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

Aug 2023

Project Reference Number

NIA_NGT0216

Project Registration

Project Title

Compressor Fleet Failure Mode and Effects Analysis for Hydrogen

Project Reference Number

NIA_NGT0216

Project Licensee(s)

National Gas Transmission PLC

Project Start

September 2023

Project Duration

0 years and 9 months

Nominated Project Contact(s)

Matthew Hammond, box.GT.innovation@nationalgas.com

Project Budget

£91,784.00

Summary

Compressor stations are key assets for the National Transmission System (NTS), providing the required pressures and flows of natural gas to meet demand and build flexibility through linepack. National Gas are currently carrying out numerous innovation projects looking at repurposing compressor units to for hydrogen as part of the transition to Net Zero, including technical feasibility, safety and commercial viability.

Failure mode and effects analysis (FMEA) studies are used to assess systems at component level in order to identify points of failure and their causes and effects. A FMEA study of NTS Compressor Stations will enable the safe operation of these systems with hydrogen by assessing the operational, safety and environmental impact of introducing hydrogen blends and 100% hydrogen to the NTS.

Third Party Collaborators

DNV

Nominated Contact Email Address(es)

Box.GT.Innovation@nationalgrid.com

Problem Being Solved

Compressor stations are currently configured for natural gas operation, with the necessary safety standards and procedures in place for the safe operation. The failure modes and effects are known for natural gas but not for hydrogen. The introduction of hydrogen will

introduce different safety risks which need to be identified and addressed before these sites can operate safely with hydrogen. Hydrogen blends and 100% hydrogen will have an impact on each component on site.

Each compressor station on the NTS is configured differently therefore a FMEA study cannot use a single generic compressor station. Gas turbines are most commonly used as the driver in the compressor train however some sites utilise electric motors. This project therefore includes surveys of different sites with a range of Original Equipment Manufacturer (OEM) equipment and to determine generic sites covering both gas turbines and electric motors which can be used for the FMEA study.

Method(s)

DNV will work closely with National Gas stakeholders including rotating machinery engineers and safety engineers to determine the generic sites to be used for the FMEA, as well as the Project Union team to determine the high priority sites, engaging through regular meetings and workshops. Two generic sites will be identified to cover gas turbine and electric motor drive types.

Data gathering will be carried out by DNV personnel, with support from the relevant National Gas operational teams. Sites visits will be undertaken to four compressor stations which give the widest representation of compression assets on the NTS, with the early stages of Project Union taken into account.

The FMEA studies for the two generic stations at 25% hydrogen blend operation will be carried out by DNV based on ISO 14224:2016 - Petroleum, petrochemical and natural gas industries – Collection and exchange of reliability and maintenance data for equipment. For the 100% hydrogen scenario only a system-level FMEA will be carried out as compression equipment for 100% hydrogen is not yet available on site.

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. The methodology used in this project will be subject to our supplier's own ISO 9001 certified quality assurance regime and the source of data, measurement process 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 made available for review.

Data Quality Statement (DQS)

The project will be delivered under the NIA framework in line with the agreed Energy Networks Innovation Process document and NGT internal policies. 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 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.

Scope

The project will consist of four work packages detailed below.

Work Package 1: Determination of generic compressor stations

DNV will use the available compressor station asset information, such as, electric motor or gas turbine as the driving unit, gas compressor, fuel skid (for gas turbines) and lube oil system types to determine common train types across the NTS network. Two types of generic compressor train/station will be created, one for gas turbine driven compressors and the other for electric motor driven compressors. These generic compressor stations will be used as the focus trains for the FMEA therefore it is important to select enough representative units to cover the typical assets across the NTS fleet.

Another factor which will be used in the selection process is the expected H2 transition timetable for each compressor station. Certain stations will experience transition to H2 introduction sooner than others, for example the Humber and Northwest Hubs. DNV will therefore take a view on common unit types situated on compressor stations in these areas. DNV expects the NGT innovation team can share some high-level information about the early H2 transitions areas of the NTS.

A short summary report will be produced explaining why the focus units have been selected.

Work Package 2: Data Gathering

Work package 2 is the data gathering exercise comprising site visits to 4 stations covering the various unit types.

Where possible local sites to the DNV Stockport office will be selected to reduce excessive travel. Also, sites will be selected where 2 or more representative focus compressor train types are available, again this will reduce the travel burden.

A list of the information required for the FMEA is detailed below. These items are likely to be held at sites or on central databases.

