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

Dec 2024

Project Reference Number

NIA2_NGET0079

Project Registration

Project Title

Fibre Health Monitoring Phase 2

Project Reference Number

NIA2_NGET0079

Project Licensee(s)

National Grid Electricity Transmission

Project Start

January 2025

Project Duration

1 year and 8 months

Nominated Project Contact(s)

Ibukun Oladunjoye

Project Budget

£350,000.00

Summary

The energy network transition will require more agile, flexible and interconnected networks underpinned by reliable communications networks in particular where services for protection and control are concerned. Operational fibre optic networks are reaching an age where some of the equipment is starting to fail whilst other parts of the network are intact and may be able to provide significant further service life. This project will examine enhanced optical sensing methods to detect and track the ageing process of fibre optic cables and associated fittings with the aim of providing accurate health information and the capability to forecast failures. The research will include new optical sensing methods as well as new algorithms to interpret the data and correlate to other data sources.

Preceding Projects

NIA2_NGET0015 - Fibre Health Monitoring

Third Party Collaborators

Adtran

Nominated Contact Email Address(es)

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Problem Being Solved

Operational telecommunications networks carry critical information which is essential to the secure and efficient operation of electricity transmission networks. Large parts of this Critical National Infrastructure (CNI) have now been in service for over 25 years and failures may become more frequent and more difficult to address. The current monitoring regime provides some information about the current status of the network but offers very limited information on asset health and potential future failures. Unplanned loss of communications requires expensive repairs and electricity network outages and, in many cases, also leads to constraints and constraint cost to

consumers. This project will investigate advanced optical sensing technologies as well as monitoring data analysis tools that aim at accurate fibre health modelling and forecasting. If successful, this will enable asset managers to avoid in service communication failures, enable forward planning of replacement interventions and extend the average service life.
Phase 2 focusses mainly on software development and management aspects.

Method(s)

To address the above problem this project will carry out research into optical sensing technologies that can be deployed at key nodes on the fibre optic network in order to monitor the optical characteristics of the fibre network and derive asset health information. The measured data will be recorded over time and analysed together with other data sources such as environmental data to create an asset health model that allows predictive asset health monitoring and management.
The focus in this project is on coherent OTDR and Brillouin OTDR inside a single demonstrator. The demonstrator will be installed on the NGET network for several weeks to months to monitor fibre optic cables of known asset condition and algorithms will be improved based on the derived information, with the goal to bring this to a TRL-8 by the end of the project.

Scope

The scope of the project consists of further development of the prototype for an OPTEL fibre monitoring system and bring the product to a Technology Readiness Level ("TRL") 8 state. The prototype was already conceptually tested in phase 1 of National Grid's Fibre Health Monitoring project. The prototype consists of an Optical Time-Domain Reflectometry ("OTDR"), Brillouin OTDR ("BOTDR") and Phase OTDR to monitor vibration, strain and temperature with the aim of assessing the current health condition of fibre optic cables and forecast future failures. The project will be delivered in two phases:

Phase 1: Improvement of the various detection algorithms
With the prototype hardware having proved its' value in the phase 1 of the Fibre Health Monitoring project, the focus will now shift to the software to detect and eventually classify the various events. Both the phase OTDR and Brillouin OTDR are in focus here. This phase will end in an Alpha trial where the prototype is to be installed at National Grid Electricity Transmission ("NGET") Enderby S/S to collect data over multiple weeks of measurements. Afterwards, a test report is to be written to summarize the findings and developments in this phase.

Phase 2: Algorithm development continuation and geographical referencing
It is not projected that at the end of phase 1 that all possible events are readily detected and classified correctly. This will need lots of data to train the machine learning algorithms. Phase 2 will continue on the phase 1 work and findings for improving algorithms and as such the prototype detection performance. Additionally, geographical positioning of the detected events on a map is in scope for this phase of the project. This phase will end in an Beta trial where the prototype is to be installed at NGET Enderby S/S to collect data over multiple weeks of measurements. Afterwards, a final report is to be written including the test results of the Beta trail, to conclude the Fibre Health Monitoring Phase 2 project.

