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NIA Project Registration and PEA Document

Date of Submission

Feb 2024

Project Reference Number

NIA2_NGET0060

Project Registration

Project Title

Robot, AI and Drone Enhanced Detection of Discharge (RAIDEDD)

Project Reference Number

NIA2_NGET0060

Project Licensee(s)

National Grid Electricity Transmission

Project Start

April 2024

Project Duration

2 years and 0 months

Nominated Project Contact(s)

Gordon Wilson

Project Budget

£2,300,000.00

Summary

Partial discharge (PD) is a phenomenon that occurs in electrical assets whereby localised energy discharges do not bridge the insulation gap between conductors. It is a sign that an asset has a defect of some kind, either from manufacture or deterioration. Initially PD may occur infrequently, occurring more often as the defect worsens until eventually the PD frequency and magnitude becomes sufficiently concerning that the asset needs to be replaced or the discharge bridges the gap causing arcing and failure. PD monitoring is carried out routinely every three months along with thermovision checks at each substation; it is time consuming, and the monitoring equipment is relatively heavy. More frequent PD checks would increase the probability of getting early warnings of asset deterioration but other than more frequent personnel checks the alternative is continuous monitoring systems that have limitations and are expensive. In the event of a dielectric failure of an asset it is sometimes necessary to establish risk management hazard zones, PD monitoring could be used to mitigate the risks and allow site work to continue.

This project will address the problem in a number of different ways to improve our ability to identify, locate and diagnose PD related defects as early as possible. The project will involve a number of workstreams:

- Use of machine learning techniques to identify the optimal locations for PD monitoring systems
- Improved diagnostic capability for understanding PD patterns taking into account influencing environmental factors using AI
- Demonstration of robot- and drone-mounted PD monitoring – assessing the capabilities and relative merits of both solutions

Third Party Collaborators

Cardiff University

Chronos Technology Limited

University of Strathclyde

Elimpus Ltd

Nominated Contact Email Address(es)

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Problem Being Solved

The ultimate consequences of the type of defect that can generate partial discharge (PD) in internal HV insulation, is failure. An abrupt dielectric failure results in a sudden and significant release of energy which is likely to be catastrophic, damaging and rendering unusable, not just the failing equipment but others in the bay and potentially adjacent bay components. The breakdown poses a safety risk to people in proximity especially where porcelain-clad equipment is involved. Where the root cause of failure is uncertain, assets of the same design may be subjected to a risk management hazard zone (RMHZ). These can extend up to 80 m or more in some cases putting routine work in jeopardy at multiple sites. Mitigation may involve requiring personnel entering the zone to perform condition assessment work for very limited times to reduce their exposure to harm where there is no alternative.

PD monitoring has been a method of detecting defects in assets since the 1980s and there is much academic research on the subject in the literature, but routine condition monitoring of substation assets has not developed significantly over recent years. Achieving earlier detection and better diagnostics of results is needed to enable more proactive management of equipment when it develops an insulation defect or if there are issues with assets newly in service arising from design, manufacture, or installation.

Method(s)

This project takes advantage of recent innovations and advances in technology to significantly advance capabilities for using partial discharge (PD) monitoring to understand and track the health of HV assets. There are several workstreams that will support the ability to apply condition monitoring continuously where that is appropriate or that will provide more efficient and effective monitoring than might be achieved by carrying it out manually.

In particular the project will explore the use of drones and robots for collecting data routinely, using machine learning (ML) to improve the use of fixed monitoring systems and artificial intelligence (AI) in improving diagnostics of asset health from PD and environmental data.

Scope

The project will focus on partial discharge from high voltage substation assets and how the collection and interpretation from monitoring PD data can be improved compared with current improvements in technology. These are intended to replace digital radiofrequency (RF) devices used quarterly which can be slow and costly. Alternate systems are available for investigative purposes but are challenging to deploy. Devices deployed on robots and drones with improved software may be suitable replacements while investigative systems designed by machine learning techniques for investigative purposes.

The fusion of PD monitoring with operational and environmental data will be carried out and subjected to advanced data analytics with the intention of producing functional decision support software demonstrators. The aim of these tools will be to show the value of enhanced PD monitoring in managing assets, and managing the network more widely through outage planning and safety management.

