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NIA Project Registration and PEA Document

Date of Submission

Jun 2022

Project Reference Number

NIA2_NGET0021

Project Registration

Project Title

New online tools for Assessment of Bushing Condition

Project Reference Number

NIA2_NGET0021

Project Licensee(s)

National Grid Electricity Transmission

Project Start

July 2022

Project Duration

1 year and 10 months

Nominated Project Contact(s)

Gordon Wilson (Box.NG.ETInnovation@nationalgrid.com)

Project Budget

£400,000.00

Summary

This project will consider the available options for monitoring bushings and, through trials and data analysis, determine both the optimum monitoring strategy and the most efficient way to collect the data.

The advantages and disadvantages of relative and absolute measurements of power factor and tan delta will be investigated. More efficient monitoring installation using a wireless voltage reference will be investigated and a new algorithm will be developed to determine true power factor on the LV side of a transformer.

Analysis of the data collected during the project will be used in the development of a new asset health index system for solid-state bushings to support a transition from age-based to condition-based asset replacement.

Preceding Projects

NIA_NGTO0050 - New online tools for Assessment of Bushing Condition (Not-ABC)

Third Party Collaborators

Doble PowerTest

Nominated Contact Email Address(es)

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Problem Being Solved

Solid type bushings such as, ERIP (epoxy resin impregnated paper) and SRBP (synthetic resin bonded paper), are attractive as they are maintenance free and pose no environmental risk from oil leakage. However, solid dielectrics can degrade over time in the

presence of a high internal electric field and thermal ageing. The most common manifestation of degradation is electrical treeing because of partial discharge (PD) activity.

Partial discharge survey tools provide a spot measurement at a moment in time; although this is a good screening tool used during substation routine inspections they are not as sensitive as a sensor connected directly to the bushing (due to the background noise) and not as specific in the source of the discharge. Moreover, the data cannot be trended over time. Permanent online PD monitoring systems have traditionally been complex and generate large volumes of data for analysis. As such, new methods of assessing the condition of solid bushings are needed which can either be installed on a temporary or permanent basis. Such methods should be able to track the change in the condition of the bushing over time. Data collection then needs to provide useful information that can be linked to asset management actions.

Installation of monitoring systems that require a voltage reference can be time consuming and require manual handling of trench covers to install wiring. This makes temporary installations undesirable, but wireless reference sources need further investigation before they can be used reliably.

Method(s)

The project will assess the advantages and disadvantages of relative and absolute power factor measurements, as well as the practicalities of installing the additional equipment required for a voltage reference. Additionally, consideration will be given to the benefits of permanently installed systems versus the concept of installing the necessary sensors and safety box, and using a portable system to acquire data for a limited time period i.e. a week or month. In the latter case, reproducibility of results will be a key consideration.

An adapter will be attached to the bushing tap ('Bushing Tap Adapter' or BTA) to measure the leakage current from which the capacitance and relative power factors can be determined.

To measure true power factor, a voltage reference is required from the VT connected to the bushing. Hardwiring this across a substation, from the VT to the monitor, can be disruptive and time consuming. The project will develop a prototype wireless phase reference to negate the need for hardwiring. Although wireless data transmission is well proven within a substation environment, the accuracy of the measurements will be challenging and will require GPS clock precision to detect the very small differences in phase angle between the measurements at the VT and the bushing tap. Such a development would reduce installation time, eliminate the lifting of trench covers and/or digging, and reduce the area impacted during the installation; combined these factors would reduce the cost of installation.

Since a large proportion of the ERIP bushings of interest are connected to the LV side of the transformer, for a true power factor measurement the transformer is now part of the measurement circuit and will influence the result obtained for the LV bushing tap; changes in tap position will also affect the measurement. The project will investigate these effects and determine if these can be eliminated algorithmically.

The BTA can also be used to detect PD signals and the project will be able to assess the potential advantages of both asynchronous and simultaneous PD monitoring along with the capacitance measurements.

