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

Jul 2025

Project Reference Number

NIA2_NGET0094

Project Registration

Project Title

Graphene based solutions for sealing new GIS using SF6 alternatives

Project Reference Number

NIA2_NGET0094

Project Licensee(s)

National Grid Electricity Transmission

Project Start

August 2025

Project Duration

1 year and 7 months

Nominated Project Contact(s)

Matti Ward

Project Budget

£631,160.00

Summary

This project builds on the development of tape and spray solution using graphene nanoplatelets in EPDM to mitigate SF6 leakage, initiated by previous NGET project. The aim is to create elastomer nanocomposites that address the leakage challenges associated with SF6 alternatives, particularly gas mixtures. These material systems will be engineered to possess similar permeability to all gas components within a mixture and provide excellent barrier properties at various operating temperatures. The key objectives are: (1) to develop material systems that can seal air mixture, C4F7N with CO2, or N2 as a binary mixture and/or tertiary mixture including the addition of O2; (2) to validate these material systems through permeability testing at different temperatures; and (3) to validate the tape solution in a representative scaled demonstrator system.

Third Party Collaborators

The University of Manchester

Nominated Contact Email Address(es)

box.NG.ETInnovation@nationalgrid.com

Problem Being Solved

SF6 is undergoing transition to alternative gases/mixtures for gas insulated equipment. This presents a critical challenge due to the complex leakage dynamics associated with gas mixtures, such as clean air (N2 and O2), Novec 4710 ((CF3)2CFCN or C4F7N) combined with CO2, or C4F7N combined with N2 and O2. These alternatives to SF6 are essential for reducing greenhouse gas emissions but pose technical hurdles in maintaining consistent insulation properties over time. This technical challenge has not been systematically addressed and necessitates the development of advanced sealing materials that are capable of mitigating leakage in gas mixtures effectively. Additionally, temperature fluctuations worsen the issue, as thermal expansion, contraction and decomposition can further compromise seal integrity.

Method(s)

Workstream 1 – Development of clamping system for tape implementation on flange gaps

Graphene nanoplatelets will be compounded with EPDM. The composite will then be moulded into tapes with tailored patterns and thickness variations for the adaptation of large-scale flanges. UoM will work with an external supplier for clamping system to be developed for sealing flanges with medium-to-large scale. The sealing performance will be validated with gas tests.

Workstream 2 – Development of thin films for tape implementation on complex structures

Graphene nanoplatelets will be compounded with EPDM. The composite will then be calendared into thin films. UoM will work with an external supplier for the development of sealing kits for nuts and bolts. The sealing performance will be validated with gas tests.

Workstream 3 – Development of NBR/graphene material systems for new installations

Graphene nanoplatelets will be compounded with NBR. The composite will then be moulded into sheets. The mechanical properties of the NBR/graphene nanocomposites related to its use as gasket products will be evaluated against conventional material system NBR/carbon black. The diffusivity and solubility of the NBR materials against various gases (Novec 4710, N2, CO2 and O2) will be measured as a function of pressure using our existing gas diffusion rig (BS ISO 15105-1:2007).

Scope

SF6 is undergoing transition to alternative gases/mixtures for gas insulated equipment. This presents a critical challenge due to the complex leakage dynamics associated with gas mixtures, such as clean air (N2 and O2), Novec 4710 ((CF3)2CFCN or C4F7N) combined with CO2, or C4F7N combined with N2 and O2. These alternatives to SF6 are essential for reducing greenhouse gas emissions but pose technical hurdles in maintaining consistent insulation properties over time. This technical challenge has not been systematically addressed and necessitates the development of advanced sealing materials that are capable of mitigating leakage in gas mixtures effectively. Additionally, temperature fluctuations worsen the issue, as thermal expansion, contraction and decomposition can further compromise seal integrity.

Existing O-rings or flange sealants utilise single-phase elastomer (EPDM) or grease which provide different barrier properties to different gases. Given that C4F7N molecules are larger and mixed with smaller N2 and O2 molecules, the varying diffusion rates can cause the gas mixture ratios to change over time. This requires sealing solutions that not only prevent leakage but also adapt to the dynamic nature of the gas mixtures. Advanced nanocomposite materials, potentially consisting of multiphases, acting as sealing materials, are considered promising candidates. These materials must be designed to create robust, impermeable barriers that maintain their integrity under operational stresses and temperature variations, ensuring the long-term stability of the gas mixture within the switchgear.

This project builds on the development of tape and spray solution using graphene nanoplatelets in EPDM to mitigate SF6 leakage, initiated by previous NGET project. The aim is to create elastomer nanocomposites that address the leakage challenges associated with SF6 alternatives, particularly gas mixtures. These material systems will be engineered to possess similar permeability to all gas components within a mixture and provide excellent barrier properties at various operating temperatures. The key objectives are: (1) to develop material systems that can seal air mixture, C4F7N with CO2, or N2 as a binary mixture and/or tertiary mixture including the addition of O2; (2) to validate these material systems through permeability testing at different temperatures; and (3) to validate the tape solution in a representative scaled demonstrator system.

Objective(s)

The objectives of the project are to compound Graphene nanoplatelets with ethylene propylene diene monomer (EPDM). This composite will then be moulded into tapes with tailored patterns and thickness variations for the adaptation of large-scale flanges.

University of Manchester will work with Quickedge Ltd to develop a clamping system to seal the composite tape on to pipe flanges. The sealing performance will be validated with gas tests.

