NIA Annual Report

TRANSMISSION

2017 – 2018

SP ENERGY NETWORKS

Enquiry please contact
James Yu, Future Networks Manager
SP Energy Networks, Ochil House, 10 Technology Avenue,
Hamilton International Technology Park, Blantyre, G72 0HT
Email: James.Yu@spenergynetworks.co.uk

Foreword

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

This is our fifth Network Innovation Allowance (NIA) Annual Transmission Report and is an overview of ongoing Transmission related projects being undertaken, and those initiated, during the regulatory year 2017/2018.

We carry out the transmission innovation with a holistic and coordinated approach encouraged by the stimulus under RIIO-1 regime. In line with the NIA Governance, our projects continue to play a key role informing the development and delivery of our Network Innovation Competition (NIC) projects and we recognise the importance of stakeholder engagement and knowledge sharing for the wider benefit of the industry. We are now looking to apply learning from relevant supporting NIA projects in the delivery of NIC projects. In the meantime, NIC projects provide the opportunities of upscaling existing NIA projects and identifying new NIA projects. The example can be found in our recently completed VISOR (Visualisation of Real Time System Dynamics using Enhanced Monitoring). As the first transmission NIC under RIIO-T1, our VISOR project delivered all Successful Delivery Reward Criteria and fulfilled its strategic role in highlighting the importance and requirements of an effective Wide Area Monitoring System (WAMS) to help retain system stability and security in the low-carbon future. VISOR has succeeded in designing, deploying and operating the first GB-wide WAMS in order to demonstrate the enhanced tools and capabilities now available. Some of our new NIA projects will be based on the infrastructure designed within VISOR and continue to explore the critical areas such as transmission system inertia, short circuit capacity and wide area protection and control as set out in our Transmission Innovation Strategy.

Our portfolio of NIA projects, together with NIC projects (VISOR, FITNESS and Phoenix), provides us a leading position on transmission innovation.

This report will provide some highlights of the progress made within our NIA projects, which is ranging from an environmental friendly insulation gas replacement trial, power collection from the transmission overhead lines to cyber security of data exchange. Its diversity and advancement represent the efforts, capacity and ambition from our committed colleagues to innovate on behalf our customers. Those projects are the result of close collaborations and engagement both inside and outside of the company.

The projects within our NIA annual report also serve as a useful reference on the innovation learnings we leveraged from other funding sources such as Horizon 2020, Engineering Physics and Science Research Council (EPSRC) and our joint work under System Operator Framework regarding transmission network supply security and reliability, such as Black Start.

We carry out the innovation in a transparent, collaborative and effective manner. As part of our Open Innovation initiative, SP Energy Networks invited third parties to submit applications at the beginning of 2017/18. These applications were requested to address the key challenges that our transmission network faces now, or will face in the future. We were encouraged and overwhelmed by the constructive and active responses from various industries across the world.

The benefits of innovation can only be materialised if we can apply the outcome generated from those pioneering projects within our core business. We continue to seek innovative opportunities to improve the way our network operates to provide tangible benefits to our customers and to facilitate the choices of low carbon technologies.

Our innovation focus remains firmly centred on our customers and stakeholders, who shape both our Transmission Innovation Strategy and innovation project portfolio that could help toward the successful delivery of RIIO-T1 and place a solid foundation for the RIIO-T2.

Colin Taylor
Director
Processes & Technology

Colin F Taylor

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Executive Summary

Our fifth 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 fifth NIA Annual Statement presents an overview of the projects we have initialised during the regulatory year 2017/2018 and an update on those projects reported during 2016/2017 which are still active.

The progress of each project aligns with the five innovation objectives set out in our Transmission Innovation Statement:

- 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 as longer term requirements (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.

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 for two purposes:

- To fund smaller projects which meet the criteria set out in this Governance Document; and
- To fund the preparation of submissions to the Network Innovation Competition (NIC) which meet the criteria set out in the NIC 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 new RIIO - T1 model for price controls with the introduction of the NIA.

This report presents SPT's NIA activities during the fifth 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. SPT 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 accessible processes;
- 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.

SPT 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 consideration is detailed within the report along with details of how our NIA activities link to SPT's innovation strategy.

2 | Progress Summary

During the reporting year 1st April 17 to 31st March 18 SP Transmission registered the following NIA project:

- NIA SPT 1701 Development of a Lone Working Device Incorporating Satellite Communications and Fault Detection

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

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

A tool for the analysis of distribution network performance under uncertain operating conditions has been developed and demonstrated. This tool manages the sampling of time series of behaviour of low carbon technology (LCT) of different types (including wind generation, PV generation and electric vehicle charging load) and of underlying "traditional" load from underlying statistically and historically based models, including the representation of diversity effects and assumptions about geographical correlation. The tool allows the configuration of scenarios of LCT deployment and of changes in underlying load to reflect, for example, future economic conditions and uptake of different technologies.

The tool embodies a simulation infrastructure to assess network performance in the resulting significant volume of sampled network states to create a database of network scenarios and results, and to identify conditions under which there is a risk of violation of network constraints and limits. A number of smartgrid interventions - including dynamic network reconfiguration, energy storage, demand management and real-time equipment ratings - have been modelled within the tool, and can be analysed for effectiveness in mitigating observed violations of network limits.

Additional modelling and analysis techniques have been developed to adapt the tool and underlying techniques for analysis of network adequacy at the transmission/distribution interface, with particular reference to the use of sampled load and generation data to assess the effect of distribution-connected LCT on voltage and fault level performance, and to assess alternative approaches to correcting apparent future capacity shortfalls.

2.2 | NIA 1505 Trial of Open Innovation in Utilities Sector

The Open Innovation (OI) model is being developed to bring together the company challenges and the innovators. It has been shown that the most innovative and game-changing ideas can come from outside the sector. In addition, it can be time and resource challenging to develop and deliver suitable projects within the business.

Scottish Enterprise awarded SP Energy Networks with funding to promote contracts with Scottish SME's by the implementation of Open Innovation. SP Energy Networks works together with Subsea 7, Weir and Doosan Babcock to share the advances done in Open Innovation inside each during the duration of the programme.

The Open Innovation programme aims to evolve the concept of innovation in the companies working on this programme. Innovation usually means focus on inside research and development to develop new technologies or processes to create new products to improve the current market or to open new markets for the company.

Open innovation changes this paradigm, involving the acquisition, licensing and use of technologies developed outside the company to solve the challenges, as well as the spin-off of technologies developed inside the company that are not used or may have applications in a different industry.

Open Innovation programmes aims to increase the number of SMEs working together with SP Energy Networks to expand and spread the talent.

2.2.1 | NIA SPT 1505 Project Progress

The project has focussed on the Stage 3 (18 months) – Delivery Phase, with a continual revision of the Planning and Approving work. This is the third progress report and covers the period of the Open Innovation programme delivery from April 2017 to March 2018, "the reporting period".

The Project Delivery Team (PDT) has undertaken the following activities during this reporting period:

Study and search of related to Open Innovation programmes that could be implemented in SP Energy Networks.

As part of the Scottish Enterprise Cohort of companies, SP Energy Networks has been an active member both in sharing information on the direction for Open Innovation and learning how best to roll-out the model. The progress made in this activity, will be incorporated into a wider Company policy – This has provided the building blocks and many learning points for ScottishPower's 2019 Year of Innovation.

Two Design workshops took place in Aug 2017, firstly for SPD – District Innovation and secondly for SP Energy Networks Frameworks.

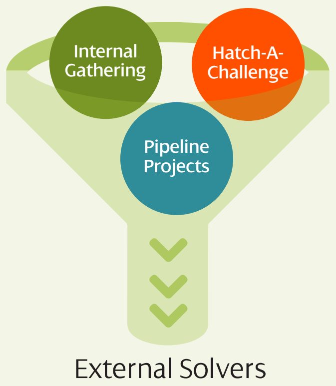
Multiple workshops have taken place with a wide range of end users from operational to specific skill sets; these have been warmly received with a growing appetite for innovation. The frequency of these events has been at least one per quarter. The progress at March 2018 can be summarised on the next page.

Design Brief Meeting at the Dealain Training Centre

SP Energy Networks is the electricity distribution and transmission network operator for central Scotland, and the distribution network operator for north Wales and Merseyside.

We want to be one of the leading network operators in innovation, and Open Innovation gives us the opportunity to integrate innovation throughout our business.

- Open Innovation has allowed SP Energy Networks to solve some of our long-standing issues, and has helped us improve our operations and processes, and better engage our staff and contractors.




