

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

Apr 2022

Project Reference Number

NIA2_NGET0018

Project Registration

Project Title

Autonomous Aerial, Thermal Inspections of Substations

Project Reference Number

NIA2_NGET0018

Project Licensee(s)

National Grid Electricity Transmission

Project Start

May 2022

Project Duration

1 year and 8 months

Nominated Project Contact(s)

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

Project Budget

£572,000.00

Summary

This project aims to investigate and validate a drone-based, autonomous system's capability of carrying out thermal condition monitoring surveys for transmission substation assets automatically. A 'drone-in-a-box' system will be installed at the Deeside Centre for Innovation (DCI) to demonstrate that such a system can fly Beyond-Visual-Line-of-Sight (BVLOS) missions and replace the current manual practices. This project will investigate and recommend the best practice of drone operation in a transmission substation environment. This project will also work closely with the Civil Aviation Authority to obtain the BVLOS licence and to fulfil other regulatory requirements for drone operation at DCI. This project will also produce a cloud-based AI model that will process the data and images collected by the drone and produce near real-time asset condition reports.

Nominated Contact Email Address(es)

box.NG.ETInnovation@nationalgrid.com

Problem Being Solved

Traditional asset management is usually conducted using a 'time-based' or 'replace-on-fail' manner. Time-based replacement is static and could lead to unnecessary replacement of functioning assets. Likewise, 'replace-on-fail' would inevitably lead to downtime, which could cost a lot more than the values of the failed assets themselves. Hence, these approaches are both inefficient and could be very cost ineffective. NGET is trying to move away from such methods and adopt a more desirable and proactive 'condition-based' maintenance regime. An important indicator of asset condition is the thermal conditions of the assets, particularly within substations. Currently, the major difficulties for high quality thermal imaging in substation are:

- Lack of sufficient data due to low inspection frequency. The current practice of taking thermal images for substation assets involve sending multiple staff to individual substations. This approach is not able to provide large enough data sets to enable meaningful condition-based maintenance
- Lack of high quality and consistent data. Since the thermal images are taken manually, they are not normalised and thus are not consistent. The quality of the images is also heavily influenced by human factor.

- Analysis of the images is done manually, which could be time consuming, considering the fact that the images are not normalised. The inconsistency of the image quality could also negatively impact the reliability of the analyses.

Method(s)

NGET recognises that the challenges highlighted above could be more effectively and efficiently addressed by employing a repeatable and automated procedure, which would be capable of performing inspections with the same or even higher quality than a human, and at the same time, capable of delivering autonomous analysis to diagnose potential damages, defects, etc., so that asset health condition could be assessed and failures may be predicted.

An automated drone inspection system, with incorporated image analysis methodology for generating inspection results in near real-time appears to be a viable option for such an automated procedure. With a 'drone-in-a-box' solution, which is a purposed built system that is capable of automatic deployment, recovery and recharging of drones without the need for manual intervention, NGET would be able to inspect assets with much higher frequency and thus obtain a lot more data to enable condition-based asset management. This solution would remove the need for sending operatives to site to perform the same inspections and thus the time and costs related with such inspections could be reduced.

The images and data collected by the drones would be uploaded to a cloud system for storage and analysis. AI (artificial intelligence) interfaced with the cloud system would use purpose-built image recognition and analysis methodology with machine learning to process all the images collected by the drones and deliver asset assessments in near real-time. This would remove the need for time consuming manual analysis and provide insights to NGET in a much more timely fashion without the risk of data overload.

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 following channels:
 - 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 6 = Low.

TRL Steps = 1 (2 TRL steps)

Cost = 2 (£500,000 - £1m)

Suppliers = 1 (2 supplier)

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

Scope

The project is scoped into 4 phases.

