SP ENERGY NETWORKS

TRANSMISSION

NIA Annual Report

2019 – 2020

Enquiry please contact

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Foreword

SP Energy Networks is committed to delivering the Transmission Grid of the future through our licensed business SP Transmission.

This is our seventh Network Innovation Allowance (NIA) Annual Transmission Report and is an overview of on-going Transmission related projects being undertaken, and those initiated, during the regulatory year 2019/2020.

The various outcomes from our NIA and Network Innovation Competition (NIC) projects have informed our RIIO – T2 business investment plan for 2021 to 2026, which can be viewed at:

https://www.spenergynetworks.co.uk/pages/our_riio_t2_business_plan.aspx

SP Transmission's Innovation Strategy drives the direction and development of all innovation projects and initiatives. It was released in 2011 as part of the RIIO-T1 Business Plan submission, and has provided the consistent, coherent and coordinated platform upon which all SP Transmission T1 innovation has been founded. This strategy has been reviewed annually, remaining robust despite the accelerating transformation of the energy landscape. It received an update by exception in 2014, and in 2018 work began on the further development of this strategy to align with RIIO-T2 aspirations. The reporting year saw extensive engagement with all key stakeholder groups, and the resulting feedback significantly influenced the final Transmission Innovation Strategy, which was released in December 2019, for further details please see Annex 6: Innovation Strategy in our RIIO-T2 Business Plan.

The new Transmission Innovation strategy represents a step-change in ambition and approach commensurate with the significant challenges and opportunities that RIIO-T2 represents.

In addition, SP Energy Networks has been actively working with the ENA and contributed to the collective innovation strategy for the GB energy sector which can be viewed at:

https://www.spenergynetworks.co.uk/userfiles/file/Electricity_Network_Innovation_Strategy.pdf

We are looking to ensure that our existing and new projects can contribute directly to the five focus areas in the near-term:

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

Our NIA projects continue to play a key role informing the development and delivery of our NIC projects. Innovation impact can only be maximised if we adopt an open and collaborative approach. SP Transmission has demonstrated strong commitment in Wide Area Monitoring, Protection and Control. During the 2019/20 regulatory period, SP Transmission was planning to trial the innovation learnings from the European H2020 projects, such as Regional Effective Inertia measurements and control. Following consultation with the UK electricity licensees, SP Transmission will consequently carry out further simulation and market due diligence under the NIA to prepare a demonstration project.

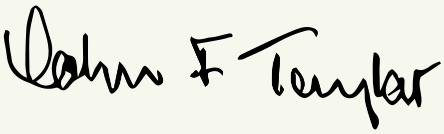
During the reporting year our focus has continued to be on the successful delivery of our existing NIC projects and on associated stakeholder engagement, knowledge sharing for the wider benefit of the industry and the transition of these projects into business as usual to realise their value for the benefit of our customers and communities.

In 2019 we launched our Year of Innovation, and we continue to build on this success in 2020 to ensure that we continue to focus on our people, who are crucial to the development and delivery of any innovation. We have seen success already by strengthening our culture of innovation and have seen people more actively engaged in innovation across the business.

We have successfully built a champion network with over 100 of our employees who make innovation real at a local level and engage their teams to pull out ideas of how we can do things differently. In addition, we have led a series of high-profile campaigns to tackle some of our most prevailing challenges.

In support of our innovation ambitions, SP Energy Networks welcomes third parties to submit innovative ideas for potential NIA and NIC projects.

Colin Taylor
Director
Processes and Technology



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Executive Summary

Our seventh Network Innovation Allowance (NIA) Annual Transmission Report has been compiled in accordance with Ofgem's Electricity Network Innovation Allowance Governance Document which sets out the regulation, governance and administration of the Electricity NIA.

This seventh NIA Annual Statement presents an overview of the projects we have initialised during the regulatory year 2019/2020 and an update on those projects reported during 2018/2019 which are still active.

The progress of each project aligns with the following key objectives:

- Innovation meeting the needs of stakeholders;
- Innovation opportunities are identified in a timely manner, which will benefit these stakeholders;
- Innovation is managed in an efficient and proactive manner;
- A balanced portfolio of innovation is pursed which includes commercial, process and technology innovation; and
- The outcome of innovation activity is adopted by the wider business to ensure that customers benefit at the earliest opportunity whilst minimising the risk to the integrity of the network.

Our NIA innovation project portfolio will continue to be shaped by on-going stakeholder engagement, both internal and external, with a view to maintaining a balanced portfolio that will address not just the near/medium term transmission issues, during the current price control period (RIIO-T1), but also those anticipated beyond 2021.

In addition to funding smaller projects, we will continue to utilise NIA Transmission funding, where appropriate, to prepare for future Network Innovation Competition (NIC) submissions.

In addition, we will aim to maximise knowledge transfer with other licensees and facilitate useful outcomes into Business as Usual at the earliest opportunity.


ELECTRICITY

1 | Introduction

SP Transmission has obligations to meet the Special Condition 3H (The Network Innovation Allowance) of the Electricity Transmission Licence, which was introduced as one of the key innovation proposals for the RIIO-T1 (Revenue = Incentives + Innovation + Outputs, 2013-2021) model for price control. The purpose of the NIA is to encourage Network Licensees to innovate to address issues associated with the development of their networks.

NIA is to provide a consistent level of funding to Network Licensees to allow them to carry out smaller innovative projects which meet the criteria set out in the NIA Governance Document.

From that point of view, NIA plays an important and integrated role in uplifting the technology readiness levels (TRL), preparing for flagship demonstrations at national level and knowledge sharing.

It is acknowledged that the transmission network will experience unprecedented change in response to realising the low carbon ambitions for the UK. In order to meet the associated challenges innovative techniques, technologies and processes will be required to develop the transmission network. This is recognised by the fact that Innovation is a key element of the RIIO - T1 model for price controls with the introduction of the NIA.

This report presents SP Transmission's NIA activities during the seventh year of its introduction, summarises progress made against objectives and highlights areas of significant new learning.

Developments in our transmission network over recent years have fundamentally been driven by an ongoing process of stakeholder engagement. SP Transmission has identified a number of key themes as a result of our ongoing stakeholder engagement which are the principal drivers behind our innovation strategy.

Following a comprehensive stakeholder mapping activity, which formed part of our Transmission Innovation Strategy published in 2011 (and subsequently reviewed in 2014) the key outputs from subsequent stakeholder engagement to date have been:

- Communicating with stakeholders to understand their needs and expectations more effectively;
- The connection of customers (demand and generation) onto the network to deliver sustainable low carbon energy through fair, clear and accessibleprocesses;
- Maintain security of supplies and maximise long term value for end-users through improved network availability and reliability processes; and
- Minimise the environmental impact of our operations.

