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

Oct 2022

Project Reference Number

NIA2_NGET0028

Project Registration

Project Title

Identification and quantification of C4F7N gas arcing by-products and their implication for GIS operation

Project Reference Number

NIA2_NGET0028

Project Licensee(s)

National Grid Electricity Transmission

Project Start

November 2022

Project Duration

3 years and 6 months

Nominated Project Contact(s)

Gordon Wilson (Box.NG.ETInnovation@nationalgrid.com)

Project Budget

£1,903,314.82

Summary

This project aims to develop underpinning knowledge on the characteristics of C4F7N gas mixtures, which may be used as alternatives to SF6, with a specific focus on the long-term gas stability to demonstrate performance in service in new equipment. It will consider credible in-service scenarios where the gas may be put under stress that could lead to changes in the chemical make-up of the gas mixture, including any changes that could result from interaction with materials used in the manufacture of the equipment and low levels of moisture and air contamination. The resulting by-products will be assessed for their potential health impacts, their reactivity with other materials and the prospect that they may be use as diagnostic markers for asset health.

Preceding Projects

NIA_NGTO002 - Long Term Stability Testing of Alternative Gases

Third Party Collaborators

Cardiff University

Nominated Contact Email Address(es)

box.NG.ETInnovation@nationalgrid.com

Problem Being Solved

SF6 has the highest known global warming potential (GWP), 25,200 times that of CO2 (latest assessment of GWP over 100-year period by Intergovernmental Panel for Climate Change – AR6), with an atmospheric lifetime of more than 3,000 years. In the UK, it is estimated that the combined SF6 installed volumes in both transmission and distribution networks is approximately 1,500 t or 35 MtCO2e, with an annual SF6 leak of 0.5 MtCO2e from 2015 to 2018. Without viable alternatives, these figures would increase significantly in the coming decades as the electricity networks phase out ageing air-blast and oil-insulated switchgear with compact

SF6 equipment.

As a result of recent advances in the investigation and assessment of alternatives to SF6 mixtures based on C4F7N are in use as passive dielectric insulation and, at low voltages, it is seeing some use as an interrupting medium in circuit breakers. It is anticipated that these mixtures will become widely available in circuit breakers at transmission voltages in the near future. Once they become available, it is likely that they will see widespread usage in a short period and could become ubiquitous in the next decade.

Burn-in failures may be reasonably be expected to occur with this technology as much as other new technologies and the possibility exists that something intrinsic to the insulation system could then be found to be a part of the cause i.e. a type fault necessitating corrective action for other assets already installed.

Limited independent information is available on the full list of by-products and their quantities when C4F7N gas mixtures are subjected to arcing, taking into account the various scenarios of practical arcing conditions. The dependence of arcing by-products (type and quantity) on applied voltage and current shapes and magnitudes, i.e., arcing energy and its delivery rate, are not fully known. Moreover, the impact of difficult-to-control factors, such as moisture and other impurities in practical GIS equipment is not clarified. The degradation of such systems also needs to be better understood to support management of these assets as they come into service.

Method(s)

This project seeks to identify and quantify the by-products created from C4F7N gas mixtures, in particular, a mixture with carbon dioxide and oxygen. The gas mixture will be subjected to both AC and impulse energisations of various degrees of severity. Conditions within the gas, such as pressure and moisture will be investigated.

The work will be laboratory based with a new set up being developed for the purposes of the project. Analysis and monitoring techniques will be explored early in the project, techniques such as high-speed spectrometry/spectroscopy, fast pressure sensors and Schlieren photography will be explored to obtain data. Using such laboratory techniques could help simpler, more practical sensors for in-service field deployment.

An additional test cell will be designed and constructed for investigating the interaction of the gas mixture under high voltage/current conditions with materials typically used in the manufacture of high voltage equipment.

Data Quality Statement (DQS):

- The project will be delivered under the NIA framework in line with OFGEM, ENA and NGGT / NGET internal policy. Data produced as part of this project will be subject to quality assurance to ensure that the information produced with each deliverable is accurate to the best of our knowledge and sources of information are appropriately documented. All deliverables and project outputs will be stored on our internal Sharepoint platform ensuring access control, backup and version management. Relevant project documentation and reports will also be made available on the ENA Smarter Networks Portal and dissemination material will be shared with the relevant stakeholders.