- Process Flow Diagrams / P&IDs
- Equipment List
- Design basis / Process Description (or equivalent)
- Cause & Effects Matrix
- Operations and Maintenance Philosophy, and Operating Logic
- Maintenance Strategy (Planned & Corrective)

Visits will be performed to each of the stations identified in Work Package 1. The data gathering is expected to take one day per site. Initial contact will be made between the DNV site engineer and the NGT site teams to ensure as much preparation work can be performed in advance of the visits to ensure best use of site time. It may be determined that several items can be gathered without the requirement for a site visit.

Work Package 3: FMEA on each unit type

All elements of the compressor train will be assessed for the two generic types for gas turbine or electric motor driven units. The assessment will include compressor trains and associated components, scrubbers, aftercoolers, fuel gas skid, protection system, fire & gas system, seal gas system and lube oil system. The Equipment Subdivision adopted for the FMEA will be the taxonomy Level 6 “Equipment Class / Unit” (Vessels, heat exchangers, compressors, pumps, gas turbines, etc.), according to ISO 14224:2016 “Petroleum, petrochemical and natural gas industries – Collection and exchange of reliability and maintenance data for equipment”. More detailed taxonomy level for Equipment Subdivision (e.g. Level 7 “Subunit”) can be adopted, where deemed practicable.

Failure modes and equipment boundaries will be defined according to ISO 14224:2016 and are dependent on the adopted failure data source. Qualitative FMEA’s will be performed, assessing the operational, safety and environmental impacts of the H2 introduction. The FMEA will be assessing the following, for each equipment:

- Failure Modes and/or Causes
- Failure Detection Methods
- Compensating Provisions
- Local Effects in terms of safety / environmental impact / compressor operability
- Global Effects (generally in terms of Network Operability)
- Severity Class Related to effects
- Qualitative Risk Evaluation – Based on a combination of Failure Rate Category and Severity Class, using a suitable Risk Matrix, which will be agreed between DNV and NGT.

Assessment will be made for two potential network gas types described below.

- 25% H2/NG blend,
- 100% H2

DNV's approach will be to perform the full qualitative FMEA on each selected unit firstly based on the 25% H2/NG blend. This part of the assessment will be based on the current equipment. For the second gas type (100% H2) the assessment will use the 25% blend FMEA as a starting point and perform a system level assessment of the additional risks due to the change in H2 concentration. The limiting factor for this element of the study will be the operational equipment doesn't exist for 100% H2 currently, therefore only system level assessment can be performed.

DNV will produce full FMEA assessments for the 25% H2/NG blend, for the 100% H2 an additional risks assessment will be produced. To complete the FMEA for the 100% H2 gas a workshop will be required to validated risk level assumptions.

The final output of the project will be a workshop with DNV and NGT personnel present to share and discuss the findings of the FMEA.

Following completion of this project there will be opportunity to perform more detailed quantitative or focused assessment on any risk areas of concern highlighted in the workshop.

Work Package 4: Project Management and Reporting

DNV will be responsible for project management, organising project meetings and the submission of project reports.

DNV will produce summary reports for Work Package 1 and 2 plus an FMEA report for a gas turbine site, an FMEA report for an electric drive site and an FMEA report for 100% hydrogen following a workshop with NGT personnel as part of Work Package 3.

Objective(s)

The objectives of the project are to:

- Determine two generic compressor stations to use for the FMEA
- Carry out site visits to four compressor stations to gather the required information
- Carry out FMEA studies for the two generic compressor stations for 25% hydrogen in natural gas blends and 100% hydrogen

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 a neutral impact on customers in vulnerable situations. This is because it is a transmission project.

Success Criteria

The following key criteria need to be met for the project to be considered successful:

- Objectives met to time and cost.
- Project findings inform the requirement for safe operation of compressor stations with hydrogen blends and 100% hydrogen and help develop the Compression Strategy for the NTS and Project Union.

Project Partners and External Funding

Lead network: National Gas Transmission plc

Lead supplier: DNV

Potential for New Learning

The project will address the impact of hydrogen on NTS Compressor Stations including safety, environmental and operability. The project will inform NGT's hydrogen compression strategy and help determine the required design and operational changes for hydrogen blends and 100% hydrogen at compressor stations. The findings from the project will be uploaded to the ENA Smarter Networks portal and will be shared via National Gas innovation social media.