In 2018 work began on the further development of this strategy to align with RIIO-T2 aspirations. The reporting year saw extensive engagement with all key stakeholder groups, and the resulting feedback significantly influenced the final Transmission Innovation Strategy, which was released in December 2019, for further details please see Annex 6: Innovation Strategy in our RIIO-T2 Business Plan.

https://www.spenergynetworks.co.uk/pages/our_riio_t2_business_plan.aspx

The new Transmission Innovation strategy represents a step-change in ambition and approach commensurate with the significant challenges and opportunities that RIIO-T2 represents.

SP Transmission recognise that consideration needs to be given to not only the RIIO-T1 period and stakeholder's immediate needs, but also how we address the longer term issues which the transmission network may face. This is being addressed through a balanced portfolio of innovation projects where we are considering some of the longer term issues which may involve technology and techniques at a lower technology readiness level as well as immediate challenges to be faced over the next decade. This is considered in detail in our Transmission Innovation Strategy.

2 | Progress Summary

During the reporting year 1st April 19 to 31st March 20 SP Transmission registered the following NIA projects:

- NIA SPEN 0035 Transient Recovery Voltage Investigation
  www.smarternetworks.org/project/nia_spen_0035
- NIA SPEN 0044 400kV Dynamic Cable Rating Retrofit Project Utilising RPMA Communications Technology
  www.smarternetworks.org/project/niaspen0044

The following sections provide a short overview of each active NIA project and summarises the progress that SP Transmission has made on them. Further details on SP Energy Networks Innovation activities can be found on our website (www.spenergynetworks.co.uk/pages/innovation.asp) and on the ENA Learning Portal (www.smarternetworks.org). Key learning associated with these projects is summarised in **Section 4**.

2.1 | NIA 1504 Managing Uncertainty in Future Load Related Investment

Uncertainty in relation to future demand and wind and PV generation output is already becoming a matter of concern in electricity network planning. Expected uptake of heat pumps, electric vehicles and other low-carbon technologies (LCT) will further increase uncertainty.

This project will develop and demonstrate (in prototype form) methods to use simulation techniques to examine a large range of 'scenarios' of future demand and generation development and output. This will be done by sampling from suitable statistical models of these and other external factors such as time-of-day and weather. The sampling approach will be designed to give a coherent picture of future network use, considering both traditional load and generation, and the uptake and behaviour of new technologies. The resulting scenarios will then be simulated and analysed individually to evaluate network performance metrics such as of power flows, constraint violations and reliability statistics. This large-scale sampling and analysis approach will result in a statistically representative database of network operating states and external conditions.

Methods to statistically interpret and interrogate this database will then be developed to identify the nature, location and factors underlying the most likely constraint violations and performance degradations, and to identify priority locations and trigger points (in terms of load growth, LCT uptake, etc.) for the deployment of interventions to solve anticipated problems.

The project analysis will focus on one grid supply point in the ScottishPower Transmission area.

2.1.1 | NIA SPT 1504 Project Progress

The project is now in its final reporting stage, with technical work being complete. A prototype modelling, simulation and analysis environment has been developed which allows the adequacy of distribution networks, and also transmission networks at the transmission/distribution boundary, to be evaluated under uncertain future conditions in terms of the day-to-day behaviour, low-carbon technologies such as renewable generation, and also the level of deployment of such resources at different scales.

This evaluation therefore involves consideration of both long-term and short-term uncertainty. Long-term uncertainty is represented by describing scenarios of uptake and deployment of technologies of interest within the network to be studied. Multiple scenarios can be considered, representing both different development and deployment paths, and different points in time along those paths. The modelling environment manages the application of these scenarios to underlying mathematical models.

Short-term uncertainty is represented through the use of statistical models to describe the behaviour of energy sources and consumers, including renewable generation and novel loads. These models are programmatically sampled in line with each long-term scenario to create a large number of snapshots of the hour-to-hour behaviour of network users, which may be focused on particular times of concern, such as winter evenings (for load constrained cases) or summer daytime (for cases with significant PV uptake). These long-term and short-term scenarios and snapshots are combined, simulated using an underlying network model, and results collated and summarized to assess the adequacy or otherwise of the network, and to characterize the conditions under which any inadequacy is experienced. The overall approach is shown in Figure 1:

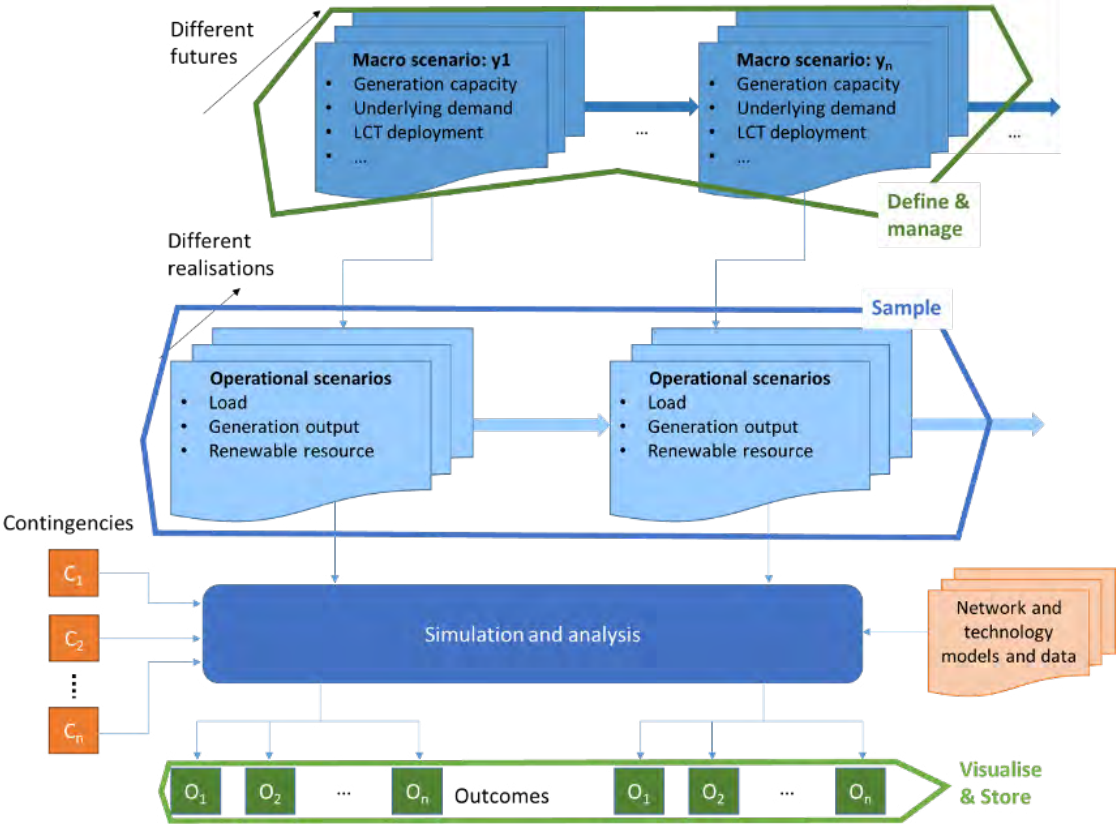


Figure 1. Overall Approach to Managing Uncertainty in Future Load Related Investment