Measurement Quality Statement (MQS):

- The methodology used in this project will be subject to our supplier's own quality assurance regime. Quality assurance processes and the source of data, measurement processes and equipment as well as data processing will be clearly documented and verifiable. The measurements, designs and economic assessments will also be clearly documented in the relevant deliverables and final project report and will be made available for review.

Risk Assessment

TRL Steps = 2

Cost = 3

Suppliers = 1

Data Assumption = 1

Assessed risk score 7 – Medium

Scope

The project will be delivered in the following six workstreams through which the resulting by-products from electrical testing will be identified, quantified and assessed for their potential health impacts, their reactivity with other materials and the prospect that they may be use as diagnostic markers for asset health:

WS1: Quantification of arcing by-products under credible fault scenarios in switchgear using commercial C4F7N mixtures

WS2: Arcing by-products: effect of moisture ingress, pressure, air on their concentration and rate of production

WS3: Reaction with other materials: effect of combined temperature and electric field

WS4: Materials compatibility with presence of by-products

WS5: SHE and legislative compliance

WS6: Feasibility of by-products monitoring for fault diagnostics, equipment condition, remaining life of C4F7N gas mixture -filled equipment

Objective(s)

This project will deliver greater understanding of the performance of C4F7N gas mixtures in operational conditions ahead of widespread use in switchgear. Specifically, the following objectives are planned:

- Identification of by-products that may require specific handling precautions in arced gas mixtures and the guidance needed for handling them
- Understand the impact of different service conditions on nature of by-products
- Investigate the potential for specific by-products to be used in monitoring asset health of in-service equipment.

Consumer Vulnerability Impact Assessment

An assessment of distributional impacts (technical, financial and wellbeing related) for this project has been carried out using a bespoke assessment tool, which assesses the project as having a positive, negative or neutral effect on consumers in vulnerable situations. To help inform the assessment, this tool considers the categories of consumers identified in the Priority Services Register.

This project has been assessed as having an overall positive impact on consumers in vulnerable situations. The assessment has identified that this project will look to reduce the costs for households over the long term as a result of reducing costs associated with early life failures and remediation as a result of adoption of new technology.

Success Criteria

At the conclusion of this project, it will be considered successful if each of the workstreams set out in the scope are delivered and new knowledge is gained which advances industry understanding of the new technology

Project Partners and External Funding

The project is supported by both Scottish and Southern Electricity Networks Transmission and Scottish Power Energy Networks. Both supporting networks will cover the cost of their own involvement with the project.

Potential for New Learning

The project will result in a number of reports that will be delivered as the work progresses. The reports will describe the work carried out and the results that are achieved. The reports will focus on novel and independent findings in the following areas:

- Identification and quantification of by-products from credible operational scenarios in high voltage switching equipment
- The effect that various factors have on the by-products in these scenarios – factors such as moisture concentration, pressure and the presence of different materials
- The health and safety implications of by-products identified
- The potential for by-products to inform asset managers of the condition of the equipment

Learning will be disseminated through defined project progress and completion reports. Learning will also be shared through conference presentations and an open dissemination event, e.g. a webinar, on completion.

Scale of Project

The project will take place in the laboratory at Cardiff University and will also involve use of a third-party high voltage facility to generate the level of current required for some tests, which adds cost and complexity. Previous work in T1 (NGTO002 Long term stability of alternative gases) went some way towards identification of by-products and it has informed the development of the scope of this large scale project, both in terms of learning and the questions that remained on completion.

The project is intended to answer a number of innovation questions and with a supplier on a framework contract achieved through tender and negotiation to be as economic as possible. A smaller scale project would deliver less as it would require a reduction in scope. Some elements could be removed and carried out later but it would be less efficient.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL6 Large Scale

Geographical Area

Laboratory-based studies to be carried out at the innovation provider's facilities and at a high voltage facility to be determined. The research is intended to be applicable to all licensees.

Revenue Allowed for the RIIO Settlement

Not Applicable

Indicative Total NIA Project Expenditure

£1,593,000

Project Eligibility Assessment Part 1

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations

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

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

The project will enable the energy system transition through facilitation of the use of eco-friendly alternatives to SF6 through investigation of safety and reliability of the technology. The replacement of SF6 may be slower if there are concerns about the rapid introduction of new technology.

