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

Oct 2022

Project Reference Number

NIA_NGGT0187

Project Registration

Project Title

Precision Thermography for Hydrogen Pipelines Inspection

Project Reference Number

NIA_NGGT0187

Project Licensee(s)

National Gas Transmission PLC

Project Start

October 2022

Project Duration

0 years and 9 months

Nominated Project Contact(s)

Peter Martin, Box.GT.Innovation@nationalgrid.com

Project Budget

£207,724.00

Summary

National Grid Gas manages the National Transmission System (NTS) in the UK and are responsible for ensuring pipelines are fit for purpose. NTS pipelines are inspected using Pipeline Inspection Gauges (PIGs), which travel along a pipeline with the gas flow, recording pipeline measurements as they move through the pipeline. Sensors on PIGs utilize a variety of technologies, each with their own benefits and disadvantages. Thermography is an evolving technology in various industries and a technology not utilized to date in inline inspection. There is potential for thermography to provide more accurate and precise data relating to the location and dimensions of pipeline defects. As we transition to transporting hydrogen, it is vital inspection techniques used provide data which accurately represents the condition of pipelines.

Third Party Collaborators

Cranfield University

RAVMAC

Nominated Contact Email Address(es)

Box.GT.Innovation@nationalgrid.com

Problem Being Solved

National Grid Gas are responsible for ensuring NTS assets are in efficient working order and safe to operate. Pipeline inspection is vital for condition-based monitoring to identify corrosion and cracks, to facilitate remediation. National Grid currently carry out inline inspection using Pipeline Inspection Gauges (PIG)s to determine the state of the NTS assets. PIGs move through the pipeline with the gas flow and use several NDT technologies such as acoustic (ultrasound) and electromagnetic resonance to validate pipeline fitness

for purpose. Whilst these technologies provide a way to detect defects, it is not uncommon for defects to be misreported. With the introduction of hydrogen into the NTS, pipelines maybe subject to greater levels of deterioration at an accelerated rate and more crack like anomalies are likely to occur. Technologies which could detect micro cracks and characterise defects or abnormal features more effectively would help to determine the condition of pipelines. This information would enable the suitability of pipelines for repurposing to be assessed, before transitioning to hydrogen.

Method(s)

Infrared thermography, thermal video, and thermal imaging is a process whereby a thermal camera captures and creates an image of an object by using infrared radiation emitted from the object either passively or actively[1]. Whilst thermography is not a new technology, the advances in its system design, hardware and computational capabilities are providing significant and new opportunities in industrial metrology applications. As a new emerging capability and area of exploration, this project also recognises adjacent inspection programmes within the existing gas network of higher 4-8 TRL value, focusing on active leak detection and repair through robotics namely LeakVision (NIA_NGN_256). With the planned introduction of Hydrogen and mixed gas transmission, this early phase research TRL 2-4 project focusses on pipeline structural integrity using thermographic inspection for pre-emptive 'condition based monitoring' and pipeline characterisation opposed to gas leakage.

Novel thermography-based systems and analysis are currently in development at Cranfield University in adjacent industrial applications such as Rail (towards TRL4), this research poses a significant early opportunity to transfer knowledge and capability into a new and more demanding environment within the energy sector.

This project seeks to explore the opportunities of using thermographic inspection as an inline internal inspection technique and identify the benefits to the gas sector. It is anticipated the research will encompass several technologies to deliver the system benefits, this will include image capture & recognition, data processing and predictive analytics including end-user interfaces.

The project will be structured into 3 delivery phases and decision points.

Phase 1 of the project will conduct exploratory research and feasibility and capture the NTS system requirements together with determining the suitability of infrared thermography techniques. Based on the outcomes of the stage 1 requirements and feasibility, Phase 2 will be undertaken at Cranfield University.

The project will provide a systematic approach to characterisation and feature measurement with the resultant data providing the ability to catalogue degradation and support the development of future standards and compliance.

The output of the project will aim to provide a viable & scalable thermographic inspection approach that can be used alongside existing inspection methods and support future hydrogen transition.

[1] "Passively" and "Actively" refers to how thermal energy is generated enabling image capture.

Measurement Quality Statement

The measurement approach used to meet Data Quality objectives will be through the identification of high calibre project partners who are experts in their given field and the use of real data and materials from National Grid sites. In this instance the project will be limited to lab testing and technology system development from TRL2 to TRL3 and therefore will combine knowledge from other industry applications with lab scale testing to inform new insights into the use of precision thermography on NTS applications. The lab tests will be carried out by Cranfield University, relying on their high-quality equipment and expertise to determine the opportunity held in this system.

Data Quality Statement

The project will ensure that data used is of sufficient quality to deliver project objectives through the development of a robust testing plan developed through the design of experiments process (Phase 2), considering key variables, and managing them through the testing. The relevant data and background information will be stored for future access within the National Grid Innovation SharePoint site.

Scope

The project will be split into 3 Phased work packages:

1) Phase 1 - Requirements, Use Case definition and initial technology feasibility (Duration – 3.5 months)
Lead – RAVMAC and National Grid; Supported by: Cranfield University

The Phase 1 work package will include:

· Knowledge gap assessment: Conduct a public database search for cross-sectoral developments in thermography across industry sectors and their potential relativity for pipeline inspection.