In Figure 1, long-term uncertainties (LCT deployment, changes in underlying demand, etc) represented by "macro scenarios", each of which describes a coherent possible future situation, and may represent a particular year in the future. Short-term uncertainties are represented (as noted above) by "operational scenarios", each of which describes a possible daily combination of load and generator behaviour. To these are added contingencies (such as protection and control systems, whose operation must be modelled to ensure accuracy of results) to give an overall set of cases to be simulated, analysed and summarized. A number of metrics are used to assess and visualise the adequacy of the network under sampled conditions, including circuit current, steady-state voltage, voltage step in a contingency, and network reliability.

Selected innovative interventions demonstrated in DNO-led innovation projects (such as dynamic equipment ratings and intelligent network reconfiguration) have also been modelled, and can be applied to networks which experience constraint violations in order to assess the applicability of such interventions in delaying or avoiding traditional reinforcement. Selective reanalysis of specific operational scenarios has been built into the simulation environment to permit efficient evaluation and comparison of the applicability of these techniques in relieving observed problems.

2.2 | NIA SPT 1604 Introduction of Environmentally Friendly Alternatives to SF6

SP Transmission has implemented a project to reinforce the 400kV and 275kV substations at Kilmarnock South to facilitate the planned amount of renewable generation capacity contracted to be connected to the transmission system in South West Scotland. A new 400kV double busbar Gas Insulated Substation (GIS) will be provided and built with a footprint designed to accommodate a total of 15 bays with an initial provision of 3 bays equipped with 400kV GIS switchgear. The employment of GIS offers benefits over Air Insulated Substation (AIS) such as reduced space requirements (10% of AIS at 400kV) high reliability, improved safety, long service, reduced maintenance requirements, and low life cycle costs.

The main disadvantage of GIS is the use of large quantities of SF6. SF6 is an excellent insulator, and is widely used in the electrical industry in high-voltage air or gas insulated switchgear, but it is a greenhouse gas with an extremely significant impact on global warming. It is one of the six gasses listed in the 1997 Kyoto Protocol designed to lower greenhouse gas emissions worldwide.

As part of the RIIO T1 Business Plan, SP Transmission aspires to identify measures to improve the overall business carbon footprint where appropriate. SP Transmission manage their SF6 inventory in accordance with industry good practice, but until recently, there was no alternative to SF6 that featured equivalent switching and voltage- withstand capabilities.

A number of companies are looking to develop environmentally friendly SF6 alternatives. GE Grid Solutions are one company who is leading this field and can now offer a revolutionary SF6-free solution, g3 which has been jointly developed with 3MTM, a leader in environmentally sustainable solutions. g3 has 98% less impact on global warming than SF6.

With performances comparable to SF6, it is a suitable technology for the development of today's new generation of clean high voltage equipment. GE Grid Solutions has been contracted to install the new 400kV GIS switchgear including a Gas Insulated Busbar (GIB) at Kilmarnock South and has confirmed that one 400kV (GIB) can be installed with g3 as part of an innovation pilot.

2.2.1 | NIA SPT 1604 Project Progress

This project is now business as usual.

Outdoor section of 400 kV gas insulated busbar containing g3 gas.

Switchgear nameplates highlight the low global warming potential (GWP) of g3 gas compared to SF6 (327-v-22, 800) and reduction of equivalent CO2 in installation

2.3 | NIA SPT 1608 Reducing Energy Losses from Transmission Substations

At present, substation energy consumption is uncontrolled and unmonitored. Energy is consumed for a number of processes (e.g. heating, lighting, battery charging or dehumidifying) to ensure network resilience and security of the electricity network. Typically, the supply for Grid substations comes from the secondary windings on 33kV neutral earthing transformers, and is unmetered. As such, substation demand is not monitored or accounted for, while it contributes to the SP Energy Networks transmission losses.

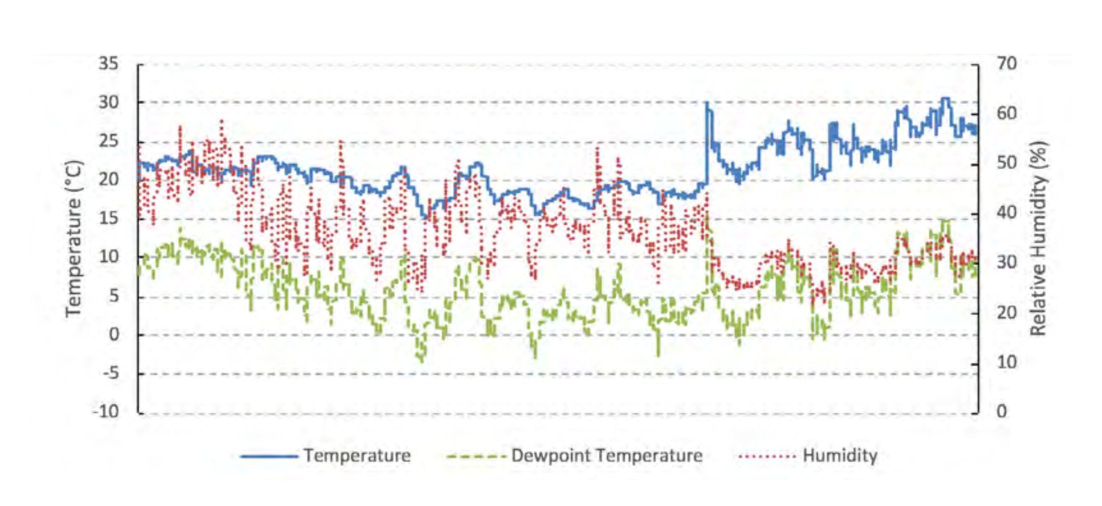
This project will initially aim to establish, through audits and metering, the baseline level of energy usage of a number of trial substations in the SP Transmission licence area, and then use the collected data to model the performance of the substation buildings. These data models will allow opportunities for energy efficiency to be identified, then enable the development for a plan for improved substation energy efficiency.

