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Scottish & Southern Electricity Networks

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Scottish Hydro Electric Transmission

Network Innovation Allowance Summary Report

1 April 2019 to 31 March 2020

Scottish Hydro Electric Transmission plc

Contents

Foreword

This report is a summary of the progress achieved by Scottish Hydro Electric Transmission plc (SHE Transmission) in Network Innovation Allowance (NIA) projects during the period between April 2019 and March 2020. NIA is targeted at smaller innovation projects which can deliver value to network customers and has been running since the onset of RIIO-T1 in April 2013.

SHE Transmission is the owner of the high voltage (132kV, 275kV and 400kV) electricity assets in the north of Scotland. Our network consists of underground and subsea cables, overhead lines on wooden and composite poles, steel towers, and electricity substations. The SHE Transmission network extends over a quarter of the UK's land mass and across some of its most challenging terrain.

Enabling a transition to a low carbon economy is at the heart of SHE Transmission's Innovation Strategy.

Our innovation direction supports the continued shift in the composition of the generation mix in Great Britain (GB), together with increased penetration of other low carbon technologies. SHE Transmission continues to closely monitor ongoing developments and takes a dynamic approach to responding to the associated challenges.

During 2019 extensive engagement occurred with our customers and stakeholders to identify how best to shape our innovation approach to their present and foreseeable challenges. The conclusions have been published in the updated **SHE Transmission Innovation Strategy**[1], in December 2019. This sets out our plans and ambitions for getting the most from our innovation activities before, during and after the RIIO-T2 price control period. The new strategy has been shaped by the learnings and benefits delivered through our RIIO-T1 innovation portfolio.

As of 31 March 2020, we have a portfolio of nine NIA projects, which are at various stages in their lifecycles. Within the project portfolio, each of the projects addresses at least one of the four strategic innovation themes, which are summarised in this report in Chapter 2 and covered in greater detail in our updated **SHE Transmission Innovation Strategy**[1] published December 2019. Since April 2019, we have registered five NIA projects.

We deem our innovation approach to be consistent with our core purpose and our need to prioritise the relevant challenges faced by our networks as well as those of the entire GB electricity sector. Whilst our projects make progress, we keep a lookout for any learning that can quickly be implemented. We also learn from our peers in the industry and engage with our stakeholders and other interested parties in the energy supply chain to ensure that our combined efforts can deliver the best possible value to GB customers.

Andrew Urquhart
Head of Whole System
Scottish and Southern Electricity Networks plc

1 https://www.ssen-transmission.co.uk/media/3725/she-transmission-innovation-strategy.pdf

1

Update to the SHE Transmission Innovation Strategy

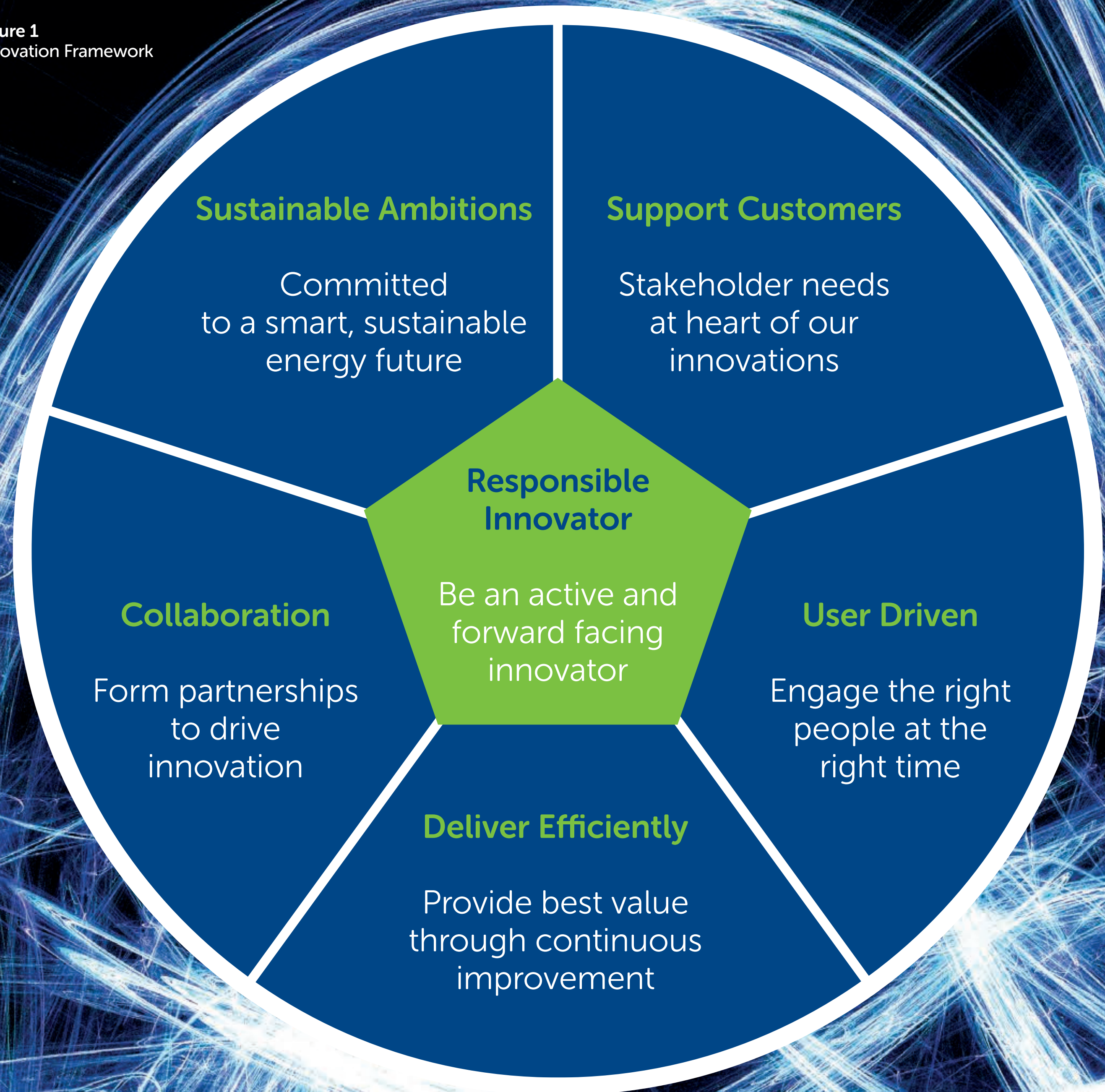
The December **2019 SHE Transmission Innovation Strategy** sets out our plans and ambitions for getting the most from innovation before, during and after the RIIO-T2 price control period. Our innovation objective is to enable the transition towards a low carbon economy, whilst maintaining 100% reliability in electricity supply and ensuring energy remains affordable for all. We see innovation as a means of identifying and proving new ways of working for the long-term benefits of our stakeholders and ourselves. This core principle is underpinned by five values shown in Figure 1.

