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

Jul 2023

Project Reference Number

NIA_NGGT0199

Project Registration

Project Title

Hydrogen Fuel Gas for GTs – Emissions Impact

Project Reference Number

NIA_NGGT0199

Project Licensee(s)

National Gas Transmission PLC

Project Start

July 2023

Project Duration

0 years and 5 months

Nominated Project Contact(s)

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

Project Budget

£192,573.00

Summary

Gas Transmission and Metering (GT&M) are committed to reducing emissions from the operation of the National Transmission System (NTS) and eliminating emissions by 2050. The transition to hydrogen provides an opportunity to reduce carbon emissions at compressor sites. The use of hydrogen as a fuel gas was investigated in the Hydrogen Fuel Gas project and it was concluded that the use of hydrogen would significantly increase the volume of NOx emissions. This conclusion was based on the temperature of a diesel flame, as no experimental work has been undertaken on a NTS gas turbine. The project will aim to quantify the NOx & CO emissions from an aeroderivative gas turbine fuelled with hydrogen and investigate potential options for emissions abatement.

Preceding Projects

NIA_NGGT0176 - HyNTS - Hydrogen Fuel Gas for NTS Compressors

Third Party Collaborators

Cardiff University

Siemens Energy Industrial Turbomachinery Ltd

Nominated Contact Email Address(es)

Box.GT.Innovation@nationalgrid.com

Problem Being Solved

Gas Transmission and Metering (GT&M) are committed to reducing emissions from the operation of the National Transmission

System (NTS) and eliminating emissions by 2050. The potential increase in NOx production from the application of hydrogen blends was identified as a major and almost certain risk in the H2F4C project, with emitted concentrations likely to exceed current permissible limits. Findings suggested that a 25% (v/v) hydrogen blend may result in a predicted increase of NOx of approximately 32%, with an increase of approximately 125% for the combustion of pure hydrogen. The project was primarily focussed on the investigation of an aeroderivative gas turbine, with emissions predictions generated using a proprietary modelling tool based on equivalent temperature from a diesel flame. The results thereby carry significant uncertainty, given potential differences in combustion characteristics.

The scale of any resultant NOx abatement technology may provide a significant impact on project investment and feasibility. Independent, non-proprietary experimental trials are recommended in order to quantify the scale of the problem, and the potential efficacy of in-combustor NOx abatement.

NOx emissions are likely to increase with the use of hydrogen as a fuel gas, and potential NOx abatement technologies require investigation.

Method(s)

Cardiff University's Gas Turbine Research Centre (GTRC) has a generic, non-premixed aeroderivative combustor capable of operating at elevated ambient conditions of temperature and pressure and quantifying the change in NOx emissions resulting from a fuel switch.

A 60 hour (approximately 4 week) experimental campaign outlined to evaluate:

· Emissions production from methane, hydrogen and diesel flames, operated at equivalent power and thermal conditions. Reactant inlet temperature would be held constant, and combustor pressure increased up to 6 bara, (1, 2 4 6 bara) scaling directly with thermal power.

· Emissions production from a 25% (v/v) hydrogen/methane blend (1, 2 4 6 bara).

· The efficacy of steam injection on NOx/CO emissions for hydrogen, and hydrogen/methane blend (1, 2 4 6 bara). Steam will be introduced in 3 increments with different reactant fractions achievable at different operating pressures. This specification will be refined with project partners.

· The efficacy of synthesised exhaust gas recirculation (N2 and H2O) on NOx/CO emissions for hydrogen, and hydrogen/methane blend (1, 2 4 6 bara). 3 increments to 10% reactant composition, or until flame becomes unstable.

For each campaign, review meetings will be held between project partners to consult on the results of any preceding work, and the potential refinement of the test matrix for the next experimental campaign. The following experimental variables can be reviewed and specified:

· Reactant ambient inlet temperature (nominally 500 K)

· Thermal power scaling (nominally 12.5 kW/bara)

· Swirl number (nominally 0.8)

· Steam fractions

· EGR fractions

A desktop review of NOx abatement technologies will be undertaken and their suitability for use with a hydrogen flame assessed.

Measurement Quality Statement

The measurement approach used to meet objectives will be through the identification of high calibre project partners who are experts in their given field. In this instance the project will be limited to experimental analysis from TRL3 to TRL4 to determine the level of NOx emitted from fuelling a GT with hydrogen, to validate desktop analysis previously undertaken,

Data Quality Statement

The project will ensure that data used is of sufficient quality to deliver project objectives by engaging with GT&M colleagues from various areas of the business. 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 4 work packages:

Work package 1 – Experimental Preparation (1 month)

Cardiff University will ensure adequate fuel supplies for the initial experimental campaigns, alongside the calibration of relevant diagnostic equipment. An initial meeting will be held between project partners to review the first experimental campaign.

Work package 2 – Experimental Programme (3 months)

This provides a window for each of the four experimental campaigns to be completed by CU. These activities will be scheduled around other GTRC work, with sufficient time to process results for presentation. A further four meetings will be held between project partners to review the results of completed work, and the plan for each following campaign. A 60 hour (approximately 4 week) experimental campaign outlined to evaluate:

· Emissions production from methane, hydrogen and diesel flames, operated at equivalent power and thermal conditions. Reactant inlet temperature would be held constant, and combustor pressure increased up to 6 bara, (1, 2 4 6 bara) scaling directly with thermal power.