2.3.1 | NIA SPT 1608 Project Progress

This project is now complete. Through the data monitoring, it was determined that the five substations had a mean consumption of 214 kWh/year/m^2. This represents the energy used for heating (206kWh/year/m^2) and for internal and external lighting (8kWh/yr/ m^2). Alongside the monitoring, Edinburgh Napier University's Scottish Energy Centre developed computer models of each of the five substations. This allowed for building construction to be considered and potential energy saving measures to have their impact modelled. These models allowed the substations to be categorised as archetypes, with each having an associated energy usage per square metre. This will allow energy usage in other substations to be more accurately estimated based on construction type, floor area and their equivalence to these archetypes.

This data and modelling gives an understanding of the energy usage within substations, and provides a starting point for work to reduce their carbon footprint. As heating is the major component of the substation energy use, controlling this is important. Any action to do this, however, must take a wide range of business stakeholders into account, as heating within the substation impacts on several technical and operational aspects. As an example, reducing heating usage during the summer months may prevent the temperature being raised unnecessarily, but it could impact on the substation's dew point. This could cause increased condensation, damaging communications and control technology, or pose issues for switching or moving components. Similarly, during the winter, heating could be controlled to keep the temperature closer to the minimum operating level to reduce energy usage. However, it would need to be possible to override this when people were working in the substation as this would be too low to be considered a safe working environment. One potential solution to come from this project is the introduction of a micro Building Energy Management System (microBEMS). This is a device which takes input from various sensors within a building – such as temperature, humidity or door sensors – and uses logic algorithms to control and optimise the heating and lighting in the building.

The report produced by the Scottish Energy Centre has been circulated amongst key stakeholders within SP Transmission and the range of possible interventions proposed has been used in the development of planned improvements at 48 SP Transmission substations (29 at 132kV, 14 at 275kV and 5 at 400kV) during the RIIO-T2 period, leading to energy savings of 1,000MWh per year. Civil works already under way prior to T2 are utilising the findings from this project to make energy efficiencies and are seeing re-consideration of long-standing practices requiring the use of heating and fans rather than air-conditioning units capable of looking after heating, cooling and humidity all in one.



2.4 | NIA SPT 1609 The Planning Data Exchange System between Network Licensees to Enable a Smarter Grid

DNOs and National Grid have a long track record of successful interaction in operational planning and investment planning coordination. However, the expected uptake of low carbon technologies and the advent of the Smart Grid will impact on the required level of interaction between the DNO and the System Operator (SO) in the future.

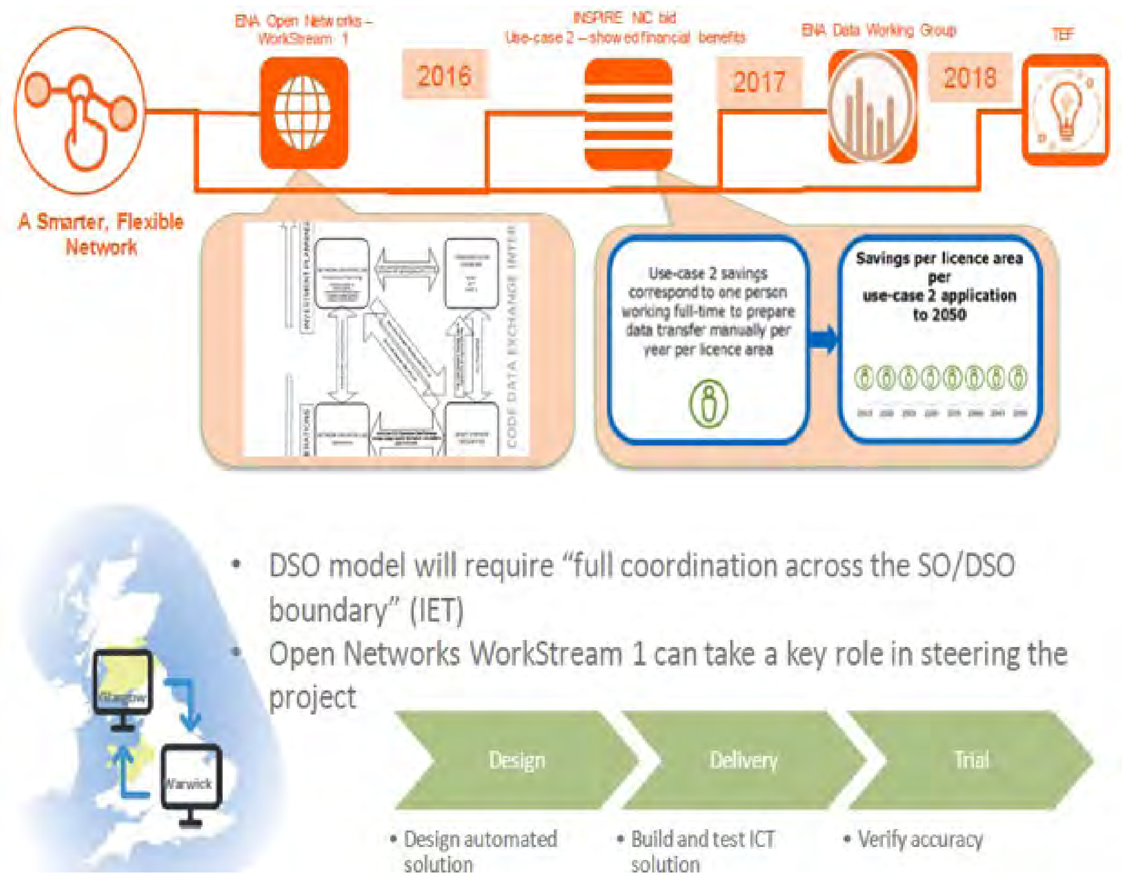
Greater interaction will be necessary as distributed energy resources (DER) become increasingly required to provide not just energy but whole-system services as well. For example, embedded generation, demand response and energy storage, along with distribution system services can contribute to system balancing. To achieve this, “full coordination across the SO/DSO boundary” will be required.

Presently, operational and planning information is transferred between the DNOs and SO in accordance with Grid Code requirements. For example, DNOs provide “Week 24” network planning data to National Grid annually and in return, National Grid supplies “Week 42” data, which is a network-equivalent data model for fault level assessments.