SHE Transmission has four innovation themes supporting our Strategic Objective to channel business activities before, during and beyond RIIO-T2. To emphasise and reinforce the Strategic Objectives, the Innovation Focus Areas have been aligned and are as follows:

- Stakeholder-led strategy,
- Safe and secure network operation,
- Sector-leading efficiency, and
- Leadership in sustainability.

The following subsections, within Section 1, expand upon each of the Innovation Focus Areas and outline their associated innovation opportunities.

Figure 1
Innovation Framework



1.1 Stakeholder-led Strategy

There will be a lot of change in the industry over the coming years. An element of this change will be driven by stakeholder choice but all of it will impact, either positively or negatively, on stakeholders. It is important to identify those impacts and work to mitigate or improve the effect. This will drive a more holistic approach to innovation, across not only our network, but through to other energy networks, an example being the development of a 'whole system approach'. We foresee innovation opportunities in the following areas:

Supporting our customers

Customer engagement

- Enable customer choice
- Improved service delivery
- Provide relevant network information
- Improved outage management

Customer engagement

- Connection queue management
- Facilitate DSO transition
- Support new commercial models
- Commercial arrangement visibility

Wider Energy System Changes

Whole system approach

- Decentralised technologies
- Whole system planning
- Demand Side Response
- Understand DER flexibility

Energy system transition

- Support electric vehicle uptake
- Facilitate decarbonisation of heat
- Hydrogen economy development
- Collaborate across energy vectors

Enhanced Connection Approaches

Using network flexibility in connections

- Accelerated connections
- Managing connection flexibility
- Active Network Management
- Tailored connection solutions

Facilitating connections

- Implement smarter connections
- Wide area network management
- Managing changing network aspects
- Interface between TO and DNO

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1.2 Safe and secure network operation

Network reliability and integrity is fundamental to SHE Transmission. Maintaining and improving our existing standards at a time of unprecedented industry change is a significant challenge. We must develop new options to accommodate flexibility, new methods of working and facilitating new commercial arrangements whilst maintaining network resilience, and safety.

With this transition will come new technologies that will challenge long-established characteristics of stable network operation including fault levels, system inertia and power quality. Well-established techniques for network management need to be updated and revised to better reflect the changing use of the network. Similarly, new technology can provide improved visibility and transparency of the network's operating characteristics, which allows opportunities to maximise network utilisation. Therefore, the potential innovation opportunities at a high level are outlined here:

Planning and Development

Network planning

- Optimised design and development
- Probablistic planning tools
- Detailed network modelling
- Generation and demand balancing capacity management

Data driven network development

- Smart network development
- Network development and stability reinforcement
- Enhanced data analysis
- Artificial Intelligence in system modelling

Asset and Network Management

Security and resilience

- Network reliability and resilience
- Countering physical threats
- Black start capability
- Extreme event planning and contingency management

Smart asset management

- Modernised enhanced control room
- Power quality management
- Operational technology developments
- Condition based asset management

Network Monitoring & Operations

Network operations & control

- Network controllability
- Smart condition monitoring
- Cyber threats
- Interactive and adaptive condition monitoring

Facilitating connections

- Grid monitoring strategy
- Enhanced transmission fault
- Enhanced network stability analysis
- Remote asset monitoring

1.3 Sector-leading efficiency

In supporting the transition to a low carbon economy, we must make sure that we do so in an efficient way and deliver the best value for consumers. Whilst identifying opportunities we will make sure to leverage maximum benefit from our existing assets, data and relationships. This will include collaborating with other parties to identify industry best practice and learning from their experience, thus helping to reduce the risk and improve the potential benefits of deploying any innovation. To this end the following innovation opportunities have been identified:

Supply chain efficencies

Transformational health and safety

- Continue driving effective safety standards
- Continually improve process safety, environment and travel performance
- Transform contractor safety, operational safety and health and wellbeing
- Minimise human interaction through data and analytics

Data driven network development

- Demand plan analysis
- Supply chain engagement to negate non-compliance
- License to operate
- Responsible buyer

Modernising our network

Integration of new technologies

- Consider novel technologies and materials
- Drive a smarter network
- Digital substation evolution
- Further develop use of HVDC technology

Efficient network modernisation

- Drive staged smarter network development
- Big Data management
- Network stability reinforcement
- Network modernisation

Network monitoring and operations

Transparent and robust decision making

- Maximise use of existing asset base
- Engage customers earlier in the design development
- Investigate market-ready data and analytic platforms
- Demonstrate efficiency in outcomes

Efficient project delivery

- Evaluate new construction means
- Alternative access arrangements
- Bespoke network solutions
- Reduced onsite testing and contruction

