Network Innovation Allowance

Summary Report

1 April 2017 to 31 March 2018

Scottish and Southern Electricity Networks

Scottish Hydro Electric Transmission

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 2017 and March 2018. 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 part of Scottish and Southern Electricity Networks (SSEN) which owns and operates the transmission network in the North of Scotland. The core value of SSEN is to provide the energy people need in a reliable and sustainable way. SHE Transmission views innovation as being central to achieving the foregoing core value. Innovation helps us to improve the management and performance of the transmission network, enabling us to provide energy in a safe, reliable, sustainable and economical way and ensuring that we deliver value to our customers.

As we continue to witness an enduring shift in the composition of our generation mix in Great Britain (GB), together with increased penetration of other low carbon technologies, our ability to maintain the integrity of our network infrastructure is consistently being tested. SHE Transmission continues to closely monitor ongoing developments and takes a dynamic approach to responding to the associated challenges. Since 2013, we have been guided by our Innovation Strategy developed as part of our RIIO-T1 submission and which was based on seven overarching objectives. We have recently published an updated Innovation Strategy which affirms our adaptability and commitment to value-driven innovation. In the document, published in March 2017, we have streamlined our innovation activities into five focus areas which reflect the most current sentiment of our stakeholders and our readiness to respond to the changing demands of future requirements.

As of 31 March 2018, we have a portfolio of six SHE Transmission-led NIA projects at various stages in their lifecycles and one led by our collaboration partners. Within our own project portfolio, each of the project addresses at least one of the seven objectives which are summarised in this report and covered in greater detail in our 2013 Innovation Strategy. Since April 2017, we have registered one NIA project which was the first one to address our updated Innovation Strategy. We deem our 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.

Stewart A Reid
Head of DSO and Innovation
Scottish and Southern Electricity Networks plc

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1 SHE Transmission Innovation Strategy

As part of the RIIO-T1 submission, seven objectives were identified and set out in SHE Transmission's Innovation Strategy document to highlight our priorities for innovation. Each of SHE Transmission's innovation projects until March 2017 was motivated by at least one of the seven objectives to try and address the needs and aspirations of our stakeholders who were pivotal in helping to identify the areas of focus. This has enabled us to meet our core purpose of providing the energy which people need in a reliable and sustainable way.

In the next section of this summary, there is coverage of an update to our Innovation Strategy which became effective in March 2017. Although the 2013 strategy is now superseded by the new one, the seven objectives mentioned here will continue to be addressed. In addition, due to the existence of projects that span across the implementation periods of the two strategies, it is likely that the contents of this strategy will continue to be published here for the foreseeable future. Below is an outline of each of the seven objectives that have shaped our innovation activities thus far:

1.1 Accelerate network development and connections including the integration of increasing amounts of renewable generation

Historically the priority of SHE Transmission has been to ensure that electricity supplies are available with minimal interruptions; to 'keep the lights on'. Over the years, we have supported innovative practices in this area to improve our overall performance.

In recent years, the challenges faced by our networks have significantly changed, driven by the UK's move towards a low carbon economy. Our transmission network is evolving from delivering energy from a small number of large generation sources to a large number of customers, to a more complex situation where it must accommodate bi-directional power flows created by an influx of new renewable generators, both large and small. Such demand for new connections is unprecedented. The transmission network, a large part of which was built 40-50 years ago, was not designed to accommodate the collection of energy from such geographically disparate source locations. The rate of increase in demand for such connections was not previously matched with innovative funding, disallowing us to meet the new challenges created by the needs of developers in innovative ways. This is an area which will benefit greatly from new innovation investment.

1.2 Minimise the cost of providing network capacity

Whilst it is clear we need to act swiftly and effectively to provide the capacity required by our customers, we must ensure that in meeting this demand we minimise the costs of the work required.

Our ultimate stakeholder is the GB electricity consumer; people who pay electricity bills have a legitimate interest in how they are made up. Given that transmission costs are a contributor to energy bills, it is important that we minimise the cost of building and running our transmission network. Our electricity connections customers and other stakeholders with an interest in the availability of grid capacity, have a direct interest in the costs associated with the development and operation of the transmission system. They wish to see costs minimised, but at the same time wish for the network to provide capacity quickly and easily to allow them to pursue their plans.

The need for SHE Transmission to ensure the costs are kept to a minimum is illustrated in quotations from two stakeholder organisations with a direct interest in the matter. These and other quotations from our stakeholders can be seen in SHE Transmission's 2013 Innovation Strategy which can be accessed by following the link at the end of this report.

1.3 Maximise the use of existing assets to deliver capacity and speedy connections

Widely favoured by our stakeholders, one of the most efficient ways to swiftly provide capacity for new renewable energy developments is to 'make the most of what we have' – to maximise the efficiency with which we use current assets. Transmission networks have capacity which is traditionally reserved to provide security of supply. This is known as system redundancy, an as yet largely untapped resource which could provide capacity for generation connections, reduce waiting times for connections and lower costs.

