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

NIA2_NGET0019

Project Registration

Project Title

Aerial E-field Inspection System for Live Overhead Transmission Assets

Project Reference Number

NIA2_NGET0019

Project Licensee(s)

National Grid Electricity Transmission

Project Start

June 2022

Project Duration

3 years and 0 months

Nominated Project Contact(s)

Siyu Gao (Box.NG.ETInnovation@nationalgrid.com)

Project Budget

£1,181,000.00

Summary

This project aims to deliver an inspection system based on E-field sensors and drone to enable live inspections for transmission OHL insulators with asset health condition assessment reports produced in real-time. This project will characterise and quantify the efficacy of E-field sensor in identifying defects in OHL insulators, perform through tests in UoM's HV laboratory to optimise the hardware configuration, construct digital twins for a range of insulators to define the electric field profiles for OHL insulators under different conditions, design algorithms to best assess the asset health conditions for OHL insulators and will re-engineer, miniaturise and instrument the commercial E-field system into a drone carriable payload. This project will also produce recommendations for drone operation and safety guidelines.

Third Party Collaborators

The University of Manchester

Nominated Contact Email Address(es)

box.NG.ETInnovation@nationalgrid.com

Problem Being Solved

The current practice for OHL insulator health management and inspection is time consuming and labour intensive. To allow in-situ inspection of OHL insulators, the circuits in concern would need to be switched-off and engineering teams would need to be sent out to climb up the selected towers to perform the testing. Taking samples of insulators for forensic analysis in laboratories would involve the same amount of people power. This intense labour requirement limits the number of inspections that can be carried out. NGET would like to carry out significantly more inspections to achieve much higher visibility and confidence in the health condition of this asset class, so that they can be managed more proactively and to ensure better system access.

Method(s)

NGET recognises that the challenges highlighted above could be more effectively and efficiently addressed by employing a live inspection system for OHL insulators that would be capable of performing inspections with the same or even higher quality than a human, and at the same time, capable of delivering health condition assessment reports in real-time, so that forensic analysis for OHL insulators would no longer be needed.

A drone mountable, electric field (E-field) sensor-based system, with incorporated on-bard computing and analysis capability to generate asset health condition assessment in real-time appears to be a viable option for such a live inspection system. All HV insulators produce E-fields when they are in live operation. The distributions of the E-fields can be altered by localised defects. With a purposely built and tunned E-field sensor system carried by a drone flying in close proximity to the OHL insulators, the E-field distributions of the OHL insulators can be accurately captured and compared with known E-field distribution profiles to produce the asset health condition assessment. This solution would enable live inspections for OHL insulators and would remove the needs for circuit switching, tower climbing and taking insulator samples away for forensic analysis. Therefore, the time and costs related for OHL insulator health management could be substantially reduced while the inspection results would be available much faster and the visibility for the overall health of this asset class could be significantly increased due to more data being made available.

Data Quality Statement (DQS):

- The project will be delivered under the NIA framework in line with OFGEM, ENA and 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. Deliverables will be shared with other network licensees through closedown reports on the Smarter Networks Portal.

Measurement Quality Statement (MQS):

- The methodology used in this project will be subject to 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.

In line with the ENA's ENIP document, the risk rating is scored 8 = Medium.

TRL Steps = 2 (3 TRL steps)

Cost = 3 (>£1m)

Suppliers = 1 (1 supplier)

Data Assumption = 2 (Assumptions known but will be defined within project)

Scope

The project is scoped into 4 work packages (WPs).

- WP1: Analysis for E-field sensor sensitivity and measurement
  - Literature review of the state-of-the-art of OHL insulator condition monitoring and the most frequent insulator faults
  - Laboratory based sensitivity experiments and analysis of commercial E-field sensors for sensor selections and tuning
  - Requirements capture and workshop for stakeholders
- WP2: HV laboratory testing and algorithm building
  - Small scale testing of E-field sensors using less complex insulator samples
  - Full scale testing of E-field sensors using the full NG range of insulator samples
  - Interpretate the test results, optimise the hardware configuration and build the health condition assessment algorithm
- WP3: Digital twin construction
  - Build digital twins for NG insulators to define the electric field profiles for different conditions. These profiles are used in WP2 as references for health condition assessment.
- WP4: UAV integration
  - Re-engineer, miniaturise and instrument the commercial E-field system into a drone carriable payload
  - Recommendation for drone operation and safety

Objective(s)

The objective of this project is to deliver a live inspection system for OHL insulators based on E-field sensors and drone. The key aspects are:

- Select the most suitable E-field sensors for the project basing on detailed laboratory experiments and analysis
- Comprehensively test the selected E-field sensors on a range of insulator samples to optimise the hardware configuration and the algorithm for asset health condition assessment
- Build digital twins for NGET insulators and define different E-field distribution profiles for different conditions
- Re-engineer, miniaturise and instrument the commercial E-field sensor system into a drone carriable payload
- Produce recommendations for drone operation and safety to NGET

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 amount of disruptions to them in the home. 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

This project is deemed as successful if the objectives are achieved. In particular, the following outputs will be important when assessing the success of the project:

