tests and validation processes for P&C equipment in low fault current environments. Research will focus on refining P&C operational processes and protocols to support with the transition to a net-zero network.

Simulating a future electrical network with marginal but prolonged fault current spikes will help to assess the performance of available P&C products. It will also assess the need for further P&C solutions required to address future network challenges.

If the project can demonstrate the potential for developing P&C products, establish simulation tests for future environments with lower fault currents, and identify necessary changes to existing P&C policies and procedures, there is a potential for the project to manage lower fault level environments.

Key learnings: During Factory Acceptance Tests (FAT), the performance results did not meet expectations for three of seven P&C devices investigated as part of this project. For the three devices, there has been ongoing support and discussions with the manufacturers on how to resolve the issues prior to deploying in the field.

The FAT is currently in the final stages for the three devices, which will then allow the project to install the devices at site. This will be followed by Site Acceptance Tests (SAT) and go live for the field trial monitoring phase of the project, running for two winter periods.

Project Partners: The National HVDC Centre, University of Strathclyde

Funded: £717,000

Project Timeline: July 2021 – March 2026

Website: https://smarter.energynetworks.org/projects/nia_shet_0033/

Corrosion Mapping

The current methodology for estimating corrosion-related deterioration on galvanised steel assets is estimated using the Galvanisers Association corrosion map. This methodology has become outdated based on advancements in meteorological practices and therefore no longer provides enough confidence for strategic decision making in asset development and management.

This has led to some inefficiencies being observed, including requiring some substations located near coastal environments to be unnecessarily enclosed, leading to increased construction costs. Additionally, the methodology can result in unreliable estimations of the remaining service life of overhead line conductors. These challenges are further exacerbated by the map's limited granularity, which fails to account for local topographical and orographic influences, affecting the presence and persistence of airborne environmental pollutants.

This project set out to determine whether the integration of more accurate and locally relevant weather and environmental data could support a more efficient and cost-effective approach to the design, construction, and maintenance of network assets across the north of Scotland.

A new corrosion map and associated data covering SSEN Transmission's operating area were provided as the final output of the project. This visualisation tool enables more precise analysis of corrosion rates and is expected to improve decision-making regarding the necessity of indoor substation installations to mitigate corrosion risks.

Based on an estimated benefit of £1.81 million per substation, a cost-benefit analysis was conducted using the most recent substation development pipeline. Of the 14 substations currently in development, it is assumed that 50% may be identified as susceptible to corrosion under the new methodology. This would allow the remaining seven substations to be constructed outdoors, resulting in potential cost savings of at least £6.8 million (discounted, risk-adjusted, 2018 real).

Subsequently, this could reduce carbon emissions by avoiding the construction of transformer buildings and the associated materials and equipment required. For the seven substations potentially built without transformer enclosures, the avoided lifecycle carbon emissions are estimated at 2,402 tCO_2e - equivalent to a carbon value of approximately £717,000.

Key learnings: Over the past year we have integrated the completed corrosion maps into ArcGIS enabling them to be used in conjunction with existing corrosion datasets. These newly developed maps are currently at an iterative stage, and a key step toward enhancing the predictive accuracy of our corrosion model is the continued collection of real-world corrosion rate data. To achieve this, deployment of corrosion coupons is required. Coupons are an industry-standard tool used to quantitatively estimate corrosion rates - specifically to monitor first-year corrosion, when the highest rates typically occur. Given the annual variability in both environmental conditions and corrosion processes, coupon deployment should be structured as a continuous programme spanning a minimum of five years and the observed results used to further refine the corrosion models.

Project Partners: Met Office

Funded: £300,000

Project Timeline: February 2023 – April 2024

Website: https://smarter.energynetworks.org/projects/nia_shet_0040/

Network Innovation Allowance

Focus areas: Smarter | Faster

Proof of Concept Digitised Condition Monitoring

Historically, when operators conduct inspections of components in our substations, they employ prior knowledge and thermal cameras to identify 'points of interest', predict expected faults, and capture images accordingly. When conducting inspections, operatives could benefit from a visual aid routine to allow for more consistent, structured data collection.

This project has successfully demonstrated a prototype visual aid routine for operatives undertaking site surveys to support condition monitoring operations and efficient maintenance planning.

The successful development and rollout of the structured approach to on-site data collection using the visual script on the operative's handheld device will lead to time and quality-based efficiencies as the relevant information and useful images will be collected. The prototype has been demonstrated at two test sites, incorporating user feedback.

Having a data collection routine on the hand-held device creates a repeatable framework for site surveys that can be followed easily and allows the data collected to be geo-tagged for location confirmation. This will, in turn, provide an opportunity to intervene with preventative measures, simplifying the inspection process and reducing the number of unplanned outages required to conduct maintenance.

The cost comparison of the current case against the proposed innovative visual script development examined the benefits from the application of thermal imaging surveys on Cable Sealing Ends (CSE) only. CSE account for approximately 20% of the eligible substation parts that require thermal imaging surveys. The total risk-adjusted potential benefit value is estimated to be £10.3 million.

Key learnings: The project will continue with the remainder of the scope to fully assess the learning to date including the development of a web dashboard to show alerts, track issues and owners, and filter to show previous relevant defects. A final report on ways to extend to other assets, condition monitoring devices, and knowledge capture will also be produced.

Using two different models of camera to assess CSE at the test sites has produced different results, which were partially due to the characteristics of the cameras used. This has highlighted a learning for the project that the camera set up could be different for each user. It is recommended that a policy note be created covering the best way to set up and use the thermal camera.

Project Partners: i4 Asset Management

Funded: £360,000

Project Timeline: March 2024 – August 2025

Website: https://smarter.energynetworks.org/projects/nia_shet_0043/

Network Innovation Allowance

Focus areas: Smarter | Safer

TOTEM 2 (Transmission Owner Tools for EMT Modelling)

The UK's power system is rapidly evolving as greater levels of renewable energy are being connected, leading to a much lower level of system inertia and lower short circuit levels. The potential for adverse control interactions between these devices is rising and needs careful consideration within the context of a potentially weaker UK power system.

This project follows on from NIA SHET 0032 TOTEM and NIA SHET 0035 TOTEM Extension to continue developing innovative tools and resources for power system modelling. These projects provided a multi-party agreement that enables the Transmission Owners to work together to acquire and validate a new system model that will enhance, as well as de-risk the integration of new technologies.

The previous TOTEM projects developed a large-scale EMT model capable of accurately simulating power electronic systems, supporting the development of mitigation strategies to futureproof the UK's energy networks during the transition to renewable energy. **The aim of the TOTEM 2 project was for Manitoba Hydro International (MHI) to advance and innovate the re-dispatch and simulation capabilities required for future-ready network analysis.**

TOTEM 2 successfully enhanced the re-dispatch tool for seamless integration with PowerFactory models, ensuring adaptability to evolving network configurations. In parallel, the project optimised the Scottish network model, significantly improving simulation performance on high-performance computing platforms—reducing run times and enabling faster, more efficient evaluation of complex operational scenarios.

Key learnings: All work packages were successfully delivered by MHI. Direct model conversion is now achievable with PowerFactory, eliminating the previous dependency on external tools. The simulation speed enhancements have resulted in a substantial reduction in run times, in line with the project objective.

SSEN Transmission's technical teams have adopted the outputs of the TOTEM 2 project into business-as-usual operations as part of the broader TOTEM toolset. A technical guide and user manual have been developed, detailing the conversion process, presenting key findings, and providing clear guidance for updating network models under various re-dispatch scenarios.