OPEN INNOVATION
Hatch a Challenge

Do you sometimes come across a challenge at work and think, 'there must be a better way to do this"?

We are looking for you to identify issues or challenges that matter to you so that we can find an innovative solution..

"At 9am every morning, the security gate bunches up with too many people. There must be a solution!"

"Due to the plate thickness of the steel and the absence of viewing glass in Endboxes it is incredibly difficult to determine the current level of compound G38. There must be a solution!"

Challenge Gathering

SP Energy Networks will be implementing a software portal to gather challenges from our internal stakeholders, and enable collaboration on ideas between departments and functional teams.

SP Energy Networks has also run numerous design challenges for our staff, contractors and suppliers to initiate the development of challenges facing both our company and our industry.

Challenge Definition

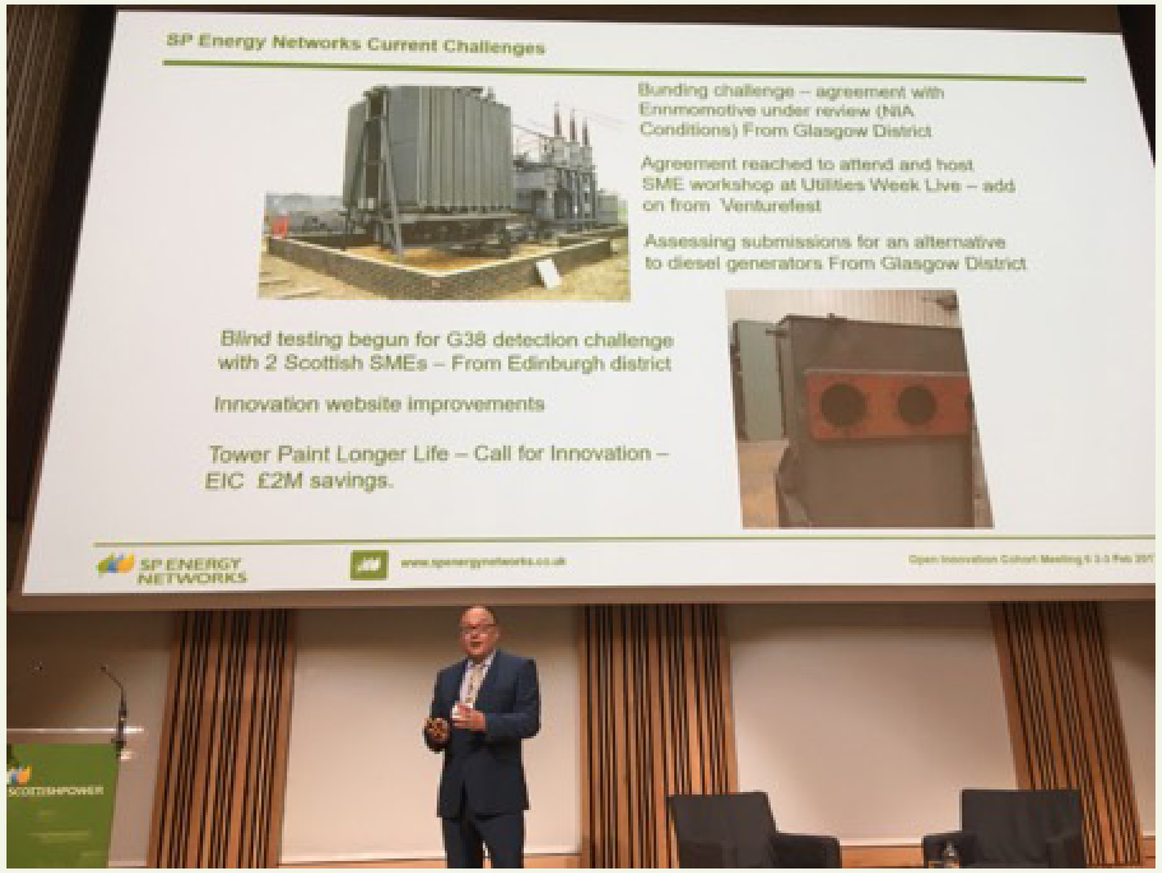
- G38 Endbox Monitoring
- HV/LV Cable Device
- New Transformer Bunding
- Diesel Generator Replacement
- Overhead Line Crossing Protection
- Substation Weed Control
- Perfluorocarbon Tracer Alternatives
- Insulation Moisture Testing
- Groundworks Analysis
- Innovative Cable Fault Location
- Neutral Conductor Detection

Solvers & Solutions

We have made use of a number of SME communities, from the Scottish Enterprise Portal and Public Contracts Scotland, to the Energy Innovation Centre.

We have also been working with Ennomotive and Ninesigma as online solver communities.

We have already awarded contracts worth £355k to SMEs for our challenges.



SP Energy Networks took part in the 2017 Venturefest Scotland Event, which is a pathway for learning about Open Innovation, and how SP Energy Networks can work with the Solver Community. SP Energy Networks ran a panel workshop covering engagement with SME's.

The Open Innovation Programme has identified key challenges that are being addressed, but more importantly the knowledge obtained in the second year will provide the legacy foundations for increased staff engagement, more sharing of knowledge and a wider take up of SME's who have untapped skill sets.

2.3 | NIA 1507 Modelling of Static and Dynamic Loads

The ultimate goal of this project is to improve the understanding of behaviour of load centres and evaluate the existing load models used in the system studies performed by SP Energy Networks.

It is expected that by achieving this, the accuracy/effectiveness of network planning and operation tools will be improved by:

- gaining a better understanding of load behaviour
- improving understanding of existing load models
- creating new methods for the estimation of load model parameters
- demonstrating a methodology for estimation of load model parameters using different load models
- assessing the interaction between different load types and the main grid.

Accurate load models can support improved decision making when considering the required system expansion. It is expected that the exploitation of the existing assets can be improved, potentially deferring network reinforcement and influencing fundamental network design principles. Last but not least, a detailed understanding of demand behaviour is a prerequisite for integration of system operation actions at distribution and transmission levels.

In order for the project to deliver these benefits, the investigators from The University of Manchester are proposing an approach for the estimation of the unknown load parameters of generic aggregated load models based on measurements recorded from the distribution/transmission system. This approach would first be demonstrated using detailed simulated studies in DIgSILENT PowerFactory. It is assumed that the research will also include processing of laboratory data records, which will be used to validate the quality of conclusions obtained through simulation studies.

2.3.1 | NIA SPT 1507 Project Progress

The work planned for this project has been undertaken in accordance with the project plan.

Firstly, the focus of the project activities was on the development of a flexible data acquisition and processing platform (short platform) for collecting data and supporting the work on characterisation of loads. An assessment of a platform design and architecture has been undertaken. From the platform, it was expected that it is capable of estimating unknown model parameters of dynamic load models. The aspects of the speed, bandwidth, as well as the reliability of communication channels used are investigated. The role of the abovementioned platform is to concentrate data obtained from Phasor Measurement Units (PMUs) into an existing Phasor Data Concentrator (OpenPDC). To allow a fast data concentration and further processing, the existing OpenPDC has been significantly modified so that a smooth and secure data transfer from the data concentrator to the processing and visualisation units has been achieved. This has enabled further development of new applications needed for advanced characterisation of load behaviour.

As a result of the assessment of optimal platform architecture, the solution presented in Figure 1 has been proposed.