· Technical requirements – Determine use cases, System boundary, functional requirements and targets, non-functional requirements, physical integration, concept design, test standards, user interface, data analysis and output parameters.

· Theoretical system design and evaluation – conduct initial physics assessments to meet proposed system requirements in support of Phase 2 commencement.

· Commercial requirements – Agree business expectations, operational requirements, system & data interoperability, financial factors, business interfaces and areas of efficiency gains.

· Implementation considerations – Assess system integration, system (& data) compatibility, human machine interface, data acquisition & management. Determine material / information supply for evaluation and test in Phase 2.

· Testing plan development – Confirm test cases, Validation and verification methodology, lab system capabilities, component / system limitations and proposed mitigations

· RASIC – Activity owners' project team roles and responsibilities, project interfaces, information and physical supply accountability

· Master Schedule – Overall key milestone plan, activities register, project review schedule, risk management and reporting.

· Phase Report - Progress status and findings and decision to proceed

2) Phase 2 - Technology demonstration and feasibility on NTS Materials (Duration – 4.5 months))

Lead – RAVMAC and Cranfield University

The Phase 2 work package will include:

· Develop thermographic system research options against targets.

· Conduct benchmarking and baseline exercise of existing pipeline inspection technologies

· Produce test plans and prepare experimental facilities

· Determine material behaviour characteristics and breadth.

· Develop functional model concept – virtual system

· Produce system design proposals and parameters

· Produce physical demonstration in laboratory environment

· Conduct DOE tests and capture results

· Evaluate options against performance envelopes.

· Develop / align digital storage methods, retrieval, and accessibility

· Define data analytics and predictive capabilities

· Provide HMI options incl.– IOT and connectivity

· Conduct 'end user' useability assessment

· Provide technical report of findings and recommendations

· Stage Report - Progress status and findings

3) Phase 3 - Reporting (Duration - 1 months)
Lead – RAVMAC and National Grid

The Phase 3 work package will include:

· Consolidated report containing technical report(s) of all phased work carried out.

· Production of progress report in March 2022 for NIA governance

· Production of Final project closure report containing conclusion, recommendations to inform NTS strategic intent

Objective(s)

Determine the use of thermography and associated system technologies to enable improved understanding of the NTS assets in preparation for hydrogen injection.

Phase 1 Objectives:

1. Determine the applicability of thermography to inspect gas pipelines.
2. Perform requirements capture on the typical degradations. (NTS assets - include existing and most prominent features)
3. Adapt thermography for surface profile mapping (to pre-defined degradations highlighted above).
4. Perform additional thermography inspection in the active mode to detect sub-surface damage
5. Gate assessment to confirm the suitability of thermography to detect pipeline damage

Phase 2 Objectives:

1. Benchmark thermography inspection against existing acoustic and electromagnetic resonance techniques.

2. Data analytics – automated feature extraction, data reconstruction and data visualisation

3. Propose and develop a TRL 4 demonstrator

4. Provide a detailed summary of full working capability including limitations and recommendations of the technique.

Phase 3 Objectives:

1. Final Project Report and Recommendations.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

The National Transmission System (NTS) is a key UK infrastructure for the transport of Gas to consumers, including those considered vulnerable. In a scenario where hydrogen replaces methane as a household heat source, it is essential the vulnerable are not excluded

by virtue of fuel inaccessibility. In cases where vulnerable consumers already utilise gas, it is likely that in a net zero future the optimum option is to provide a consistent energy solution. The transition to hydrogen within the NTS provides continuity of access to the vulnerable of hydrogen as a replacement to methane, with ongoing benefits of efficiency and economy of scale within a closely regulated environment. This project supports the transition of the NTS to hydrogen which in turn supports the availability of gas to the vulnerable.

Success Criteria

The key research questions that this proposal aims to answer are:

1. Can thermography be used as a condition monitoring tool to detect gas pipeline inner wall damage and degradation?

2. Is there potential for thermography to be applied as a non-contact technology in high-speed PIG mounted applications with restricted field of view?

The success criteria will be to determine the feasibility of the detection capabilities of thermography in a dynamic system, such as in-line inspection.

Project Partners and External Funding

Gas Network – National Grid Gas PLC

Technical & Industrial Leads – RAVMAC Ltd

Academic Partner - Cranfield University

No external funding

Potential for New Learning

Thermography is being explored as an inspection technique in other industries, but has not yet been investigated as a potential in line inspection technique for pipelines. The feasibility of thermography as an inline inspection technology will be assessed as part of the project. The new learning created through this project is:

- Test data to prove that common pipeline defects can be detected utilising thermography
- Development of data storage, processing and analysis requirements for pipeline inspection
- Preliminary safety assessment for the use of thermography in pipelines
- Assessment of thermography against other inspection techniques
- Enable the suitability of pipelines for repurposing for use with hydrogen to be assessed.