1.4 Maintain and improve safety and environmental performance

SHE Transmission's primary responsibility to its stakeholders – including employees, contractors and customers – is to ensure their safety. Safety is the number one value of our company where we pride ourselves on 'doing everything safely or not at all'.
In keeping with our commitment to sustainability, SHE Transmission's target every year is to achieve zero environmental incidents. These priorities are shared by our stakeholders who have expressed their desire for safety and sustainability to be identified as priorities in a number of ways.

1.5 Maintain and improve network performance

The past performance of our transmission network has been excellent. As the UK's energy infrastructure evolves to accommodate more widespread generation sources, we must adapt to ensure this high standard of performance is maintained. It is notable that customers appear to take this aspect of SHE Transmission's responsibilities as 'a given'. This is reflected in the infrequency that system reliability was mentioned as a priority by our stakeholders. In contrast, we strongly believe that in line with our company's core purpose of providing the energy people need in a reliable and sustainable way, this should remain a focal point for our future development. As such, maintaining and improving network performance is one of our innovation objectives.

1.6 Provide more accurate information on the short and long term asset condition information to allow more informed decision making

There is a desire amongst stakeholders that SHE Transmission makes the best possible use of existing assets. A key way of doing that is to ensure that assets are maintained and replaced at the right time – before they fail, but at a time when they have contributed as much as possible to the network. Currently our assets are replaced in line with a standard methodology agreed jointly with National Grid (NG), Scottish Power Transmission (SPT) and SHE Transmission. We believe that to meet our customers' needs we must make the most of existing infrastructure to maximise security of supply and minimise costs. We must gain a better understanding of how our assets age and fail, and put in place an asset replacement programme which best meets this. Similarly, innovations and techniques can allow the re-use of existing assets in new roles such as the use of insulated crossarms to allow existing towers to carry higher voltages.

1.7 Remain at the forefront of innovation to maintain our record of providing the highest standards of service at the lowest possible cost

New ideas, improvements to process and design, and innovation have been key to SHE Transmission's success to date and are fundamental to our ability to adapt to the challenges of the future. To deliver the changes and improvements our stakeholders desire, we must maintain a strong culture of innovation within SHE Transmission, by actively promoting and supporting new idea generation to provide the feedstock for tomorrow's innovations. We are building on our underlying innovative flair and will utilise the Network Innovation Allowance (NIA) to push the boundaries and accelerate the rate and effectiveness of innovation on the network.

2 Update to the SHE Transmission Innovation Strategy

As part of our ongoing review of evolving challenges and priorities, we have recently published our new Transmission Innovation Strategy for the next relevant years. The new strategy outlines our vision for a value driven innovation culture and confirms our intention to be able to respond to the changing demands of future requirements. Starting this year, projects' progress for projects started after March 2017 will be reported against the new strategy. A link to this new strategy is provided at the end of this report.

Our updated innovation strategy is driven, like all we do, by our corporate values: Safety, Service, Efficiency, Sustainability, Excellence and Teamwork. The foregoing values and our business drivers have led us to identify key themes and priority areas for innovations, as outlined below:

Asset health and Productivity (Service, Safety)
- A more complete and holistic understanding of the life cycle of our network assets
- Completing the implementation and exploitation of Condition-Based Risk Management and delivery of the benefits
- Cost-effective asset monitoring and accurate knowledge of the state of our assets
- New methods of asset health assessment
- Optimising the timing and nature of interventions

Network Reliability/Availability and Efficiency (Service, Efficiency)
- Network Performance according to operational targets and contractual obligations
- Voltage Control
- Reliability of supply, reduction of outages and faults, rapid and effective response to faults
- Maintaining high system availability and the optimum level of redundancy
- Interface with System Operator(s)

Commercial Innovations (Service, Excellence, Teamwork)
- Constraint Management
- Disintermediation, cyber security, blockchain transactions
- Big data analytics, machine learning and automation
- Service provision and supply chain evolution; identification of hidden costs
- Improved decision-making, procurement, standardisation, and policy
- Optimised planning, timing and sizing of load-related investments

Environmental and Safety Impact (Safety, Sustainability)
- Reduction/Elimination of SF6
- Health and safety performance improvement
- Impact reduction of site access
- Flood protection

Management of losses (Service, Efficiency)
- Understanding where losses occur
- Optimising loads for efficiency
- Asset security, protection, and countering metal theft

The foregoing priority areas will be dealt with mostly by devising and developing ways to address the associated challenges from the areas. Additionally, there will be some focus on trial and evaluation of solutions already developed by others, or the fast-follower adoption of ideas tested by our peer organisations. We will also scan the horizon for new possibilities, by working with our supply chain to find solutions to our immediate problems, and through calls for innovation via the Energy Innovation Centre (EIC) and the Energy Networks Association (ENA).

3 NIA Project Portfolio

In the year to 31st March 2018, 8 projects were funded under SHE Transmission's NIA. Of these 3 projects closed, and 1 new project was registered.

An important feature of SHE Transmission's NIA projects is that each satisfies at least one of our Innovation Strategy objectives.

Table 1 below shows all the registered NIA projects for the reporting year and how each maps onto our 2013 Innovation Strategy objectives.

