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NIA Project Registration and PEA Document

Date of Submission

Feb 2020

Project Reference Number

NIA_NGTO0050

Project Registration

Project Title

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

Project Reference Number

NIA_NGTO0050

Project Licensee(s)

National Grid Electricity Transmission

Project Start

March 2020

Project Duration

0 years and 4 months

Nominated Project Contact(s)

Gordon Wilson (box.ngetinnovation@nationalgrid.com)

Project Budget

£7,000.00

Summary

Bushings pose a challenge in assessing their condition and determining a meaningful asset health index, which would assist in the management of this asset class. Even when oil sampling can be performed this is carried out on a very infrequent basis as they are typically inaccessible even during outages without scaffolding for the purpose of taking a sample. For dry-type bushings there is no oil to sample. Consequently alternative methods of assessment are required, which would ideally allow more frequent assessment of condition. This project will apply online bushing monitoring on a continual and temporary basis to assess the relative benefits of each. The project will further consider the advantages simultaneous partial discharge (PD) monitoring brings to the assessment of the bushing but more broadly to other connected assets.
Although this project will focus on transformer bushings, the technology may applied to through wall bushings.

Nominated Contact Email Address(es)

box.NG.ETInnovation@nationalgrid.com

Problem Being Solved

Oil-filled bushings have been traditionally condition assessed using periodic oil samples sent for offsite dissolved gas analysis. This methodology is capable of detecting the main degradation mode, namely, internal partial discharge; if undetected, the generation of gases can lead to explosive failure. However, bushings are only accessible during outages and require access platforms or scaffolding, typically during a planned maintenance activity. Results causing concern lead to a need for additional samples which proves costly, as the outage and access requirments are generated solely for the purpose of oil sampling.
Modern solid alternatives have no oil to be sampled even though partial discharge is still the most likely precursor to failure. 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. Furthermore, 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.

Method(s)

Solid type bushings such as, ERIP (epoxy resin impregnated paper) and SRBP (synthetic resin bonded paper), are attractive due to being maintenance free and pose no environment risk from oil leakage. Nevertheless, 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 as a result of partial discharge (PD) activity. In the specific case of bushings the trees grow between the stress grading foils progressively shorting these out; this changes the capacitance of the bushing. When too many foils have become shorted the bushing is liable to fail. Due to the degradation mechanism two complementary detection techniques are available:

1. Monitor for partial discharge activity – this tells the asset owner that degradation is taking place but not the severity or how much damage has already occurred. Radiometric techniques, such as RFI (radio frequency interference) monitoring, provide spot data during routine substation inspections and can detect internal PD activity; this is the first chance to detect a developing problem. RFI data can be used as the trigger for more detailed monitoring to track the development of the PD through a permanent monitoring solution.
2. Monitor the capacitance and power factor of the bushing – these measurements can either be performed as a relative measurement, comparing all three phases, or by using a voltage reference (from a Voltage Transformer on site), the 'true power factor' can be determined. Relative measurements have shown success, but suffer from variability in system voltage; having a voltage reference provides a means to provide more consistent and meaningful data which can be more readily compared with factory, nameplate or previous field test results.

The project will assess the advantages and disadvantages of relative and absolute 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.
The BTA can also be used to detect PD signals. Any measured PD may originate either from inside the bushing or from outside the bushing i.e. from inside the transformer tank, on the bars connected to the bushing, or on equipment in proximity to the bushing. On one hand this is a disadvantage in terms of assessing the health of the bushing, but the presence of PD is an indicator of some developing problem, so detection of an issue inside the transformer is advantageous; appropriate signal processing is required to discriminate and identify the source of PD in detail. The project will therefore also assess the potential advantages of both asynchronous and simultaneous PD monitoring along with the capacitance measurements.
In addition, the leakage current sinusoidal waveforms may be captured over a short time period so as to allow for Fourier analysis and detection of harmonic content present in the current; the presence of harmonics may indicate a system issue, including an overvoltage condition, or may indicate the presence of a DC offset related to geomagnetically induced currents.
In addition, the capture of fast transients on the system, picked up through the bushing tap, will provide indiciation of possible root causes of deterioration. The role of fast transients, related to lightning and switching activity, is poorly understood in terms of bushing reliability in the field; traditional but infrequent offline testing provides little value in this area. Online monitoring is a means to improve situational awareness with respect to the bushing population.

Scope

The project will take place in two initial phases.

