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 2017

Project Reference Number

NIA_NGGT0123

Project Registration

Project Title

RUL Determination for Compressors 2

Project Reference Number

NIA_NGGT0123

Project Licensee(s)

National Gas Transmission PLC

Project Start

November 2017

Project Duration

1 year and 8 months

Nominated Project Contact(s)

Neil Tansley , Box.GT.Innovation@nationalgrid.com

Project Budget

£302,190.00

Summary

The Remaining Useful Life (RUL) determination for compressors NIA project (NIA_NGGT0079) “phase 1” concluded in 2016 and made an initial investigation into whether prognostic techniques, used to determine the Remaining Useful Life (RUL) of assets in other industries, could be applied to a gas transmission compressor fleet for the first in the UK. The project showed some positive results and significant potential for the underlying approach in compressor unit failure modelling.

However, further work, including physical examination and confirmation of manifestation of predicted degradations in at least one compressor unit, is required to develop a reliable and proven model that can be used to improve our understanding of compressor turbine asset deterioration enough to inform future investment planning and targeting, including maintenance and replacement policies for asset management. The phase 1 project suggested a number of ways to proceed and after internal review of the outcomes this “phase 2” successor project has been developed with the original project partner to drive the further development required to achieve this goal.

This project is also distinct and complementary to the recently launched Compressor Data Analytics (CDA) NIA project (NIA_NGGT0079) that leverages some of the same data sets and analytical systems. While the CDA project is focused on accurate prediction of short term “non-fatal” failures, such as failures to start and running trips on “day or hour ahead” timescales, this project is focussed on accurate prediction of end of life failures that could lead to permanent or prohibitively-expensive-to-repair failures. The two projects will therefore take different approaches to solve different problems around compressor unit failure prediction.

Preceding Projects

NIA_NGGT0079 - Remaining Useful Life (RUL) determination for compressors

Third Party Collaborators

DNV

Nominated Contact Email Address(es)

Box.GT.Innovation@nationalgrid.com

Problem Being Solved

The Remaining Useful Life (RUL) determination for compressors NIA project (NIA_NGGT0079) “phase 1” concluded in 2016 and made an initial investigation into whether prognostic techniques, used to determine the Remaining Useful Life (RUL) of assets in other industries, could be applied to a gas transmission compressor fleet for the first in the UK. The project showed some positive results and significant potential for the underlying approach in compressor unit failure modelling.

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Method(s)

The project will continue the Prognostic Modelling approach initiated in phase 1 of the project to develop and test a degradation/wear profile and/or Health Index function for compressor units, based on observed changes in compressor performance parameters.

Stage 1
The first steps will be to determine a Health Index function and Remaining Useful Life model for a model of gas turbine by enhancing the prognostic modelling approach explored in the phase 1 study.
Stage 2
Once this Health Index model is established historical operational data for several years to the current day for the other gas turbines of same model in the fleet will be analysed, to determine if any other of these other gas turbines is showing similar characteristics to units that have failed. This approach will be used to establish the Health Index function and Remaining Useful Life for each gas turbine of that model.
Stage 3
The initial model developed for a specific type of gas turbine will then be used for the other gas turbines of various models (e.g. Avon, RB211, LM2500, Cyclone, Titan), using historical operational data. It will then be determined if the other models of gas turbine are showing similar performance deterioration characteristics to that proven through the previous stage. The project will then establish the Health Index function and Remaining Useful Life for each of these models of gas turbines, as a basis for developing unit-specific deterioration models.

Key deliverables are as follows:

1. Health Index function and Remaining Useful Life analysis for a model of gas turbine (using historic data set)
2. Extension and refinement of the Health Index function and Remaining Useful Life analysis for the remaining gas turbines of same model in the NGGT fleet.
3. Insights that will trigger investigations to confirm whether any identified issues are reflected in actual asset condition (for example through site investigations, strip-down, laboratory analysis etc.)
4. Testing of extendibility of Health Index / Remaining Useful Life models to other gas turbine models.
5. Comparison of Remaining Useful Life models with any existing gas turbine deterioration models for use in strategic investment planning analysis and recommendation of improvements
6. Final report and next steps

Scope

National Grid Gas operates and maintains around 75 compressor units across 24 sites. With varying degrees of criticality these units are essential to the continued and strategic supply of gas to the UK. In order to meet the increasingly challenging economic climate and drive to increase start reliability and availability and decrease operating costs there is a greater requirement to be smarter with the management of these assets. One area with potential to reduce costs and increase reliability is that of the timing of maintenance and replacement.

The project will enable the prediction of future compressor unit performance which will support the development of proactive, optimized asset management strategies. This will allow the costs of replacement/maintenance to be fully balanced against the risks of asset failure. Future maintenance and replacement investments can then be selected, planned and targeted based on service risk, rather than the current time-based maintenance approaches. This will allow risk and cost to be better balanced within our compressor maintenance policies, delivering greater value to customers.

National Grid has experience previously of a compressor unit failing due to high cycle fatigue, and operates a number of units of similar design. Prognostic modelling has been identified a potentially viable solution for determining the onset of such potentially serious problems which can eventually led to such types of unit failure. Safe and reliable operation could be maximised, and unplanned maintenance outage costs could be planned for and minimised, if accurate determination of remaining useful life of the gas turbine could be established.

Objective(s)

To develop, refine and prove a prognostic Remaining Useful Life modelling approach for gas generators/turbines. To develop a successful fleet-specific approach for unrecoverable failure prediction and operational response to the mitigation of this risk.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

To determine which, if any, gas generators/turbines of a particular model are showing the same symptoms of impending failure due to high cycle fatigue as previously failed units of the same model and determine the remaining useful life of each gas turbine.