1.4 Leadership in sustainability

As we deliver innovation, we aim to prioritise the areas which will provide long term benefit. When thinking into the future, sustainability is a crucial component to consider, whether for environmental, social or economic impacts. When developing these opportunities, it is important for us to support governmental initiatives, such as government targets for EV car or decarbonisation. This holds the following innovation opportunities:

Maximise benefit to customers

Supporting communities

- Enable local communities' use of low carbon technology
- Realise social and economic benefit from investment
- Supporting vulnerable customers
- Enable local community engagement in energy markets

Connecting for society

- Promote decarbonised and decentralised economy
- Review wider societal impacts of our investment
- Consider our investment affordability for consumers and generators
- Deliver low carbon energy connections

Mitigating climate change

Carbon saving emissions

- Design new more energy efficient substations
- Implement energy efficiency to existing substations
- Support losses policy
- Decrease equipment losses

Energy efficiency and optimisation

- Set and deliver science-based targets
- Develop and implement SF_6 Strategy
- Embedded carbon reduction
- Reduce direct and indirect Greenhouse emissions from our activities

Reducing our environmental impact

Promoting natural environment

- Positively contribute to UN and Scottish biodiversity strategies
- Develop environmentally sensitive operations
- Consider network visual impact
- Collaborate on measuring biodiversity net gain

Optimising resources

- Life cycle and cost benefits
- Promote circular economy principles
- Waste minimisation initiatives
- Asset replacement strategy

2
Summary of Progress

This Section summarises the nine NIA Transmission Projects which have been active during the review period. The summaries include key project details and achievements during the year.

Each project accumulates knowledge and learning which aligns with one or more Innovation Focus areas. The relevant Innovation Focus Area is denoted via the inclusion of its icon.

Stakeholder-led strategy

Safe and secure network operation

Sector-leading efficiency

Leadership in sustainability

2.1 NIA_SHET_0014 Partial Discharge Monitoring to Reduce Safety Criticality

Key activities

This project installed two different technologies to monitor substation Partial Discharge (PD), to investigate if it was possible to continually monitor and trigger notifications in the event of unusual PD activity. With the PD monitors installed initially a base PD level was obtained; this progressed with a real-time PD alarm notification system established.

Expected outcomes

The project will be considered a success if it can determine the viability of continuous PD monitoring as a tool for the management of safety critical assets on the network.

Progress

This project has positively demonstrated that real-time PD alarm notification systems could be set up and maintained. Both PD monitoring systems correctly triggered and identified a source of mechanical PD which was placed within the substations to investigate their accuracy.

Innovation Focus Areas

Stakeholder-led strategy

Safe and secure network operation

Sector-leading efficiency

Leadership in sustainability

Funded	Start/end date	Website
£1,300,000	January 2015 / October 2020	https://www.smarternetworks.org/project/nia_shet_0014

2.2 NIA_SHET_0020 Remote Asset INertial Monitoring & Alerting Network (RAINMAN)

Key activities

The Remote Asset INertial Monitoring and Alerting Network (RAINMAN) system was the first remote wooden pole monitoring to be trialled in GB. The pole mounted devices looked for changes in the tilt, roll, pitch, spring, and twisting. The communication medium was also novel, as it was the first time in GB that a low power wide area network (LoRaWAN) was used. This made the remote monitoring possible.

Expected outcomes

The project will be considered successful if the installed system can provide timely, reliable and accurate warnings of wooden pole movement or failure, which can then be replicated into a cost effective and economic solution.

Progress

Over the duration of the project the communication medium LoRaWAN made it possible to reduce the size and cost of the pole mounted unit. LoRaWAN's furthest data transfer recorded between a pole mounted device and the collection station was 52km. The trial successfully proved it was possible to collect movement information, however the reliability of the data and the high failure rate of the pole mounted devices indicated further product development and testing was necessary.

Each device could produce many 1000s of data movement notifications during a storm event; as interesting and positive as that is, it highlighted the need to identify the critical movement information due to the large volume of notifications. This again flags the requirement for additional data analytical tools or processing to enhance the product prior to commercialisation.

Innovation Focus Areas

Stakeholder-led strategy

Safe and secure network operation

Sector-leading efficiency

Leadership in sustainability

Funded	Start/end date	Website
£1,087,000	July 2016 / March 2020	https://www.smarternetworks.org/project/nia_shet_0020

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2.3 NIA_SHET_0023 Line Inspection by Semi-Autonomous Systems (LISAS)

Key activities

Using robotic devices which can carry onboard monitoring equipment and have the ability to travel along an overhead line without requiring continual human intervention could allow the conductors to be accurately monitored, with substantially more of the network being monitored. This project looks to explore the requirements and capabilities of semi-autonomous robotic devices for overhead lines.

Additionally, with the new types of overhead line composite conductor being proposed there is an opportunity to explore the development of a robot capable of condition monitoring using this new technology.

Expected outcomes

The project aims to provide processes and procedures for the use of an overhead line robotic device. This will be achieved through the development of a clear specification for overhead line robotic condition monitoring.

Progress

A specification has been produced for the provision of a suitable semi-autonomous device for overhead line inspection and assessment. There have been delays in identifying suitable suppliers and developers of devices appropriate for trial, so the project scope has been reduced to evaluate the types of robotic devices commercially available on the market against the developed specification.

Innovation Focus Areas

Stakeholder-led strategy

Safe and secure network operation

Sector-leading efficiency

Leadership in sustainability

Funded	Start/end date	Website
£230,000	June 2018 / November 2020	https://www.smarternetworks.org/project/nia_shet_0023

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2.4 NIA_SHET_0025 Zero Missing Phenomenon

Key activities

This project will investigate the zero missing phenomenon that has arisen due to the increase in reactive power compensation equipment on the electrical transmission network. The investigation will focus on understanding the decaying DC current problem produced through the use of shunt reactors: its likelihood, its cause, potential consequences and risks, and the ability of existing AC circuit breakers to interrupt it. It will also outline any potential mitigation options and test their efficacy through network studies. The planning, training, operation and maintenance requirements of any viable mitigation options will also be explored.