Project Partners: Manitoba Hydro International (MHI)

Funded: £100,000

Project Timeline: May 2024 – March 2025

Website: https://smarter.energynetworks.org/projects/nia_shet_0045/

Focus areas: Smarter | Safer

SETTLE

Inverter-based resources (IBRs) such as wind farms and solar photovoltaics introduce new system stability challenges onto the network compared to traditional fossil fuel-driven synchronous generation. IBRs can interact electrically with the network and with each other in ways that are difficult to predict and understand, leading to oscillations on the grid. These inverter-based oscillations have been experienced on power systems worldwide and can pose a serious threat to system security.

To manage IBR-based oscillations, there is a need to innovatively monitor, visualise and analyse to help network operators alert, identify, locate, and understand oscillation modes. In addition, control and mitigation tools can help network operators take appropriate actions to mitigate the escalation of such oscillations.

The current method of managing oscillations is to increase the strength of the system by changing the generation dispatch and/or restricting the taking of major system outages.

SETTLE bridges earlier work carried out under the INSIGHT project (SIF Discovery and Alpha Phases) and its potential Beta Phase. **The objective is to deliver clear oscillating tracing, categorisation, measurement and modelling that provides the foundation for new control and planning tools to be developed and demonstrated in a future phase of the project.**

The project leverages new technology to test the developed project learning, including the use of innovative equipment and methodologies that could benefit the industry if proven successful. By tackling theoretical novel systems, the project embraces risks that might deter more conventional initiatives.

SETTLE supports decarbonisation efforts by minimising reliance on carbon-intensive generation sources typically used during balancing actions, thereby reducing associated CO_2 emissions. From a system reliability perspective, enhanced network stability lowers the risk of both localised and widespread blackouts, ensuring a more secure electricity supply.

Key learnings: As the project is in early-stage development, no outcomes have been achieved yet as part of the project plan. Once it progresses, these lessons will be reported on in future reports.

Project Partners: The National HVDC Centre, University of Strathclyde, Imperial College London, BVM Systems

Funded: £1,187,416

Project Timeline: January 2025 – December 2027

Website: https://smarter.energynetworks.org/projects/nia_shet_0051/

Focus areas: Smarter | Greener

System Short Circuit Tests

The transformation of the electricity system, driven by the increasing integration of power electronic sources, has significantly altered system fault behaviour. Unlike traditional synchronous machines, these new sources do not contribute high fault currents, presenting new challenges for system planning and protection.

Accurate calculation of system short circuit currents (or fault levels) is an essential planning task required to adequately rate equipment, set protection and historically evaluate system strength during asset energisations. As the system evolves, maintaining high confidence in fault modelling and calculation methods is essential to ensure that protection systems can reliably detect and clear faults, safeguarding the stability and reliability of the transmission network. To address these emerging challenges, Engineering Recommendation G74 was updated in July 2021 (G74-2) in the UK.

This project aims to validate the outcomes of the G74 review by recording system behaviour in response to the application of two separate fault disturbances carried out on the Transmission network.

The project involves developing a short circuit test scope for two proposed test sites, creating test procedures for executing both short circuit tests and conducting the tests ensuring suitable system monitoring is available for the recording of data. Following the tests, analysis and validation of the results will be undertaken.

By collating data on network configuration, generation, and demand during tests, the system can be accurately modelled in line with the new G74-2 guidance. This will allow for a robust assessment of the accuracy of current short circuit calculation techniques. This type of system testing has not been conducted on the UK's transmission network for several decades, as the network's performance was previously well understood. However, the significant changes in the generation mix and system dynamics now deem this necessary.

Funded: £250,000

Project Timeline: February 2025 – March 2026

Website: https://smarter.energynetworks.org/projects/nia_shet_0055/

Network Innovation Allowance

Focus areas: Smarter

Virtual Energy System Data Sharing Infrastructure (DSI) Pilot – SSEN-T Component

There is currently a lack of process and mechanism for data sharing amongst transmission operators and the National Energy System Operator (NESO). Currently, for transmission operators, base network models are shared through the System Operator Transmission Owner Code Procedure (STCP) Grid Code Requirements with NESO.

The current process has many challenges, including significant manual resources being required in validating and converting network planning data, for it to be exchanged between organisations. Given the significant policy development around DSI and Ofgem's Flexibility Market Asset Registration work, and the expected inclusion of the DSI as a regulatory requirement for RIIO-3, real demonstration and testing at scale is required.

The Digital Spine Feasibility Study is a pre-cursor to this project. The programme is endorsed by DESNZ and Ofgem who have asked the NESO to take the lead in developing a pilot and minimum viable product. The outputs of the wider project led by NESO, with contributions from SSEN Transmission, SSEN Distribution and National Grid Electricity Transmission, has the potential to deliver significant benefits to the economy and to net zero.

This project aims to create a common data sharing infrastructure, in a secure, resilient and scalable way, to achieve an ecosystem of connected digital twins, as we transition to net zero.

The NIA2_NGESO081 project to which this project contributes will be delivered with ongoing cross-sector and in-sector collaboration, building on wider initiatives driving change in the energy sector. The development of the proposed 'data preparation nodes' and how they can be deployed, used, and scaled will be vitally important to future applications of the data sharing infrastructure and its wider use cases for other licensees in engaging with the DSI.

The project could offer benefits, including enabling a seamless process for search, find and consumption of data that can be scaled, especially if more frequent base model sharing is required in the future. It could also improve safety and grid resilience through more effective and frequent modelling, reduction of outage planning queues, and deliver open data and digital market enablement in our digitalisation strategy.

Project partners: National Energy System Operator, SSEN Distribution, National Grid Electricity Transmission

Funded: £111,000

Project timeline: January 2025 – May 2025

Website: https://smarter.energynetworks.org/projects/nia_shet_0053/

Focus areas: Smarter | Safer

Overhead Line Wind Speed Monitoring

As we transition to net zero, there is a growing need to simultaneously ensure that we are maximising the capacity and efficiency of the existing transmission network. A key enabler of this is the deployment of grid-enhancing technologies.

Collecting accurate wind speed data across long sections of our overhead lines (OHLs) is currently minimal as there are very few weather stations close to these locations. As a result, wind speed data is often interpolated by regional sources. There is a growing need to collect weather data with greater detail across different locations to improve asset management, operational planning and monitoring.

The project scope involves using enhanced Distributed Acoustic Sensing (DAS) technology, which utilises the optical fibres embedded within the OHL earth wires (OPGW), by transmitting optical signals through the fibre to detect and analyse acoustic disturbances.

The system measures acoustic signals caused by vibrations of the towers and the lines. Each event along the line is acoustically coupled to the optical ground wire (OPGW) and propagates down the OPGW. This is done without installing any sensors on the line or towers. A panel is installed at the substation and is connected via a dark wire (unused existing fibre).

At the conclusion of the trial, the project partner will deliver a comprehensive report analysing the captured wind speed data. This will be compared against data from the nearest Met Office weather station to assess accuracy and reliability.

If successful, the outputs of this project will provide windspeed data with positive implications for many of our grid enhancing technology projects such as Dynamic Line Rating (DLR), REVISE and Ice Mapping. Wind speed is a key component in DLR calculations and being able to increase the effectiveness of DLR via improved windspeed data could lead to an increase in grid capacity on our OHLs. This helps to support the energy system transition by increasing efficiency and reducing constraint of renewable energy.

