Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

NIA Project Registration and PEA Document

Date of Submission

May 2022

Project Reference Number

NIA_SHET_0036

Project Registration

Project Title

Condition Assessment of SF6 Alternatives (CASA)

Project Reference Number

NIA_SHET_0036

Project Licensee(s)

Scottish and Southern Electricity Networks Transmission

Project Start

May 2022

Project Duration

3 years and 8 months

Nominated Project Contact(s)

Tim Sammon – Innovation Programme Delivery Manager

Project Budget

£700,000.00

Summary

As part of Network for Net Zero strategy, SSEN transmission are migrating to alternative gases which have lower carbon footprint than sulphur hexafluoride (SF6) for Gas Insulated Systems (GIS) within the transmission network. However, there is industry wide knowledge gap in the key features related to condition monitoring of the alternative gases which may result in an inability to correctly manage future GIS that use the alternative gases. This research will provide full understanding of the condition monitoring requirements of the alternative gases to allow engineers to identify an incipient failure and carry out repairs, mitigating potential lost revenue or regulatory fines.

Nominated Contact Email Address(es)

transmissioninnovation@sse.com

Problem Being Solved

Gas insulated systems (GIS) currently use large volumes of pressurised sulphur hexafluoride (SF6) gas which has a high global warming potential (23,500 times that of CO2). As regulations regarding the use of this gas in our industry become stricter, it is necessary for alternative gases to be developed as a replacement for SF6 in GIS.

Catastrophic failure of high-value GIS equipment often starts with a small defect, usually introduced by a manufacturing error, which can lead to gas ionisation and rapid charge acceleration causing partial discharge (PD). Charge motion arises because of the stress of an applied electric field, which drives the breakdown process. The internationally accepted methods for measurement of PD are given in IEC Standards 60270 and 62478. PD produces a wide array of effects including optical emissions, chemical by-products of the gas mixtures, acoustic emissions, electromagnetic and electrical effects. Measuring these effects and correlating data with parameters such as AC-phase can reveal vital information on the type, severity and location of the defect allowing remedial action to be taken by network operators and preventing potentially catastrophic failures.

The physics of the discharge is inextricably linked to charge movement from gas ionisation. Measured signals, and therefore

diagnostic rules, are fundamentally linked to the type of gas in the system. Very little is understood about the factors and trends in PD data which best indicate the type, severity and location of defects in systems insulated by the new alternative environmentally friendly gas mixtures.

As outlined above, there is a knowledge gap in the key features related to condition monitoring of the alternative gases which may result in an inability to correctly manage future GIS that use the alternative gases. It is important to have a full understanding of the condition monitoring requirements of the alternative gases to allow engineers to identify an incipient failure and carry out repairs, mitigating potential lost revenue or regulatory fines.

Method(s)

The project will propose new steps in understanding the underlying physics of partial discharge in the alternative gases, for example, direct PD measurement, or simultaneous measurement using radio frequency and conventional techniques may yield vital information on the shape of the underlying current pulse which is otherwise unavailable using either technique separately.

Using a new technique developed by the University of Cardiff which allows true simultaneous measurement, where all PD data is captured from the source irrespective of the relative sensitivities of each measurement system, better characterisation of the PD properties of alternative gas mixtures will be possible.

Scope

To give effective diagnostic information concerning the severity of PD activity and the integrity of an insulation system, the project will establish the defects in alternative gas mixtures:
(1) Correlations between RF PD data, conventional PD data, and data from other systems such as optical and acoustic.
(2) Establish characteristic PD patterns for the appropriate alternative gases that are most sensitive to the type, severity and location of the defect.
(3) Establish characteristic PD features which may be extracted in the absence of a phase-reference.

The principal objectives will be as follows:
• Commission an experimental test setup that will allow the study of PD events for a variety of discharge sources and geometries such as sharp protrusions, voids, free metallic particles, surface discharges and floating components in a full-scale system.
• Characterise phase-resolved partial discharge patterns for various alternative gas mixtures across a range of defect topologies, identifying features that reveal defect type, severity and location. Develop and test a new system for ‘true simultaneous measurement’ of RF and conventional PD signals, analysing phase-resolved data, individual pulse characteristics, and directly measured current pulses.

• Validate findings and enhance understanding of PD physics in alternative gases through on-site measurements and PD monitoring data from online UHF sensors and gas samples. Comparison with lab data will establish correlation and variations that are key to characterising the defect.
• Explore recommendations for extension to the IEC60270 and IEC62478 measurement standards. The outcomes will widen applicability of the standards and the quality of diagnostic information available to power network equipment operators in the future.

Any developments which can facilitate the use of SF6 alternatives produces a net environmental benefit to consumers through the reduction of SF6 use in GIS.

Objective(s)

By understanding the characterisation of the Partial Discharge properties of alternative gas mixtures giving greater confidence to network operators when assessing the integrity of online GIS.
The strategies proposed will provide key insights into the type and severity of defect(s) in these systems resulting in a greater chance of detecting defects earlier and therefore intervening in a planned way when the implications are less severe. Knowledge acquired over the course of the investigation will contribute to advancing industry and international measurement standards, while providing vital diagnostic data to network operators.
The reduction in use of SF6 assists in meeting our T2 business plan objective of reducing our greenhouse gas emissions by 1/3, as well as being consistent with government net-zero emissions targets.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

The knowledge gained from this research project will help reduce the equipment failure and support preventative maintenance, thereby reducing network vulnerability and unplanned power outages which can negatively affect all consumers including those that are vulnerable.

