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NIA Project Registration and PEA Document

Date of Submission

Aug 2023

Project Reference Number

NIA2_NGET0040

Project Registration

Project Title

Surge Arrestors Health Assessment by Monitoring Partial Discharge (SAHARA)

Project Reference Number

NIA2_NGET0040

Project Licensee(s)

National Grid Electricity Transmission

Project Start

September 2023

Project Duration

2 years and 1 month

Nominated Project Contact(s)

Tinashe E Chikohora

Project Budget

£320,750.00

Summary

Surge Arrestors (SA) protect expensive critical substation entry points and equipment from surges e.g., transformers. Currently maintenance personnel carry out SA visual checks or analyse the counters/leakage current monitors (where present) to get an indication of any malfunctions, defects or ageing problems. Thermovision goes further but does not detect all deteriorations. These passive reactionary checks are unreliable and cannot guarantee cost-effective timely replacement. This project establishes a methodology for a continuous online partial discharge (PD) monitoring system of 132kV, 275kV and 400kV surge arrestors relating discharge signals against defects to predict early failure and inform replacement to avoid abrupt expensive failures and catastrophic costly outages. This will form part of a modern pro-active condition monitoring & asset management strategy applicable to other high voltage (HV) asset classes.

Nominated Contact Email Address(es)

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Problem Being Solved

Surge arrestors (SA) perform an important role in a substation to shield equipment from damage against surges, lightning or switching impulses. The typical root cause of SA failure is attributed to internal moisture ingress through leaks in the end caps and in rare cases deterioration of the metal oxide varistor blocks. Detection or prediction of both failure modes is beyond the human eye. There is a huge gap in understanding emerging common failure modes i.e., at the moment, there is no existing technique to detect partial discharge deterioration. Even where SA have LCM500 type or permanent type current leakage units, these monitoring techniques are still largely site based and are not feedable into any cloud-based system.

There is need for forensic condition assessment of a range of 132kV, 275kV and 400kV porcelain surge arrestors to establish remaining life especially for those that have passed 20 years in service. NGET requires more capability to detect early failure indications to migrate from an unoptimised replacement strategy. On the other hand, unplanned asset failures are not only costly, but disrupt substation operations whilst depleting reliability.

Method(s)

In principle, through laboratory-based work, known defects acting as PD sources will be intentionally introduced into arrestors to ascertain whether the online PD monitoring systems will detect the discharge correctly as expected. The PD activity will also be measured using conventional laboratory capacitively coupled techniques (which cannot be applied in the field) for comparison. If the effectiveness of the online PD monitoring system is proved successful, the application of the PD monitoring systems will then be extended to arrestors in the field.

During this phase, the arrestor stacks with the artificially introduced defects will be tested independently (approximately at 77kV). If PD is picked up, then the stacks can then be re-tested at 230kV but this time together with 2 sound stacks without defects. Defects to be introduced may include:

- Introduction of water / moisture into the surge arrestors
- Introduction of voids between adjacent metal oxide varistors (MOV) discs
- Introduction of MOV discs with (significant) delamination of the metallised electrodes
- Dislocation of the MOV discs within the stack within the surge arrestor in relation to spacer and contact plates

Arrestors will be selected from those which are considered to be in an end-of-life condition and/or are due for replacement. The likelihood of these arrestors having signs of degradation will be greater than those which have recently been introduced into service. This will also allow these arrestors to be removed from service, following the on-line condition assessment, for a forensic investigation to take place to ascertain the source of the PD if present.

On site, the Ultra Transient Earth Voltage (TEV) Monitoring system (UTM) will be equipped with an external node that supports up to four weatherproof capacitive sensors that will be mounted at strategic points around the surge arrester supporting metalwork. The UTM Hub will require a 240/110V power supply and hence will need to be located as close as possible to the nearest available mains outlet point.

In the discovery pilot phase, a similar approach was conducted by EA Technology when they conditionally assessed arrestors from 14 sites as part of project A2539_4 and identified signs of degradation through electrical ageing effects. A pilot PD survey was performed to arrestors at the National Grid Capenhurst substation site where several monitoring techniques were assessed. Although this did not pick up any signs of imminent failure of the arrestors, it proved that the techniques employed would be able to identify PD over background levels.