Objective(s)

This project has five distinct work packages with their own objectives all aimed at improving PD monitoring capability:

1. Advanced Techniques for UHF (ultra high frequency) PD Location in Electrical Substations
   a. Development and benchmarking of a substation-wide online PD location system which utilises advanced analytical tools, AI and new antenna designs to significantly improve substation-wide PD location accuracy compared with that of existing systems
2. Advanced Substation Partial Discharge Monitoring
   a. Develop a multiplexed RF PD survey monitoring system which incorporates multiplexed wideband antennas suitably positioned around a substation and integrated with weather station data and substation load data
   b. Implement advanced data analytical methods, ML and AI techniques to be applied with the aim of producing functional asset decision support software demonstrators
3. UAV PD Locator
   a. Modification of electronic design of integrated PD monitoring on a drone (UAV) with low weight, power consumption and footprint to provide suitable flying time
   b. Antenna improvement for the drone-based PD monitor
   c. Development of automated flight control and post flight analysis software
4. PD Locator based on agile robot platform

a. Integration of RF PD monitoring on a quadrupedal robot for substation PD inspection
b. Evaluation of the relative merits of drone, robot and manual PD monitoring for routine inspections

5. New Partial Discharge Detection System
   a. Development of a new RF PD system synchronised with GNSS (Global Navigation Satellite System) integrated into a drone for data collection.
   b. Correlation of the RF sensor detection data with real discharge events in a controlled process to ensure that the new RF sensor can be shown to detect such PD activity

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 a small overall positive impact on consumers in vulnerable situations. The assessment has identified that this project will look to reduce the costs for all households over the long term as a result of reducing costs associated with managing defective assets and the impacts they can have on deliverability of capital works.

Success Criteria

The project will be successful if the following is achieved:

- A new design of aerial placement for fixed, continuous PD monitoring is developed and shown to be more effective than existing systems
- Operational and environmental factors can be successfully integrated with PD monitoring and it can be demonstrated that these are likely to improve management of defective assets
- At least one of the projects focussed on a different platform for period PD monitoring will prove to be an effective and efficient method for data collection.

Project Partners and External Funding

The workstream “New Partial Discharge Detection System” was previously registered in 2023 as “Smart Detection of PD using UAV” by SPEN. SPEN retains an interest in the project and will fund its own involvement.

The Advanced Techniques for UHF PD Location in Electrical Substations workstreams is partly funded by an EPSRC iCase award.

Potential for New Learning

The project will deliver reports for each of the workstreams within the overall work package. 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:

- Application of AI to the optimisation of antennae arrays for UHF PD monitoring to maximise location accuracy for a given substation geometry and new approaches to detection of the onset of travelling waves.
- Development of advance data analytics toolsets and interfaces for RF PD results combined with the most valuable additional data collected simultaneously.
- Benefits of robots and drones in collecting RF PD data for substation assets

Development of a new RF PD monitoring device using GNCC synchronisation

Learning will be disseminated through defined project progress and completion reports. In addition, conference and journal papers are planned to share learnings. UAV and robot detectors will be demonstrated at future Energy Innovation Summits.

Scale of Project

Elements of the project will be carried out in different settings depending on the workstream and stage of the project. The settings will include:

- Desktop studies
- Workshops and test laboratories
- An open area for drone testing with PD sources
- De-energised and energised test facilities
- Substation environment

The project has been scaled with the intention of delivering efficiently and with reasonable expectation of success. Project ideas were sought publicly with the projects perceived to be of most value going ahead. Both drone projects are included as they approach the

problem from different angles – a PD monitor known to be effective in substation monitoring but developed and optimised for the smallest possible drone. The second is a new PD detector with an alternate synchronisation method which has already been tested in a drone but requires testing and development to demonstrate its capability as a PD detecting device.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL6 Large Scale

Geographical Area

The project will be carried out at two universities, two PD monitoring device facilities and two test centres, one of which is NGET's Deeside Centre for Innovation. Suitable NGET substations will be used for site trials but have not been selected yet.

The results will likely be applicable to all UK based networks regardless of geographical location.