Expected outcomes

The project will provide an improved understanding of the zero missing phenomenon DC current problem due to shunt reactor switching and associated challenges. It will also determine the capability of existing circuit breakers to interrupt the prospective DC fault current. It is hoped that the project conclusions will influence future circuit breaker design and the use of shunt reactors on the network. The project will also identify any mitigation options and strategies, and determine how they might be implemented.

Progress

Analyses of 10 circuit configurations susceptible to the zero missing phenomenon have been conducted. The investigations have been condensed into a technical guidance note for the Transmission System Planning Team. This guidance note explains how to identify the zero missing phenomenon, and factors that affect its impact. The guidance also offers Planners a choice of mitigation options and strategies.

Innovation Focus Areas

Stakeholder-led strategy

Safe and secure network operation

Sector-leading efficiency

Leadership in sustainability

Funded	Start/end date	Website
£128,500	October 2018 / June 2020	https://www.smarternetworks.org/project/nia_shet_0025

2.5 NIA_SHET_0026 Refase

Key activities

Refase is a new control product that allows measured values from up to 50 current transformers to be acquired passively using a single optical fibre core over distances up to 50km. By centralising current measurements, this method negates the need for multiple protection relays, complex time synchronisation systems at measurement points, and telecommunications equipment among the distributed protection and control devices. This project will conduct a series of desktop trials, which if successful will progress into field trials, to benchmark the performance of the Refase system against existing protection methods.

Expected outcomes

Synaptec is the company behind Refase, who will conduct protection and control testing in line with requirements for the GB Transmission network at their laboratory. The solution will then progress to further testing at SHE Transmission's Braco research and development substation where it will be evaluated for use on the live transmission system. If successful Refase will be installed on a live 132kV circuit with the performance benchmarked against existing protection methods. This will provide an understanding of the system's suitability for business as usual adoption, and will include a comprehensive business case and benefits realisation plan.

Progress

The first stage of laboratory testing has been completed successfully. The project is progressing to the next stage, with the necessary protection and control panels being built for testing at Braco research and development substation. If successful, installation is planned on a live 132kV site in late 2020.

Funded	Start/end date	Website
£388,360	June 2019 / June 2021	https://www.smarternetworks.org/project/nia_shet_0026

Innovation Focus Areas

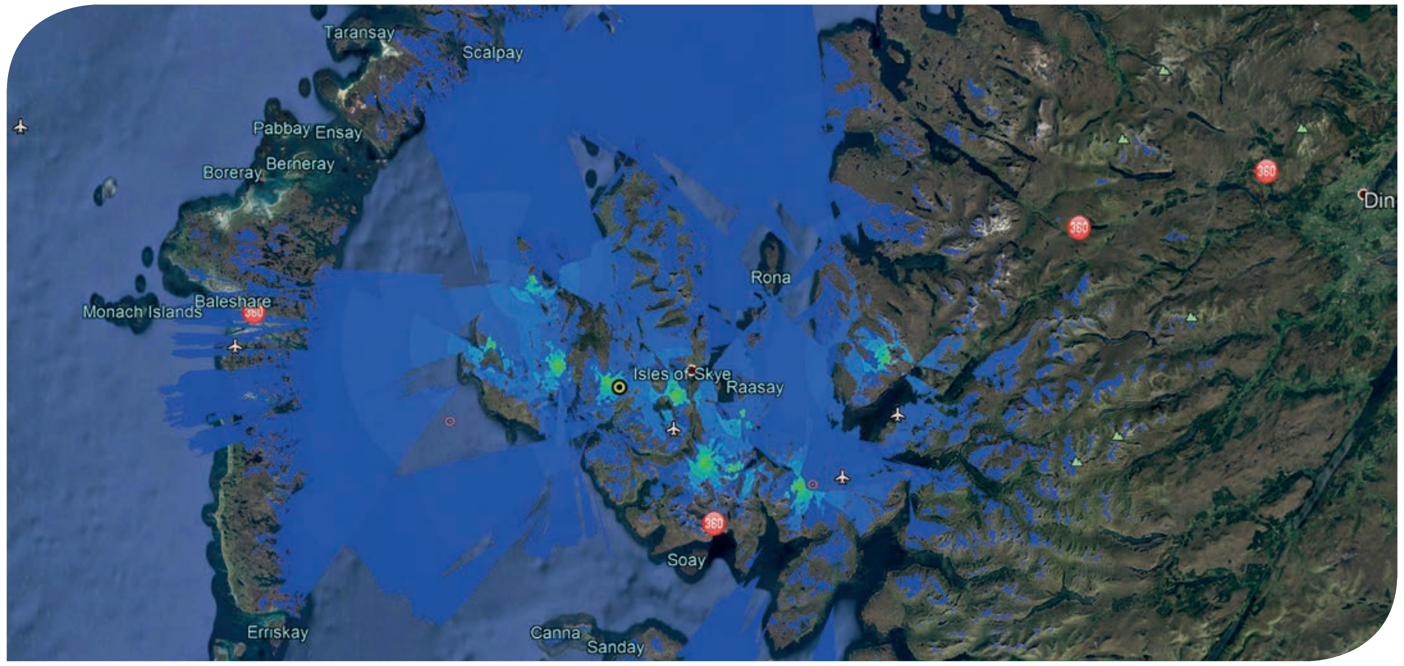
Stakeholder-led strategy

Safe and secure network operation

Sector-leading efficiency

Leadership in sustainability

2.6 NIA_SHET_0027 Expanding Lora



Key activities

LoRa enables long-range data transmissions with low power consumption for small data information packages. This is potentially an economic and reliable method for monitoring communication in rural areas where mobile telephone coverage is limited. This project will investigate how to connect off-the-shelf purchased LoRa enabled monitoring equipment, as well as how to view and make use of the resulting data.