The “Week 24 Authorised Network Model” is an official snapshot in time of the distribution network and sets the baseline for all subsequent data exchange. This model includes all the detailed network data,including topology, connectivity, electrical parameters, and all embedded generation up to 1MW. It also contains the long-term (i.e. >12 months) demand and generation forecasts.

The existing method of information collection and submission between the DNO and SO is highly dependent on key personnel extracting data from a number of different systems manually. Furthermore, the analysis of the data is undertaken in uniform manner without taking into account the characteristics of the DNO region. This process is not sustainable when the requirement for more frequent transfers of a richer set of information is taken into consideration.

A holistic approach is required to clarify the existing and future roles of DNO, TO and SO in an involving (but also changing at accelerated pace) energy sector. This project is aiming to provide a tool to facilitate such a transition.

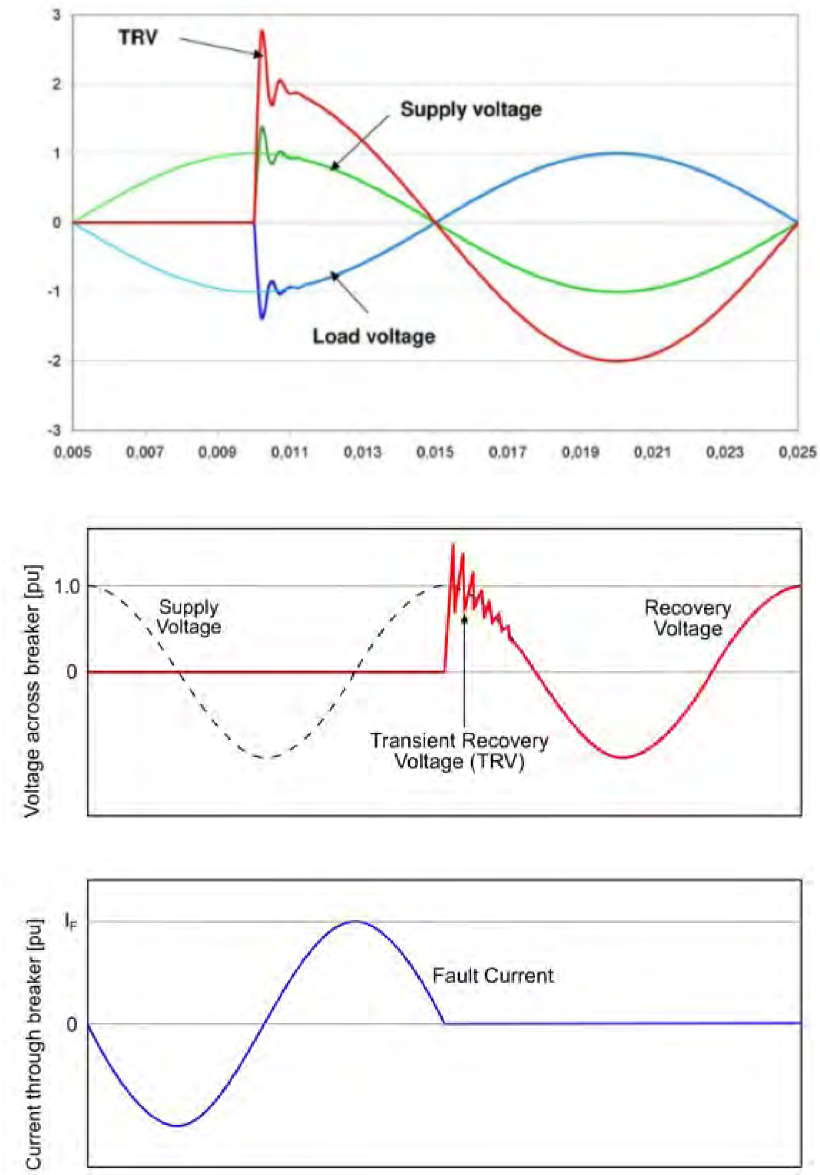


2.4.1 | NIA SPT 1609 Project Progress

The ENA Open Networks project Work Stream 1 Product 12 recognises that an increased frequency of data transfer between Transmission and Distribution would be beneficial. Discussions are on-going with the GB System Operator and Distribution licencees to define how this can best be trialled.

2.5 | NIA SPEN0035 Transient Recovery Voltage Investigation

Transient Recovery Voltage (TRV) can be defined as the voltage which appears across a circuit breaker's terminals upon interruption of the current resulting from a switching operation. When specifying circuit breakers, designers are often unsure about the TRV requirements that should be requested, particularly when switching e.g. series reactors or transformer circuits. This can lead to issues including over specification of TRV capability within circuit breakers or a requirement for additional TRV studies, both of which lead to additional cost.



This project proposes a technical method that involves engaging researchers to investigate the issue of TRV and produce conclusions that will impact circuit breaker selection and application in a variety of networks. The investigations will address the TRV issue through network modelling, estimating the prospective TRV, identifying potential consequences and risks, and the means to mitigate these. The planning, training, operation and maintenance requirements of any viable mitigation options will also be established.

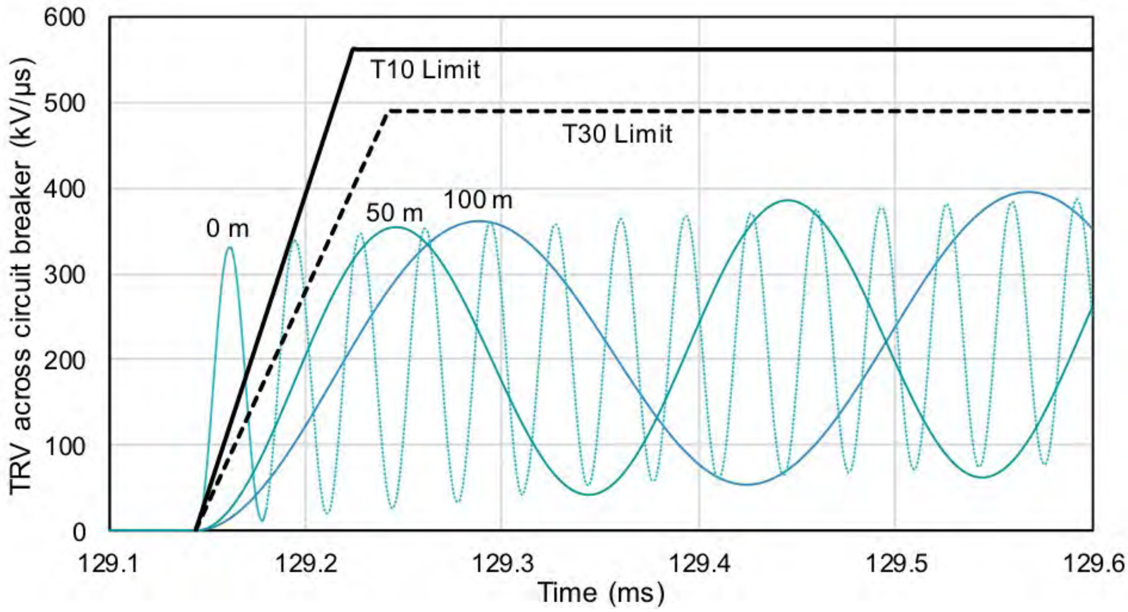
The scope of the project covers voltage levels from 33 kV up to 400 kV and considers the characteristics of the SPT, SPD, SPM, SHET and SHEPD networks. Based on the outcome, standard TRV requirements can then be established. Also, guidance will be formulated on how to identify cases where this standard TRV capability is insufficient and how to remedy the situation.