Project Number	Project Name	Accelerate development and connections	Minimise new capacity costs	Maximise use of existing assets	Safety and Environment	Network Performance	Accurate Asset performance	Innovation leaders
NIA_SHET_0004	Dynamic Line Rating – CAT1	●	■	●	●	●	●	●
NIA_SHET_0011	Lightning Protection				■	●	●	●
NIA_SHET_0014	Partial Discharge Monitoring to Reduce Safety Criticality			■	●		●	●
NIA_SHET_0018	Transformer Intrascope Phase 2			●	●	●	■	●
NIA_SHET_0019	Automatic Thermovison Surveys (ACTS)					■	●	●
NIA_SHET_0020	Remote Asset INertial Monitoring & Alerting Network (RAINMAN)			●		●	■	●
NIA_SHET_0021	Composite Core (ACCC) Inspection	■		●		●	●	●

KEY: ● **Primary Objective** ■ **Relevant Objective**

Table 2 below shows all the registered NIA projects for the reporting year and how each maps onto our 2017 Innovation Strategy key focus areas.

Project Number	Project Name	Asset health and Productivity	Network Reliability/Availability and Efficiency	Commercial innovations	Environmental and Safety impact	Management of losses
NIA_SHET_0022	Transmission System Fault Level	■	●		●	

KEY: ● **Primary Objective** ■ **Relevant Objective**

4 Summary of Progress

4.1 Strategy Objective 1: Accelerate Network Development and Connections

4.1.1 NIA_SHET_0021 Composite Core (ACCC) Inspection

Start Date: December 2016

Duration: 24 months

Description:
This project is a technical method to develop a carbon fibre inspection prototype. This is the first stage in the eventual development of a tool that can be incorporated into on-conductor travelling devices for routine inspection of strung Aluminium Conductor Composite Core (ACCC) in commission. The ultimate aim of the project is to provide confidence to network licensees to adopt and leverage the potential benefits of using ACCC in the sustainable and cost-effective unlocking of much needed network capacity.

Expected Benefits:
A tool for validating the integrity of the ACCC composite core at commissioning and in service will provide the following benefits:

- There will be less likelihood of conductor failure in service due to preemptive intervention thereby ensuring reliable network performance
- It will enable wider adoption of ACCC and unlock the benefits offered by the conductor such as:
  - Quicker circuit capacity uprating without need for reinforcing weight bearing components
  - Potential capital expenditure (CAPEX) savings through reduced numbers of structures on new line designs
  - Potential life cycle cost savings through reduced losses in operation

Progress:
The first deliverable of this project has been completed. In the completed stage, a non-destructive testing (NDT) technique known as Laser Shearography has been identified as the most effective technique for detecting defects on the exposed ACCC composite core. The images below show some of the results from using the technique on a sample of composite core.

Figure 1. Wrapped and Unwrapped images of impact damaged core

4.2 Strategy Objective 2: Minimise New Capacity Costs

4.2.1 NIA_SHET_0004 Dynamic Line Rating CAT-1

Start Date: April 2009

Duration: 108 months

Description:
The project is aimed at evaluating an innovative system with potential to provide real time monitoring of overhead line networks. The method involves measuring the tension of the line system and then in conjunction with known line characteristics accurately calculating the remaining capacity in the circuit.

Expected Benefits:
- Securement of Transmission line outages, given increased confidence in current carrying ability of the adjacent circuits under normal load and fault conditions
- Facilitating the management of new generation connections onto the existing transmission network prior to the completion of more timely and necessary system reinforcements;
- Advanced warning of impending clearance violations through sag monitoring
- Matching of line ratings to load and weather conditions

Progress:
The project is now complete. CAT-1 field units were successfully installed with the real-time field data viewable on the SHE Transmission SCADA system. Onward analysis of the raw data evidenced capacity availability on the trial line. Additional investigation of the data has opened further investigation avenues into alternative line parameters that could be measured more cheaply as well as seven-day forecasting tools. The image below is a screenshot of the user interface showing how the data from the field sensors is presented on the SHE Transmission SCADA system.