This approach to capturing wind speed data is new to the GB network. The project will provide valuable insights by comparing this method with traditional weather station-based monitoring.

As this type of monitoring approach has not been tested to date on a network with similar conditions to SSEN Transmission's, there will be learning in terms of its performance in the Scottish Highlands. Here there are more frequent and intense wind gusts, complex airflows influenced by mountainous terrain, and higher humidity levels, which could affect the vibration sensing technology differently compared to the relatively stable wind conditions to where it has been trialled to date.

Project partners: Prisma Photonics

Funded: £150,745

Project timeline: March 2025 – August 2026

Website: https://smarter.energynetworks.org/projects/nia_shet_0054/

Network Innovation Allowance

Focus areas: Greener | Smarter

Condition Assessment for SF_6 Alternatives (CASA)

Gas insulated systems (GIS) being used across GB's electricity network currently rely heavily on pressurised sulphur hexafluoride (SF_6) gas, which has a high global warming potential. Aligning with our commitment to reducing greenhouse gas emissions by one-third as part of our RIIO-T2 business plan objective, we are migrating towards alternative gases with lower carbon footprints within the transmission network.

With increasingly strict regulations regarding the use of SF_6, it is imperative to develop and adopt alternative gases for use in GIS. The failure of high-value GIS equipment often originates from small defects, typically caused by manufacturing errors. This defect can lead to gas ionisation and rapid charge acceleration, resulting in partial discharge (PD).

To ensure the integrity of GIS, this project aims to provide an understanding of the characteristics of PD properties in alternative gas mixtures. CASA will enable network operators to have greater confidence in assessing GIS equipment and mitigating the risk of equipment failure.

The project will facilitate the early identification of potential failures and enable engineers to conduct necessary repairs through effective condition monitoring of alternative gases. The knowledge acquired through this project will contribute to advancing industry and international measurement standards, while providing vital diagnostic data to network operators.

Key learnings: Cardiff University have delivered the first six progress reports, providing positive learnings to date. For example, in the last year, the results published in our ISH 2025 conference paper indicate a significant influence of gas composition on the surface discharge performance of epoxy insulation, with all tested alternative gases exhibiting distinct effects on the discharge mechanisms. These findings will be useful in developing condition monitoring techniques for sustainable alternatives, especially for GIS applications.

Through the knowledge acquired so far, multiple technical papers have been published via IEEE, and key findings have been presented at international conferences, including CIGRE in August 2024.

Project Partners: Cardiff University

Funded: £700,000

Project Timeline: May 2022 – December 2025

Website: https://smarter.energynetworks.org/projects/nia_shet_0036/

Focus areas: Greener Smarter

OHL Foundation Uplift

The method for designing overhead line (OHL) foundations has not changed considerably since the 1920's. Initial research work undertaken by the University of Dundee identified that the 'frustum method', which is adopted by most Transmission Operators in the UK and forms industry standards, is generally over-conservative and, in some cases, potentially underestimates foundation uplift capacity by up to 25%.

The project is aiming to improve the current methodology for calculating the uplift capacity of steel lattice tower foundations. This includes gaining a better understanding of the optimal shape and surface of OHL designs, as well as identifying opportunities to use less material and space for foundations.

The removal or reduction of over-conservative design for OHL foundations would reduce the amount of construction materials required and require smaller-scale excavations. This would provide a significant reduction in carbon emissions associated with the construction of OHLs, causing less disruption to the surrounding land and reducing associated costs for energy consumers.

The potential cost savings from the Foundation Uplift method were estimated to be at least £4.7 million (risk-adjusted) during the lifetime of the assets. The potential lifetime cost saving for using OHL foundation uplift on identified projects is estimated to be at least £8 million.

Considering the use of the new method for calculating OHL foundations in five SSEN Transmission OHL projects (totalling approx. 1,500 towers), the estimated carbon saving is approximately 1,600 tonnes of CO_2e. This is equivalent to the annual electricity consumption of over 2,200 households.

Key learnings: Test results from the University of Dundee's centrifuge have shown that by including a chamfered edge on the top edge of concrete foundations, we can increase the uplift capacity of the foundation and also reduce the volume of concrete by 18%, resulting in significant carbon savings.

Due to the positive results from the centrifuge testing, The University of Bristol were engaged to conduct large scale testing of the new foundation design and to further validate the results. This large-scale testing has now been completed with the results correlating with the results from the centrifuge testing. A final detailed report of the project findings is in draft and the results and recommendations on how to exploit this learning further will be published within the project closedown report.

The project has been disseminated during the Energy Innovation Summit, with a model on the stand to show the different foundation designs tested as part of the project. The research findings were also presented at the All Energy event.

Project Partners: National Grid Electricity Transmission, University of Dundee

Funded: £584,307

Project Timeline: December 2022 – May 2025

Website: https://smarter.energynetworks.org/projects/nia_shet_0039/

Focus areas: Greener | Safer

Pollution Monitoring

Environmental pollution and harsh weather conditions are some of the main issues for electric utilities, causing flashovers and unplanned outages. Contaminants can accumulate on the surface of insulators and when combined with moisture, these pollutants form a conductive layer that significantly increases the risk of outage or flashover events occurring. Currently, there is no pollution measurement information available across the network, which could help to avoid or mitigate these risks.

This project has installed pollution monitoring sensors on a section of a 132kV overhead line located on our network to monitor leakage on insulators, capturing and sharing information remotely.

Using the sensors, the project aims to characterise the risk of equipment degradation due to pollution and assist with designing and maintaining OHLs in pollution-high-risk areas of the network. With this, early design mitigation and maintenance procedures can be carried out to prevent faults due to flashovers. As we continue to grow the network to support the energy transition, the challenge of managing these risks will only grow. Therefore, addressing these issues now is critical to ensuring the resilience and cost-effectiveness of future energy systems.

If the system can reduce the number of unplanned outages caused by flashovers and/or the need to carry out maintenance, then this will help ensure reliability of supply, reduce costs for consumers and avoid financial penalties associated with faults. Additionally, having data related to pollution risks could be useful information for communities to help them take steps to reduce pollution risks.

A short section of 132kV OHL was used as the innovation use case, with potential benefits from risk reduction estimated to be at least £108k (discounted, risk adjusted, 2018 real). In addition to risk reduction benefits, there are also environmental benefits associated with pollution monitoring by reducing the need for unplanned outages.

If the outcomes of the project reduce the prevalence of flashovers, then more renewable energy will be transferred through our network, resulting in a reduction of the average carbon intensity of the power grid. The potential CO_2e saving over a 45-year lifecycle may reach 86.9 tonnes of CO_2e.

Key learnings: The pollution monitoring system has successfully been installed on a section of a 132kV OHL at an expected pollution case site. Data collection, including sampling, is ongoing from the site. The results will be analysed over the monitoring period, which is taking place from March 2025 to February 2026.

Project Partners: La Granja Insulators

Funded: £220,000

Project Timeline: July 2023 – March 2026

Website: https://smarter.energynetworks.org/projects/nia_shet_0042/

Focus areas: Greener | Faster

Pole Mounted Switchgear

To connect new assets from an existing circuit, rather than direct from a substation, requires the use of a teed connection or switching station. In certain circumstances, there is a requirement to switch a teed circuit which is currently limited to a ground-mounted solution, for example, a switching station. These are expensive, require long programme development time, longer construction time. It can also be a challenge to gain consent to construct a building in a remote location and is carbon intensive.