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£2,070,000

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:

This project supports the energy transition to a net zero network by reducing outage requirements, increasing availability and reliability of transmission assets when greater electrification of energy demands it. It will achieve this through earlier identification of insulation defects in high voltage assets allowing for better management of those assets through to replacement. It will provide information about similar assets and how they are monitored to achieve the same goal. In the event of failures of assets that result in other assets of the same design that, through risk assessment, have to be placed in RMHZs, this project may lead to relief from the restrictions to enable work such as renewable connections to continue.

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 substantially a research project with some elements of development work or building on previous work but going back to scratch with software or hardware designs to build improved versions.

Dielectric failures of assets are the most disruptive. The investigation and clean-up of a disruptive failure can take weeks or months affecting the site. RMHZs can sterilise multiple sites for months or years while the root cause is established and mitigated. These are high impact low probability (HILP) events and therefore difficult to quantify and define financial benefits. Nonetheless NGET has had experience with these events in the past, with the anticipated increase in capital projects to deliver the energy transition a repeat cannot be countenanced. This project is expected to help prevent such events in an efficient and effective way and mitigate them if they do.

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

The project will be applicable to both distribution and transmission assets, particularly those in air insulated substations (AIS) where there is typically more space and PD can be detected more easily.

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

At the completion of the project further work may be required to implement any of the technologies as business as usual activities. This project will assess the likely cost of any recommended implementation of the different technologies. The implementation of drones for periodic assessment is likely to be cheaper than robots based on the cost of the devices but this project will assess their relative effectiveness to support future decision making.

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

Results will be shared with all licensees, and they may be applicable to all owners of AIS high voltage assets. However, NGET will focus on transmission assets for this project. It will be the responsibility of others to determine the extent to which the assessed technologies might be directly applicable to not only their assets but their asset management approach to monitoring high voltage 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.

NGET carried out a procurement event to solicit project ideas from innovation solution providers. The projects were evaluated for novelty as part of the assessment process. NGET is unaware of similar projects being undertaken and as part of the NIA approval process no other networks have made us aware of projects that might result in duplication.

Any residual risk of duplication will be addressed through dissemination of progress with other licensees.

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

There are technical risks associated with any innovation project as the proposed solution may not work. The project is anticipated to generate sufficient benefit to justify the expenditure over many years so the success of the project will only become apparent over a longer period of time.

Drones have been assessed in substations, including by NGET as part of project “Autonomous Aerial, Thermal Inspections of Substations” (NIA2_NGET0018) but this has not been for partial discharge monitoring. NGET has also worked with an RF PD supplier on drone-based PD as part of a feasibility project but as part of this project the drone and interface with the monitoring will be completely redesigned along with new aerials to be designed and tested.

Substation inspections using robots has been investigated and was part funded by “EPRI Substations (P37) and Analytics (P34) 2021-2025” (NIA2_NGET0008). This did not include PD monitoring but did inform the selection of robot. The chosen robot has been interface with acoustic PD monitoring but this is not NGET’s preferred method of detecting PD, since it detects surface PD rather than internally generated PD; this will be the first integration with an RF PD monitor.

Relevant Foreground IPR

The foreground IPR will be the knowledge gained in the development of the drone technologies, the software used for their use and the analytical tools. It will also be embedded in the integration of the RF PD monitoring with the selected inspection robot. IP will also be generated in the innovative work using AI and ML techniques for aerial location for UHF PD monitoring and the work associated with integrating and understanding RF PD data and the demonstrator tools exploiting the analysis. The IP will rest in the reports that are generated as part of the project which will be available to other networks on request.

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

The project will evaluate various new technologies for enhancing PD monitoring – periodic and continuous. The key learnings will be around the use of these technologies that are developed during the project. NGET is not engaged in the development of new technologies for condition monitoring activity as part of its Business as Usual activities.

The outputs of this project cannot be directly related to benefits for consumers in the short term, there would be significant risk in using business funds.

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

NIA funding is appropriate in this context as enables NGET to access learning about new technologies for PD monitoring more quickly than if the market were to explore this potential use case. Without the project it is unlikely that any of the innovation suppliers involved would explore it and the improvements would not become available.

This project has been approved by a senior member of staff

☑ Yes