2.5.1 | SPEN0035 Project Progress

The project was formally kicked off in 2019 with SSEN as partners, Mott McDonald as project supplier and the EIC acting as PM. The project is nearing completion and work should be finished by July 2020. The project has been delivered in a number of stages:

- Literature Review
- Methodology
- Network Configurations Studies – Reports have been delivered on configurations including series and shunt reactors, transformers and long overhead line configurations.
- Technical Guidance and Final Report

An online webinar is planned to disseminate learning and the final report will be completed by July 2020.



Plot showing the influence of cable length on the transient recovery voltage waveform for a circuit breaker clearing a fault at the terminals of a nearby 275 kV series reactor. The directly connected (0 m cable length) case shows that the rate-of-rise of the recovery voltage is outside of the standard IEC envelope, whereas longer cables reduce the rate-of-rise and allow circuit breakers with standard capability to be used.

2.6 | NIA SPEN0044 400kV Dynamic Cable Rating Retrofit Project Utilising RPMA Communications Technology

As the penetration of low carbon technologies increase in the UK greater circuit loading will be experienced on the transmission network. Under certain loading scenarios the power flow on transmission circuits may need to be constrained, which can result in multi-million pound constraint payments. Rather than undertaking costly network reinforcement schemes, with long lead times and environmental impacts, one option is to operate the network using dynamic ratings.

One such circuit where the declared capacity is likely to cause future constraint issues is the Torness to Thornton Bridge (Crystal Rig) 400kV circuit. In order to defer or avoid network reinforcement one potential option to increase circuit capacity is to operate and plan the carrying capacity of the cable circuits based on their real-time thermal behaviour.

An optical fibre laid alongside a power cable can be used to determine real-time thermal behaviour. Installing a fibre optic temperature sensing circuit at the same time as laying a power cable is relatively cost effective; however if you have to excavate an existing circuit then the costs escalate. The problem to be addressed, therefore, is finding a cost effective retrofit dynamic capacity rating (DCR) solution with supporting communications technology that can be deployed easily.

To ensure that the measured data is securely transmitted Random Phase Multiple Access (RPMA) wireless communications technology is proposed. While RPMA technology has not been used by SP Energy Networks before it does provide significant advantages for ultra-rural, isolated, hard-to-reach or targeted meter locations. Utilizing globally available unlicensed spectrum in the 2.4GHz band, RPMA's properties of robust interference tolerance, wide geographic coverage, high network capacity, and low power support, allow devices to be connected more efficiently than ever before.

The project will investigate the feasibility of using the RPMA wireless technology coupled with point sensors and integrated with a DCR scheme to provide a cost effective retrofit dynamic rating solution to evaluate real-time thermal behaviour of strategic cable circuits.

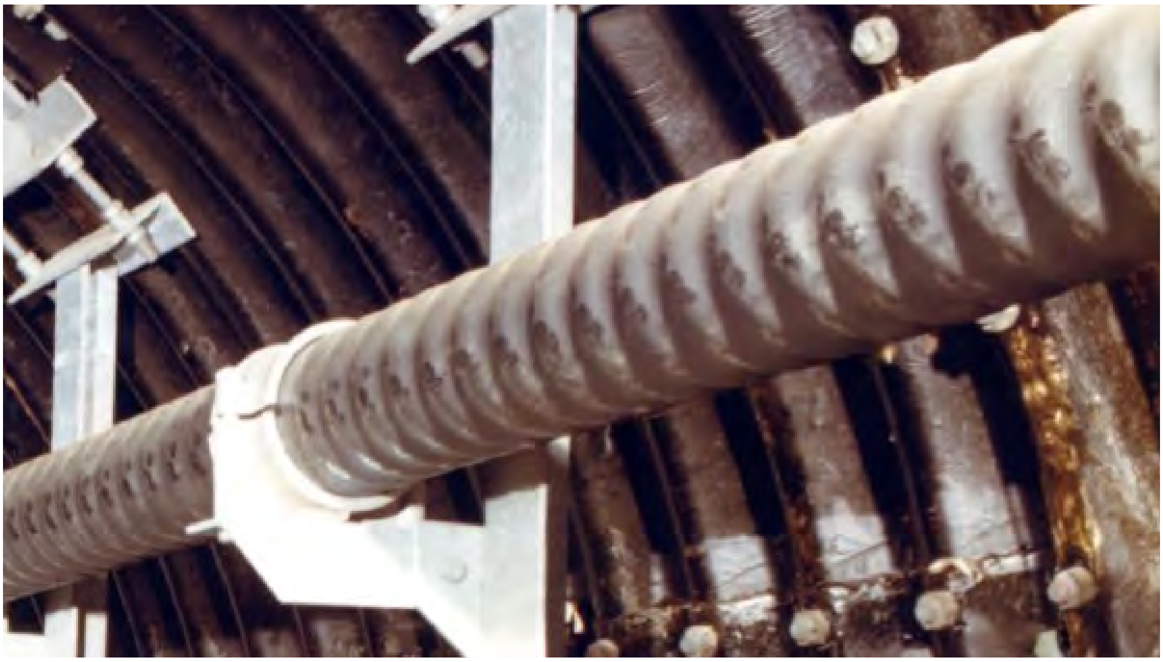
The key business benefit is the potential to determine additional headroom capacity on a cable circuit which could eliminate or defer network reinforcement, and avoid the various costs and risks during the associated outages, and extend the life time of network assets.