There are currently no overhead line mounted switching design solutions at or above 132kV in the UK, therefore, this project looks to consider solutions that offer value for new connections and make the best use of critical resources whilst protecting network operability.

This project will explore an overhead line switching solution that can be applied to teed circuits to support the ambitions of providing quick and efficient connections. This initial NIA project is a feasibility assessment with two phases: initial visualisation and definition of functional requirements; and defining a conceptual design.

The outcome of the initial feasibility assessment will provide an initial visualisation and definition of functional requirements to define a conceptual design.

The pole mounted switchgear is an alternative solution that is potentially cheaper and can be deployed quicker due to a reduction in the construction programme. A full switching station could take 3 to 4 years to design, consent, and construct compared with approximately 1 to 2 years for the design, consent, and construction of a pole mounted switchgear solution.

Key learnings: Initial workshops have been held to identify potential use case sites and undertaking cost analysis. As this project is in the early stages, more progress will be reported in future reports.

Project partners: Energyline

Funded: £61,000

Project timeline: December 2024 – August 2025

Website: https://smarter.energynetworks.org/projects/nia_shet_0049/

Network Innovation Allowance

Focus areas: Greener | Smarter

Aquila Lite

The aim of the project is to develop and understand how multi-vendor interoperable HVDC systems could be implemented and commercially established ahead of future demonstration. A technical model development will be performed and the outlines of a commercial framework investigated.

In a world-first and as part of the project, SSEN Transmission has successfully demonstrated a software interface that allows for HVDC multi-vendor interoperability – allowing different manufacturers' systems, such as controls and main circuits, to work together, eliminating the need for costly AC/DC conversion when transferring power between them.

This work marks a significant breakthrough in realising the potential of the offshore HVDC grid network to deliver vast amounts of renewable energy to meet national clean energy and energy security ambitions.

As well as reducing capital investment costs associated with the construction of converter stations required to switch power between different systems, the technology reduces risk in the supply chain by avoiding reliance on a single supplier. Without interoperability, relying on a sole manufacturer (or vendor) to provide the bulk of the technology required for the developing offshore HVDC grid could expose future network operations to outage risks.

It has led to the development of a cutting-edge multi-terminal, multi-vendor HVDC control approach developed by The National HVDC Centre, which is owned and operated by SSEN Transmission in partnership with other transmission operators and the National Energy System Operator.

Key learnings: The Aquila Lite project was first demonstrated in collaboration with principal contractors GE Vernova and Mitsubishi at the recent IET ACDC International Conference, the first of several intended demonstrations across vendors.

While specific lessons are still emerging, early findings highlight the importance of robust collaboration with HVDC manufacturers and the need for comprehensive legal and operational frameworks to ensure seamless multi-vendor interoperability. Continued stakeholder engagement is crucial to capture all requirements and ensure the effectiveness in the next implementation.

Project partners: The National HVDC Centre

Funded: £477,000

Project timeline: December 2024 – August 2025

Website: https://smarter.energynetworks.org/projects/nia_shet_0050/

Focus areas: Faster | Greener

Low Profile 132kV Steel Poles

Steel lattice towers are proposed for future wind farm connections above 300m however, they come with high costs, long lead times, and environmental impacts. Currently, wooden poles are not a suitable alternative due to capacity limitations and are not robust enough to withstand climatic conditions above 300m. In addition, creosote preservation used on wooden poles is due to be removed from the market in 2029 at the latest, which creates a need for us to explore alternatives to using wood poles.

Our Low Profile 132kV Steel Pole project developed a new innovative and resilient design for overhead powerlines at elevations above 300m and can support with the accelerated delivery of our future network. The collaborative project has used the expertise of framework contractor partners alongside operational staff at SSEN Transmission.

The design reduces steel usage and eliminates the need for permanent access tracks for maintenance and the need for concrete foundations, as they are directly buried in the soil. In addition, enhanced safety features were built into the design, including more attachment points for fall arrest systems, handles to transition from the pole to the cross arm when climbing, and increased working space on cross arms.

The poles are visually aligned with existing wooden poles to reduce the visual impact of our network and aim to improve the consenting process compared to large lattice towers. The project could support faster energy connections due to a reduction in construction lead times and could save up to 50% on construction costs compared to traditional steel lattice towers.

The new design has been scoped out for use on future upgrade or reinforcement projects across our network, with estimated cost benefits to be £9.8 million at the end of the RIIO-T3 regulatory period.

The project was recognised by industry experts and shortlisted as a finalist for Best Innovation - New Technology Product, at the Scottish Green Energy Awards, standing out among more than 140 entries as a leading example of innovation in the energy sector.

Key learnings: Prototype structures were erected and passed initial testing at PLPC's facility in Carluke. The prototypes were used to gain feedback from stakeholders on visual impact of the structures, constructability and maintenance. It was noted by our operations team that there were significant safety improvements in climbing the steel structures vs wooden poles.

Following the prototype structure testing, finalised versions of the structures were tested at an accredited ENA test station in Turkey. The structures were tested to their maximum design loads to measure how they reacted and were witnessed by our internal engineering and policy and standards teams. The structure foundations were then tested both physically and via finite element analysis (FEA) by University of Dundee to confirm the maximum structural loadings. All testing was successfully passed and documented by the project team.

Following the successful testing, new internal specifications have been created, and the design has now been accepted in BAU deployment. The first deployment has already begun on a high-altitude customer windfarm connection with the structures to be built in early 2026.

Project partners: PLPC, Energyline, Norpower

Funded: £1,100,000

Project timeline: January 2022 – November 2024

Website: https://smarter.energynetworks.org/projects/nia_shet_0034/

Focus areas: Faster | Greener

220kV Single Circuit Low Profile Designs

Current low-profile overhead lines (OHL) are insufficient in capacity to support large individual or aggregated electrical loads. As a result, alternative transmission structures such as steel lattice towers, New Suite of Transmission Structures (NeSTS), steel poles, or underground cables have been considered, each presenting an increase in construction costs compared to traditional 132kV wood or steel pole designs.

This project aims to develop a 220kV low-profile design that replicates the visual aesthetic, reliability standards, and construction methods associated with wooden poles.

Building upon the success of a previous NIA project to design a new 132kV Low Profile Steel Poles, this project is incorporating learnings to provide a solution for connecting large single-point windfarms, or aggregated renewable energy connections, at low to medium altitudes. The project is also developing a reliability level 2 design for use on the Main Interconnected Transmission System (MITS).

Aiming to develop a new design that will be smaller in comparison to steel lattice towers, the expected project outcomes include savings in materials such as concrete and steel, as well as carbon emissions. In addition, it is hoped that the new, smaller design will provide communities hosting infrastructure with an alternative option that reduces the visual impact.

The proposed new 220kV low-profile structures will offer a cost-effective alternative to support connecting more renewable energy to the transmission network. Initial analysis has identified a possible 60% reduction in construction costs per km of 220kV low-profile poles in contrast to conventional steel lattice towers.

Projections indicate cost savings ranging from £2.5 to £9.5 million for all identified lines by the end of the RIIO-T3 regulatory period. Over the assets' lifespan, an average of £34 million in cost savings can be achieved through the implementation of the 220kV design.