- Phase 1: Core system engineering
 - Requirement capture
 - Timeline planning
 - Workshop for stakeholders
- Phase 2: System development and Trial
 - Visual line-of-sight (VLOS) trial: A 6-month VLOS trial would be held in the Deeside Centre for Innovation (DCI). During this trial, the system would be tested in DCI under direct visual line-of-sight of a remote pilot using a pre-planned drone route, configured to acquire images of the assets from the same position and angle, ensuring that post-processing will be able to accurately determine the asset being inspected.
 - Intelligent obstacle avoidance: This part of the project is to develop and demonstrate the capability of the drone to avoid obstacles in a substation environment intelligently
 - Develop BVLOS operating safety case and trial plan: This part of the project would involve working closely with the Civil Aviation Authority (CAA) to obtain an authorised Beyond visual line-of-sight (BVLOS) Operating Safety Case (OSC) and related licence.

- AI prototyping and producing preliminary results with trial data: Development of image processing and the AI model would take place simultaneously with the trial.
- Phase 3: BVLOS capability demonstration
 - To obtain CAA approval for BVLOS operation
 - To demonstrate the full functioning system at DCI
- Phase 4: Capability roadmap and summary report
 - To summarise all the learnings and evidence in the previous phases and produce a scalable model for larger BaU (business as usual) deployment

Objective(s)

The objective of this project is to assess and demonstrate an autonomous drone system's capability of performing condition monitoring surveys (CMS) in a transmission substation environment. The key aspects are:

- Validation of the drone's ability of navigation in a substation environment, especially in avoiding planned and unplanned obstacles
- Validation of the drone's capability of taking normalised thermal and RGB images of substation assets
- Development and validation of an AI that is capable of processing the images collected and produce CMS result with high quality in near real-time
- Obtain BVLOS approval from the CAA to enable a full BVLOS trial of the whole system at DCI

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

Financial distributional impact:

This project ensures that NGET is at the forefront of adopting the latest and most advanced drone technologies available for transmission substation asset inspections. With knowledge gained in this project, NGET could remove the manual work required for such inspection and thus could achieve substantial efficiency and related savings. Also, with access to more and better-quality asset data, it is possible that NGET would be able to adopt condition-based asset management and data driven decision making at a much higher speed, extending asset lives and reducing outages, which would also deliver savings. The project will not restrict benefits delivered to vulnerable consumers based on any vulnerability class.

Technical and wellbeing impact:

Based on the findings and recommendations in the project, energy networks may start adopting drone systems to perform substation inspections, which would be able to improve efficiency and result in savings. The vulnerable consumers will benefit through reduced expenditure as a whole. The consumer impact of any of the methods or solutions developed in this project is not dependent on any of the following factors: Dwelling and location (potentially including tenure) Readiness for digital technology Personal and social factors (for example, households with disabilities and medical conditions, or which speak English as a foreign language).

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:

- Development and dissemination of energy network specific knowledge related to the deployment of drone technologies for CMS in transmission substation environment
- Validation of the drone system's capability of obstacle avoidance in a transmission substation environment and its ability of taking normalised thermal and RGB images for substation assets
- Validation of a purpose-built AI model's capability to deliver asset health condition reports using the images and data collected by the drone system
- Development of an operating safety case which would allow the CAA to issue a BVLOS licence for drone operation at DCI

Project Partners and External Funding

Not applicable

Potential for New Learning

The potential new learnings from this project are:

- Best practice for deploying a drone system in a transmission substation environment
- Best practice for employing a drone system to perform condition monitoring surveys for substation assets
- Effective usage of AI and machine learning to deliver near real-time analysis of asset health condition via thermal images and RGB

images taken by the drone

- Recommendations of operational procedures and safety measures for site staff to allow best use of the drone system
- Requirements for obtaining a BVLOS licence from the CAA for drone operation in a transmission substation environment
- Deployment roadmap for mass adoption of drone system in transmission substations

The learning will be disseminated through the publication of project progress and closedown reports on the ENA portal.

Scale of Project

The scale of the project includes the following.

- Installation of a 'drone-in-a-box' system at DCI
- VLOS trial of the drone system at DCI
- Development of intelligent obstacle avoidance using the data collected at DCI
- Development of AI for image recognition and asset condition analysis using the data collected at DCI
- BVLOS trial of the drone system at DCI
- Various reports, recommendations and project materials
- Dissemination events and workshops

Technology Readiness at Start

TRL4 Bench Scale Research

Technology Readiness at End

TRL6 Large Scale

Geographical Area

The project will mainly be site based. Most of the work will be carried out at Deeside Centre for Innovation in Wales.