Scale of Project

The project comprises visits to four compressor stations and a desktop study into two generic compressor stations which represent the NTS compressor fleet. Visits to four compressor stations was determined to be sufficient to gather data on a range of assets which represent the NTS compressor fleet. Two generic compressor stations were determined to be sufficient to represent the two driver types utilised on the NTS (gas turbine and electric motor) and the other assets on site. With fewer site visits the range of assets deployed on the NTS may not be covered.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL3 Proof of Concept

Geographical Area

United Kingdom – Warwick, Stockport and operational sites to be selected during the project.

Revenue Allowed for the RIIO Settlement

None – hydrogen focused innovation project.

Indicative Total NIA Project Expenditure

£91,784

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 project will provide key safety and operational insights into operating compressor stations with hydrogen blends and 100% hydrogen in the network. This information can be used across the NTS Compressor Fleet and enable hydrogen in the NTS.

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)

N/A

Please provide a calculation of the expected benefits the Solution

Value tracking

	Data Point	Data Point Definition
Maturity	TRL2-3	The project will utilise known methodologies applied to a new application (hydrogen in compressor stations).
Opportunity	100% of single asset class	The project will cover compressor stations on the NTS.
Deployment costs	-	The project is not delivering something that will be deployed on the network.
Innovation cost	£91,784	The cost of the innovation includes a desktop study, site visits (travel), reporting and project management.
Financial Saving	-	The project may result in financial savings if the findings can be used to avoid costly changes to compressor station configurations however this

will not be realised within this work.

Safety	-	The project could be used to build safety procedures for the operation of compressor stations with hydrogen.
Environment	-	The project will not have any direct CO2 savings but will help enable hydrogen in the NTS.
Compliance	Support compliance	The project will support compliance with relevant safety standards for safe operation of compressor stations with hydrogen in the future.
Skills & Competencies	Individuals	Individuals directly involved with the project will gain an understanding into the failure modes of current compressor station designs with hydrogen.
Future proof	Supports business strategy	The project will help enable hydrogen in the NTS and support the energy transition.

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

There are 24 compressor stations located throughout Great Britain. The project approach is to determine generic compressor station configurations, meaning the outputs can be applied to all compressor stations on the NTS.

There are no compressor stations on Gas Distribution Networks, only the Transmission System.

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

This project will focus on generic compressor stations and the roll out of this method across all compressor stations will not be the focus of this work. There is potential to build on this work and look to apply the methods and findings to existing compressor stations across the UK.

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 from this project could be applied to other operational sites on gas networks. Although the project will focus on compressor stations and the components of these, there may be learnings which apply to other kinds of gas sites, such as Above Ground Installations (AGIs).

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.

There will be no duplication of activities done as part of this program. This project will address a gap in National Gas' ongoing innovation work looking at repurposing compression assets.

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 as it provides new information on compressors for operation with hydrogen, which aligns with ongoing innovation work streams looking at repurposing compression assets. The impact of hydrogen blends and 100% hydrogen on the safety, environmental and operability on compressor stations is not yet known. The desktop study will apply known methods for the assessment of failure mode causes and effects and apply this to hydrogen blends and 100% hydrogen.

Relevant Foreground IPR

This project will not result in any new Foreground IPR as the study will be carried out using existing methods.

Data Access Details

Details on how network or consumption data arising in the course of an NIA funded project can be requested by interested parties, and the terms on which such data will be made available by National Gas can be found in our publicly available "Data sharing policy relating to NIA projects" at www.nationalgas.com/gasinnovation. National Gas data access is managed IAW provisions under 2.15-2.18 for the current NIA Governance Document.

National Gas already publishes much of the data arising from our NIA projects at www.smarternetworks.org. You may wish to check this website before making an application under this policy, in case the data which you are seeking has already been published.

Data Quality Statement (DQS):

The project will be delivered under the NIA framework in line with the agreed Energy Networks Innovation Process document NGT internal policies. 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 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 ISO 9001 certified quality assurance regime and the source of data, measurement process 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 made available for review.

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

Hydrogen is not currently present in the NTS or on compressor stations, either in the process gas or fuel gas. Hydrogen is being directed as a future energy solution but RIIO-2 business funding does not allow the development of hydrogen ready solutions and therefore this project cannot be undertaken as part of BAU activities.

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 impact of hydrogen on the safety, environmental and operability of compressor stations on the NTS requires early stage research and assessment and therefore carries additional exposure to risk. The NIA funding reduces exposure to risk.

This project has been approved by a senior member of staff

☑ Yes