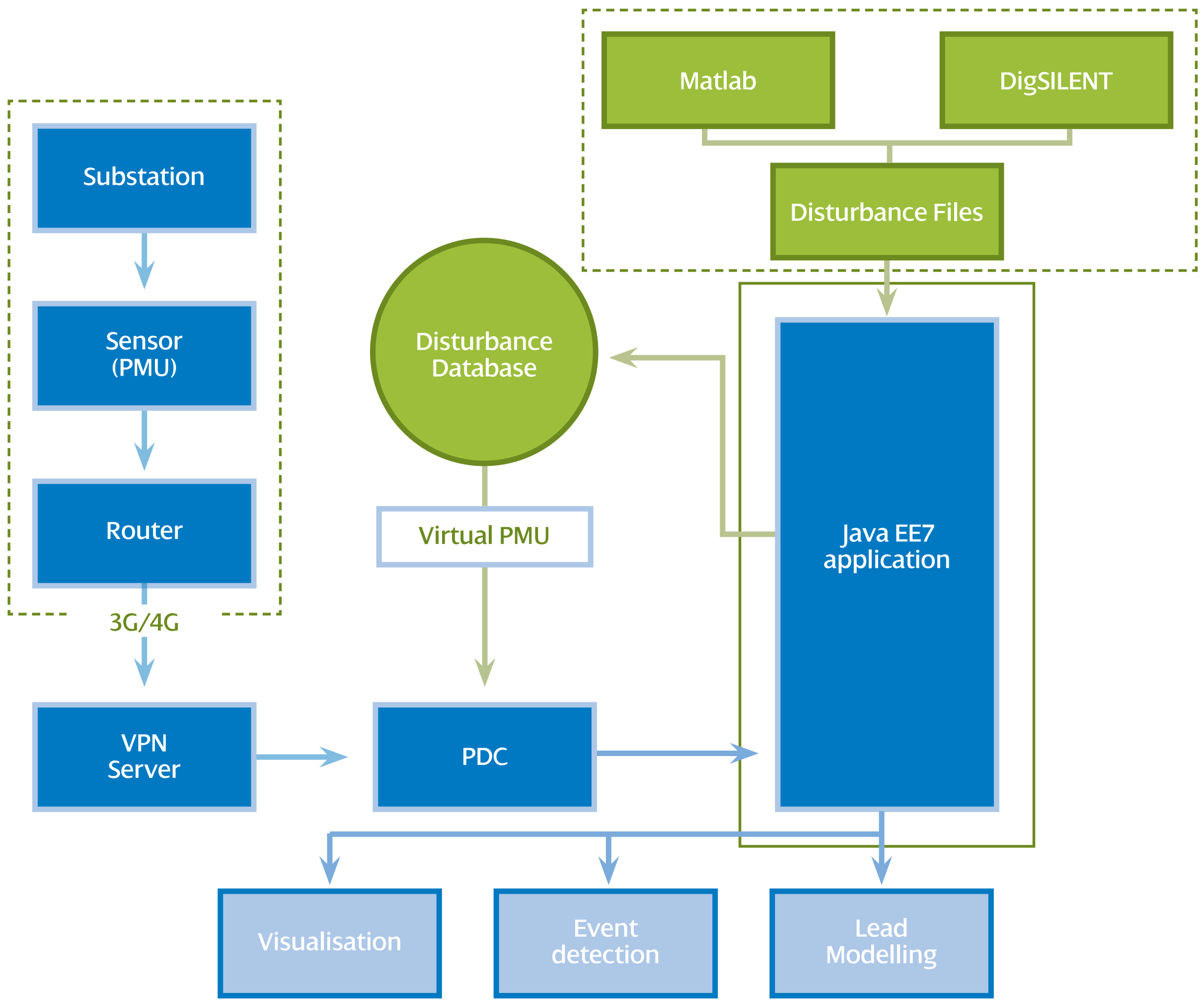


Figure 1 Optimal Platform Architecture

As it can be observed from the above Figure, the connection between PMUs and the PDC is established over a secure VPN connection (VPN Server in Figure above). Lots of work has been invested into the design of a secure VPN (note: this task has been successfully accomplished thanks to exceptional skills of the researchers involved in the project). This has been achieved using a proxy router. After the data reaches the PDC building block, connection with the Java EE7 application is established over fast access data buffers. The Java EE7 application runs the event detection algorithm on the phasor measurements received by the PDC. If a relevant disturbance (here a voltage drop) is detected, then the corresponding measurement samples are saved within a disturbance database, depicted as the green hexagonal block in Figure 1. Simultaneously and in a separate execution thread, the load model parameter estimation algorithm developed in Year 1 of the project is triggered, with the detected disturbance as its input. Two of the most important data channels within the Java EE7 application are represented by Matlab generated synthetic signals and dynamic power system simulations within DIgSILENT. It is expected that these two data sources will be extensively used during platform testing. As it can be observed, next to the visualisation application, two major applications, a) Event detection and b) Load Modelling, i.e. estimation of unknown load model parameters, are developed.

The above platform has been tested using data obtained using Real Time Digital Simulator (RTDS). The RTDS was used as a source of data obtained over PMUs. For this purpose, a high fidelity load modelling has been undertaken in RTDS (using RSCAD software package). The stability of the operation of the entire chain (RTDS, communication to the platform, event detection, estimation of unknown load model parameters) has been tested over a longer period. During this period the stability of the operation of the entire system has been significantly improved.

The platform is now ready for processing realistic data. The spectrum of its application goes beyond pure characterisation of load centres.

2.4 | NIA SPT 1601 – Power 2 Tower: Stage 1

There are many requirements for monitoring along the length of, or at specific points on, overhead lines – examples include dynamic line rating, partial discharge measurement on tower based cable sealing ends and fault location. However, the provision of 230 Vac single phase supplies to individual towers to power the monitoring equipment is problematic and unlikely to yield economically viable solutions.

This collaboration with Elimpus is the first of a proposed three stage development of a monitoring system that can be used along the length of a transmission line, comprising of tower-mounted, wirelessly communicating monitoring platforms which are powered by energy harvesting from the immediate environs of the transmission tower.

The monitoring system solution would be such that measurements made from one tower can be wirelessly transmitted to the next tower and so on until the data reaches an access point, such as a substation or a fibre optic cable joint. Hence, the tower-mounted hardware (TMH) units will have three functions:

1. Power management
2. Local monitoring
3. Store and forward node for adjacent TMH units comprising the system.

This project is based on the following design assumptions:

- The tower mounted hardware will be non-invasive, not requiring any outage for installation.
- The TMH unit will be bolted to the tower steel-work and will be lightweight to facilitate rapid deployment.
- The TMH design will be based on commercially available, power-efficient components that will be designed for operation under all weather conditions commonly encountered on OHL routes.
- TMH unit design life-expectancy > 10 years.
- No periodic maintenance of the TMH units will be required.
- The data output of the monitoring system will be compatible with SP's business systems.

2.4.1 | NIA SPT 1601 Project Progress

Aeolian vibration: a prototype rig has been developed using piezoelectric harvesting devices attached to a variable frequency, mechanically oscillated arm. Tests are being conducted to establish the likely energy yield in advance of developing a tower mounted prototype.

Earth wire current: The large dynamic range of the current presents a challenge to develop a harvesting device that can withstand fault current, yet efficiently harvest from the lower level of current present under steady-state conditions. Hardware to monitor the earth wire current over a period of several weeks has been developed and is awaiting installation.

Electric field: guided by advice from the overhead line team, the original design of this device has been changed to allow installation under energised line conditions. The new design allows a simpler installation method and is awaiting trial.

2.5 | NIA SPT 1603 – Trialling Long-Lasting Tower Paints

SP Energy Networks's transmission towers require to be painted on an on-going basis to protect the steelwork from adverse environmental impact. For non-corroded steelwork, a two coat paint system or, on occasion, a single coat paint system is applied. The current policy of once every 12 years is based on known paint technology at the time of implementing the policy. The formulation being used has been essentially fixed for a good number of years and there are now a range of coatings available which purport to be able to provide 25 years or more of protection.

Before these could be applied or any potential change to coating practice made, it is necessary to evaluate their performance against the needs of the industry and with relevance to the surface preparation achievable in practice and typical application environment.

It is recognised that significant financial and system access benefits could be realised through the modification of the current policy to longer painting cycles based upon the application of a more enduring paint treatment and consequently SP Energy Networks is seeking longer-life alternatives.

This project will test a range of candidate coating systems to identify which are suitable for application to UK electricity pylons, what the repainting interval should be for these new coatings and what the relative cost of adoption would be.

An evaluation report will rate the performance of each coating system as regards the practical and laboratory tests carried out. It will assess the costs of each coating system relative to the control (present-specification coating) by conducting a life-cycle assessment and rate each coating on metrics to include ease of application. Finally, it will recommend the coating system best meeting the requirements and whether any additional work is necessary before wide-scale adoption.

2.5.1 | NIA SPT 1601 Project Progress

This project has now been completed and a project close down report will be made available on the ENA Learning Portal.

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

SP Transmission Limited (SPT) have 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 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, SPT aspires to identify measures to improve overall business carbon footprint where appropriate. SPT 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.

2.6.1 | NIA SPT 1604 Project Progress

One circuit of 400kV GIB has been installed with g3 gas as a green replacement for SF6. This has reduced the total amount of SF6 gas used at site by 1.4 tonnes which has been replaced by 625 kg g3 (g3 is a lighter gas than SF6). During the 40 years in service at Kilmarnock South Substation, the use of g3 rather than SF6 will reduce the CO2 equivalent emissions due to the leakage of gas (at rates less than allowed by the design) by an estimated 38,110 tonnes. This is equivalent to taking 8,161 cars off the road for one year.