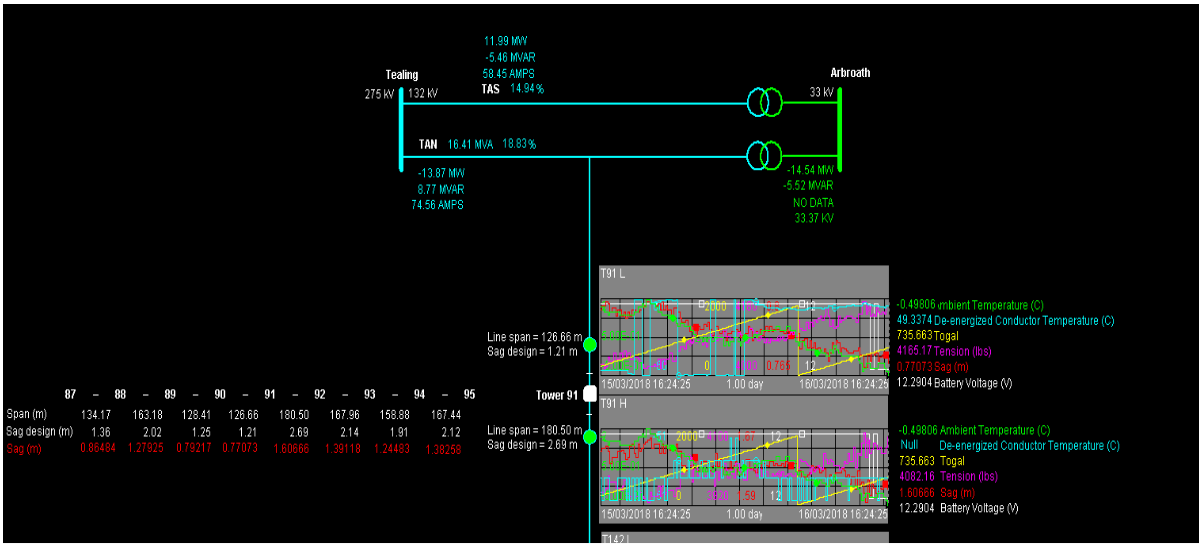

Figure 2. Information viewable on SSEN Transmission SCADA system

4.3 Strategy Objective 3: Maximise Use of Existing Assets

4.3.1 NIA_SHET_0014 Partial Discharge Monitoring to Reduce Safety Criticality

Start Date: January 2015

Duration: 45 months

Description:
The scope of this project is to install online trial Partial Discharge (PD) monitoring systems incorporating alternative technologies and suppliers at selected sites and integrate with SHE Transmission's SCADA system in order to collect, store and analyse output PD event data to establish if this can be used to improve the management of safety critical plant. Learning from this project will also be used for further work to incorporate PD failure precursors into control and protection schemes.

Expected Benefits:
The most significant benefit from this project is safety. If equipment is isolated from the network prior to disruptive failure, then the risk to safety will be minimised. Furthermore, where assets have been earmarked for replacement as a result of them being identified as having high safety criticality, deferring their replacement through the continuous monitoring method proposed in this project will have a financial benefit.

Progress:
So far, installation and commissioning of two independent PD monitoring systems has been completed at three nominated sites. The last and most recent installation faced some delays because of access issues due to system security requirements. This has led to a change to

Scottish & Southern Electricity Networks extend project duration to enable completion of Supervisory Control and Data Acquisition (SCADA) integration.

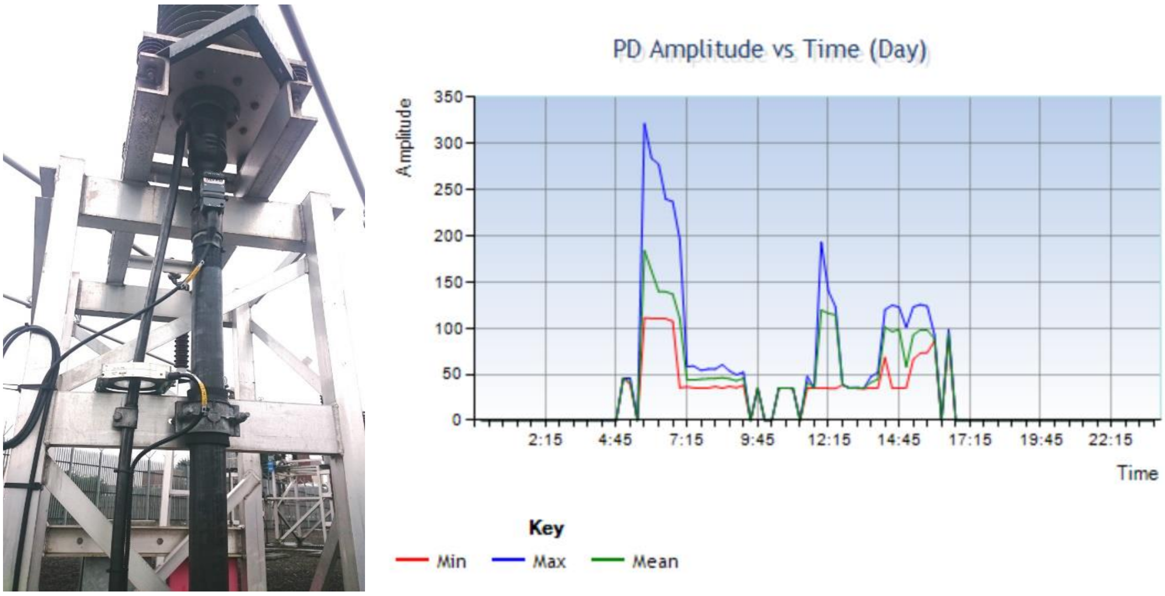

Figure 3. Cable sealing end with Transient Earth Voltage (TEV) and High Frequency Current Transformer (HFCT), the graph shows monitored PD events

4.4 Strategy Objective 5: Improve Network Performance

4.4.1 NIA_SHET_0011 Lightning Protection

Start Date: December 2013

Duration: 36 months

Description:
This project involves building and verifying simulation models of lightning strikes on lines at 132kV and above with towers that have high footing resistances. This will enable investigation of protection options which will inform decisions on lightning protection approaches.

Expected Benefits:
This project's aim is to optimise the design of lightning protection for towers with high footing resistance in order to reduce costs. At the moment, the choices are limited and the process is largely based on trial and error until the resistance is acceptable. This project, if successful, might avail alternative options and the ability of informed decision making. It is therefore envisaged that savings of up to £30k may be made per tower with high footing resistance.