Justification for undertaking the innovation project is based on supporting net zero and energy system transition.

Success Criteria

The project will be deemed as successful if all items in the scope, objectives and learnings are achieved and this will contribute to advancing industry and international measurement standards.

Project Partners and External Funding

The project will be undertaken using NIA funding by Scottish Hydro Electric Transmission supported by university partner – Cardiff University.

Potential for New Learning

The outcomes will widen applicability of the standards (IEC60270 and IEC62478 measurement standards) and the quality of diagnostic information available to power network equipment operators in the future. There will be knowledge gained in terms of key features related to condition monitoring of alternative gases GIS within electrical substations.
Learnings from the project will be disseminated via internal and external stakeholder event which will be conducted during the project. The learnings will also be shared within the annual project report and at relevant dissemination events such as the Energy Networks Innovation Conference. Other Transmission Owners, as users of SF6 alternatives will be invited to provide input during initial work scope creation and milestone reviews to ensure the maximum benefits from the research.

Scale of Project

This project is designed to get maximum learning for minimal cost. Currently very little is understood about the factors and trends in partial discharge data which best indicates the type, severity and location of defects in systems insulated by the new alternative environmentally friendly gas mixtures. Therefore, a new technique needs to be developed that provides better characterisation of the partial discharge properties of alternative gas mixtures. A project at smaller scale would limit the ability to fully understand the condition monitoring requirements of alternative gases in substation plant equipment.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL4 Bench Scale Research

Geographical Area

The project will be undertaken in the Scottish Hydro Electric Transmission licence area in Scotland. This research project is performed in collaboration with Cardiff University, Wales where the investigation will be conducted.

Revenue Allowed for the RIIO Settlement

No allowance has been made for this type of development within the RIIO-T2 settlement. No savings are expected during project implementation; future savings may be possible depending on the outcomes of the project and future adoption of the learnings.

Indicative Total NIA Project Expenditure

The total expenditure expected from the project is £700,000. 90% of which £630,000 is allowable NIA expenditure.

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

To enable a safe and reliable transition to the use of eco-friendly alternatives to SF6, it is imperative that the new gases are fully validated and their use within our equipment understood. Without a full understanding of the PD characteristics of the alternative gases, the industry is taking a greater risk during operation as early failure detection will be less achievable. Although operators, in some cases, have accepted this risk, the lack of understanding in this area may inhibit others from installing SF6 alternatives and slowing progress towards the energy system transition.

How the Project has potential to benefit consumer in vulnerable situations:

N/A

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

N/A

Please provide a calculation of the expected benefits the Solution

This is an investigative research project.

Please provide an estimate of how replicable the Method is across GB

The learnings are of interest is not limited to Scottish Hydro Electric Transmission, all transmission and distribution network operators across GB will benefit from this research work. Moreover, the recommendations will support extension of IEC60270 and IEC62478 international measurement standards and advancing the whole industry.

Please provide an outline of the costs of rolling out the Method across GB.

This research project is at low TRL level, consequently the costs for rolling out the method across GB network will be established as the project progresses.

Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

☐ A specific piece of new (i.e. unproven in GB, or where a method has been trialled outside GB the Network Licensee must justify repeating it as part of a project) equipment (including control and communications system software).

☐ A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)

☐ A specific novel operational practice directly related to the operation of the Network Licensees system

☐ A specific novel commercial arrangement

RIIO-2 Projects

☐ A specific piece of new equipment (including monitoring, control and communications systems and software)

☐ A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven

☑ A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)

☐ A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology

☑ A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution

☐ A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

The strategies proposed will provide key insights into the type and severity of defect(s) in the Gas Insulated systems using alternative gases resulting in a greater chance of detecting defects earlier and therefore intervening in a planned way when the implications are less severe. Knowledge acquired over the course of the investigation will contribute to advancing industry and international measurement standards (IEC standard 62748 and Section 11 of IEC standard 60270), while providing vital diagnostic data to network operators.

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

n/a

Is the default IPR position being applied?

☑ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

To date, no other projects have been undertaken to research condition assessment of SF6 alternatives. Other GB TOs have been involved in developing the scope of work and problem statement, so it is unlikely to lead to duplication of any other project.

If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

N/A

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

Very little is understood about the factors and trends in partial discharge data which best indicate the type, severity and location of defects in systems insulated by the new alternative gas mixtures. This presents a risk that the proposed techniques may not provide sufficient information on the shape of the underlying current pulse and that the methodologies may not provide better characterisation of the partial discharge properties of alternative gas mixtures. These factors combined present the innovative nature of the research required.

Relevant Foreground IPR

Any new intellectual property which are completed as part of the NIA project will be made available to other relevant networks licensees. No background IPR is required.

Data Access Details

See Network Innovation Competition (NIC) and Network Innovation Allowance (NIA) Data Sharing Procedure at https://www.ssen.co.uk/InnovationLibrary/Distribution/

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

NIA has been deemed the best method of supporting the delivery of this project. Development projects funded by NIA give suitable financial support to investigate areas for potential development that could not be funded by BAU as no allowance was made in the RIIO-T2 settlement.

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project

This project can only be undertaken with the support of NIA due to the overall costs and timescales required. There is significant research work that will be undertaken which has inherent risk involved with it. Moreover, the benefits from the project can be applied to all future GIS infrastructure projects that will use alternatives to SF6.

This project has been approved by a senior member of staff

☑ Yes