Scale of Project

This project is a lab scale testing activity that will provide insight into whether there is an opportunity to utilise thermography for inspection of the NTS. The learning will be relevant to NTS materials X52, X60, X65 and X80 and will consider the impact on X70. This learning will be transferrable to LTS and other DN applications and other assets on both transmission and distribution networks.

This proposal will investigate an early requirement capture stage that will establish the requirements of the inspection, the type of damage, its detectability and data analytics to allow comparative assessment of thermography against the existing technology implemented in the field.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL3 Proof of Concept

Geographical Area

United Kingdom – Warwick and Cranfield (Bedfordshire)

Revenue Allowed for the RIIO Settlement

None – Hydrogen network focused project

Indicative Total NIA Project Expenditure

£207,724.00

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:

To ensure that the transition to hydrogen is carried out safely, pipeline integrity management systems need to be developed to ensure that further risk is not introduced with the transportation of hydrogen in comparison to natural gas. The suitability of pipelines for repurposing will need to be assessed using pipeline inspection technologies. It is possible that hydrogen will cause accelerated degradation of pipeline materials and defects, but this can be managed with effective pipeline inspection and maintenance. Increased accuracy of inspection techniques in determining the location, type and dimensions of defects would enable defects to be remediated effectively, where required. Improved accuracy also has the potential to indicate the growth rates of defects in hydrogen environments, enabling pipeline operators to determine required inspection frequencies. The inspection of pipelines at optimum frequencies along with effective maintenance and repair would ensure the safe transition to and operation of hydrogen pipelines.

How the Project has potential to benefit consumer in vulnerable situations:

Although this project does not directly affect vulnerable consumers the energy transition may and as such, we must consider the effect of the work we are doing through the NIA funding. The National Transmission System (NTS) is a key UK infrastructure for the transport of Gas to consumers, including those considered vulnerable. In a scenario where hydrogen replaces methane as a household heat source, it is essential the vulnerable are not excluded by virtue of fuel inaccessibility. In cases where vulnerable consumers already utilise gas it is likely that in a net zero future the optimum option is to provide a consistent energy solution. The transition to hydrogen within the NTS provides continuity of access to the vulnerable of hydrogen as a replacement to methane, with ongoing benefits of efficiency and economy of scale within a closely regulated environment. Ensuring robust NTS assets and consistent hydrogen production options will support the transition of the NTS to hydrogen which in turn supports the availability of gas to the vulnerable.

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)

RIIO-1 Question N/A

Please provide a calculation of the expected benefits the Solution

There will be no direct benefits from this project. The project results could enable us to determine the state of our assets in a more efficient manner than currently available today and therefore could provide savings in the future application.

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

The project is focussed on metallic pipeline materials however this system could be relevant to other networks that undertake inspection activities and will be opened to the wider gas network group.

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

The cost of rolling out this technology is unknown and further development on the application and commercial model is required. This will be investigated as part of the project.

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 technology developed in this project will be applicable to the pipeline operators and could offer better assessment of the assets, resulting in improved diagnostics, and optimised repair and maintenance.

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

RIIO-1 Question 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.

The project will start with full literature review following by a complete report on the prior art before initiation of the relevant work packages. There will be no duplication of activities done as part of this program. The initial literature assessment already indicates that proposed method here will be novel.

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 continued development of thermography technologies in industrial applications, particularly in image recognition and processing afforded by computational advances in ML & AI are extending research into alternative and new applications and environments. With associated research continuing to gain momentum in this area and the advent of new industrial digital capabilities, it is now viewed as a serious alternative to explore for gas pipeline inspection. The ability to research fast sensor data integration time, enhanced data processing capability and mapping visual information could transform high-fidelity data consumption in challenging dynamic environments making thermography an attractive alternative solution or supportive technique when compared with the likes of magnetic and acoustic systems.

Relevant Foreground IPR

The results of the project will enable us to determine the application of thermography on the NTS and the potential to develop systems for deployment on PIG systems. IPR will be managed as per the NIA governance document. Where background IPR has been created on the thermography system this will be required to utilise any foreground IPR created. This will be determined through the contracts for the project.

Data Access Details

Data for this project, and all other projects funded under the Network Innovation Allowance (NIA) funding scheme, can be found or requested in a number of ways:

· A request for information (RFI) via the Smarter Networks Portal at https://smarter.energynetworks.org. National Grid Gas Transmission regularly publishes much of the data arising from our innovation projects on the ENA portal, before submitting a RFI check this website.

· Via our managed mailbox box.GT.Innovation@nationalgrid.com. Further data can be shared upon request through the innovation mailbox. Each request will be assessed by the GT Innovation Team for its merits and viability.

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

The technology is a novel system not yet developed for the gas industry and therefore is a low TRL system with high levels of risk associated. It is therefore relevant for NIA funding.

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 prior work has been undertaken for the rail industry and in order to develop this for the gas industry NIA funding is required to enable the collaboration with the academic partners and industrial partners. The application and technical challenges around the application require early stage research to be conducted and therefore carries additional exposure to risk – the NIA funding reduces exposure to the risk and enables the feasibility of the technology to be used for pipeline inspection to be assessed.

This project has been approved by a senior member of staff

☑ Yes