Progress:

The project is now complete. The PhD thesis produced as part of the project has been reviewed in SHE Transmission. As a result, a technical guidance note for lightning protection management has been drafted based on the recommendations from the thesis. The note is under review from engineering policy and once it's approved, it is expected that the future design of new Transmission overhead line circuits will use the learning from this project.

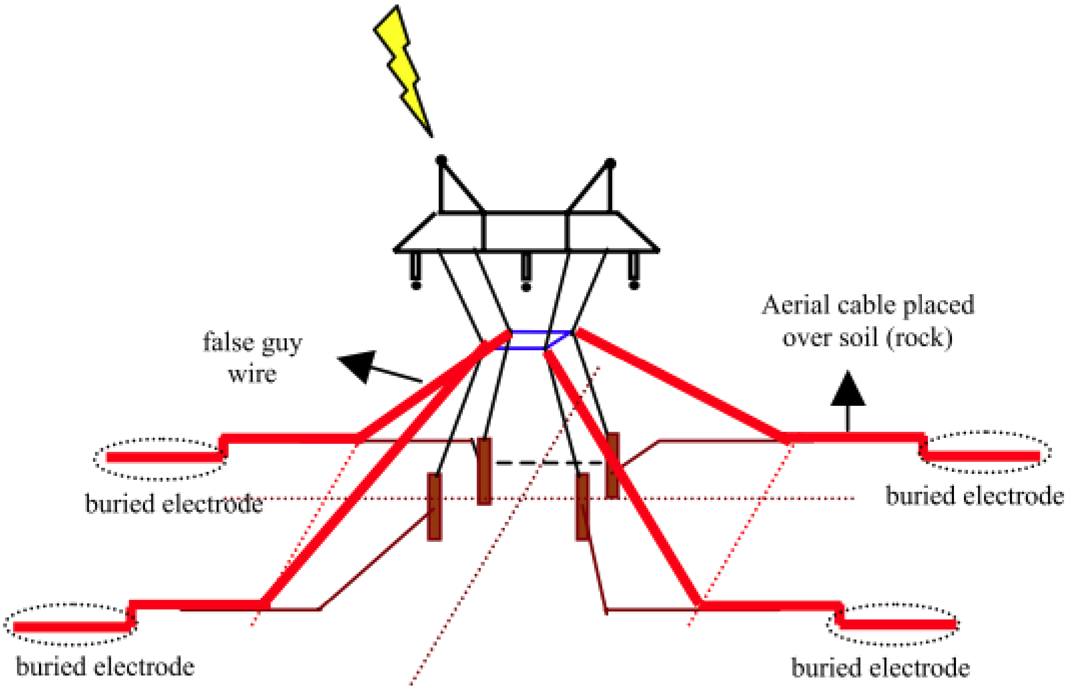

Figure 4. Illustration of one of the lightning performance improvement measures

Source: Heriot Watt University, PhD research project report

4.5 Strategy Objective 6: Accurate Asset Information

4.5.1 NIA_SHET_0018 Transformer Intrascope Phase 2

Start Date: December 2015

Duration: 37 months

Description:
The transformer intrascope system has been developed in phase 1 of this project as an asset management tool to assist with the condition assessment of internal paper winding insulation within electrical power transformers. It is in the form of a controllable probe which can be inserted through the hatch of a defective transformer to analyse the chemical composition of the Kraft paper insulation to assess the health of the asset in situ.

This project seeks to improve upon and overcome the limitations of the phase 1 design to allow for better access, physical range, positional control and visual imaging capability, whilst accepting any improvements that can also be made to spectroscopic measurements. The scope of the project is to have a fully refined, assembled and functional intrascope probe system which has been both mechanically and functionally proven within a laboratory-based environment and via field trials.

Expected Benefits:

- Correlation with and increased confidence in using existing methods such as dissolved gas analysis of insulation oil for condition assessment of power transformers;
- Maximising the operation of existing transformer assets by delaying expensive asset replacement;
- Collection and storage of retrievable, reliable and potentially improved condition information of our existing fleet of transformer assets;
- The system can be used as a lower cost tool for investigation of commissioned, faulted and decommissioned out-of-service transformer assets compared with conventional off-site transformer de-tanking;
- Increased confidence in the condition of transformer assets connected to the network.

Progress:
The project has made progress with an imaging system having been manufactured and modified to address deployment issues identified after a stage review by SHE Transmission. The next phase of the project will be to perform field trials on some real transformers. Sourcing real transformers for the trial inspection has been challenging thereby necessitating further extension of the project duration.