Objective(s)

The main objective of this project is to bring the prototype to a TRL 8 state for future deployment in the National Grid network. This is to be achieved by:

Improvement of the coherent OTDR detection algorithm: With a coherent OTDR one can detect a wide range of events. For autonomous detection, a machine learning algorithm will be used to identify events along the network. During phase 1 first data was collected with the coherent OTDR in different weather conditions and this data will be used to train the algorithm to identify for instance rain, wind and thunderstorms. However, there is a wide range of applications and key to a robust ML algorithm is to have a lot of data for extensive training. Within phase 2 of the fibre monitoring project, the focus will be for the improvement of the detection algorithm to gather as much data as possible the ML algorithm.

Improvement of the Brillouin OTDR detection algorithm: In addition to a coherent OTDR, the prototype product also includes a Brillouin OTDR. Brillouin measurements are ideal for the detection of strain and temperature. In phase 2 of the project, the focus will be on achieving autonomous event identification for Brillouin OTDR.

Geographical referencing of events / faults: With the prototype it is possible to identify anomalies in the fibre network. In phase 1 it was for instance possible to identify locations with increased stress on the fibre. However, the prototype module provides the distance from the measurement device to the location, not a geographical location. In order to find out the geographical location of the fault, one needs to correlate the measurement data with geographical data.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

Financial distributional impact:

The project is expected to support energy networks to deliver and manage essential operational telecommunications network equipment more efficiently and at lower cost through predictive asset management. If these savings are achieved, the financial distributional impact of this project aligns with the simplest case discussed in OFGEM's 'Assessing the impact of economic regulation' report. The report confirms that the savings as a percentage of household income are more significant for lower income deciles and therefore the achieved benefits will be particularly valuable to vulnerable consumers. The pricing structure for energy transmission will not be impacted, e.g. benefits delivered as part of this project can be passed on to all consumers including households using a prepayment meter.

Technical and wellbeing impact:
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)

Energy technology and usage profiles:
The results of this work can be applied regardless of energy technology and will not differentiate between consumer usage profiles.

Success Criteria

The success of this project can be measured based on the extent to which the objectives have been achieved, i.e. the successful development of optical sensing technology enabling the detection of onset of failure modes and forecasting of failures allowing predictive asset management of fibre optic cables, i.e. repair, refurbishment and replacement. During phase 1 of the project, high strain was identified as such potentially preventing damage to the fiber asset. For further effectiveness, the product needs to be brought to a technology readiness to be able to deploy the technology in the network and allow non-expert users to identify potential degradation events and allow for pro-active maintenance.

Project Partners and External Funding

Adtran are our project supplier

Potential for New Learning

This project has the potential to deliver significant new learning in the field of fibre optic monitoring. Currently most monitoring technologies can detect loss and discontinuities but so far, the correlation between various failure modes such as broken fittings or deterioration of materials associated with the fibre optical cable itself and its supporting structures has not been demonstrated. The impact of environmental factors in the ageing process will also be considered and new machine learning algorithms will be developed and trained to provide further insights. Additionally, novel optical sensors will be tested with regards to their capability to provide more detailed information on asset condition and expected life.
The learning will be disseminated through the publication of the final project report and depending on opportunity through publication and presentation of research papers at conferences and through the ENA and CIGRE.

Scale of Project

The scale of the project includes a laboratory-based development and test phase followed by a small-scale site trial at a single NGET substation. The substation tests will allow evaluation of implemented algorithms and improvements. The goal is to bring the prototype product from TRL-5 to a TRL-8 state.

Technology Readiness at Start

TRL5 Pilot Scale

Technology Readiness at End

TRL8 Active Commissioning

Geographical Area

The project will be partly laboratory based at the respective suppliers' premises and partly site based. The site demonstration and validation will be carried out at an NGET substation.

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£315,000

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:

The energy system transition will require a shift to renewable energy resources which in turn are leading to reduced fault levels and inertia as well as a change to the characteristics of fault currents. Protection systems are going to rely on secure communication channels more than ever. Similarly, situational awareness and wide area control schemes as well as enhanced asset management will also drive more reliance on operational telecommunications services which are supported by NGET's fibre optic OPTEL network. It is therefore critical to monitor the health of the fibre optic network, prevent service failures and enable cost optimized predictive asset management in order to deliver the energy system transition.