Expected outcomes

This project will be successful if off-the-shelf LoRa enabled monitoring devices can be purchased at an acceptable unit cost, installed easily and the resulting real-time field data viewable within a short timeframe.

Progress

This project is in the initial investigation stage. There are a number of LoRa enabled monitoring devices which are commercially available. At the lower cost end of the scale are devices that measure a single parameter. Generally, the costs increase with the number of measurement parameters. The off-the-shelf LoRa enabled devices are easily installed, however there is a level of IT knowledge required to retrieve the monitored data.

Funded	Start/end date	Website
£46,500	September 2019 / December 2020	https://www.smarternetworks.org/project/nia_shet_0027

Innovation Focus Areas

Stakeholder-led strategy

Safe and secure network operation

Sector-leading efficiency

Leadership in sustainability

2.7 NIA_SHET_0028 Phasor Instream Data Processing (IDP)

Key activities

As technology has developed, projects such as VISOR have shown the potential benefits in electrical phasor system measurements and their onward applications. One of the outcomes of the VISOR project highlighted the need to identify the requirements of a phasor measurement system at the component architecture levels. The System Operator Transmission Owner Code (STC) has recently changed to include requirements associated with phasor measurements. This project aims to investigate the different system architectural options which would facilitate real-time phasor data manipulation and transfer to other Parties.

Expected outcomes

Development and presentation of several different system architectures suitable for real-time instream data processing, along with the benefits and potential obstacles.

Progress

Working with SHE Transmission's protection and control experts the requirements associated with phasors data has been specified, thus allowing an external work package to be tendered.

Innovation Focus Areas

Stakeholder-led strategy

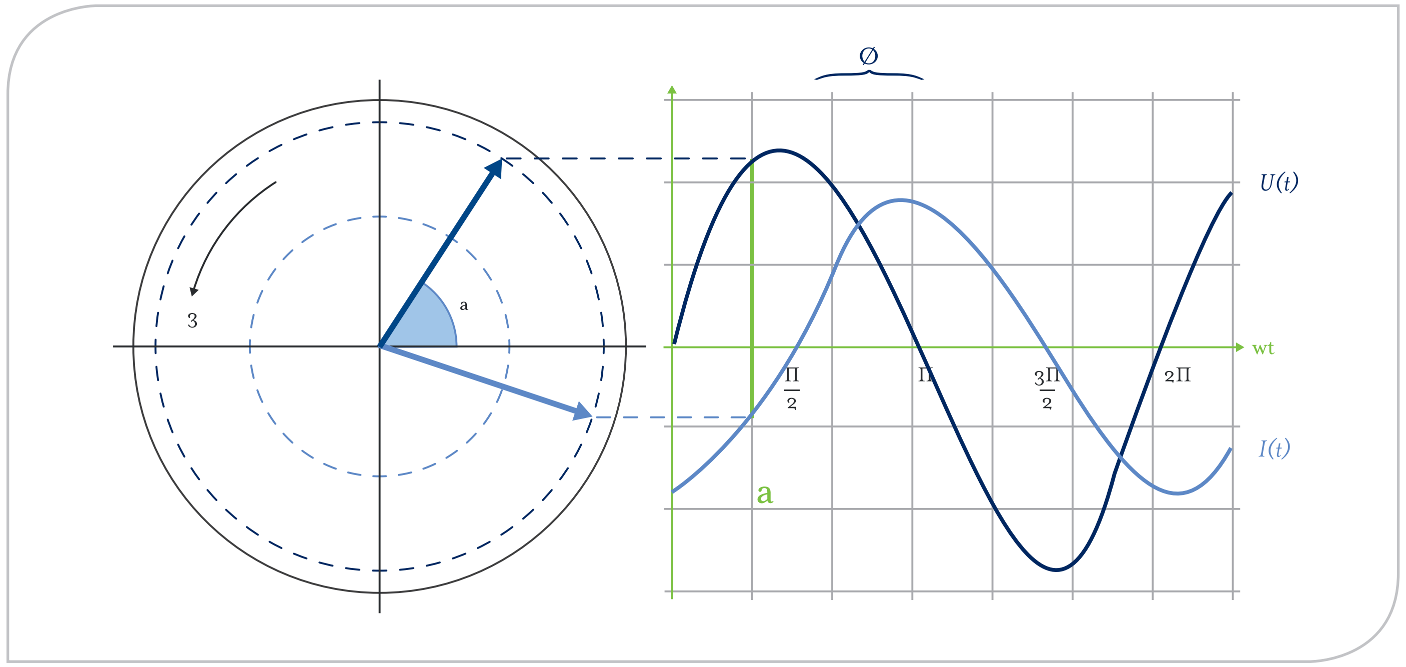
Safe and secure network operation

Sector-leading efficiency

Leadership in sustainability

Funded	Start/end date	Website
£68,200	September 2019 / September 2020	https://www.smarternetworks.org/project/nia_shet__0028

2.8 NIA_SHET_0029 Phasor Based Monitoring for HVDC



Key activities

The GB Electrical Transmission Network is expanding with an increase in the number of High Voltage Direct Current (HVDC) connection applications. This project aims to build upon learnings from the VISOR and MIGRATE projects and explores the possibility of a phasor wide area network monitoring and its application in controlling the incoming power from HVDC connections.

Expected outcomes

The project at a computer simulation level will explore if it is possible, and efficient, to control electrical energy output from an HVDC power source via phasor measurements at key locations across the Transmission Network.

Progress

A tender has been developed which identifies the tasks necessary to explore if it is possible to control the output of an HVDC connection via wider network electrical phasors measurements. If this is successful, then additional investigation will follow to compare today's standard HVDC control in comparison to one based upon phasor system measurements.