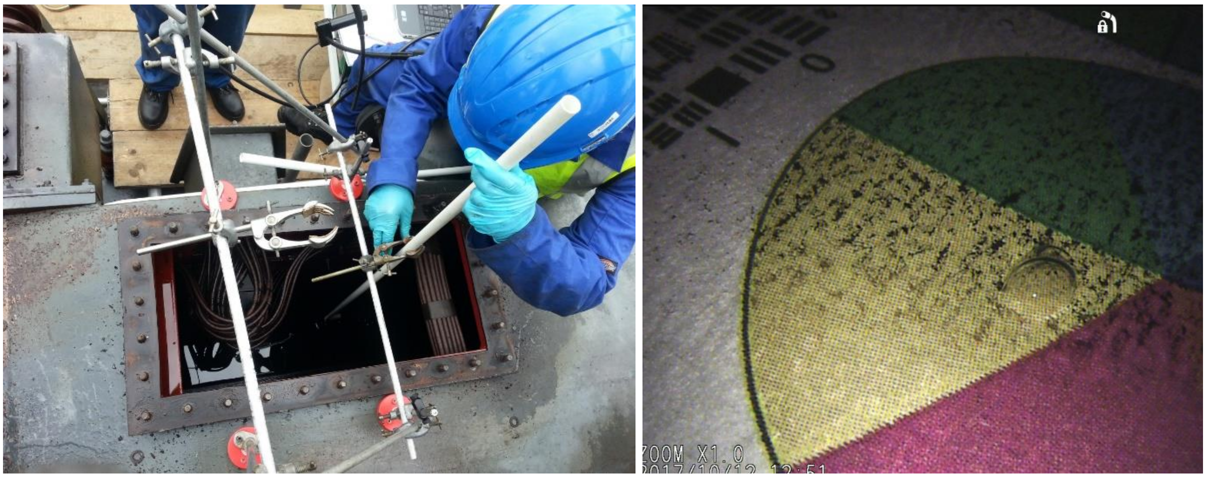

Figure 5. Accessing transformer windings with Phase 1 intrascope prototype and intrascope resolution 600dpi printed object submersed in oil depth 10m

4.5.2 NIA_SHET_0019 Automatic Thermovision Surveys (ACTS)

Start Date: April 2016

Duration: 15 months

Description:

The project is trialling a fully automated live thermal imaging system at a supergrid substation. The aim of the project is to develop a continuous monitoring system for temperature hot spots in the substation which would raise alerts centrally to enable timely intervention prior to permanent failure.

Expected Benefits:
This project’s method will be able to identify developing faults on equipment such as Static Var Compensators (SVCs) which are inaccessible during routine thermovision surveys performed using hand-held cameras. If unplanned outage is avoided through proactive management of developing faults, better reliability of the network will be realised.

Progress:
The project has been completed. Current outcomes of the project show that the system can monitor and alert with regards to larger items within the substation. However, the resolution appears to be too low for accurate measurement of smaller areas of SVCs.

Figure 7. Installed thermal imaging system with representative image

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

Start Date: July 2016

Duration: 44 months

Description:
This project is trialling a new alert system to establish if timely, reliable and accurate warnings can be provided for sudden and small incremental movements of wooden poles. The project also aims to demonstrate the viability of low power wide area wireless communications for hostile, hard to reach areas. In addition, a resilient autonomous power source will be developed to provide lasting power for the sensors installed on the poles.

Expected Benefits:
This project has the potential to address the challenges associated with pin-pointing deteriorating poles and also significantly off-centre poles following a storm, in hard to access locations. The 132kV Trident line which runs across Skye was chosen to trial RAINMAN as it is very representative of the rural and mountainous terrain of the SSEN network. Being able to monitor the poles for signs of flexing and lean distortion will help focus mitigation measures therefore preventing permanent failure. In addition, where sudden pole movement is detected and needs immediate intervention, response teams will be able to quickly identify which poles are affected and get to them quickly, rather than relying on walking foot patrols to identify problem poles. There is potential to significantly reduce the time associated with pole damage faults which cause circuit outages.

Progress:
The project has made progress during 2017/18 with the successful deployment of 809 pole mounted units covering 70km of the Skye 132kV Trident Line. Hourly status reports and unusual movement notifications are being received from 75% of the installed units. Work is underway to increase the number of units reporting and also assess the suitability of Low power wide area wireless communications.

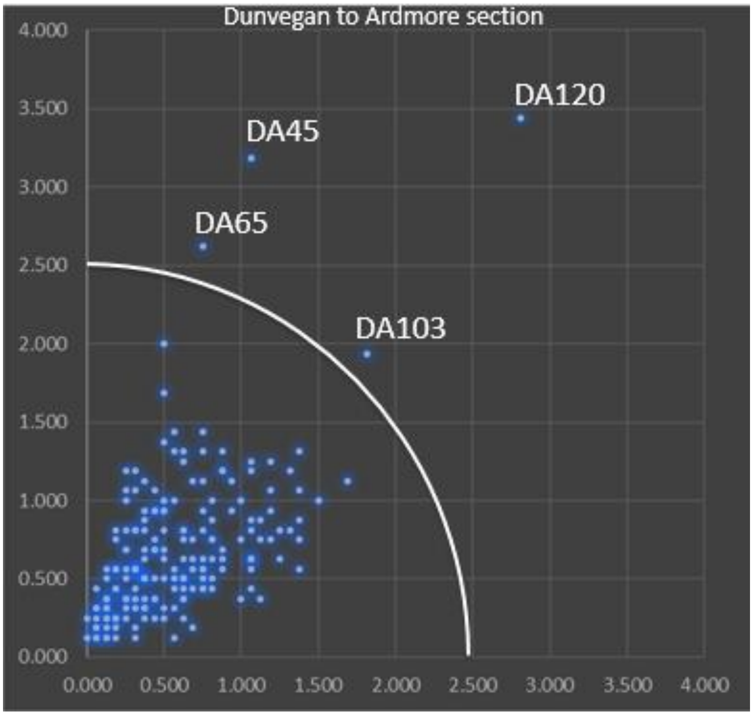

Figure 9. Pole mounted device installation and plot of degree of Roll (Y-axis) and degree of Pitch (X-axis), highlighting poles outside normal scale (DA45, DA65, DA103 and DA120)