- Validation of the E-filed sensors' capability in detecting defects in HV transmission OHL insulators
- Validation of the effectiveness of the health condition assessment algorithm
- Validation of the different E-field profiles for OHL insulators under different conditions
- Development of the E-field sensing system into a drone carriable payload and demonstrate the full system's capability

Project Partners and External Funding

Not applicable

Potential for New Learning

The potential new learnings from this project are:

- Best practice for deploying drones for performing live inspections for overhead transmission assets
- The knowledge of E-field distributions of different HV OHL insulators under different conditions, e.g., normal operation, under different weather conditions, impacted by different localised defects
- The engineering challenge in converting commercially available, sizable and ground-based sensor systems into a compact, miniaturised, drone carriable payload that is able to perform the same functionality
- Recommendations for operational procedures and safety measures for engineering staff to enable best use of the drone system to perform live OHL insulator inspections

The learning will be disseminated through the publication of project progress and closedown reports on the ENA portal. Various workshops and dissemination events would also be planned.

Scale of Project

The scale of the project includes the following.

- Construction of a test rig for testing the E-field sensors and insulators to quantify the parameters required
- Laboratories based MV tests for the E-field sensor system with a selected range of less complex insulators to understand the sensitivity, replicability and accuracy of the sensor system under different insulator conditions, e.g., normal, affected by localised defects, under different levels of pollution, etc.
- Laboratories based HV tests for the E-field sensor system with the full range of NG OHL insulators
- Development of digital twins for NG insulators to define the electric field distribution profiles for different conditions
- Development of insulator health condition assessment algorithm based on the E-field measurements
- Re-engineer, miniaturise and instrument the commercial E-field system into a drone carriable payload
- Various reports, recommendations and project materials
- Dissemination events and stakeholder workshops

Technology Readiness at Start

TRL4 Bench Scale Research

Technology Readiness at End

TRL7 Inactive Commissioning

Geographical Area

The project will mainly be carried out on the premises of the University of Manchester.

Revenue Allowed for the RIIO Settlement

Not Applicable

Indicative Total NIA Project Expenditure

Total NIA expenditure: £1.063m

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 energy system transition will require networks to move away from time-based and 'replace-on-fail' asset management and to adopt a more proactive, condition -based asset management practice. This project supports the energy transition by having the potential to substantially improve the efficiency and effectiveness for managing the health of transmission OHL insulators by significantly reducing the labour requirement while able to produce the health assessment reports at a much faster rate. With better asset management for the OHL insulators and therefore healthier OHL insulators, network outages could also be reduced and better system access could be enabled.

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 (RIIO-1 projects only)

Not applicable

Please provide a calculation of the expected benefits the Solution

The benefits of this project are based on the assumption that the labour requirement for carrying out the inspections for OHL insulators could be reduced by more than 90%. The NPV benefits over the next 15 year is £2,862k.

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

The E-field sensor and drone based solution proposed in this project is designed for HV transmission OHL insulators. Network licensees that have such assets in their networks could adopt them to improve the health management for their OHL insulators.

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

The costs of deploying this solution are highly dependent on the drone model and E-field sensors selected and they will be investigated in the project. Drone pilot training cost and purchase for relevant hardware are expected.

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

This project is aiming to deliver an inspection system based on E-field sensors and drone to enable live inspections for transmission OHL insulators. A successful project would produce such a system ready to be used alongside with the digital twins for insulators and the various recommendations. These outcomes should allow relevant licensees to evaluate whether they could adopt such a system for their own 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)

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.

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

There have been a few projects in the UK that explored using drones to inspect OHL assets, e.g., NIA_SPEN_0063 and NIA_WWU_03. However, they were focused on using drone technologies to replace visual inspections and the drones would not fly in close proximities to the assets, which is vastly different from the objectives of this project. In this project, the drone would fly in close proximities to live OHL assets in order to measure the electric fields accurately. The inspection system that this project aims to deliver would also produce asset health condition assessment for OHL insulators in real-time, which has not been done before. Any risk of duplication will be addressed through dissemination of progress with other licensees and being open to co-operate with licensees working in similar areas.

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

Currently, there is no solution available in the market that is capable of performing live inspection for OHL insulator and produce the

asset health condition assessment for the insulators in real-time. This project aims to deliver such a system and this is why this project is innovative.

Relevant Foreground IPR

The foreground IPR will mainly be the drone carriable E-field sensor system, including the hardware, the software and the asset health assessment algorithm for OHL insulators. The experimental outcomes, digital twins for insulators, the recommendations for drone operation and safety, etc. are also part of the foreground IPR. The background IPR for the E-field sensor will be contributed by the manufacturer of the sensor.

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

This project involves flying drones in close proximities to live OHL insulators. This is considered as high risk to BaU operations since malfunctioning of the drones could short circuit the OHLs and cause unwanted outages. Such risk level is unacceptable to BaU and thus BaU is not the appropriate funding mechanism for this project.

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 operational risk steams from the potential malfunctioning of the drone when flying in close proximities to OHL assets. The malfunctioning could cause short-circuiting and unwanted outages. This kind of risks would not be tolerated in normal operation. In a fully controlled environment, there is no risk of causing network outages while effective mitigation methods could also be safely developed. Therefore, NIA, rather than BaU, is the appropriate funding mechanism for this project.

This project has been approved by a senior member of staff

☑ Yes