Innovation Focus Areas

Stakeholder-led strategy

Safe and secure network operation

Sector-leading efficiency

Leadership in sustainability

Funded	Start/end date	Website
£321,000	October 2019 / April 2021	https://www.smarternetworks.org/project/nia_shet_0029

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2.9 NIA_SHET_0030 Technical Assessment of Cable Management Approaches

Key activities
Testing of underground transmission cables follows well established traditional methods; however new testing technologies are emerging at distribution level. This project will investigate the modern cable testing technologies, along with the benefits and potential hurdles.

Expected outcomes
To learn and understand the new testing and diagnostic approaches for electricity cables operating at 132kV and above. A recommendation of the preferred testing methods, along with the creation of an implementation strategy for SHE Transmission.

Progress
Engagement from internal cable experts helped develop a scope of works, to identify the shape of the project. An external tendering process has led to a suitable supplier being identified to conduct the research.

Innovation Focus Areas

Stakeholder-led strategy

Safe and secure network operation

Sector-leading efficiency

Leadership in sustainability

Funded	Start/end date	Website
£59,800	December 2019 / December 2020	https://www.smarternetworks.org/project/nia_shet_0030

2.10 Collaboration Projects

This year SHE Transmission have collaborated with Scottish Power Transmission on their Transient Recovery Voltage Investigation project. The project was run in parallel with the Zero Missing Phenomenon project. The outcome of the Project included guidance information to help the Transmission Planning team identify and mitigate potential transient recovery solutions. For further information on the Transient Recovery Voltage investigation project please consult the Scottish Power Transmission progress reports.

3
Highlights of the year: Areas of Significant New Learning

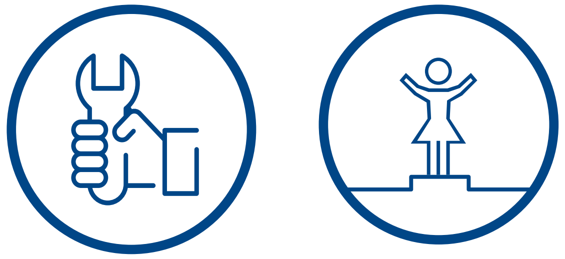
In this section, more details are provided on the Zero Missing Phenomena (ZMP) and Partial Discharge (PD) Monitoring projects. Both projects focus on opportunities within the Safe and Secure Network Operation and Sector Leading Efficiency innovation themes.

The ZMP project optimises network system design with an enhanced probabilistic planning tool and documentation for the industry highlighting transparency and robust decision making. The PD Monitoring project investigates smart asset management compared to condition based asset monitoring and also looks into ways to improve safety, health and wellbeing processes relating to substation electrical assets.

3.1 The importance of electrical system modelling

SHE Transmission Zero Missing Phenomenon (ZMP) project explores improvements in planning procedures which could be adopted by the whole industry, to help accommodate the Transmission Network as it expands to incorporate renewable forms of energy. The increase in renewables brings two main challenges:

- the reduction in traditional (fossil fuelled) power stations; and
- a corresponding decrease in reactive power resulting in an increase in the number of reactive power compensation equipment (e.g. shunt reactors).



The ZMP is defined as an AC current not crossing zero value (or line) for a certain duration (hence the name "zero missing"). This can occur during simultaneous energisation of inductive equipment (shunt reactor) and capacitive equipment (cable or harmonic filter) or under fault conditions. Under the occurrence of ZMP, there is a possibility of damage to the circuit breakers if they are required to open at a non-zero current value. ZMP constitutes a new challenge to network operators as there are defined fault clearing times set by our protection standards to meet the requirements of the system operator.

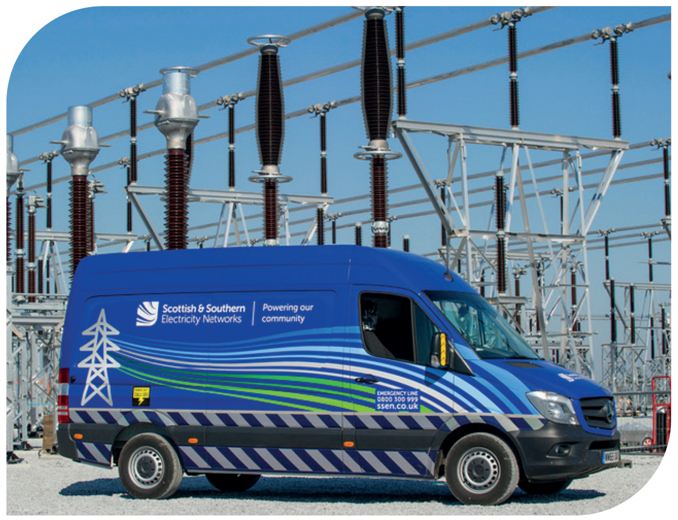


Figure 2 shows a normal circuit (with traditional loads) experiencing a fault.

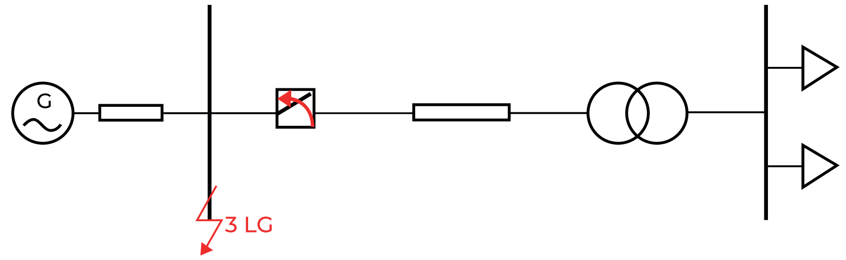


Figure 2: Simple circuit diagram showing a fault

Figure 3 shows what happens to the current flowing through the circuit breaker from the previous diagram. The "interruption" by the circuit breaker can safely occur any time that the current crosses zero amps.