4.6 Strategy Objective 7: Remain at the Forefront of Innovation

This is an overarching objective which motivates all SHE Transmission NIA projects. Improvements are constantly being sought to ensure that value can be delivered to our customers. The projects summarised in this document reflect the culture of innovation in SHE Transmission and SSEN as a whole. Our focus on innovation complements our work in research and development, where new processes, services, products and technologies are created, which will enable us to remain a successful company in the future.

SHE Transmission collaborates with peers and captures knowledge with the potential to deliver value. In the last year, a project led by Scottish Power Transmission and for which SHE Transmission was a collaboration partner, closed with some significant learning. The project, 'Trialling of Long-Lasting Tower Paints', produced useful learning some of which was around the processes of providing coatings on towers. This learning has been presented to SHE Transmission asset management personnel who will now take the learning into account on a case by case basis.

4.7 Network Reliability/Availability and Efficiency (Service, Efficiency)

4.7.1 NIA_SHET_0022 Transmission System Fault Level Monitoring

Start Date: June 2017

Duration: 24 months

Description:

This project will explore passive fault level monitoring via comparing actual transmission fault current calculations and observed fault current values.

Expected Benefits:

With the natural developments of the electricity network, initial investigation suggests that the amplitude of fault current will reduce, however our present protection instrumentation which trips the electricity supply is set to respond to a sudden high spike in current. Monitoring the network for intermediary rises in current will help determine as to whether the amplitude of fault current is reducing and if so will provide data to help formulate mitigation measures.

Progress:

Specially designed power quality monitoring equipment has been successfully installed. Evaluation of the data collected positively identifies infrequent low level current raises, however there are consistency concerns associated with the power quality monitoring and therefore the equipment requires further development. Work is underway to better understand the power quality monitoring equipment with its placement at Peterhead where system parameters are well known.

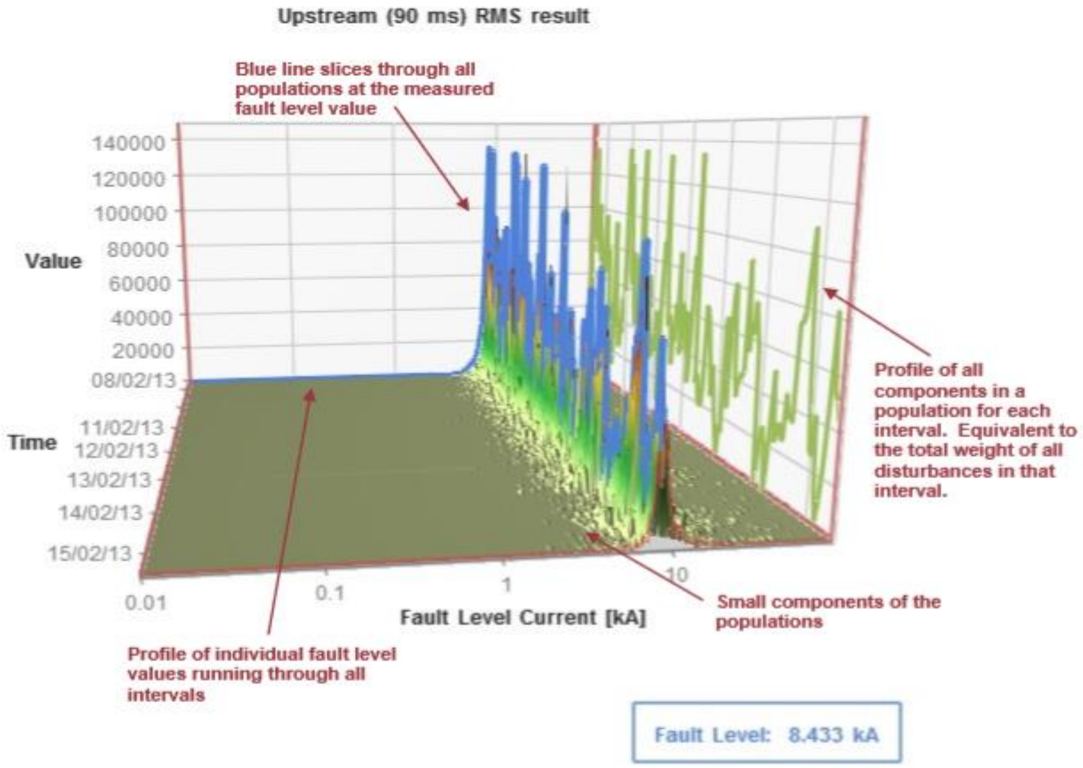

Figure 6. Representation of data from the power quality monitoring equipment

5 Highlights of the year: Areas of Significant New Learning

SHE Transmission has closed three NIA projects in the last reporting year. Two of these projects have produced significant learning. It is expected that the learning from one of the projects will go into full deployment once internal policy approval has been granted. The section below looks at the two projects in greater detail.