To determine whether the same prognostic modelling approach can be adopted for other gas turbine models in the fleet, which may include Avon, RB211, LM2500, Cyclone and Titan models. To determine the remaining useful life of each of these other gas turbine models.

To determine whether Remaining Useful Life analysis using prognostic modelling can be used to improve NG's understanding of compressor turbine asset deterioration to inform future investment planning and targeting, including maintenance and replacement policies.

Project Partners and External Funding

Project Partner – Cogsys Ltd

External Funding – None

Potential for New Learning

The knowledge gained from this project will prove the effective application of prognostic modelling to determine Remaining Useful Life and further enhance NGGT's compressor investment strategy, enabling future optimisation of replacement and maintenance policies and delivering a balanced approach based on risk minimization and customer value. This optimized approach will generate additional cost savings above our current time-based investment policy.

Scale of Project

Desk based analysis and site based trial.
Analysis will be undertaken off-line using prognostic modelling tools and algorithms developed specifically for this project. There is the potential to develop prognostic models for use in a live environment to continuously assessing failure potential and to alarm deviances from expected parameters, but this is out –of-scope for this project.

Technology Readiness at Start

TRL4 Bench Scale Research

Technology Readiness at End

TRL7 Inactive Commissioning

Geographical Area

National Grid, GB wide; Cogsys, Warrington; DNV GL, Hovik (Norway)

Revenue Allowed for the RIIO Settlement

None.

Indicative Total NIA Project Expenditure

£302,190

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

n/a

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

n/a

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

Predicting asset life and optimizing maintenance will result in reliability improvements of the compressor trains; which will consequently result in financial savings which will be passed on to NGGT customers. It is difficult to quantify savings at this stage of the project. However, for an annual compressor maintenance budget in the region of £10m, estimated savings are in the region of 5% or £500,000 per year. This will need to be confirmed by this feasibility study and subsequent field trials.

Please provide a calculation of the expected benefits the Solution

By having advanced notice of the Remaining Useful Life of the asset, interventions can be planned further in advance to mitigate the degradation of units, allowing greater flexibility in the allocation and timetabling of maintenance. This will enable reduced costs though the efficient use of operational resources, spares and the ordering of specialist components. Better knowledge of Remaining Useful Life will improve the accuracy of risk monetisation for compressors, enabling the optimal timing and prioritisation of future investments, including major overhaul and refurbishment activities.

Without the ability to accurately predict RUL, a catastrophic loss of a compressor train (and when a compatible gas generator/turbine replacement is no longer available) may cost ~£10million or more to return the unit to service. In a worst-case scenario, the permanent failure and total loss of an operating compressor unit could lead to disruption to the flow of customer gas and a supply/demand intervention being performed by the System Operator. The cost of this "Buy Back" option could run to several £million per day for the duration that the unit remained critical to the network for an extended period.

Improved confidence in the ability to predict asset failure may potentially allow us to reduce our holdings of spare units. However, an extensive period of testing, which would prove the ability of the method to identify potential failure events, would be required before this saving could be realised, estimated to be £2-7 million from avoidance of buying spare units, plus £100-500,000 opex per year for avoided ongoing maintenance).

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

The solution will be demonstrated for a single type of compressor unit within the National Grid fleet initially and then for the remaining types, the underlying method is intended to be sufficiently machine/platform/OEM independent that it can be developed to be applicable to all machines on the transmission network. National Grid Gas Transmission is currently the only network licensee to operate compressor units.

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

Currently the rollout costs cannot be reliably estimated because they will depend significantly on the outcomes of the research; the necessary algorithms can only be confirmed as this project develops. Additionally the costs will depend on the specifics of the interface requirements of the compressor units which may vary by model, type, version, age etc. The project will establish an estimate of these costs.

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

This project will develop and prove a new method for identifying which gas turbines can be deemed unhealthy for operational purposes with respect to high cycle fatigue and determine the Remaining Useful Life and future failure risk for a compressor gas turbine asset. This will allow future costs/risks of failure to be measured and enable replacement/maintenance policies to be developed based on a better understanding of risk. Understanding the risk associated with the asset in its current form, thereby either extending the life of the asset, deferring investment or reducing the whole life costs of ownership is expected to deliver better value to customers. Although our focus is on gas turbines, the principles developed could be applied to any asset type (see below).

The prognostic modelling reliability data analytics approach will be developed in this project specifically for rotating machinery in a gas transmission application, but there is an opportunity to apply this learning to any asset type which collects (or can be adapted to collect) detailed asset health/performance data on site (e.g. water bath heaters; pressure regulators) for any Network Licencee. This detailed health/performance data can then be modelled in a similar way to predict possible/imminent component failure and assess Remaining Useful Life.

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

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

Is the default IPR position being applied?

☑ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

This project builds on and is a continuation of research undertaken in the Remaining Useful Life (RUL) determination for compressors NIA project (NIA_NGGT0079). National Grid Gas Transmission is also the only Network Licence that operates compressor units and therefore this project is addressing a unique problem. Appropriate internal stakeholders have been consulted and no duplication has been identified since the NIA_NGGT0079 project started.

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

National Grid Gas Transmission is the only network licensee to operate gas compressor units. National Grid has not tried this approach previously because neither: practicable/proven algorithms, sufficiently telemetered compressor units, nor sufficiently powerful computer processing capability, have existed to solve the problem historically.

Relevant Foreground IPR

n/a

Data Access Details

n/a

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

National Grid will not fund the project as part of business-as-usual activities because the technique is both at a low TRL and unproven in a gas transmission application in the UK and so cannot be considered a business-as-usual activity.

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

There is a specific risk that the technique may be unsuccessful in achieving the stated success criteria due to insufficiency of algorithm, technical insight, data or computational power or due to unforeseen complexity of correlation of parameters.

This project has been approved by a senior member of staff

☑ Yes