Revenue Allowed for the RIIO Settlement

Not Applicable

Indicative Total NIA Project Expenditure

Total NIA expenditure: £514,800.00

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 from time-based and 'replace-on-fail' asset management to condition-based asset management. This project supports the energy transition by having the potential to improve the effectiveness and efficiency of condition monitoring surveys for transmission substation assets and thus could allow faster adoption of condition-based asset management and data driven decision making. With better asset management and therefore healthier assets, network outages could also be reduced.

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 manual condition monitoring surveys can be replaced by an autonomous drone system. The NPV benefits over the next 15 year is £796k.

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

Drone technologies can be used by all network licensees. In assessing the potential benefits of the project, the estimation is that there are 150 potential NGET sites that could adopt the drone system to replace manual condition monitoring surveys.

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

The deployment of this drone-based solution is highly dependent on the guidelines and regulations governed by the CAA. As part of this project, deployment requirements and costs in a transmission substation environment would be investigated. The costs of deploying this solution to voltage levels other than transmission levels would require detailed study and will depend on the relevant use cases.

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 will investigate the feasibility of employing a drone-based solution to perform condition monitoring surveys in a transmission substation environment. A successful project will demonstrate that this may be achieved, and licensees may use the learning to deploy their drone-based solution to do similar. Specific OSC and BVLOS licence from the CAA would still be required for any projects where this solution would be utilised.

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.

This project focuses on investigating and validating BVLOS operation of a drone-based autonomous system in a transmission substation environment to carry out condition monitoring surveys. There are other projects that focus on different asset types, i.e., overhead lines (OHL), gas pipelines, etc. This project does not duplicate them. The transmission substation environment is vastly different from OHL and gas pipelines and is much more challenging for drones to operate since assets in transmission substations tend to be situated in much closer proximities with each other. The solution from this project is expected to be much more sophisticated and robust and would be specific to transmission substation environment. 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

Condition monitoring surveys are currently being carried out manually at a low frequency. This manual-based method is not providing enough data in quantity or quality to enable condition-based asset management and data driven decision making. Though there are drone-based solutions offered in the market, none of them are able to provide BVLOS solution for HV transmission substations. This is mainly due to the lack of intelligent obstacle avoidance in the said solutions. To operate drones safely in an HV transmission substation environment, it is crucial that the drones can avoid planned and unplanned obstacles. This project aims to address this issue and development intelligent obstacle avoidance capability using the selected drone system. This will enable drones to fly BVLOS missions in HV transmission substations, which is not currently possible. This is why the project is innovative. This project, if successful, would be able to provide an autonomous drone-based solution that could greatly improve the data quality and quantity which would help NGET to adopt condition-based asset management and data driven decision making faster.

Relevant Foreground IPR

The foreground IPR will be the outcomes of the VLOS and BVLOS trials, the BVLOS licence, the Operation Safety Case (OSC), the AI model and the related algorithm for image recognition and asset health condition analysis, recommendations for best practice and procedures of drone operation in a transmission substation environment, etc. The supplier will contribute the background IPR for drone technologies.

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 transmission substation assets. This is considered as high risk to BaU operations since malfunctioning of the drones could cause short-circuiting or other types of failures in transmission substations which could cause unwanted outages of the network. 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 transmission substation assets. The malfunctioning could cause short-circuiting in transmission substations and unwanted outages might follow as consequences. This kind of risk would not be tolerated in normal operation. If the project shows that this kind of risk cannot be safely mitigated by implementing intelligent obstacle avoidance and other safeguards, then it is likely that no further implementation of such a drone system will take place. The solution proposed in this project is also highly dependent on the regulatory approval from the CAA and it is possible that the CAA might withhold the approval. Due to these risks discussed, NIA, rather than BaU, is the appropriate funding mechanism for this project.

This project has been approved by a senior member of staff

Yes