Data Quality Statement (DQS):

- The project will be delivered under the NIA framework in line with OFGEM, ENA and NGGT / 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. Relevant project documentation and reports will also be made available on the ENA Smarter Networks Portal and dissemination material will be shared with the relevant stakeholders.

Measurement Quality Statement (MQS):

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

Risk Assessment

TRL Steps = 2

Cost = 1

Suppliers = 1

Data Assumption = 2

Assessed risk score 6 - Low

Scope

This project supports development of a condition monitoring strategy for solid state bushings and the use of condition monitoring data in determining a health index for the same assets. The goal will be to demonstrate that bushing replacements can be deferred, in some cases indefinitely. This will reduce the future cost of electricity transmission and increase resilience of the network by reducing outage requirements for planned replacement works. Reducing costs and increasing resilience underpin the ambitions for a transition that is fair for all customers and supports greater electrification of energy.

Although this project will focus on transformer bushings, the technology may be applied to through wall bushings

Objective(s)

The objective of this project is to deliver sufficient results from monitoring of bushings at three sites to deliver understanding of the following:

- Comparison of true and relative power factor measurements
- Develop algorithms to enable calculation of true power factor of bushings on the LV side of transformers taking tap-changers into account
- Evaluate the influence of weather conditions on the measurement of condition indicators
- Cost benefit analysis of temporary vs. permanent installation of bushing monitors.The relative value of monitoring partial discharge as well as power factor when partial discharges could have an alternative source on the substation
- Development of an asset health methodology for solid state transformer bushings

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 replacing resin impregnated bushings. 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

The project will be considered successful if as a result a bushing monitoring strategy can be designed based on the outcomes, and if results may be used in an asset health methodology to enable life extension of resin impregnated bushings.

The project will also be considered successful if true power factor can be measured on the LV side of transformers without need to hardwire a connection to a voltage source (i.e., a voltage transformer on the substation)

Project Partners and External Funding

Not applicable

Potential for New Learning

There are a number of innovations to be undertaken that will support an optimised condition monitoring strategy beyond the financial benefits of asset replacement deferral discussed below. These benefits will come from the following learning that is expected to be delivered by the project:

- Continuous vs. Periodic monitoring - the project will provide information on the economics of permanent and periodic monitoring of solid-state bushings taking into account equipment and installation.
- Identification of alternatives to hardwired connections to a VT (voltage transformer) to enable true power factor monitoring. This learning will reduce the time required for installation of monitoring equipment and removes a potential health hazard as safe installation

of cables may require lifting trench covers.

- Numerical methods for eliminating the effects of a transformer and tap-changer when the voltage reference is on the other side of the transformer from the bushings. One of the more challenging aspects of the project it will facilitate the use of true power factor.
- Increase understanding of the benefits of partial discharge (pd) monitoring for bushings when the source of pd is unclear. Elimination of background noise will be a data analysis challenge.
- Interpretation of data to provide information about bushing condition towards development of a health index.

Learning will be disseminated through industry conferences in addition to standard NIA reporting.

Scale of Project

By phasing the project as planned, the complexity can be increased in manageable steps. By rotating the bushing monitors between sites, but leaving the bushing tap adapters and sensors for other contextual data in place, the robustness of the solution can be rapidly assessed, and key questions addressed such as the pros and cons of permanent versus temporary monitoring. It is envisioned to install three systems allowing different bushing types to also be included within the scope. Sites would be picked based on either known bushing issues and relative proximity to each other to allow for easy removal and relocation. It is anticipated to use three sites to perform the work.

Utilisation of the Deeside testing facility in the future would provide a unique opportunity to build on the initial work and investigate the impact of DC offset and harmonics on the measurements. It would be difficult to find a similar testing facility to undertake this work in Europe.

Technology Readiness at Start

TRL4 Bench Scale Research

Technology Readiness at End

TRL8 Active Commissioning

Geographical Area

The site trials will be undertaken at National Grid substations to be determined at the start of the project. Data analysis will be desk based. The condition monitoring solution proposed is not limited to a particular geographical area.