2.6.1 | SPEN0044 Project Progress

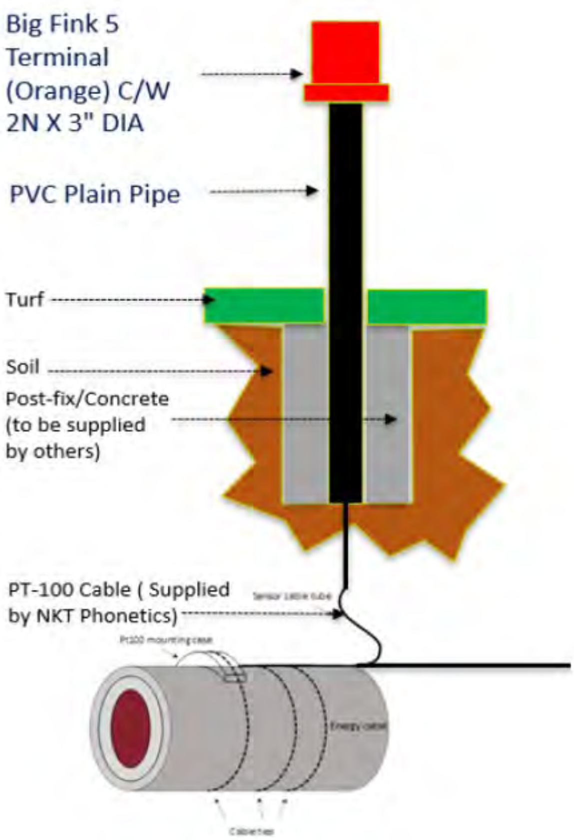
Potential 'hot spot' and monitoring locations where identified. In total seven locations where identified, five in the ground and two cable tunnels. Validating the results of the initial propagation simulation is an important step on a path to achieve optimal wireless network coverage. In order to de-risk the project a site survey was undertaken in June 2019 to validate the signal propagation model used in the communication network design. To conduct the field survey and RF Testing for RPMA, Trilliant, the telecoms provider, developed a portable self-contained RPMA base station which was deployed at Burnt Hill radio hill site to facilitate baseline signal measurements in conditions closely approximating the final installation. Appropriate signal strength for communications was subsequently confirmed at the monitoring locations.

A sensor unit with redundancy (two PT100 sensors per unit) for retrofit deployment on cable installations was designed and developed. These were subsequently deployed at the seven identified monitoring locations during the cable circuit outage.

Cable tunnel where the sensor unit was deployed.



A telemetry post to integrate with the sensor units was developed and the associated civil bases installed at all seven monitoring locations ready for the installation of the telemetry posts

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3 | NIA Activities Linked to SP Transmission Innovation Strategy

3.1 | SP Transmission Innovation Strategy

SP Transmission's Innovation Strategy drives the direction and development of all innovation projects and initiatives, and has been strongly influenced by the views of a wide range of external stakeholders and collaborators.

The SP Transmission Innovation Strategy was released in 2011 as part of the RIIO-T1 Business Plan submission, and has provided the consistent, coherent and coordinated platform upon which all SP Transmission T1 innovation has been founded. This strategy has been reviewed annually, remaining robust despite the accelerating transformation of the energy landscape. It received an update by exception in 2014, and in Q3 2018 work began on the further development of this strategy to align with RIIO-T2 aspirations.

During the reporting year saw extensive engagement with all key stakeholder groups, and the resulting feedback significantly influenced the final Strategy, which was released in December 2019.

The new strategy represents a step-change in ambition and approach commensurate with the significant challenges and opportunities that RIIO-T2 represents. The six key transitional challenges identified are:

1. Improving the sustainability of our network and business processes and empowering our consumers;
2. Whole System Approach: overcoming boundary restrictions between electricity and gas transmission owners (TOs) and distribution network operators (DNOs), transport and telecommunications sector with increased customer engagement;
3. Integrating new technologies and enabling digitalisation, standardisation and cyber security;
4. Challenges related to black start;
5. Maintaining system security and stability: in light of reduced grid services, lower system strength, and increased grid dynamics and interactions; and
6. Evolution of our transmission network and associated uncertainties: including new requirements for reinforcement and the replacement, operation and maintenance of aging assets.

Also crucial to the step-change in our Innovation approach is a greater emphasis upon enabling a Whole System approach, empowering consumers, addressing consumer vulnerability and achieving sustainability through innovation.

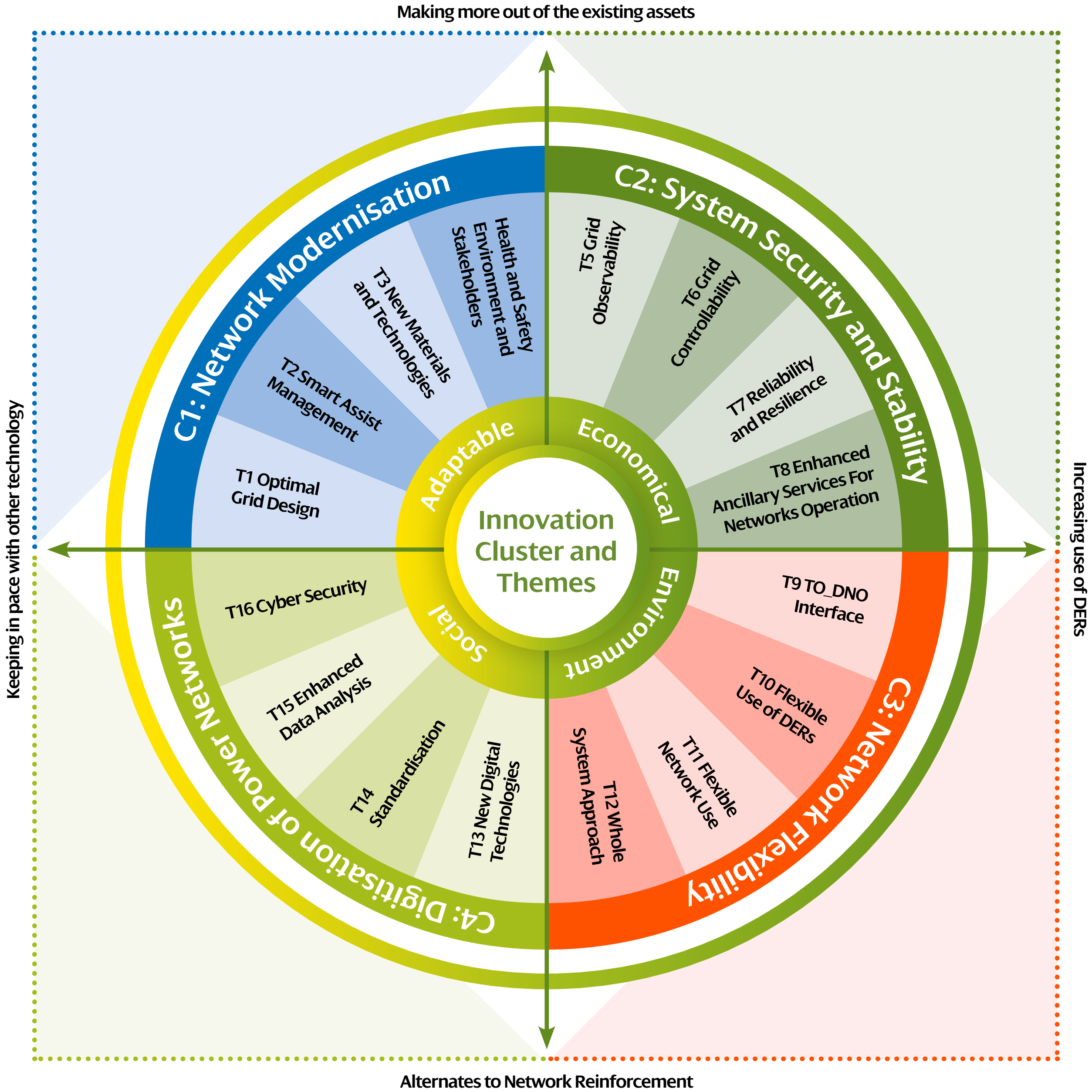
These advancements are supported by equally important step-changes in SP Transmission's innovation process and culture, together with a more robust strategies for translating innovation into business as usual and collaborating with third parties.