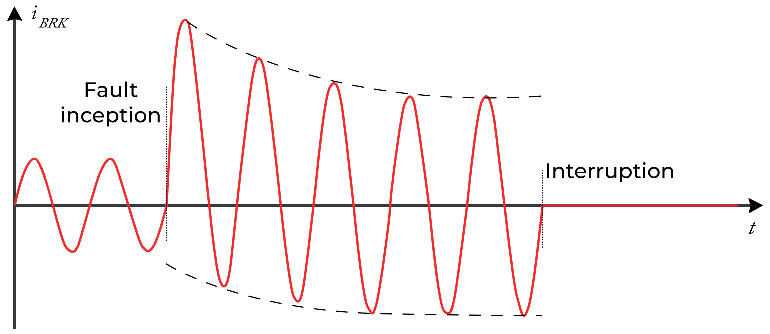


Figure 3: Graphical representation of current flowing as a result of the fault in Figure 2

Figure 4 shows a different circuit with a shunt reactor connected, to regulate reactive power due to a windfarm connection, under fault conditions.

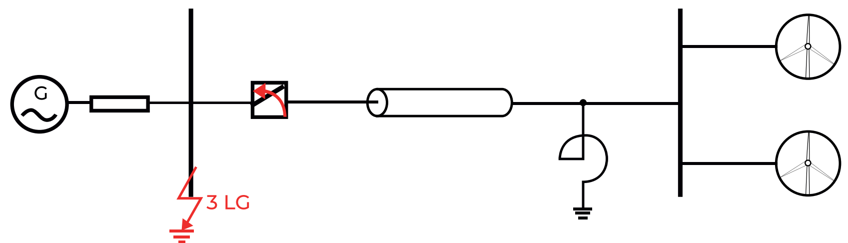


Figure 4: Circuit diagram with a shunt reactor and connected wind generation showing a fault

Figure 5 shows the current flowing through the circuit breaker in the figure above. This time after the fault occurs the decaying DC contribution from the shunt reactor offsets the AC current so that its oscillations do not cross zero for a length of time. This highlights where the main issue with ZMP lies, as it is unclear when it will be "safe" for a conventional AC circuit breaker to break the current and clear the fault.

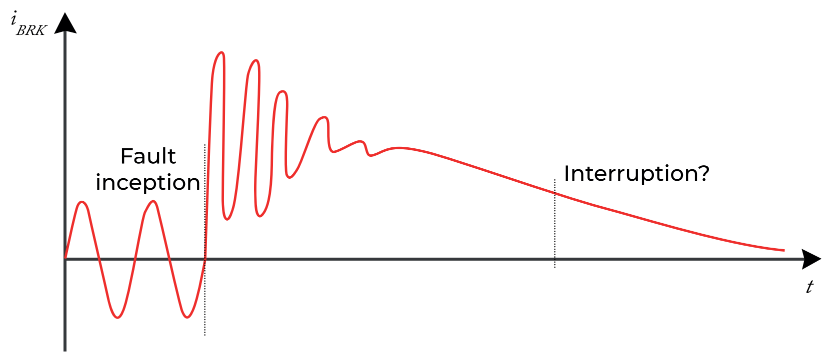


Figure 5: Graphical representation of current flowing as a result of fault in Figure 4

It is therefore necessary to understand the causes and severity of the ZMP problem. This was carried out via a combination of literature review and modelling analysis of the ZMP. It found that the following factors must be taken into consideration when assessing the risk of the occurrence of ZMP:

1. The background running arrangement of the critical network configuration, as under certain running arrangements some circuit breakers are at risk of experiencing energisation-related ZMP.
2. The service voltage of the substations/circuits within the network configuration.
3. The switching phase angle on the voltage-to-ground with switching at the instant when the voltage crosses zero causing the most onerous conditions for energisation-related ZMP. This was assumed always fixed at the most onerous level.
4. The construction type (air-core or iron-core/oil-filled) of the Shunt Reactor.
5. The rating of the Shunt Reactor.
6. The construction type of the transmission line (OHL/underground cable).
7. The technical characteristics of the transmission line (conductor size/type, circuit length).
8. The compensation level of the reactive power gain of the transmission circuit.

The investigations also highlighted a selection of countermeasures to manage ZMP, such as:

- Circuit-breakers with pre-inserted resistors;
- Point-on-wave controlled switching;
- Energisation in sequence;
- Variable shunt reactors; and
- Sequential switching.

The project has successfully analysed a number of standard network configurations that are susceptible to the Zero Missing Phenomenon, to help deduce suitable mitigation measures. The analysis was also used to determine the severity and effects of the ZMP. The learning from this project will be summarised in a technical guidance document to be used by Transmission Planners to assist during their system studies. This document will assist the GB Transmission business by providing a structured approach to address the ZMP problem that is becoming more prevalent as SHE Transmission transitions to low carbon.

3.2 Smart substation health and wellbeing asset management

Partial Discharge (PD) Monitoring is a method of measuring the electrical equipment's health and wellbeing as it can detect the breakdown of electrical insulation or electrical surface contacts that are loosening via weathering. Each source of electrical PD within a substation is very distinctive and as it is unique it means the source of the PD can be identified and traced.

The PD Monitoring project was established to investigate if it was possible to set up a continuous PD monitoring system within a substation which could subsequently generate PD notifications for prolonged and abnormal high levels of PD. Two different types of PD monitoring equipment were installed by HVPD and Elimpus, at two SHE Transmission Substations. The systems implemented quite different approaches to PD detection and monitoring, as follows:

- The HVPD system uses PD sensors which are physically attached to the electrical equipment. This means, the source of PD can be implicitly identified by the sensor. The PD events can be plotted against the AC current flow and an experienced person analysing the information can pinpoint the source of the PD.

HVPD partial discharge monitoring sensor

HVPD partial discharge monitoring sensor

- The Elimpus system uses an arrangement of RF antenna receivers distributed around the substation in order to pinpoint the source of PD. Based upon clever mathematics the likely location of the PD source recorded by each aerial is plotted and where the lines intersect this is the location of the source of PD.