2.7 | NIA SPT 1605 Cable Diagnostics for HVDC Cables

The application of HVDC cables over long distances is on the increase and it is becoming clear that the ageing characteristics of the insulation in such cables are not well understood. As this is a project to obtain better understanding, the method is one of understanding what is currently known about the ageing characteristics and then to consider what else needs to be done to address the knowledge gap.

From the gaps in the knowledge identified through the review, a systematic and logical experimental work plan will be developed to understand partial discharges in HVDC cable systems. The work plan will be based on laboratory experimentation as well as computer simulation (where appropriate) to allow a better understanding of how partial discharges are generated in a HVDC cable system and the mechanism responsible.

The new knowledge generated from this research will inform subsequent innovation activities that are expected to lead to improved asset management techniques with benefits including the following: -

- Asset replacement before failure.
- Reduced number of faults.
- Targeted investment on cables that are in greatest need of replacement.

2.7.1 | NIA SPT 1605 Project Progress

A second year progress review of the project was conducted by the Department of Electronic & Electrical Engineering University of Strathclyde and all reviewers were satisfied with the project progress. Following the review, the second-year report was submitted to SP Energy Networks in satisfaction of the condition of funding.

The literature review showed that nanodielectric materials (when used in cable insulation) indicated a superior performance over XLPE by exhibiting a higher operating temperature, a better space charge suppression and an environmentally friendly property. The research is now re-focused on the nanoparticles doped polymer insulation materials for potential use in HVDC cables rather than nanoparticle-doped field grading materials.

To meet the demands, nano-Al2O3 /LDPE and nano-Al2O3/ PP were chosen to be investigated as candidate material and their results obtained would be compared with existing HVDC cable insulation material. A few nano-Al2O3/ LDPE thin film samples were produced in the Chemistry Department at University of Strathclyde. However, the quality of samples produced was not good enough due to limited experience and lack of proper equipment.

To solve these problems, a 3-month academic visit to Tsinghua University, Beijing, China was scheduled to manufacture nano-Al2O3/ LDPE and nano-Al2O3/ PP thin film samples and to conduct PEA measurements for thin film samples. Both unmodified and surface-modified nano-Al2O3 will be made with varying contents, i.e. 0 wt%, 0.5 wt%, 1 wt%, 3 wt% and 5 wt%. For each formula, 20-30 samples are expected for the subdequent electrical and chemical tests such as DC breakdown test, DC conductivity test and DSC analysis.

In addition, space charge behaviour of the prepared samples will also be studied in Tsinghua University as space charge retention is one of the most important characteristics of DC insulation material to be overcome. DC breakdown and DC conductivity measurement are expected to be done within six months after visiting.

2.8 | NIA SPT 1606 Reuse of Existing Concrete Assets

There is a very large asset base of concrete structures within ScottishPower that are approaching or have potentially reached the end of their service life. Current practice within ScottishPower is to demolish these concrete structures and replace them with new steel structures.

It has been identified that alternative methods are available that can possibly extend the lifespan of the existing structures. Where it is identified within the concept design that certain existing structures can be reused then ScottishPower want to investigate the viability of this. To realise the potential benefit of this, ScottishPower wants to review current practice and identify a methodology that is more sustainable, requires less outage time to construct and is more economical.

The aim of this project is to create an assessment process and specification to determine whether these existing concrete assets are suitable for reuse. This project will develop a methodology to determine the assessment criteria, reuse, strengthening and repair process. The methodology will then be used to implement the recommendations from the design assessment which will be collated through the design reporting stage.

This will allow recommendations to be implemented within each asset replacement programme to allow existing concrete assets to be re-furbished as appropriate. It is anticipated that this approach will allow ScottishPower and the wider industry to achieve cost and time savings on major construction projects which in turn will provide increased network resilience by reducing outage requirements. The reuse of these structures will also support ScottishPower's sustainable development policy.

2.8.1 | NIA SPT 1606 Project Progress

The methodology created as part of this NIA project was applied to three substations, Westfield 275kV, Gateacre 132kV & Colwyn Bay 132kV. At each site a single bay was tested. These tests included carbonation testing were the depth of carbonation is determined by an area of freshly broken concrete surface of which phenolphthalein indicator is then applied. The solution remains clear on contact with carbonated concrete but turns pink on contact with un-carbonated concrete.

The second test carried out was to determine Chloride Ion content. Testing for chlorides is carried out by drilling into the structure to collect dust samples. Between 2-5 dust samples are taken at incremental depths to evaluate the depth variation in chloride concentration. The samples are then bagged and sent to a laboratory for testing to determine the chloride ion content.

The third test was a cover-meter survey to measure the depth of concrete cover to the steel reinforcement. For substation structures, the survey is carried out on one face of each column from ground level up to a reasonable height. The steel reinforcement within the concrete can be mapped onto the surface of the structure and recorded by camera to be assessed against the relevant drawings. This information is particularly useful to determine degradation rates due to carbonation.

The final test carried out was the Schmidt rebound hammer test. The Schmidt hammer is used as a means of estimating the hardness of the surface layer of concrete by measuring the energy absorbed when a spring-loaded plunger is fired at the concrete surface. The resultant numerical hammer readings provide an indication of surface concrete quality and can be used to provide an approximate correlation with concrete strength. A group of readings, arranged in a grid, should be taken on different faces of the structure with a mean value taken from the readings.

The results of the testing reports fed into the structural analysis stage to determine if or any reduction factors would be applied to each structure being analysed.

A full structural assessment has been carried out for the line landing gantry at Westfield 275kV, the strained gantry at Gateacre 132kV and the disconnector structure (JW8) at Colwyn Bay 132kV substations. The assessments were carried out in accordance with the processes set out in the NGTS and Eurocodes.

With the structural analysis completed, draft structural reports have been issued for comment. Once complete the final reporting on the project can begin.

2.9 | NIA SPT 1607 Non-Intrusive Assessment Techniques for Tower Foundations

The tower structures that make up the transmission overhead line network can be extended with good maintenance and strategic replacement of steelwork. While it is easy to observe and identify the corrosion level of the steelwork on a lattice tower evaluating the condition of the steelwork and concrete where buried is very difficult.

The current approach for evaluating the condition of existing tower foundations involves excavating around the foundations so they can be visually inspected. This excavation increases the complexity, cost and environmental impact of the inspection. The foundations are subject to targeted assessment during, or before major works; every tension and angle tower is assessed as well as a sample 20% of suSP Energy Networkssion tower foundations. Due to the intensive labour and time effort involved, it is normal practice to intrusively inspect only a sample of towers.

This project will measure the suitability and performance of two non-intrusive approaches, vibration and ground penetrating radar, both separately and in combination in determining the condition of buried tower structures.

The scope of this project is to undertake laboratory tests and practical trial applications on a sample of transmission towers to provide validation and quantification of the potential benefits of the techniques under consideration.

2.9.1 | NIA SPT 1607 Project Progress

This project has now finished and both ground penetrating radar (GPR) and vibration measurements were confounded by uncontrolled and uncontrollable variables. A more controlled experiment would minimise these variables. The aspiration to measure unknown geometry of underground foundations was considered overly ambitious.

A less ambitious series of measurements on foundations of known geometry has the potential to identify features to be matched with known foundation geometry. As the survey progressed, it emerged that none of the foundations surveyed had significant damage. Surveys of a foundation with significant damage would allow for reliable correlation.

2.10 | 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, battery charging or dehumidifying) to ensure network resilience and ensure the 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 substation energy efficiency.

2.10.1 | NIA SPT 1608 Project Progress

We have installed energy and environmental monitoring equipment in the sample of the transmission substation identified for this project.

We have been monitoring heating and lighting energy consumption together with internal room temperatures along with humidity for twelve months now. The next stage is to analyse this data and make appropriate recommendations regarding energy efficiency improvements.

2.11 | 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.

2.11.1 | NIA SPT 1609 Project Progress

Discussions are on-going with the GB System Operator (SO) and Distribution Licensees regarding the project scope.

2.12 | NIA SPT 1610 Innovative Approach for Transmission Harmonic Issues

This is the second stage of a project looking at harmonic filters on the transmission network. This follows on from a feasibility study (NIA_SPT_1506) which looked at the optimisation of the location and size of harmonic filters across a section of the network in a coordinated manner. Harmonic Filtering has been previously looked after by individual developers, and this project will make a good contribution so that customers can made reduced investment to safeguard the quality and standards of electricity supply.