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

Not applicable

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

Not applicable

Please provide a calculation and/or description of the expected benefits of the solution

This research project will investigate C4F7N gas mixture by-products in scenarios that could arise in credible fault conditions. The learning is expected to reduce the risk of failure of new technology and where that arises from a type-fault avoid the need for similar assets to undergo remedial work. Avoided cost for new technology is difficult to estimate but an NPV calculation based on expected numbers of circuit breaker installations, failure and mitigation costs indicates savings in the range £1.84m to £9.71m over a 10 year period.

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

The research is focussed on transmission assets. All three of the GB transmission utilities will receive project updates and the opportunity to ensure the project delivers learning that can be directly applied.

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

It is difficult to estimate costs of rolling out the research across networks until the project starts to deliver results. Any significant learning that could result in avoided troubles and failures with assets will be disseminated to suppliers as well as other networks.

Requirement 3 / 1

Involve Research, Development or Demonstration

Projects 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

Involve Research, Development or Demonstration - Please select all that apply

☑ 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 research is being conducted to understand potential issues with the use of gas mixtures with lower GWP than SF6 at transmission voltages. It is therefore learning that may be directly applied to other networks installing similar assets at similar voltages. The disseminated results will be shared with all licensees so that the reasons for the conclusions may be understood. It will be the responsibility of others to determine to what extent it applies to other equipment types and different voltages but the underlying work from this project is likely to help.

Not applicable

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. Networks must explicitly mention similar projects that they have considered and how these differ.

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

NGET has shared the project details with SSEN Transmission and SPEN to confirm that all the transmission owners believe this project is necessary, beneficial and does not duplicate other research projects. There are some superficial similarities to another NGET T2 project NIA2_NGET0006 “Non-invasive In-situ Monitoring and Interpretation of SF6 Alternatives in GIS Equipment” as it will also look at potential by-products but it differs in the following ways: this new project is focussed on SF6 alternatives in new circuit breakers rather than retrofilled passive insulation in busbars, this project will deliberately create fault conditions to generate by-products and this project will focus on gas mixtures with a carbon dioxide component, the existing project focuses on nitrogen instead.

Any residual risk of duplication will be addressed through dissemination of progress with other licensees and being open to co-operate with licensees working in this space.

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

Not applicable

Additional Governance And Document Upload

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

NGET has conducted similar research in T1 (NGTO002 “Long term stability of alternative gases”) and this project builds on the work

carried out by considering fault scenarios, quantifying by-products and considering their implications. Some aspects of this work may have been carried out by equipment manufacturers but not published, the level of similarity is unknown, and this work will be independent, published and gives specific consideration to how utilities handle by-products and whether the by-products could prove useful for condition assessment purposes.

Relevant Foreground IPR

The foreground IPR will be the knowledge gained about the generation of by-products from C4F7N gas mixture or mixtures under credible fault conditions and their implications for human and equipment health.

No Background IPR is required.

Data Access Details

Data for this project and all other projects funded under the Network Innovation Allowance (NIA), Network Innovation Competition (NIC) or the new Strategic Innovation Fund (SIF) can be found or requested in a number of ways:

- A request for information via the Smarter Networks Portal at https://smarter.energynetworks.org, to contact select a project and click 'Contact Lead Network'. National Grid already publishes much of the data arising from our innovation projects here so you may wish to check this website before making an application.
- Via our Innovation website at https://www.nationalgrid.com/uk/electricity-transmission/innovation
- Via our managed mailbox box.NG.ETInnovation@nationalgrid.com

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

This is a research project that will lead to knowledge that may underpin future decisions about replacement of SF6-filled assets on the network with alternative insulating arrangements where cost comparisons would not favour the use of technology with a shorter proven track record of performance. Investigation of these technologies is most appropriately supported through NIA as no allowance for such investigations were 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

There are technical risks associated with any innovation project as the proposed investigations may not generate actionable results.

While commercial benefits have been estimated for this research project based on reasonable assumptions, commercial benefits that might justify funding other than NIA cannot be guaranteed.

This project has been approved by a senior member of staff

☑ Yes