· Emissions production from a 25% (v/v) hydrogen/methane blend (1, 2 4 6 bara).

· The efficacy of steam injection on NOx/CO emissions for hydrogen, and hydrogen/methane blend (1, 2 4 6 bara). Steam will be introduced in 3 increments with different reactant fractions achievable at different operating pressures. This specification will be refined with project partners.

· The efficacy of synthesised exhaust gas recirculation (N2 and H2O) on NOx/CO emissions for hydrogen, and hydrogen/methane blend (1, 2 4 6 bara). 3 increments to 10% reactant composition, or until flame becomes unstable.

Work package 3 - Desk Based NOx Abatement Review (3 months)

SE will undertake a desk-based review of NOx abatement technologies, providing an outline of both in-combustor and post-combustion options. The review will provide indicative costs, and suitability of options for SE turbines in the NG fleet. This will be presented to NG and added to a final written report.

Work package 4 – Project Management and Reporting (4 months)

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

Objective(s)

The objectives of the project are to:

· Quantify the difference in NOx production with a switch from natural gas to hydrogen/hydrogen blends with an aeroderivative gas turbine.

· Quantify difference in CO production with a switch from natural gas to hydrogen/hydrogen blends with an aeroderivative gas turbine.

· Quantify the impact of steam injection and synthesised exhaust gas recirculation on NOx production

Review potential options for NOx abatement technology for use with 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 emissions abatement technology for hydrogen compression, and develop the future hydrogen compression strategy on the NTS.

Project Partners and External Funding

Gas network – National Grid Gas PLC

Academic Lead – Cardiff University

Industrial Lead – Siemens Energy

Potential for New Learning

The project will provide insight into the levels of NOx and CO emitted when fuelling an aeroderivative gas turbine with hydrogen, help to identify the scale of NOx emissions and understand the potential for abatement technologies to manage emissions. The findings from the project will be uploaded to the ENA Smarter Networks portal and will be shared via GT&M innovation social media.

Scale of Project

The project is an experimental, academic study which will provide insight into the levels of NOx emitted from an aeroderivative gas turbine fuelled with hydrogen. Previous desktop work undertaken used a proprietary modelling tool based on equivalent temperature from a diesel flame to determine NOx levels. The results thereby carry significant uncertainty, given potential differences in combustion characteristics This learning could enable the level of NOx to be estimated and validation of the previous modelling work undertaken.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL4 Bench Scale Research

Geographical Area

United Kingdom – Warwick & Cardiff

Revenue Allowed for the RIIO Settlement

None - Hydrogen network focused project

Indicative Total NIA Project Expenditure

£192,573

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 supports the decarbonisation of gas turbines which currently utilise methane as a fuel gas. One of the key challenges of fuelling a gas turbine with hydrogen is the anticipated rise in NOx emissions. The project will quantify the NOx emissions to determine the scale of the challenge, and begin to assess the potential for abatement technologies to manage emissions, facilitating the use of hydrogen as a fuel gas.

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

As the benefits of this project will be environmental it is difficult to It is difficult to quantify the benefits. The opportunity to fuel a gas turbine with hydrogen at NTS sites would reduce carbon emissions generated. The project will also inform the hydrogen strategy for the NTS.

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

The project is focussed on fuelling a gas turbine with hydrogen on the NTS; however, the research undertaken and learning from the project will assist with future hydrogen conversion projects for onshore gas infrastructure and industry.

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

N/A – The Project does not intend to rollout anything, but knowledge and information generated through the lifecycle of the project. Consideration of the business case for utilising the hydrogen to fuel gas turbines and impact on NOx emissions shall form part of the final report.

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

Only GT&M currently operate gas turbines; however, the research and analysis undertaken in this project will inform the strategy for hydrogen in the energy transition.

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. Although emissions predictions have been generated for utilising hydrogen as a fuel gas for gas turbines on the NTS, no experimental validation has been conducted.

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

Previous work undertaken has investigated the feasibility of repurposing a gas turbine to be fuelled with hydrogen; however emissions predictions were generated using a proprietary modelling tool based on equivalent temperature from a diesel flame. The results

thereby carried significant uncertainty, given potential differences in combustion characteristics. Experimental analysis will be undertaken in this project to validate previous predictions and quantify emissions.

Relevant Foreground IPR

The project will help to determine the levels of NOx and CO emitted when fuelling an aeroderivative gas turbine with hydrogen, help to identify the scale of NOx emissions and understand the potential for abatement technologies to manage emissions. Work previous undertaken under NIA project “Hydrogen Fuel Gas for NTS Compressors” has identified the requirement for this 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

Gas turbines are currently not fuelled with hydrogen on the NTS, and we need to determine the impact of emissions before implementation. 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 emissions challenge around fuelling a gas turbine with hydrogen on the NTS requires early stage research and assessment and therefore carries additional exposure to risk. The NIA funding reduces exposure to risk and enables feasibility assessment of hydrogen production technologies.

This project has been approved by a senior member of staff

☑ Yes