Benchmarking against other innovative organisations led us to select the ENTSO-E Research and Innovation framework to structure our new Strategy, leading to a shift from a project-based approach towards a cluster-based approach, creating groups of innovations to solve key system transition challenges in a holistic, interconnected way.

These clusters cover:

- **Cluster 1:** Network Modernisation (Themes 1-4)
- **Cluster 2:** Security and System Stability (Themes 5-8)
- **Cluster 3:** Network Flexibility (Themes 9-12)
- **Cluster 4:** Digitalisation of Power Networks (Themes 13-16)

Energy System Transition Challenges for the Future Transmission Network



3.2 | ENA Innovation Strategy

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

https://www.spenergynetworks.co.uk/userfiles/file/Electricity_Network_Innovation_Strategy.pdf

With regards to the ENA Innovation Strategy, we are looking to ensure that our existing and new projects can contribute directly to the five focus areas in the near-term:

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

3.3 | Culture of Innovation

In 2019 we launched our Year of Innovation, and we continue to build on this success in 2020 to ensure that we continue to focus on our people, who are crucial to the development and delivery of any innovation. We have seen success already by strengthening our culture of innovation and have seen people more actively engaged in innovation across the business.

We have successfully built a champion network with over 100 of our employees who make innovation real at a local level and engage their teams to pull out ideas of how we can do things differently. In addition, we have led a series of high-profile campaigns to tackle some of our most prevailing challenges.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4 | Areas of Significant New Learning

The following identifies area of learning on a project by project basis:

4.1 | Project Learning: NIA 1504 Managing Uncertainty in Future Load Related Investment

A number of points of learning have been gained from this project.

- The macro-scenario/operational-scenario approach has been found to be very useful in characterizing different sources and timescales of uncertainty, and in focusing engineering attention on the judgements necessary to consistently represent different possible future outcomes in terms of network development, demand change and deployment of new technologies.
- Flexible and modular approaches to the integration of statistical models (for example, of EV behaviour and of renewable generation output), and of simulations models of the power network have been found to be relevant in allowing the straightforward use of location-specific models based on historical data for appropriate to the network being studied. They also permit the replacement of models with more accurate or efficient versions as these become available.
- Selective re-simulation of constraint violating conditions, together with the use of simplified models for selection of appropriate interventions, has proven valuable in minimizing the simulation cost of assessing the applicability of smartgrid interventions.
- Large amounts of data are produced by this style of analysis. Care is needed in the management, presentation and visualisation of these results in order to achieve efficiency in the simulation process, and to make these results maximally accessible and useful to network engineers while retaining the ability to investigate particular situations in detail.
- The value of graph databases in identifying potential network reconfigurations, and for evaluating their effects on the expected reliability indices of the network has been demonstrated.

4.2 | Project Learning: NIA SPT 1604 Introduction of Environmentally Friendly Alternatives to SF6

The experience we have learned from the use of an alternative dielectric gas to SF6 in the 400 kV gas insulated busbars at Kilmarnock South has allowed SP Energy Networks to specify that non-SF6 alternatives shall be used for all new 275 kV and 400 kV gas insulated busbars. This will support our vision to become a sustainable network operator as outlined in our RIO-T2 Business Plan. The employment of this equipment will avoid adding approximately 6,000 kg (140,000 t CO2 eq.) of SF6 during the RIIO-T2 period.

4.3 | Project Learning: NIA SPT 1608 Reducing Energy Losses from Transmission Substations

A potential area of learning for this project is in changes to substation worker behaviour. Some level of substation energy loss is related to inefficient management of heating levels within substations. This may be due to workers leaving heating or lighting on unnecessarily or setting it higher than is necessary, for example. It is possible that a behavioural campaign, such as signs on site, could reduce energy usage. Additionally, if sensors could be fitted at each site to capture environmental parameters of temperature, illumination levels and humidity then this could help provide early warnings to Control Centres of issues with heating or lighting at these sites.

4.4 | Project Learning: NIA SPT 1609 The Planning Data Exchange System between Network Licensees to Enable a Smarter Grid

There is no learning to report at this stage of the project.

4.5 | Project Learning: NIA SPEN 0035 Transient Recovery Voltage Investigation

The project has provided a great deal of learning about the TRV problem and any potential consequences and associated risks. The project identified a number of scenarios where TRV may be problematic and has outlined mitigation measures including useful 'rule of thumb' guidance. The deliverables have included a set of guidance notes which will improve the network planners ability to make decisions on options for TRV mitigation and enhance training of graduate staff in this area.

4.6 | Project Learning: NIA SPEN 0044 400kV Dynamic Cable Rating Retrofit Project Utilising RPMA Communications Technology

Key learning was in the engineering design and development of the sensor unit in order to ensure appropriate connection to the cable jacket of a 400kV fluid filed cable.

'Hot' spot locations by their nature are deeper and therefore more expensive and time consuming to excavate. The cement bound sand (CBS) that surrounded the cable was very hard in places and consequently time consuming to remove which again added to the cost of excavation works.

SP ENERGY NETWORKS

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