Key learnings: Strategic decisions regarding the potential use cases for the 220kV pole have influenced the design approach, with constraints related to the design specification, constructability, operation and maintenance, contributing to delays in the project's progress. The project is currently assessing and developing different design styles using expertise from in the business and the project partners.

Project Partners: Energyline, Norpower, PLPC, Allied Insulators

Funded: £1,430,000

Project Timeline: March 2024 – September 2025

Website: https://smarter.energynetworks.org/projects/nia_shet_0044/

Network Innovation Allowance

Focus areas: Faster | Greener

Non-Intrusive Foundation Testing

Overhead line (OHL) foundations are a key component within the structural and mechanical support system for overhead line towers. An understanding of the condition is required for routine monitoring and to contribute to decisions about line refurbishment, upgrade, replacement and during the design of a refurbished or upgraded line. However, this is difficult to assess without undertaking a costly and disruptive excavation.

Non-intrusive techniques can be used and have been available for many years but are inadequately researched/developed for use in OHL foundations to base refurbishment and replacement decisions upon.

This project will carry out the development, testing, and trial of a new method with an aim to achieve a reliable non-intrusive foundation assessment.

The identified limitations of the existing techniques will be investigated, including a survey of existing literature, evaluating the suitability of commercially available equipment through controlled testing in a small test environment that will assess different soil and backfill conditions.

Varying steel sections will be inserted into the backfill and soils of varying types assessed, and the rate of corrosion will be predicted and then measured, to determine the reliability of the measurements. If sufficient, then a procedure will be created to include the new learnings and allow users to generate measurements that are required to produce a reliable corrosion rate. Other activities include investigating soil resistivity contributions and echo testing waveform interpretation.

A model will be produced and then later a prototype tool that allows a test engineer to arrive on-site with a predetermined waveform of a theoretically perfect foundation. If the test engineers' results differ from the theoretical model, it will be possible to determine, in real-time, if there are any variations. If major variations are found, then other techniques could be used to further investigate the foundation.

Key learnings: The first stage of the project has been successfully completed which involved background research and the development of test plans and designs based on the information gathered. This involved carrying out ultrasonic concrete measurements across projects where foundation intrusive investigations are currently ongoing.

Project Partners: Xytecs Ltd

Funded: £570,000

Project Timeline: June 2024 – March 2026

Website: https://smarter.energynetworks.org/projects/nia_shet_0047/

Focus areas: Faster | Smarter

Year Ahead Outage Optimiser (YAhOO)

Planned outage management has become ever more challenging due to the increased volatility and complexity created by the massive integration of renewable energy sources on the electricity network and the reinforcement of the system to facilitate the transfer of increased generation volumes.

Currently, our outage planning team creates and submits year-ahead outage plans to the National Energy System Operator (NESO). These plans are scrutinised and approved by the NESO and afterwards, it is the outage planners' responsibility to maintain and amend the year-ahead plan. This is currently a manual, time, and effort-exhaustive process, carried out using Microsoft Excel. It is anticipated that as the network grows in complexity, so will the process of managing outage planning.

This project is exploring the use of decision support algorithms to improve the efficiency and effectiveness of planned outage management processes.

Given the volume of outages planned, decision-support algorithms can help manage the complexity of changes and additions in the outage plan by automating the assessment of the impact of changes, offering proposed rescheduling solutions within defined parameters, and considering weighted variables.

The project will look to understand the current outage planning process and design new algorithms for decision support, automation, and optimisation and build a decision-support model web application based on constraint programming to enhance the outage planning process. Finally, generated results and assessment of the benefits of the new methodology will be studied. The end goal of this project is to have a prototype that can be used to test the new algorithms and gather feedback from our outage planners

Key learnings: The first project phase - design and workshop with outage planners – has been completed. This was coordinated to gain an understanding of the current processes and tools used to identify how decision support algorithms can help the planning of outages.

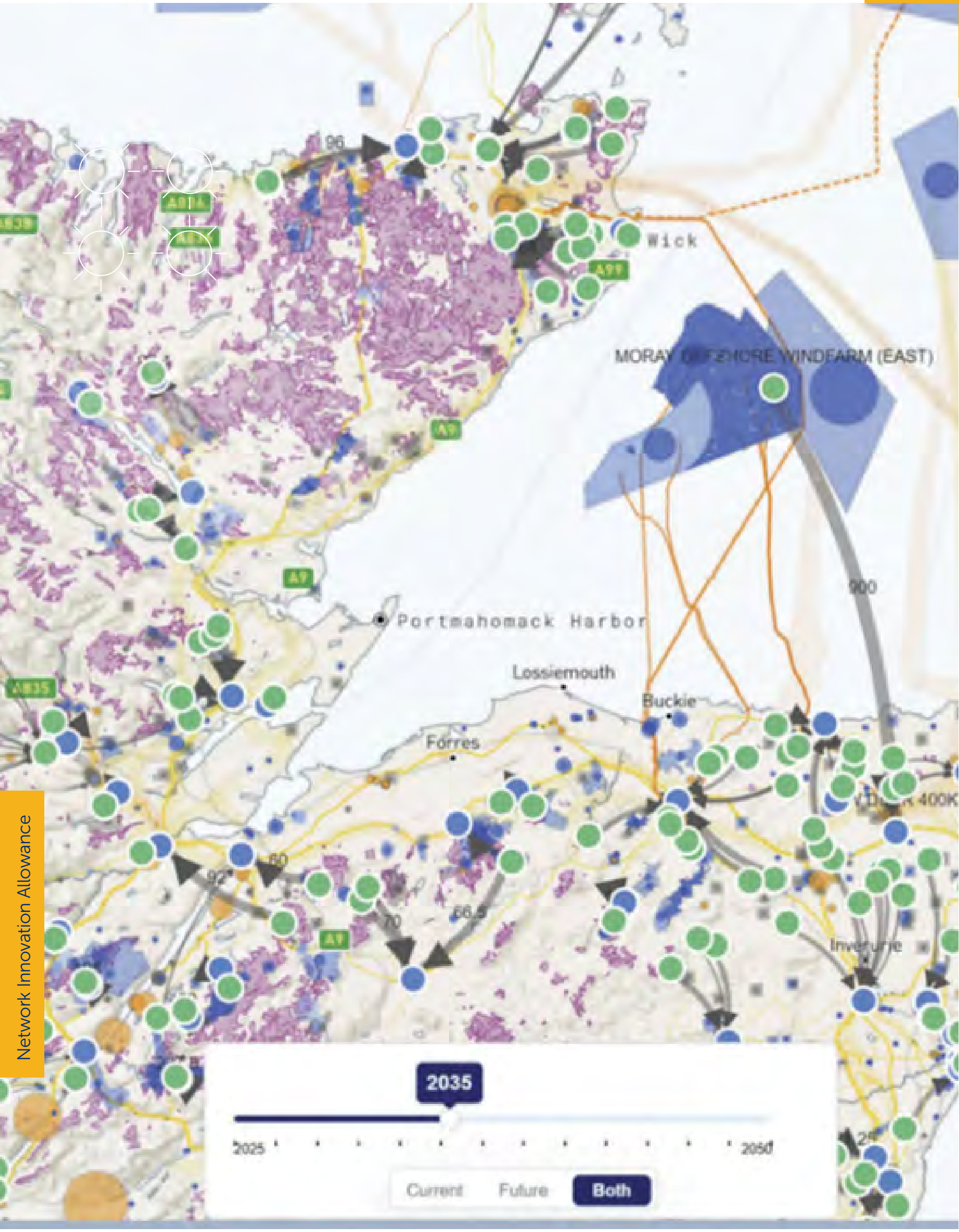
The project was extended by 4 months to allow for a thorough design review for decision support algorithms to be carried out.