Revenue Allowed for the RIIO Settlement

NGET will use funding allowed for condition monitoring to pay for planning and operational costs associated with installation of the monitoring equipment.

Indicative Total NIA Project Expenditure

£360,000

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. If the project is successful, bushing replacements should be deferred at least 10 years, but many would be deferred to the end of the transformer asset lives meaning the outages for bushing replacements would not be required at all.

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 benefit of this project assumes that the project enables deferral of solid-state bushing replacements, in some cases for at least 10 years minimum and that others will be deferred indefinitely as they will remain in good condition until the transformer is replaced. An NPV calculation has been performed taking into account the cost of the project and an annual business as usual cost for condition monitoring. Deferral of assets that might be replaced on age for 10 years following the completion of this project have been taken into account and show a positive NPV of £220k over 25 years.

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

The calculation of benefits is based on 25 sites. The methodology could be extended to more sites and, as newer bushings tend to be solid-state rather than oil-filled, it will be extendable to the majority of sites in time.

Further work may be required to extend the learning to through-wall bushings, but the knowledge gained should be a firm foundation for this work.

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

It is highly unlikely that continuous online condition monitoring (of any type) will be applied everywhere; it will most likely be installed on a "as-needed" basis on the most critical assets and those identified as having a failure mode/issue that can be tracked and intervention planned before asset failure. This would limit the cost of rolling out the method to the cost of purchasing the equipment and installing it at sites.

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

With the outcomes of this project UK licensees will have the knowledge to choose whether continuous or temporary monitoring is the best solution for gaining asset health data for bushings. Although the project involves a particular supplier of test equipment the outcomes will be applicable to other commercially available equipment. Other Licensees will be able to learn from the monitoring equipment installation practices developed as part of this project and adapt them as necessary to their own requirements.

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.

Note that a similar project with the same name was approved in RIIO-T1, however, the level of site work required was put at risk by the Covid-19 pandemic and the project was closed without any progress made to achieve the aims. The scope of this project has some overlap but with additional focus on wireless voltage source and the development of algorithms to take the transformer and tap-changer effects into account.

NGET received no feedback when registering the previous project that this overlapped with other activities and is still unaware of any activity that would be considered similar.

Any residual risk of duplication will be addressed through dissemination of progress with other licensees and being open to co-operate with licensees working in this space.

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

The project will provide a systematic repeatable method of assessing degradation in solid bushings allowing a quantifiable methodology for generating bushing health indices. Furthermore, it will investigate new ways of using bushing monitoring (both power factor and partial discharge) and determine if temporary relocatable systems provide an effective alternative to permanent monitoring. These have not been previously attempted in the UK or elsewhere to the best knowledge of those involved.

Relevant Foreground IPR

The foreground IPR will be the knowledge gained through site trials and data analysis following monitoring of three substation sites that will enable development of a solid-state bushing condition monitoring approach and knowledge about how to turn the information into asset management decisions about these assets.

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 whether the technology provides the information required to defer asset replacement and how long it takes to collect the information – there is uncertainty over whether it can be collected in weeks allowing the monitoring equipment to be mobilised and used on many transformers or whether it must be installed over longer periods. It is also uncertain to what extent the information gained during this project will be of benefit to other assets i.e., can they be monitored for a shorter period based on the learning from this project. The project will therefore help to determine whether the investment in bushing monitoring in this way is of economic benefit.

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

As mentioned above, NGET will use regulated allowances to pay for an element of the work, specifically planning and operational costs of installing the monitoring recognising that monitoring assets is not in itself innovative.

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

There are technical risks associated with any innovation project as the proposed solution may not work or the benefit will not be as great as expected, the possibility that the wireless acquisition of true voltage will not be possible is of greatest risk and a wired connection may be required affecting the success of an element of the project.

The project is anticipated to generate sufficient benefit to justify the expenditure over 25 years so the success of the project will only become apparent over a longer period.

This project has been approved by a senior member of staff

☑ Yes