Over the course of the project it was proven that both PD monitoring systems can be adapted successfully to monitor substation PD continuously.

In the first year of installation the base levels of PD were monitored. The conclusion from the first year was that the Elimpus system was more user friendly as access to a web-viewer was provided and it was easy to see which of the substation zones were experiencing normal and higher than normal PD events. The monitored information from HVDP was accumulated weekly and emailed across. This information showed the number of PD events that the equipment witnessed over the preceding seven days. Working with the PD data it was very clear to see that both forms of information were equally helpful, however they covered very different stages of investigation.

The Elimpus PD monitoring equipment was a great initial whole substation PD evaluation tool, as it could identify if the PD was being generated from the down leads of an overhead line circuit or on the bushing of a transformer. Within the Elimpus system it was also very easy to explore a spiked PD episode and the weather conditions at the time.

The HVPD monitoring equipment came into its own when more information was required on a specific piece of electrical equipment. The complex nature of the way the information was presented meant that it needed to be interpreted by a PD specialist.

In the years that followed, PD notification levels were set within the two different substation PD monitoring systems. PD trigger testing was conducted at both substation locations to see if and how the two different PD monitoring systems would respond to an unusual PD event.

Elimpus partial discharge monitoring aerial

Zone 2

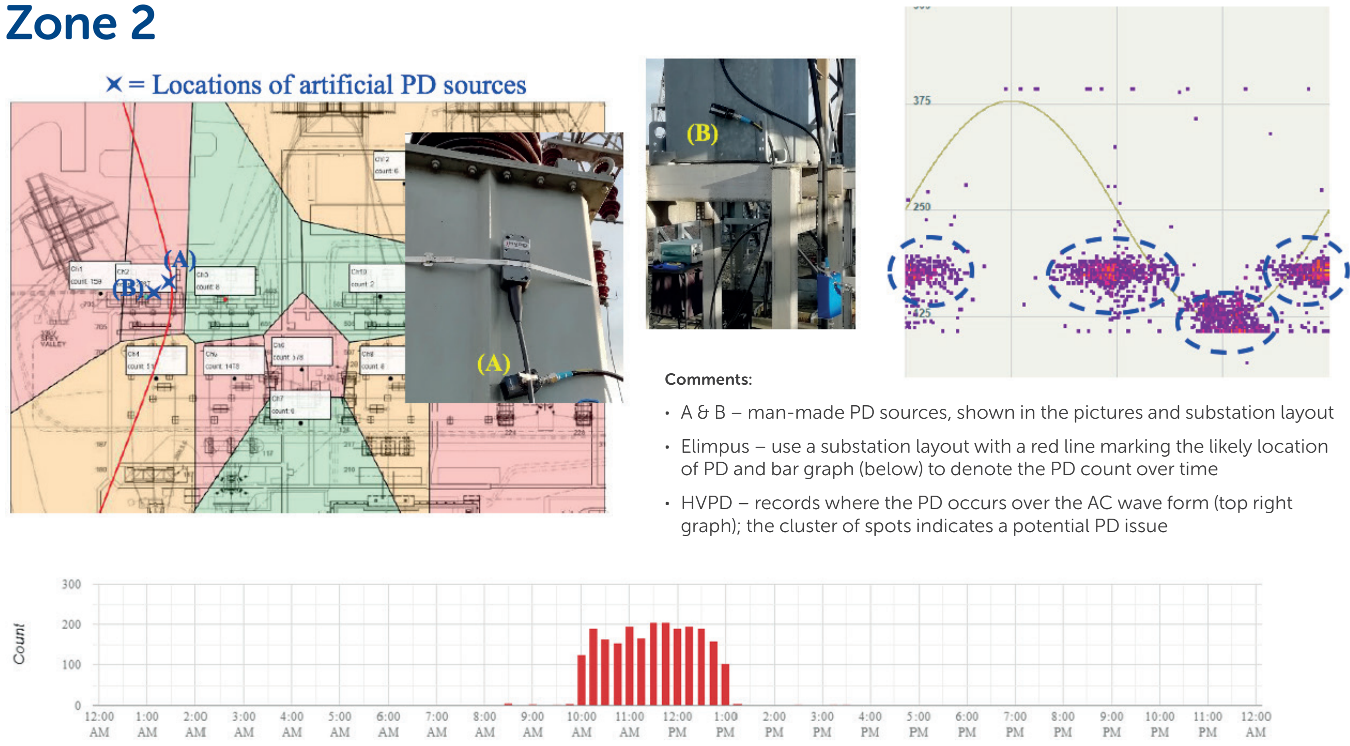


Figure 6: PD Monitoring Testing and Results

The pictures show where the two artificial sources of PD were placed. The coloured picture of the substation with the red line which crosses point A and the bar chart along the bottom is the information from the Elimpus substation. The graph to the top right is the PD information from HVPD due to the device D. Both Elimpus and HVDP provided reports on the unusual levels of PD and were correctly able to identify them as man-made.

This project has produced a significant amount of learning about monitoring PD; positively PD can be detected with a good level of accuracy. Knowledge has been gained on the infrastructure necessary to host the site equipment and the different ways of getting the information to a suitable location from which further analysis of notifications can be set. The learning from this project is helping to shape SHE Transmission's future innovations into condition-based substation asset monitoring and smart asset management.

4 Further information

The new SHE Transmission Innovation Strategy, published in December 2019 can be found at the link below:

2019 SHE Transmission Innovation Strategy

https://www.ssen-transmission.co.uk/media/3725/she-transmission-innovation-strategy.pdf

Further details of all the NIA projects summarised above can be accessed through the following link:

ENA Smarter Networks Portal – SSEN Projects

http://www.smarternetworks.org/project-results/1

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