Scope

a) Phase 1 – Literature Review

A literature review will be carried out in parallel with phase 2 of this project. This review will include unpacking of the application of in-service PD monitoring systems up to extra high voltage (EHV) systems, understanding related PD signatures and common degradation and failure modes of surge arrestors

b) Phase 2 – Development of PD Detection Systems for application to Outdoor Surge Arrestor Systems

The project will utilise current commercially available PD sensors and monitoring equipment. This phase will yield PD monitoring systems that revolve around EA Technology's UTM system. Some work will be required to develop weatherproof ingress protection (IP65) enclosures for the equipment.

c) Phase 3 – PD Monitoring of Surge Arrestors with Artificially Introduced Defects

During the laboratory based testing, the surge arrestors will be analysed for PD activity using both a traditional laboratory based capacitively coupled technique as well as the UTM system, which will be deployed in the field. The purpose of this phase of the project is to ensure that the UTM system is capable of detecting PD activity and the sensitivity in relation to other traditional detection techniques.

d) Phase 4 – In Service Monitoring of Surge Arrestors

In consultation with National Grid, a number of sites will be identified where surge arrestors are reaching their end of life and are more likely to have experienced degradation through natural ageing. The arrestors of these sites will be fitted with the PD monitoring equipment, and the PD signals will be monitored over a period of time (3 months). It is proposed that the arrestors from a total of 12 sites will be monitored for PD activity using a total of 4 PD monitoring equipment sets will be provided. As part of the installation of the PD monitoring equipment, a survey will be performed on the site, using corona cameras and emission detectors.

e) 3.5 Phase 5 – Forensic Analysis of In-Service Surge Arrestors

The forensic analysis of the surge arrestors will include:

- Visual inspection of the external surge arrestor surfaces, MOV blocks, grading rings/seals, insulators & cataloguing of quality control data
- Hydrophobicity analysis of the external surge arrestor surfaces
- Direct current and impulse testing of MOV blocks
- Logging of data relating to PD, fingerprint testing, thermographic data, number of surge events and leakage current

Objective(s)

The project aims to establish and validate a methodology for continuous PD monitoring of 132kV, 275kV and 400kV surge arrestors by relating PD signals to defects within the surge arrestor to be able to predict early failure. Mobile monitoring sets will be installed in identified substations for up to 3 months to yield a technical and asset management strategy directive report.

This approach intends to avoid replacement based on age but alternatively be proactive to signal early failure and provide a means to either extend the life of current assets. In summary, National Grid is undertaking the project on surge arrestors to:

a. avoid associated catastrophic failures,

b. avoid arising unplanned costly outages,

c. prioritise or defer replacement,

d. improve overall network security by ensuring critical equipment is shielded from extreme events

e. improve operational health and safety and

f. reduce associated carbon footprint arising from unplanned interventions or remedial processes.

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 enhance network resilience, least cost decision making, transmission capability and operability that will ultimately reduce exposure costs for households.

Success Criteria

This project will provide a means to detect SA electrical degradation and will establish if online monitoring can avoid untracked deterioration into catastrophic failure. If successful, the methodology will qualify applicability not only to surge arrestors but other plant including cable sealing ends, switchgear, bushings and other insulating systems.

Directly from this project, a method for the condition assessment of surge arrestors will have been identified, with the methods and required sensors.

The related forensic investigation work will enable any field measurements to be ratified and correlated to the type of defect found and provide a mechanism for interpretation of field data.

Project Partners and External Funding

N/A

Potential for New Learning

There are several widespread issues and concerns with surge arrestors not only at transmission level but also on the distribution networks that are experiencing similar failures. The technology application will provide a learning platform to harness information on defect detection and correlation with online monitoring techniques. This type of approach and information does not exist, so the project enables an insight into this new learning which can then be assessed, trialled, and applied to other asset classes beyond this project's scope.

Scale of Project

If the effectiveness of the online PD monitoring system is proved successful, the application of the PD monitoring systems will be extended to arrestors in the field beyond the initial 12 sites and be adopted as SA replacement strategy for NGET. As already mentioned, the monitoring system can then be adopted to perform a similar role to several asset classes.

Technology Readiness at Start

TRL4 Bench Scale Research

Technology Readiness at End

TRL8 Active Commissioning

Geographical Area

National Grid will provide access to selected substations to install and remove the conditional based monitoring equipment on the surge arrestors in the required timescales. NGET's Deeside Centre for Innovation (DCI) or the University of Manchester will serve to meet any required high voltage testing of the surge arrestors whilst particular and further testing will be conducted at EA Technology's laboratory in Capenhurst.