SP Energy Networks is currently developing an extensive network in South West Scotland for the connection of a number of windfarms. The harmonic performance of this network has to be evaluated with the aim of:

1. Developing a coordinated, efficient and cost-effective harmonic filtering solution.
2. Setting harmonic emission limits for each windfarm.
3. Substantially reducing the risk of harmonic non-compliance for both SP Energy Networks and windfarm developers.

The extensive use of cables in the transmission and windfarm networks indicates a risk of lower-order harmonic resonances in the network. It is expected that the high resulting voltage gain factors will dictate the installation of a number of harmonic filters, even if the background harmonics in the existing network are within acceptable limits and the harmonic emissions from the windfarms are low. An optimised harmonic filtering solution may require installation of filters on the transmission network and/or the windfarm connection points.

2.12.1 | NIA SPT 1610 Project Progress

The SP Energy Networks PowerFactory network model including the cable, transformers, overhead lines and lumped MV windfarm collector network models were analysed to ascertain the suitability for the harmonics studies to be carried out as part of the project. The proposed network to 2025/26 is very complex, so detailed optimization of the number and types of contingencies to be studied was carried out.

All the nodes in the network were assessed to optimize the most relevant 275 kV, 132 kV, 33 kV and 11 kV nodes to be monitored as part of the harmonics studies. Additionally, a verification process and high level analysis of the 275 kV background harmonics supplied by SP Energy Networks for use in the harmonics studies was carried out.

2.13 | NIA SPT 1701 Development of a Lone Working Device Incorporating Satellite Communications and Fault Detection

The main objectives of this project is the development of a system which will allow emergency calls to be made when mobile phone service is unavailable, and will have the functionality to place an emergency call when a fall is detected.

This project will have two main work packages:

1. System Development

The system will be developed, and the system will be integrated into the viewing platform software.

2. Testing and demonstration

The system will be tested in a controlled environment, and will be debugged and certified. This will allow a fully-functioning demonstration system to be delivered for field testing and training.

2.13.1 | NIA SPT 1701 Project Progress

This project has not made any progress due to issues which arose in the contract stage, resulting in no collaboration agreement being signed. As a result, no work has been carried out on this project to date.

3 | Collaborative NIA Projects Led By Other Transmission Companies

3.1 | NGET 0088 Transformer Research Consortium

This project was started in April 2013 and is scheduled to last four and a half years. This research project being undertaken by the University of Manchester builds on initial work undertaken assessing ester based alternatives to conventional insulating oil and seeks to enhance understanding of transformer health and the key variables that can lead to premature failure. The research focuses on ageing indicators, partial discharge diagnostic, dissolved gas and thermal analysis.

While this project is being undertaken at laboratory scale consideration is being given to system application issues. The outcome of this project is expected to inform asset management policies with the aim of optimising operational and capital expenditure.

It is believed that the work packages will provide outcomes that can realistically be deployed in short to medium term timescales that will allow SP Energy Networks asset managers to benefit from new test methods and data collection techniques that will directly contribute towards the transformer asset decision making. This development of transformer specifications that include online monitoring and condition data collection techniques that reduce maintenance costs and provide more accurate condition assessment information.

The ongoing research into alternative fluids should give the required confidence for the deployment of these fluids at higher voltage levels. This will provide network operators with a solution that has environmental and fire safety attributes that traditional mineral oil does not have.

3.1.1 | NIA NGET0088 Project Progress

This project has been registered as a joint project by National Grid (NIA_NGET0088), and therefore they will provide a progress summary in their NIA Annual Report 17/18 consequently; no project progress has been included in this report. However, we, as an active partner of the project, will outline our New Learning for this project under Section 5.

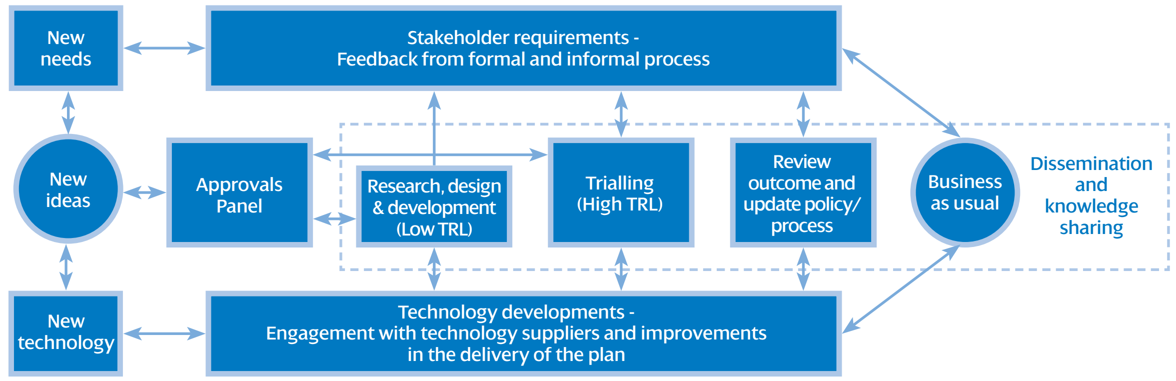
4 | NIA Activities Linked to SPT Innovation Strategy

It is recognised that innovation cannot be a prescribed by rigid process but must stimulate creativity and new ideas. However, to ensure good governance, SPT has applied an over-arching framework to ensure that it is managed efficiently and delivers the benefits without constraining creativity.

The five innovation objectives within SPT are:

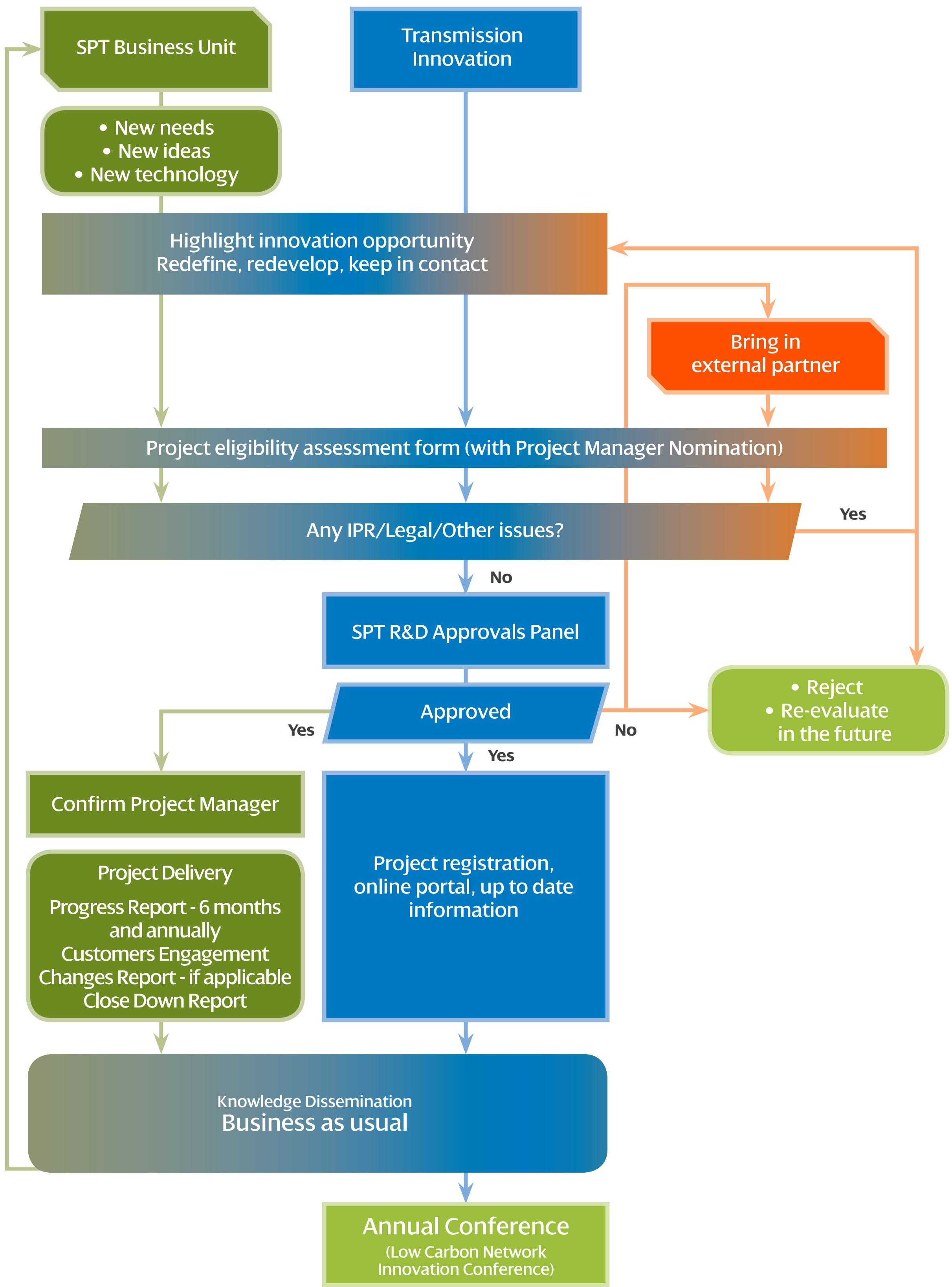
1. Innovation meeting the needs of stakeholders;
2. Innovation opportunities are identified in a timely manner, which will benefit these stakeholders;
3. Innovation is managed in an efficient and proactive manner;
4. A balanced portfolio of innovation is pursed which includes commercial, process and technology innovation. Our activity has a relevant focus on developments at different technology and commercial readiness levels which balances radical with incremental innovation; and
5. 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.