Phase 1

An initial assessment of an online continuous system will be undertaken by:

- Installing continuous online bushing monitoring at a number of National Grid sites.
- Collecting data with and without a voltage reference.
- Rotating monitoring systems between sites and assess reproducibility of the data.
- Contextual data such as load, MW/MVAr, tap position etc will also be captured as a means to understand possible variations in the raw diagnostics data.

Phase 2

- Trial newly launched bushing monitoring system with integrated PD monitoring.
- Benchmark against Phase 1 results.
- Assess benefits of simultaneous power factor and PD measurements.

After sufficient confidence has been gained in the reliability and repeatability of the data generated during Phases 1 and 2, a potential follow-on project utilising the facilityies at Deeside is envisaged. Here the power frequency waveform could be distorted by injecting a DC offset and/or harmonics, and the effect on the output of the monitoring system investigated.

Objective(s)

To provide National Grid with the knowledge to be able to undertake condition assessment programmes of solid type bushings based on onsite condition monitoring measurements, and to provide tools to detect early bushing deterioration and prevent catastrophic failure.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

Identification of more robust parameters for detection of deterioration in bushing condition, appropriate to the National Grid fleet of bushings, and the application of monitoring to reduce the probability of failure of bushings and improve grid system reliability.

Project Partners and External Funding

N/A

Potential for New Learning

The learning from the project will benefit all network operators as it will be applicable to high voltage solid state bushings.

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

TRL6 Large Scale

Technology Readiness at End

TRL9 Operations

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 and performed by Doble PowerTest. The condition monitoring solution proposed is not limited to a particular geographical area.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£7,000

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:

n/a

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)

At present the strategy for ERIP bushings is to replace at end of anticipated life at an estimated 40 years. National Grid has 189 ERIP bushings between 25 and 40 years old installed on transformers (out of a total population of 289 ERIP transformer bushings) and understanding the deterioriation of condition as they approach end of life could result in life extension. The same technology could potentially be extended to ERIP wall bushings
In the event that monitoring ERIP assets can defer replacement an average of 10 years this would defer capital investment of £12.6 m for 10 years from 2025 to 2035.

Please provide a calculation of the expected benefits the Solution

Assumed cost of implementation would be £300k for the Innovation with first replacements taking place in 2025. Deferral of the first 63 three phase sets for 10 years would provide approximately £3m benefit in deferred capital expenditure. The assumed benefit is therefore £2.7m over the next 15 years.

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

The knowledge gained from the project is applicable anywhere in the UK. Nevertheless, 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. Armed with the outcomes of this project UK license holders will have the knowledge to choose whether continuous or temporary monitoring is the best solution for gaining asset health data for bushings.

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

The cost is negligible (excluding the instrumentation) and would only require changes in specifications to codify the project outcomes.

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

The learning regarding the benefits of relative versus true power factor measurements, as well as the pros and cons of temporary versus permanent bushing monitoring will benefit all network operators in determining how best to conduct condition assessment on solid-type bushings. The methodologies developed within the project will be directly transferable to other owners, although most beneficial to UK TSOs since the economics of online monitoring tends to favour more expensive assets which are skewed toward transmission owners. Nevertheless, bushings on key DNO circuits would also likely benefit from the outcomes of the project where monitoring could be justifiable on higher risk or criticality 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)

Managing Assets - Managing assets throughout their lifecycle

☑ Has the Potential to Develop Learning That Can be Applied by all Relevant Network Licensees

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.

No other UK license holder is attempting this work. From discussions with Doble PowerTest it is believed that two non-UK based utilities have attempted using portable online capacitance monitors to provide temporary monitoring (as an alternative to permanent moitoring) thereby sharing the cost of one monitor over multiple sites. Neither company has published data or results which can be used to support a wider application of the approach; nor have they discussed the cost benefit of this approach (which in reality would be geography and regulatory model dependent).

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

The project is innovative because it will deploy technology not previously implemented by National Grid or any other UK licence holder. It 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 ad partial discharge) and determine if temporary relocatable systems provide an effective alternative to permanent monitoring.

Relevant Foreground IPR

n/a

Data Access Details

n/a

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 has to 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.

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 uncertainties of the project are detailed above and the learning from the project will be directly relevant to all Network Licensees. For thisreason, NGET believes this project is appropriately funded through NIA, and material from the project will appropriately disseminated.

This project has been approved by a senior member of staff

☑ Yes