Further to this, the composite material will be developed into thin films for tape implementation on nut and bolts. Quickedge Ltd will assist in developing a sealing kit for these complex structures. The sealing performance will be validated with gas tests.

The next objective will be to develop a nitrile butadiene rubber (NBR) /graphene composite for new installations as a gasket material. Graphene nanoplatelets will be compounded with NBR. The composite will then be moulded into sheets. The mechanical properties of the NBR / graphene nanocomposites related to its use as gasket products will be evaluated against conventional material system NBR/carbon black. The diffusivity and solubility of the NBR materials against various gases (Novec 4710, N2, CO2 and O2) will be measured as a function of pressure using our existing gas diffusion rig (BS ISO 15105-1:2007).

Lastly, validation of effectiveness on a large-scale demonstrator with final reporting and recommendations on adapting the solution to oil switchgears.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

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 reduced transmission operating costs for managing SF6 emissions. Other considerations including the projects impact on supply, immediate health and safety in the home have been made in carrying out this assessment.

Success Criteria

- Continuous EPDM/graphene tapes prepared for the use with the flanges (with valve for gas release and collect)
- Clamps successfully made for different key shapes of the flanges on-site
- Super-thin film (tape) developed for nuts, bolts and other complex structures.
- Develop NBR compounds and tape for novel gases (similar properties as the EPDM developed in Phase 1 and validated by permeation tests)

Project Partners and External Funding

University of Manchester are project supplier

Potential for New Learning

- Develop new operational practice to minimise SF6 leakage and extend asset operational life without costly early capital replacement.
- Potential future flexible clamp design for different types of sealings for different transmission and distribution equipment.
- Future dynamic sealing applications with broader materials selections for other electrical components
- Potential sealing applications for non-PFAS substitutes

Scale of Project

Environmental: SF6 is the largest controllable element of NGET's direct emissions at around 285,000 tonnes CO2 equivalent in 2018/19. This project will support the delivery of the NGET's corporate target of a 50% reduction in SF6 emission reductions compared with its 2019 level.

Technology: This project will boost the development of the novel sealing solutions for in-service emergency repair. The technology and materials know-how developed are readily transferable to new gasket for new equipment in wide ranging sectors.

Policy: In the new F-gas regulation 2024, production of virgin SF6 will be banned in Europe by 2035. This will inevitably cause a reduction of virgin SF6 production from gas manufacturers pre-2035. Better sealing technology will minimise the need to purchase new/recycled SF6.

Economics: The RIIO Insulation and Interruption Gas Emissions Output Delivery Incentive (IIGIt) can result in either financial incentives or penalties depending on SF6 related emissions above or below the baseline leakage across the total SF6 inventory.

The investment is required to deliver the pilot demonstration at representative equipment scale. This is needed to demonstrate the efficacy of this innovative solution. The calculated cost benefit is £631,160 and is further justification of the investment.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL5 Pilot Scale

Geographical Area

The project will be carried out at the University of Manchester, with Quickedge Ltd producing some hardware at their facility. Future testing will be done at select National Grid operational substations known to have active SF6 leaks.

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£568,044

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:

The aim of the project is to ultimately create a solution to seal uncontrolled gas leaks to the atmosphere thus reducing CO2 emissions.

The project outcome will minimise SF6 (and equivalent CO2 emission) which will prolong the operational life of existing assets. This will avoid expensive capital replacement schemes that could be better utilised to other more pressing issues.

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

The expected benefits of this project will be based on the success of the three solution workstreams – Development of the gaskets, thin film and the clamping system. NGET is committed to reducing SF6 emissions by repairing these leaking assets. A review over the last 12 months SF6 Top-up figures and the potential for repairs using these solutions based on a review of leakage types and the projected repair costs against emissions fines of assets left unrepaired will deliver benefit of £5.9m and associated containment of 3,000kg of SF6 gas.

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

There are currently 48 known SF6 Leaks in which this project can potentially address across the network. As the existing assets age, it is inevitable through deterioration we expect more leaks across more substations.

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

This will be informed by the project finding.

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 same operational practice and solution can be adopted by relevant network licensees for use on their SF6 assets.

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.

We have reviewed the smart network portal to avoid potential duplication. In the phase 1 project, key switchgear experts of the other two transmission operators (SSEN and SPEN) were involved in the project dissemination. They were all in agreement that a phase 2 project is necessary. To the best of our knowledge, there is no innovation project looking at sealing complex structures using super-thin film filled by 2D materials and addressing the potential leak issue of C4F7N in the coming decade as more will be installed online.

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

The innovation of phase 2 include: 1) implementation of the tape materials developed from phase 1 for large-scale flanges through pilot trials; 2) development of super-thin films using the tape materials system developed from phase 1 aiming at sealing nuts, bolts or other complex structures; 3) adaptation of the graphene-based fillers into NBR material system and develop new sealing materials systems with better performance for sealing of SF6 alternatives such as C4F7N gas mixtures for new installations.

Relevant Foreground IPR

N/A for this project

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 apart of it's business and usual activities

There are still research and development activities required to mature the solution to be ready for business as usual. The innovation on C4F7N (new SF6-free equipment) is completely new and of lower TRL.

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

The NIA project is required to upscale the TRL of the proposed solution. Through representative scaled pilot trials, this will give greater confidence to NGET and other network operators to implement such solution as part of their business as usual

This project has been approved by a senior member of staff

☑ Yes