Figure 2 below outlines the general R&D management structure within SPT.



As part of our long term innovation strategy, stakeholder engagement will be central to ensuring that our innovation plans are meeting customer's expectations. The involvement of stakeholders is also a vital source of ideas for innovation – particularly the academic community, equipment suppliers and other network operators (DNOs and TOs).

Figure 3 illustrates the NIA development process at SPT.



Our approach to innovation development is summarised in Figure 4 below which contains five steps:

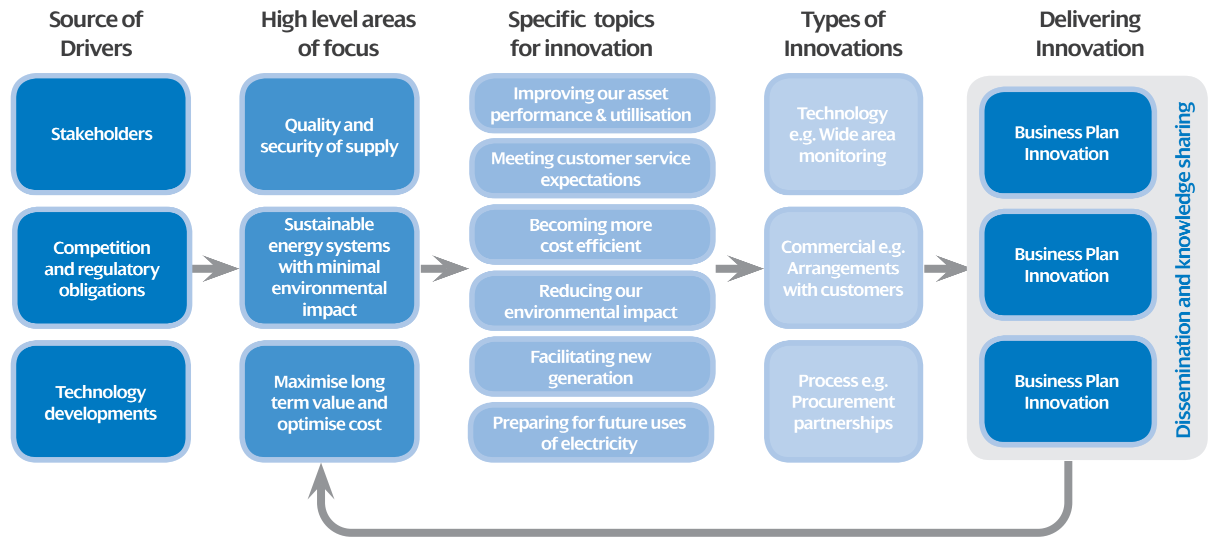


Figure 4 SPT Approach to Innovation Development

In order to realise our future network vision we have identified the following five dimensions that require to be addressed:

1. **Visibility:** The combination of monitoring devices, computing process and communications infrastructure provides an effective means to present the real time information for wide area monitoring. This visibility can cover almost all the aspects regarding transmission network performance, ranging from steady state thermal limitation of critical boundaries to sub-synchronous oscillation behaviour in the local area. This visibility provides a new dimension and reference for system operation and protection.

2. **Controllability:** The visibility of transmission network at the GB level requires review of some control algorithms which had been designed based on a centralised approach. Smart grid control involves many more controlled elements than in the conventional design, together with greater uncertainty in generation. The increasing complexity requires new approaches to observing, modelling and controlling the interactions between generation, transmission, distribution, and load. How to react to the information available requires a defined and coordinated approach to ensure that the existing supply quality and reliability standards are not compromised, and that customers can realise maximum benefit from the latest technology.

3. **Intelligence:** As a result of the improved visibility and control of the network, active management of generation output around network constraints will improve the time required to connect new demand and generation. Wide area monitoring combined with real time asset ratings, will ensure that maximum capacity is utilised before reinforcement is required. Processing of network data will also inform designers of when reinforcement is required and inform the deployment of appropriate, cost effective, solutions.

4. **Interoperability:** The variety of new technologies deployed on the network will require to be interoperable such that new solutions can be readily integrated, for example through the application of technology standards such as IEC61850. We will work with the wider industry nationally and internationally to develop open-access standards. Reliable and secure communication systems will also be required to transfer data across the network combined with IT systems that can effectively manage the new data that is generated. This will require a significant extension of our communications systems using internal and external services to achieve the necessary coverage.

5. **Commercial Mechanisms:** Our network will be reliant on commercial arrangements with network users as there are close linkages with many of the technology solutions.

To achieve these five dimensions, we consider three different ways in which we invest in the network. These investments can be described as follows:

Enablers: This includes smart-ready asset replacement and other investments which create a robust foundation and enabler for the smart grid applications. These are considered as "no regrets" investments which can be deployed in a top-down manner and are an essential component of the network. Having the enabling technology in place will allow us to flex between different future scenarios. Typical enablers are Remote Terminal Units for SCADA with expansion capability and the installation of additional network monitoring.

Applications: This is the implementation of a solution which has an immediate application to directly address an output within RIIO-T1 such as meeting load growth, facilitating new customer connections or improving quality of service. Where we have proposed a smart application, a cost benefit analysis (CBA) will be undertaken as in most cases a comparison with a traditional solution can be made. Typical applications are real time thermal ratings, intelligent voltage control or active network management.

Future Proofing: Where a positive business case exists, we will identify where additional enabling technologies are considered to be of long term benefit to customers, although not necessarily required in the short term. This category is also regarded as top-down investment as it is required to further enable other applications in the longer term. Future proofing investments are also subject to a CBA to ensure that they are efficient investments for the customer. Typical future proofing includes oversizing conductors for future load requirements and switchgear being pre-wired for sensors and automation.

The variety of new technology and commercial arrangements deployed on the network are vital to meeting the future requirements of our customers in a responsive and cost-effective way. However, it will be through the effective management and stewardship of the existing asset base that we will ensure value for money and that a sustainable network solution is delivered.

4.1 | SPT NIA Project Mapping with Innovation Strategy

Network Investment			Figure 5 NIA Projects Mapped to SPT Innovation Strategy	Specific Dimension				
Enabler	Application	Future Proofing		Visibility	Controllability	Intelligence	Interoperability	Commercial Mechanism
✓		✓	NIA 1504: Managing Uncertainty in Future Load related Investment		✓	✓		
✓	✓		NIA 1505: Trial of Open Innovation in Utilities					✓
✓	✓	✓	NIA 1507: Modelling of Static and Dynamic Loads	✓	✓	✓	✓	
✓	✓		NIA 1601: Power 2: Tower Stage 1					
	✓		NIA 1603: Trialling Long-Lasting Tower Paints					
	✓	✓	NIA SPT 1604: Introduction of Environmentally Friendly Alternatives to SF6					
	✓	✓	NIA SPT 1605: Cable diagnostics for HVDC cables	✓	✓	✓		
	✓	✓	NIA SPT 1606: Reuse of existing concrete assets					
	✓	✓	NIA SPT 1607: Non-Intrusive Assesment Techniques for Tower Foundations	✓				
	✓		NIA SPT 1608: Reducing Energy Losses from Transmission Substations	✓	✓			✓
✓	✓	✓	NIA SPT 1609: The Planning Data Exchange System Between Network Licensees to Enable a Smarter Grid	✓	✓	✓	✓	
✓	✓	✓	NIA SPT 1610: Innovative Approach for Transmission Harmonic Issues	✓	✓	✓	✓	
			NIA SPT 1701: Development of a Lone Working Device Incorporating Satellite Communications and Fault Detection	✓	✓			
✓	✓	✓	NIA NGET0088: Transformer Research Consortium	✓	✓	✓		

5 | Areas of Significant New Learning

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

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

Statistical representations of time-varying LCT behaviour which decompose the complex overall behaviour into models addressing different timescales have found to be satisfactory in describing both within-day behaviour for simulation of network operation (and smartgrid interventions) and seasonal trends. Additionally, preprocessing of historically-based statistical models has been found effective in generating fast-to-sample models of LCT types (such as EV clusters) which display diversity effects.