Project Partners: N-SIDE

Funded: £382,000

Project Timeline: September 2024 – September 2025

Website: https://smarter.energynetworks.org/projects/nia_shet_0048/



Focus areas: Faster | Smarter

REACT (Rapid Evaluation Areal Connection Tool)

The UK's annual electricity demand is expected to double by 2050 to meet net zero goals, leading to a tenfold increase in transmission connection applications. This surge emphasises the need for optimal site selection for new developments, and for developers to obtain information on network availability at a given location before applying for a connection.

REACT is a geographic visualisation planning tool designed to help stakeholders navigate the complexities of upgrading the power grid to achieve net zero. By visualising power flows and analysing planned generation, demand and storage, including contracted substation pipelines, alongside other decarbonisation pathways, REACT enables the network licensee to optimise network development.

The project started as a SIF Round 2 project, successfully completing the Discovery and Alpha Phases involving National Grid Electricity Transmission (NGET) and SGN. During the Alpha phase, a digital web-based transmission-level geographical planning tool was developed and demonstrated. Due to the limited project timeframes, the tool only covered a part of SSEN Transmission's licence area.

This NIA project aims to deliver a standalone tool covering the entire SSEN Transmission licence area based on the output of the Alpha phase. It also includes developing new scenarios to understand scheme status/likelihood of success, plus other user-driven experimental features.

Whilst this phase of the project focuses on SSEN Transmission's licence area, the longer-term plan is to expand the tool to develop it at a UK-wide level. Given that REACT provides a more holistic view of the network, it is believed that this insight would help reduce wind curtailment through more informed decision-making.

In addition, the tool aims to reduce environmental impact by building a more optimal network that considers the entire network at an early stage. This is supported by the ability to visualise and understand the interactivity between different future network scenarios.

Key learnings: The project is in the early stages of development through the NIA fund. An initial standalone REACT database and new app version, based upon the original tool, was rebuilt with an optimised user interface layout including a demo gallery.

Project Partners: Olsights, MapStand

Funded: £1,000,000

Project Timeline: January 2025 – December 2025

Website: https://smarter.energynetworks.org/projects/nia_shet_0052/

Strategic Innovation Fund (SIF) Portfolio

Discovery phase: **3** projects

Beta phase: **2** projects

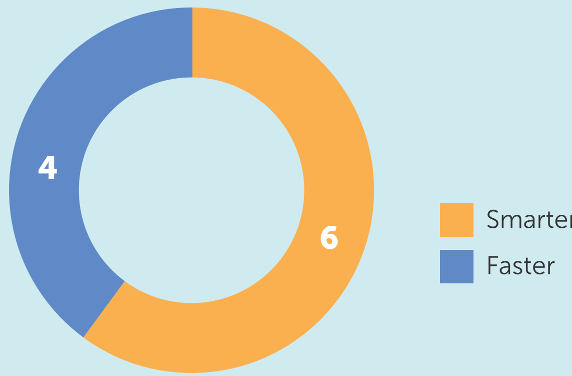
Alpha phase: **5** projects

12 project partners

£5.82m funded

SIF Metrics for FY24/25

Focus areas



These projects are funded by network users and consumers under SIF, an Ofgem programme managed in partnership with UK Research and Innovation (UKRI). Learn more about SIF here.

The SIF mechanism is designed to drive the innovation needed to transform gas and electricity networks for a low-carbon future. Funding is competitive and only awarded to those projects that demonstrate innovation, offer value for money to the consumer and will help deliver net zero in accordance with Government targets.

SIF consists of three project phases:

- **Discovery:** Feasibility studies to de-risk technical uncertainties associated with the project's area of interest.
- **Alpha:** Using the findings of the Discovery Phase to develop a proof-of-concept.
- **Beta:** Develop full-scale demonstrators towards a maturity that either achieves or approaches Business as Usual (BAU).

The following pages provide insight into the progress made on SIF projects during the past financial year.

Focus areas: Smarter | Faster

Network DC Circuit Breakers

Electricity is predominantly transmitted through networks in the form of alternating current (AC). However, we now need to connect large amounts of wind power from remote locations over long distances. To do this, we need to make use of high-power direct current (DC), rather than AC. There is a need to increase the DC transmission network to meet the UK's net-zero energy targets. Direct Current Circuit Breakers (DCCBs) could help combine HVDC links that join two points in the network and an export cable from a wind farm in one hub, without needing to build additional convertor stations to change the electricity current from DC to AC and back.

DCCBs can save valuable space by reducing the number of transmission assets, reducing impacts on local coastal communities and those who would otherwise be disrupted by expanded transmission infrastructure. It also reduces costs by avoiding the need to build additional infrastructure. This approach increases the DC network's flexibility, allowing wind power to be routed more efficiently to centres of demand with reduced constraints and likely reduced curtailment on the wind generation.

Network DC will investigate and define the use of DCCBs, an innovative technology untested in the GB and European markets. DCCBs will allow us to bring multiple wind farms into a DC system, containing the impact of any single failure safely and securely.

Without DCCBs, additional switching stations or point-to-point links will be required to support a 50 GW+ ambition for offshore wind and the growing network of HVDC connections around GB will be less flexible and responsive, leading to higher asset costs, and/or system operating costs. However, the NESO, transmission owners, offshore wind developers and interconnector operators remain uncertain of the performance characteristics, network design implications, reliability, market availability and cost of DCCBs.

This project brings together international partners to accelerate the readiness of DCCBs for installation into the design of the emerging HVDC networks in GB and outlines a clear pathway for the installation of the first DCCBs. The project will address uncertainties by demonstrating performance of DCCBs with detailed testing of protection and control philosophies, informing new technical specifications and addressing regulatory and commercial barriers.

Key learnings: There is regular ongoing engagement with project partners to address technical issues. Significant progress has been made at the National HVDC Centre in developing the use case model within the real-time simulation environment. Work package two, which is looking at the design philosophy, has been extended by two months and will now continue through to July 2025. The project team is currently focused on analysing simulation results to support the success criteria.

Multiple technical papers have been developed and published as part of this project, including two papers at the IET ACDC 2025 conference, and one at the IEEE PowerTech 2025 conference.

Project Partners: The National HVDC Centre, University of Edinburgh, Carbon Trust, National Energy System Operator (NESO), SuperGrid Institute

Funded: £6,097,127

Project Timeline: September 2023 – June 2027

Website: https://smarter.energynetworks.org/projects/10067854/

Focus areas: Smarter

INCENTIVE (Innovative Control and Energy Storage for Ancillary Services in Offshore Wind)

Inertia in the GB electricity network is falling. Without novel solutions, adding additional renewable generation capacity will become increasingly challenging, leading to significant instability events on the onshore networks and increasing the operating cost of the GB network system. Historically, renewable generators have not treated system inertia as their problem, as system inertia has been high due to the presence of (mostly fossil fuelled) synchronous generation. However, we are already seeing renewable generation curtailed due to low system inertia.

The INCENTIVE project has investigated how offshore wind farms (OWF) can provide inertia to the onshore networks. This will provide grid stability and reliability at a lower cost and reduce the need for additional infrastructure by co-developing and co-locating inertia services with OWF developments.