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£290,750

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 provides a benefit to the electricity network, the consumer, and GB's energy transition by:

a) Prolonging asset life through improved asset condition monitoring and maintenance

b) Informing timeous and correct asset replacement to maintain substation reliability

c) Protecting transformers and switchgear that ensures robust service of key network supplies

d) Improving key operational decision making to manage the network

e) Avoiding catastrophic failures and reducing arising associated carbon footprint

f) Improving overall health and safety by minimising related deaths or injuries

g) Protecting substations from effects of unforeseen extreme weather/network events e.g., lightning and surges

Catastrophic failure situation can potentially destroy other surrounding assets within a substation. The disruptions may cause blackouts that could affect the industry, business, transportation, hospitals, and the public. This necessitates the mobilisation of a repair crew to assess the damage, clear the site and remove the debris and then order, and manufacture alternatives, rebuild and install equipment on site, test and commission equipment, before the substation returns to normality. The project will be critical in averting the carbon footprint that would otherwise materialise from the actions above.

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

Considering a cost benefit duration of 25 years which coincides with the technical asset life of a typical surge arrestor, the assumption for the benefit estimation is that this project will result in deferred asset replacement yielding potential savings/NPV benefits over the next 10 years of approximately £700,000.

This project has the potential to deliver the same benefits to the client that monitoring other units such as transformers offers. Some of those benefits have already been mentioned above, namely:

a) Reduce costs by prolonging asset life

b) Reduce costs by choosing the right asset for replacement

c) Reduce costs by avoiding or minimising asset failures

d) Reduce costs associated with blackouts

e) Reduce environmental impact by all of the above

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

The outcomes of this project will be informed from and can be shared with the wider networks across GB with potential of adoption as best practise.

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

The estimated costs of rolling out the method across GB will be reviewed during project delivery after the research effort has progressed.

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

There are several widespread issues and concerns with surge arrestors not only at transmission level but also on the distribution networks that are experiencing similar failures. The technology application will provide a learning platform to harness information on defect detection and correlation with online monitoring techniques. This type of approach and information does not currently exist, so the project enables an insight into this new learning which can then be assessed, trialled, and applied to other asset classes beyond this project's scope.

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.

This proposed technology exists but is unique in that it has not been carried out before on surge arrestors. There is little data present for the correlation of online monitoring data and forensic information to provide a holistic condition assessment technique. The transferred knowledge will be in relating PD signatures to destructive and non-destructive sources of discharge in medium voltages.

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

To date NGET has not conducted a similar study of this kind in such detail which includes the correlation of in situ analysis, laboratory testing and forensic assessment of EHV surge arrestor assets. The project offers a new and unique approach to assessing the condition of the arresters and will also provide evidence that the technique can then be applied to additional asset classes.

Relevant Foreground IPR

Foreground IPR will be created in the form of documented analysis which will generate confidence in measurement techniques and demonstrate relationships between measured values and activity.

The suppliers will contribute to the background IPR in terms of knowledge, knowhow, software and data relating to:

· The already understood analysis of partial discharge on medium voltage assets and initial research into analysis of partial discharge on high voltage assets.

· Use of the UltraTEV Monitoring system and Astute service, together with all waterproof accessories. Technical specifications include:

o Astute Monitor Enclosed product specification (3473-PRSPC-UTM2_AE-V01.00.00)

o Weatherproof CPD Node product specification (3473-PRSPC-UTMN1_CPDWP-V01.00.00)

o Weatherproof Node product specification (3473-PRSPC-UTMN1_WP-V01.00.00)

NGET will contribute background IPR in the form of knowledge and data relevant to its operation across the electricity transmission network in England and Wales.

The default IPR position will be applied to 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

The proposed solution is innovative in nature, with a component level of risk that is unsuitable to Business as Usual (BaU) implementation straightaway 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 project will undertake innovation in a fully controlled environment where there is no risk of causing network disruptions/outages and where surveys and investigations could also be safely developed. Due to the innovative nature of the project as evidenced in this document, NIA, rather than BaU, is the appropriate funding mechanism for this project.

This project has been approved by a senior member of staff

☑ Yes