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

The likelihood of a fibre fault 1.83%
The likelihood of an equipment fault leading to loss of service 1.19%
Likelihood of a severe double fault with system impacts due to a fibre failure is 1.83%*(1.83%+1.19%) = 0.055%
Impact estimate is £5M and hence annual value of risk associated with such an event is £2,759
The benefit is not very sensitive to these assumptions given the low return and we rely more on the asset management benefits below.

Innovation scenario:
By monitoring 5 routes on a circular basis, relocating one device each year and monitoring the highest risk circuits we are able to extend the asset life of the fibres from 40 to 48 years before replacement.

Value of the total length of wrap over 2570km is £107,940,000 at £42k per km.

Cost to achieve:
Innovation cost £962,000
Annual support cost for 5 devices: £25k
Cost to relocate or initial enablement of one device: £17k
Cost of device deployed by Magdalene: £100k + £7k paperwork and admin

In summary this would require £603k for first deployment and then every 20 years a replacement of OTDR at £535k
Annual support and relocation cost of £42k

Over the life of the fibre this gives us an NPV benefit of £3,041,118

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

The aim of the project is to develop the required enhanced optical sensing technology and machine learning tools with a view of future market availability to all GB networks. This technology can be applied by all licensees which use a fibre optic operational telecommunications network.

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

First deployment plans from National Grid indicated 5 to 10 units. The cost for these units would be in the range of £85,000 + additional software cost. The unit cost will go down when volume goes up. Once fully developed, it is expected that each device can monitor multiple fibres at each substation with a range of 50-100km. In order to get full network coverage, it is estimated that NGET may need around 60 monitoring devices in total.

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 Fibre Health Monitoring project focuses on enhancing the reliability of fiber-optic networks embedded within the power grid. The goal is to implement asset management to enable predictive maintenance. This is particularly useful for network licensees to secure critical communication. Once this is achieved, it will support the timely planning of fiber network replacement interventions, thereby securing critical communications for protection, automation, and control systems.

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.

A review of ongoing and previous projects has not shown any duplication with regards to this work. Fibre optic sensors have been studied for temperature sensing (UKPN IFI and others) as well as noise and vibration sensing (NIA_NGET0034) however no application to fibre optic health assessment or application of coherent OTDR has been reported to date, except for the first phase of the Fibre Health Monitoring project (NIA2_NGET0015) of which this is the follow-up project.

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

Recent developments in optical sensing technology have led to new opportunities for analysis of optical signals in fibre optic telecommunications networks. Multiple sensing technologies are combined to try and enhance the asset monitoring capabilities, which is novel. The project will also apply new Machine Learning (ML) algorithms to the sensor data and correlate with other data sources such as environmental and operational data.

Relevant Foreground IPR

The foreground IPR created in this project will be embedded in the project deliverables, i.e. the reports, design documentation, requirements specifications, test results, software and demonstrator configuration. ADTRAN will bring their own background IPR to the project with regards to optical sensing, Machine Learning and data processing. The learning from this project can be used by other licensees without access to the background IPR.
The agreed management and licencing of IPR would be strictly in accordance with the executed agreement between the parties.

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

There is currently significant uncertainty regarding the feasibility, and accuracy of the proposed method. The new sensing technology has not been generally applied in any commercial products for power utility asset monitoring, and has not been extensively tested yet. It is likely that it will be capable to detect signs of ageing but the method is yet unproven and the accuracy of asset health modelling remains to be validated. The commercial and technical risks are described in more detail below.

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

Technical risks:
The new optical sensing technology is in the early stages of research and its capability to provide insights regarding asset health for fibre optic cables is yet unproven. There is also no in service experience of this technology on fibre optic networks validating the results. Similarly, the ability to apply Machine Learning tools to the data and model asset life accurately remains to be proven. Whilst there is a good chance that the project will deliver the expected benefits, there are also some technical risks making NIA funding necessary.

Commercial risks:

The above technical risks contribute to significant uncertainty regarding the effort required to develop a product ready for market rollout. This risk is holding back the development and investment. By proving the key use cases for this technology, further development will be possible, and a market-ready product can be developed for the benefit of licensees and consumers.

This project has been approved by a senior member of staff

- [x] Yes