OWFs and their associated grid infrastructure providing inertia to the onshore network is not an incremental innovation, but a step-change in thinking that could be replicated globally. The project has built a cross-industry understanding of how offshore wind could provide inertia using BESS with GFM converters and STATCOMS with grid forming converters and super capacitors.

Key learnings: The project has found that offshore wind in conjunction with an INCENTIVE STATCOM or INCENTIVE BESS can provide necessary and cost-effective stability services to the onshore grid.

While technical testing confirmed that the devices could stabilise the onshore grid, current Grid Code requirements and testing practices do not give a full picture of all the system strength benefits of these technologies - with the tests rating other technologies more highly.

The project proved the economic benefits of the INCENTIVE solutions in providing cost-effective stability services to the onshore grid. However, the current market incentives were found to be unclear. By potentially undervaluing the contribution of grid-forming devices to system strength, and by imposing onerous requirements on inertia contribution, the current stability market framework places novel inverter-based stability assets at a disadvantage. Furthermore, there is uncertainty around whether these services will become mandatory in the future.

Revising the Grid Code requirements and market mechanisms to better reflect the value of these technologies would encourage offshore wind developers to adopt them as BAU. This would enhance grid stability and support greater integration of renewable energy.

Project Partners: National Energy System Operator (NESO), University of Strathclyde, Carbon Trust

Funded: £1,122,973

Project Timeline: June 2023 - October 2024

Website: https://smarter.energynetworks.org/projects/10067856

Focus areas: Smarter

SYSMET (System Strength Measurement and Evaluation)

Increasing connections of Inverter Based Resources (IBRs) on the electricity grid, such as wind farms and solar photovoltaics, can lead to weak network conditions, leaving the power system more susceptible to poorly damped oscillations. With an increasingly higher penetration of power electronics devices appearing on the grid, fundamental frequency Short Circuit Level (SCL) is no longer appropriate in detecting potential instabilities. Currently, there is a lack of real-time monitoring of system strength amongst network owners, creating a real risk to electricity supply.

The SYSMET project will develop a reliable and consistent set of measurement tools to provide full visibility of system strength as an enabler for operational decision making.

The SIF Alpha Phase work focused on testing and validating candidate solutions in simulation and laboratory testbeds, engaging with potential technology providers, and defining a governance process for trial implementation.

SYSMET aims to provide a reliable fit-for-purpose monitoring tool - measuring frequency-dependent impedance at the transmission level. It also looks to deliver a GB-wide standardised approach to measure system strength. The project could be an enabler for manufacturers to develop fit-for-purpose innovative devices that can help the industry.

Key learnings: During the Alpha Phase, a representative Electromagnetic Transient (EMT) model of the power system was developed in power systems CAD (PSCAD) through close collaboration between the three network operators and Imperial College London. A series of test cases were simulated to examine how factors such as perturbation size and frequency sweep intervals influence system strength. The Impedance Margin Ratio (IMR) was used as the key metric to assess and report the system strength in each scenario.

To compliment the PSCAD model, the National Physical Laboratory (NPL) investigated how the proposed system strength measurement approach described may be susceptible to variations caused by random voltage and current noise whether they be naturally occurring or caused by the digitisation of measurements. The results showed that the addition of artificially generated noise does not significantly alter the IMR.

Project Partners: National Grid Electricity Transmission, UK Power Networks and National Physical Laboratory (NPL), Imperial College London, SSE Renewables

Funded: Discovery £110,914 | Alpha £532,701

Project Timeline: Discovery (March 2024 - June 2024) | Alpha (October 2024 - April 2025)

Website: https://smarter.energynetworks.org/projects/10129395/

Focus areas: Faster | Smarter

REVISE (Revisiting and Evaluating Environmental Inputs on Line Ratings)

The transmission network is increasingly curtailed due to the limited amount of electricity that can be transferred by existing circuits; with constraint costs expected to peak at £1-2.5 billion a year by 2025. Overhead line (OHL) circuits in GB are rated using TGN26 methodology, owned by National Grid Electricity Transmission, which uses static environmental parameters developed in the 1980s and applied uniformly across GB.

An overhead line located in southern England would have the same rating if it were in the Scottish Highlands despite the variation in climate. Therefore, for many places across GB, environmental parameters used to calculate overhead line ratings are divergent from those present. REVISE proposes a novel technique to cost-effectively minimise curtailment.

The project aims to replace the current guidance for applying static line ratings, detailed in TGN26, with an updated methodology. It is believed that the outputs will lead to an enhanced grid via an increase in capacity or increase network safety by highlighting areas requiring reinforcement.

Potential project benefits include the reduction of costs in managing power flow constraints and connection costs by allowing smaller and less costly overhead lines to be viable for a larger number of connection schemes. In addition, circuit rating increase could be achieved with little or no physical works required, with associated embedded carbon savings.

Key learnings: The Alpha phase showed that for the past 10 years, circuits have spent very little time above seasonal ratings - out of 180 OHL circuits analysed, only 27 had substantial time over seasonal limit with an average of only 0.03% of their operating time over their seasonal limits. This suggests that circuits may be underutilised and that the limit may be too conservative.

Results show wind is the predominant factor impacting line rating calculations, followed by ambient temperature and solar radiance. There is large interannual variability in the frequency and severity of low wind speed and high temperature events. Weather station records show there is a large regional variation in the frequency of meteorological exceedance events indicating the likelihood of benefits in regionally varying static line ratings.

A prototype methodology was developed to evaluate line ratings with averaged weather data. Two locations (Kinloss and Hawarden) were selected. Results suggest there is headroom to increase the load on these lines by modest levels (1-5%) without exceeding static weather assumed line rating levels or the calculated line ratings with weather data included.

Project Partners: National Grid Electricity Transmission, National Energy System Operator, Met Office, University of Strathclyde, Energyline

Funded: £171,300 Discovery | £433,149 Alpha

Project Timeline: Discovery (March – June 2024) | Alpha (October 2024 – April 2025)

Website: https://smarter.energynetworks.org/projects/10130442/

Strategic Innovation Fund

Focus areas: Faster | Smarter

BluePrint (Building Industry Collaboration and Methodologies for Developing Offshore Wind Behind Constraint)

The Blueprint project Discovery Phase has supported the overall efforts in accelerating offshore wind connections to the GB network and reducing constraints in the context of the holistic network design (HND) by identifying the key risks and challenges to network development and exploring how these can be effectively addressed.

This was achieved by characterising the regulatory, commercial and technical risks and gaps to offshore wind and transmission infrastructure development in constrained areas to better understand what is stopping build-out and connection of nationally vital GW-scale offshore wind farms. In addition, the project identified and prioritised potential mitigations and solutions for these risks and gaps, to avoid delayed offshore wind connections and/or high constraint payments.

Through this process, a range of issues were identified and grouped under the topics of network reinforcement, network utilisation and industry collaboration and communication. From these issues, a selection of the most impactful mitigations and solutions were identified by the project partners. All these potential mitigations were prioritised on whether:

- The risk and/or challenge is not being addressed/ has not been addressed in any project or initiative.
- Addressing the risk and/or challenge will directly impact the aim of the project in a positive way i.e. offshore wind connections will be expedited and/ or network constraints will be reduced

Key learnings: An Alpha Phase application has not been submitted for the Blueprint project. While the outcomes of Blueprint have unearthed several relevant possibilities for valuable follow up projects, the lack of an Alpha Phase submission is largely due to no GB licensed network being able to take the role of the lead network.