Some learning has been produced on the relative economic value of traditional and novel interventions to provide additional network headroom: further work is ongoing to understand the relationship between the amount of headroom required, the cause of the shortfall (e.g. load and generation types) and the economic characteristics of possible investment and operational actions.

5.2 | Project Learning: NIA 1505 Trial of Open Innovation in Utilities Sector

The internal Hatch-A-Challenge process steps and the internal infographic for information gathering has been refined to reflect the learning arising.

There is a need to understand the use of internal communication tools, and improve their use. Our internal Yammer posts have kept the wider audience updated on the progress to date, sharing the experience but also identifying potential Open Innovation champions.

Share learning has been realised through internal knowledge dissemination events for the employees of the company. These have included Learning Lunch Sessions.

5.3 | Project Learning: NIA 1507 Modelling of Static and Dynamic Loads

Key learning points are provided below:

- Different architecture for collection of PMU data can be used. The proposed architecture, called "flexible data acquisition and processing platform" offers a broad range of opportunities and through its flexible design options for using both real-time PMU data streams from actual substations, as well as from Matlab/DiGSILENT environment, through dynamic simulation of a power system
- The well-known OpenPDC, used world-wide as a Phasor Data Concentrator, has limitations which do not allow it to be used for real-time data visualization, posing a need for its modification.
- A new OpenPDC, obtained through modifications of its functionality enables real-time data visualization and creation of new Wide Area Monitoring, Protection and Control (WAMPAC) applications.
- Integration of data obtained from OpenPDC through a real-time platform compatible to the Java EE7 enterprise standards offers a full flexibility and easy integration of WAMPAC applications.
- Developed applications a) Event detection and b) Estimation of unknown load model parameters integrated into the platform perform as expected using Matlab obtained signals.
- The platform has been thoroughly tested using data obtained from Real Time Digital Simulator, which also offers functionality of Phasor Measurement Units (so called virtual PMUs). During the testing period the stability of operation of the platform has been significantly improved.
- A need for creation of communication channels to real-time operated PMUs installed in actual substations will open new opportunities and mechanisms for obtaining the information about behavior of load centers in SP Energy Networks.
- It was concluded that the platform developed could be used for other power system applications based on the Smart Grid paradigm. (usage of smart sensors, ICT and novel algorithms for power system monitoring, protection and control.

5.4 | Project Learning: NIA SPT 1601 Power 2 Tower: Stage 1

The project has benefitted from a greater understanding of the practicalities of installing prototype hardware devices on the OHL towers. However, results from field trials are required before major learning points with respect to the harvesting devices can be reported.

5.5 | Project Learning: NIA SPT 1603 Trialling Long-Lasting Tower Paints

The project has now been completed and the following recommendations have been made:

R1. Further development of the wet-blast process to improve efficiencies and practicality of application to OHL structures, and to substitute conventional algaewash/wire-brush preparation treatment; thus, improve the adhesion of the coatings applied, extending service longevity, and reduce overall maintenance costs.

R2. Perform further laboratory and field trials to quantify any enhanced performance of the 'control' coating when applied to wet-blasted substrates, and the associated potential cost-saving benefits. Testing could comprise:

(1) Further Prohesion test assessment of the Q-panels coated with the ZInga-, the 'control'-, and the SP Energy Networkscer Coatings' 3-coat urethane alkyd systems for an extended period to assess their long-term comparable performance.

(2) Perform 4500h Prohesion test of sweep-blast prepared Q-panels coated in the 'control' coating system, to determine whether substrate protection is extended, and compare against the Stage 2 panels ('control' and Zinga) tested within this project. Enhanced protection by 'sweep-blast'-prepared 'control'-coated substrates could potentially further extend maintenance periods and provide lifetime cost savings.

(3) Long-term monitoring of the Zinga-coated trial towers (A49, A50) to determine re-coating maintenance interval, enable calculation of Zinga coating 'life-time costs', and assess longevity of protection comparable to HDG towers coated with the 'control' coating during the same trial period and located in similar environment.

(4) Wet-blast preparation of multiple HDG- and legacy-coated towers, with immediate application of the 'control' coating to quantify associated costs and assess long-term protection comparable to towers coated with the Zinga- and 'control' system during this project.

R3. Research the historical performance of OHL towers, owned by international DNOs, purported to have been coated with Zinga during recent years, to gain perspective of potential service-life performance of the coating in the UK.

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

The project at Kilmarnock South 400kV has allowed SP Energy Networks to understand the practical challenges of using alternative gases in a GIS installation. This has included:

- SP Energy Networks working closely with GE has established that the existing Personal Protective Equipment used when handing SF6 is adequate for use when handling the new g3 gas.
- ScottishPower Safety Rules applicable to working in compartments filled with SF6 have been updated to include precautions for working with g3 gas.
- Portable g3 gas sensors and leak detectors have been developed by GE in conjunction with manufactures of this equipment.
- On-line continuous SF6 gas monitoring systems have been modified to allow compartments with g3 gas to be monitored also. A complete system for monitoring the leakage of gas in all SF6 and g3 compartments has been installed and is currently being commissioned.
- Different filling devices and appropriate labelling have been utilised to clearly identify g3 sections compared to SF6 to ensure against accidental filling using the wrong gas.

5.7 | Project Learning: NIA SPT 1605 Cable Diagnostics for HVDC Cables

The main objective of this project is to study the effects of nano-filler, filler content and surface modification on their microstructures and electrical performance. In addition, results will also reveal whether PP nanocomposite could be used as one of the potentially eco-friendly insulation materials for HVDC cable.

Although a considerable amount of literature is now available on the results of space charge measurements, the precise mechanisms of how space charge dynamics are affected by the nanophase regions in nanocomposites are still debated. So the space charge study of LDPE nanocomposite and PP nanocomposite are necessary to understand this.

Comparisons will be made between LDPE / nano-Al2O3 and PP / nano-Al2O3 samples and it will help to determine which kind of alumina nanocomposite is more suitable for HVDC insulation. The conclusions will be useful to design and assess recyclable HVDC cable insulation in the future.

Owing to the better intrinsic properties of PP relative to LDPE, it is hoped that PP based nanocomposite would be a more promising option for HVDC insulation material with higher operating temperature and less space charge accumulation.

5.8 | Project Learning: NIA SPT 1606 Reuse of Existing Concrete Assets

The learning from the project so far has been that data collection for historic sites is difficult due to a loss of quality in the data when it was converted to microfilm many years ago. The reduced quality of the drawings makes it difficult to see the overall dimensions and in particular the reinforcement details. Whilst collecting site data it has been found that quality of data has been varied with some sites providing better quality information than others.

With gaps in the information this increases the risk as assumptions may need to be made which could lead to wrong conclusions being drawn. To mitigate this risk a risk matrix has been introduced to account for gaps in on-site data which will provide a decision tree approach for a person to consider when deciding the approach to take.

There are a large number of testing methods available but through development of the methodology it has been found that a small standard suite of testing is better to be applied rather than specifying a large number of tests that will cost a lot of money. The more testing could actually be counterproductive as it could possibly skew the results. Therefore a standard testing suite is considered more appropriate with the addition of further testing to be included if considered to be necessary by the engineer or if results are inconclusive.

The majority of concrete structures tested were found to be in a reasonably good condition with only low levels of corrosion which would indicate that certain structures can be re-used with certain restrictions. Although, as expected some did exhibit severe signs of degradation which will make it difficult to re-use these structures.