5.1 Assessing the possibilities unlocked by what the data said

At the end of March 2018, the Dynamic Line Rating – CAT 1 project was concluded. A dynamic rating system avoids reliance on conservative static ratings based on worst case scenarios.

Instead, increased power flows can be allowed to capitalise on conducive environmental conditions monitored in real time. The major constraint with increasing power flows on power circuits is the increased conductor expansion due to the heating effect of current flowing in a resistive path. The sag resulting from the conductor expansion leads to concerns about infringing the safety clearances stipulated under the Electricity Safety, Quality and Continuity Regulations (ESQCR). As such, on a basic level, this project intended to demonstrate the espoused benefits of increasing network capacity through the tracking of changing circuit conditions and correlating it with the ground clearance levels. The project successfully demonstrated a means of viewing real-time field data on the sag of the conductor on the trial circuit and analysis of the data provided evidence of potential spare capacity. Overall, the tension information from the CAT-1 device has provided greater insight into how both the environmental conditions and the current circuit loading influence the ground clearance levels of the conductor.

To a large extent, the conclusions above were anticipated at the start of the project. What the data revealed, however, from the field sensors may have unlocked significant unexpected learning with the potential for far reaching possibilities. Analysis of the field information highlighted that the radiant temperature sensor tracked the tension measurements, with a high level of accuracy. The radiant sensor is placed directly under and oriented in the direction of the conductor. Due to its placement, the radiant sensor absorbs a portion of heat from the conductor and if wind passes by it is cooled in a similar manner to the conductor. Data analysis showed that the radiant sensor readings had a direct and consistent correlation with the tension device readings. On the basis of this finding, it can be reasonably concluded that the radiant sensor alone could potentially provide the required level of confidence in deploying a dynamic line rating system. The significance of the learning lies in the potential cost savings from installing a sensor that is less intrusive and can be more quickly installed without need for circuit outage, where circumstances allow. In addition, there could be unlimited technical possibilities in the field of monitoring in general if the radiant sensor capabilities observed in this project can be proven beyond reasonable doubt. It is deemed that further investigation of radiant sensors is warranted and there may be scope for a future project to ascertain the extent of potential applications of the technology.

5.2 Firmly on a path to tackling the cost of lightning protection

One of the projects that have just completed within this reporting year is 'Lightning Protection'. The project was motivated by the challenges of providing effective lightning protection on lines with high tower footing resistance, as is usually the case where soil resistivity is high due to dry and rocky ground. A transmission line's earthing system needs to be designed to sufficiently disperse lightning stroke currents into the ground to limit voltage stresses across line insulation which result in back-flashover. Where mitigation is necessary to lower the tower footing resistance, the associated costs of the available options can be very significant. The mitigation options that have been considered for this project include surge arrestors, double shield wire, counterpoise and underbuilt wire. This project therefore intended to gain a deeper understanding of the behaviour of transmission lines under lightning strike conditions, determine new alternative techniques of lightning protection and create recommendations to inform further development of SHE Transmission's lightning protection policy based on its 400kV tower design and lightning data from Scotland.

After three years of study, a full PhD thesis has been produced with recommendations on ways of providing lightning protection. The major learning point produced is that the general requirement for a tower footing resistance target of 10 ohms or the goal to reduce the resistance as far as possible may be too conservative if it disregards the actual lightning activity and associated phenomena in the soil of the system under consideration. Investigations from the project have shown that where there is a back-flashover rate of 0.1 flashes per 100km per year, which is the case based on lightning activity of the studied area in Scotland, a target tower resistance of 50 ohms should be acceptable as it still provides appropriate lightning protection for the transmission line. Depending on the size of a line project, if design authorities take the foregoing recommendations into account for their specific project's circumstances, there could be significant savings from the initial capital outlay. To make use of this learning, SHE Transmission has been reviewing a draft technical guidance note based on the project outputs as part of the policy approval process. If approval is obtained, the learning outputs from this project are expected to be rolled out into business as usual.

5.3 Looking out for quick wins and learning from others

Other than the closed projects stated in the last section, any useful learning that is gained from projects in flight will be recommended for use in business as usual. This is the approach that is taken even for projects in flight. Any lessons gained from our current portfolio of projects so far or between now and the 2018 LCNI conference will strongly feature in the conference presentations to ensure that all GB network licensees can make informed choices about exploiting the learning for their own networks. We will also continue to use our engagement with our peer organisations to learn from their experiences and to fast-follow whenever we can see the potential to deliver value for customers.

6 Further Information

The complete SHE Transmission Innovation Strategy can be found on the link below:

2013 Transmission Innovation Strategy

The new SHE Transmission Innovation Strategy, published in March 2017 can be found on the link below:

2017 Transmission Innovation Strategy

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

ENA Smarter Networks Portal - SSEN Projects

7 Contact Details

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