This is partly due to time and resource constraints in preparing an Alpha Phase proposal. Additionally, ownership of the problem is unclear as no current GB licensee has ownership over the offshore network build, so have struggled to justify it as a topic to lead on.

Project Partners: National Electricity System Operator, National Grid Electricity Transmission, Carbon Trust

Funded: £167,891

Project Timeline: March 2024 – June 2024

Website: https://smarter.energynetworks.org/projects/10102926/

Business Innovation Portfolio

Our Business Innovation portfolio is funded from other sources outwith the regulatory stimulus of NIA and SIF.

Our portfolio has a mix of projects, including those funded by SSEN Transmission, that are low-risk and high-maturity solutions that will add proven value to improve our network operations, and includes some projects that are funded through additional external financial mechanisms.

The next few pages of this report provide insight into some of the projects that SSEN Transmission is working on within our Business Innovation portfolio.

Focus areas: Smarter | Greener | Safer

Dynamic Line Rating (DLR)

As part of our North of Beauly DLR project, we are installing the largest DLR system in the UK, with full operation expected by the end of 2025.

DLR uses sensors to monitor power lines, considering environmental temperature, wind speed, solar radiation, and cloud cover to determine the maximum amount of power that can be safely carried, without making conductors sag beyond our safety standards.

There is real alignment between wind power and the technology, making it ideal for maximising network efficiency in areas where it is windy. The higher the wind speed, the better - as it cools conductors down, which in turn, allows us to increase the amount of power flowing through the line.

Our pilot project covers the network between Beauly and Dounreay, covering 10 circuits with 58 sensors being installed. Currently 42km of DLR has been installed on our network between Connagill and Gordonbush. By the end of May 2025, our DLR network will cover more than 300km of network – across the ten circuits – which will make it the largest system of its type in Britain.

The sensors collect and send data about conductor temperature into a cloud-based algorithm which calculates the real-time conductor rating, and forecasted rating. This dynamic rating is then communicated to the NESO and used as part of NESO's operation of the balancing mechanism and generation constraints.

Whilst network reinforcement ultimately has a greater impact on capacity, DLR provides a boost to the grid that, working alongside reinforcement, can help to maximise efficiency across the network and ultimately saves the energy consumer money, by alleviating constraints.

Once the full number of sensors have been installed by May 2025, calibration and monitoring of the system will be performed over several months. Following this, communication testing with NESO will be undertaken with the hope of rolling out the system for full operation by the end of the year. In addition, we are currently considering other applicable circuits that could benefit from DLR to continue rolling out the technology across the network.

Project Partners: Ampacimon

Project Timeline: February 2021 – December 2025

Transmission Network Digital Substation (TReNDs)

The TReNDS project is exploring the opportunities presented by a fully digital substation secondary system design, based upon the IEC 61850 and associated suite of standards.

With a move away from the conventional substation design, the TReNDS project involves the concept of replacing the bulk of traditional copper cables found in our substations with new fibre optic communications, increasing the speed of deployment and technological progress.

This technology comes with several advantages, not only providing significant savings in project delivery time, enhanced cybersecurity, and increased efficiency in control room footprint, but also reducing the environmental impact. As a testament to the pioneering work that will be delivered through this project, the project secured funding through Ofgem's RIIO-T2 Non-operational IT reopener.

The TReNDS team have been working collaboratively with other GB Transmission owners, digital substation solution providers, internal field unit stakeholders, and project teams to develop solution that can be delivered successfully for our pioneer digital substation project. Following the successful demonstration of typical bays like feeder, SGT, busbar and also innovative voltage selection scheme, which will be first of its kind deployment globally, we are progressing through Technical Authority approval and system level testing.

Furthermore, we are actively engaging with our principal contractors within our supply chain, sharing our development to date and discussing strategies for scaling standardised implementation across our transmission network, building a compelling business case for widespread adoption.

Mobile Substations

Mobile substations offer the ability to maintain connections whilst major plant is being maintained or replaced. The first of its kind in northern Europe, SSEN Transmission will utilise mobile substation technology to enable grid upgrades with significantly reduced outage durations, i.e. time disconnected from the grid and lost generation of clean renewable energy.

Conventionally, a substation upgrade would require a new substation or an extension, which would be much more expensive, time consuming, and carry a higher carbon footprint due to site clearance, construction and materials. The mobile substation offers the ability to replace equipment in-situ whilst maintaining connections. In this way, outage durations are significantly shorter and the environmental impact is much lower.

Bird Flight Divertors

Bird flight diverters (BFDs) are used all over the network as a way of mitigating bird collisions. BFDs are installed on overhead lines to increase visibility and reduce collision risk in sensitive areas, identified through detailed bird surveys and risk assessments in project development.

The installation of BFDs is needed on our lines for multiple reasons: to protect both birds and transmission assets. Aviary collisions with overhead lines (OHLs) can result in short circuiting which can lead to OHL faults such as unexpected blackouts and damaged equipment. The installation of BFDs is also an environmental requirement from organisations such as NatureScot.

We always aim to avoid sensitive habitats and species abundant in our operational area in the north of Scotland, but where avoidance is not possible, we focus on mitigating potential environmental impacts. The installation of BFDs on high-risk spans is one such mitigation. As we expand our transmission network to meet climate targets, it's imperative that we design, build, and operate our assets in ways that protect and enhance the natural environment, safeguarding sensitive habitats and species along the way.

The integration of drone and robot technology addresses the need for safer, faster, and more cost-effective methods of installing BFDs on our transmission network.

Traditional methods such as hot stick or mobile elevated working platforms (MEWP) come with safety risks, time constraints, and outage requirements. By eliminating the need for human presence on the line and providing access to remote or challenging terrain, drones offer a safe and efficient solution as we transition to net zero.

220kV Conversion Tower Mod Design

Given the capacity increase requirements across the network, and the infrastructure that is required to support larger connections, options to upgrade our existing L7c steel lattice towers to support a higher voltage (220kV) are being explored in this project. An increase in voltage would mean the internal and external clearances would need to increase.

This project will undertake a design study which will convert the existing 132kV line to a 220kV line without the need to reconstruct or install new lines. The study will review the feasibility of using composite cross arms to extend the area between the tower and conductor allowing a higher voltage to be passed through without the need for a larger tower.

Enabling tower upgrades to a higher voltage will ensure security and reliability of supply through the ability to increase OHL rating and capacity. In addition, it will avoid building new OHLs, therefore reducing future impact on communities and the embedded carbon associated with the building of infrastructure.

Partner Projects

Project Name	Funding Stream	Link
BLADE	SIF Beta	https://smarter.energynetworks.org/projects/sif_blade_beta/
Scenarios for Extreme Events	SIF Alpha	https://smarter.energynetworks.org/projects/10078787-1/
SF_6 Whole Life Strategy	SIF Discovery	https://smarter.energynetworks.org/projects/11061098-nget-sf6-whole-life-strategy-sifiesrr-rd2_discovery/
Comms Connect	SIF Discovery	https://smarter.energynetworks.org/projects/10061243/
HIRE	SIF Discovery	https://smarter.energynetworks.org/projects/10103531-nget-hire-sifwspfar-rd3_discovery/

Ideas good, great, and small are all welcome.
Let's innovate together.

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