It was found that the structural assessments demonstrated that the columns and beams of the structures assessed are underutilised and have sufficient capacity to withstand the loads acting on the structure under the Ultimate Limit State (ULS) combination. However the gantry structure assessments have shown a potential area of concern, of which directly appears as a failure under the strict criteria of the NGTS environmental loadings assessment process.

These results are driven by a change in the way ice is allowed for under the National Grid guidance which recently changed to utilise the Eurocode BS EN 1993-3-18. The Eurocode imposes a much larger ice thickness allowance on the conductors, compared to earlier versions of the NGTS limitation, which leads to the subsequent increase in deflections. To mitigate this it needs to be considered if a previous version can be utilised. A relaxation the of loading is available via NGTS 3.01.045 which allows for judgement to be made where experience exists in the management of the substation assets gained over approximately 50 years. This should be considered in light of the analysis results and a view taken on whether an alternative approach is necessary.

Structures that were previously considered end of life may now be re-used with only minor remedial works, although this will be considered against a scoring matrix that will consider the risk and whole life cost. There is still work to do to develop the scoring matrix that structures can be scored against which will allow a person to decide if a structure can be re-used. Work on this will continue over this period before the final reporting commences.

5.9 | Project Learning: NIA SPT 1607 Non-Intrusive Assessment Techniques for Tower Foundations

Prior to the commencement of surveys, research was undertaken to identify a suitable ground penetrating radar (GPR) device. A range of products are available on the market, each of which has its respective advantages and disadvantages. A suitable GPR for Non-Intrusive Assessment Techniques for Tower Foundations requires the following:

- Ability to penetrate depths of three to four meters
- As fine a resolution as possible to detect irregularities in foundations
- Rugged and able to be used on off-road and difficult terrain
- Weather resistant

Depending on the effectiveness of the methods demonstrated, further optional deliverables may be pursued including software and training to facilitate the use of the techniques by those without extensive knowledge of noise and vibration analysis experts.

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

From undertaking building studies initial indications are that, in some cases, heating levels are in excess of requirements. We did not, initially, consider humidity as part of our considerations however we have now added humidity measurement as this has an impact on electrical equipment integrity.

5.11 | 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.

5.12 | Project Learning: NIA SPT 1610 Innovative Approach for Transmission Harmonic Issues

An assessment was made on the impact of using lumped parameter models instead of more detailed windfarm MV collector networks. This involved some initial screening studies and comparisons between the frequency dependent impedance characteristics of both approaches to the MV model.

Some software script in Digsilent PowerFactory's proprietary language (dpl) was written to automatically run harmonics studies and simulations under various contingencies and system conditions. This software will be used as the basis for the main analysis in the project.

Following optimization of the contingencies in the 2025/2026 cases; the network elements that had the biggest impact on harmonic distortion on the network were identified, and the reasons why were studied and verified against expectations.

5.13 | Project Learning: NIA SPT 1701 Development of a Lone Working Device Incorporating Satellite Communications and Fault Detection

As a result of work issues with this project, there has been no learning generated at this stage.

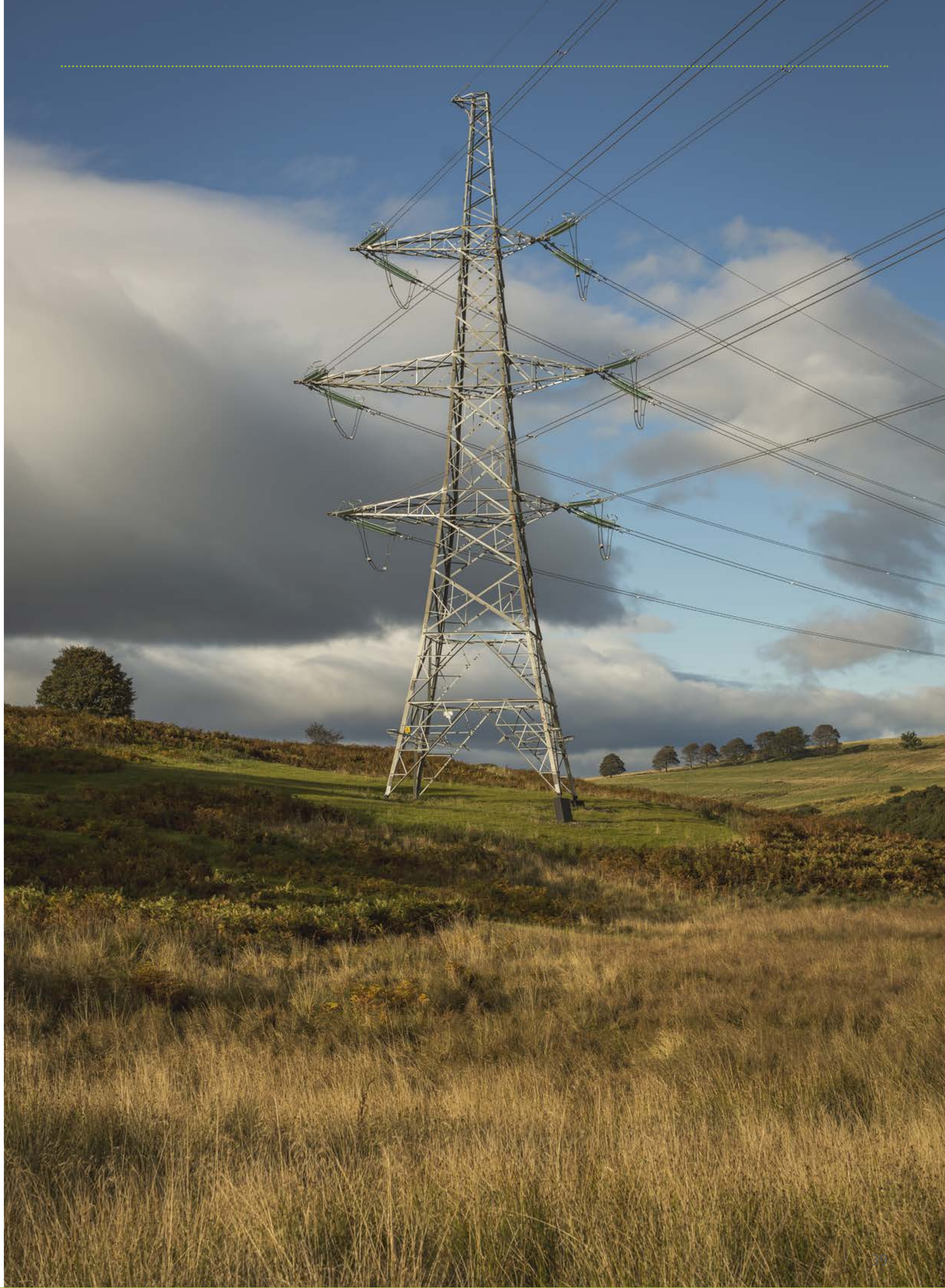
5.14 |Project Learning: NIA NGET 0088 Transformer Research Consortium

Phase 4 of the Transformer Research Consortium (TRC) project commenced on 1st April 2017. The consortium consists of Scottish Power, National Grid, SGB-SMIT, Weidmann, Shell, EPRI, M&I Materials, Cargill, TJ|H2B and The University of Manchester. The research scope of TRC-Phase 4 focuses on investigation of: condition assessment; asset management; thermal modelling; and discharge and breakdown mechanisms with aim to improve the efficiency and reliability of transformers in operation. The research work is split into five work packages (WP), with three WPs started in the first year and other two due to start in September 2018.

WP1 aims to provide recommendations on condition based transformer loading guide which does not exist in the current IEC standard loading guide. Initial results confirmed that the bubble inception failure criterion is dependent on the paper condition like moisture. Future tests will investigate the impact of various loading scenarios, e.g. short-term emergency loading, on the failure criterion for both new and aged insulations.

Although alternative liquids including esters and gas-to-liquid have increasingly been applied in transformers, there have not been maintenance guides available to manage these liquids in operation. WP2 has produced a prototype dual temperature test cell to mimic the oil paper insulation ageing of transformers in operation. Yearlong ageing experiments have been planned to investigate the conventional ageing indicators and to explore new ageing indicators for both mineral oils and alternative liquids.

Determination and optimisation of the winding hot-spot temperature is essential for managing the loading capability and thermal ageing of transformers. WP3 has been working on Computational Flow Dynamics (CFD) based thermal modelling. Critical geometric dimension parameters have been identified and impacts of manufacturing deviations have been assessed, which would help the transformer design review in future.



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