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NIA Project Registration and PEA Document

Date of Submission

Jun 2014

Project Reference Number

NIA_NGGT0035

Project Registration

Project Title

Investigation of flow physics in gas pipe network

Project Reference Number

NIA_NGGT0035

Project Licensee(s)

National Gas Transmission PLC

Project Start

October 2014

Project Duration

3 years and 8 months

Nominated Project Contact(s)

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Project Budget

£169,000.00

Summary

Dynamic operation of the National Transmission System (NTS), where users are starting up (ramp-up), shutting down, and/or changing flow rates quickly, can produce challenging scenarios on the gas transmission network. At a wider network level, the manifestation of this behavior is a quick changing flow pattern which calls for a rapid reconfiguration of the system. Where as on a local subsystem the result can be fast transient effects which may have an adverse impact on the compressors and other equipment which momentarily impose high stresses on pipe walls and high velocities, among other issues. This collaboration research project with the University of Manchester has been established to investigate novel methods used to determine a new, more accurate ramp rate model.

Third Party Collaborators

The University of Manchester

Engineering and Physical Sciences Research Council

Nominated Contact Email Address(es)

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Problem Being Solved

Drastic changes in flow rates can have adverse impact on pipes and associated network equipment such as Compressors and Valves. This can be attributed to manifestation of fast transient effects such as flow (hence pressure) spikes, flow/pressure oscillations (pressure waves) and high velocity. Normally the largest flow changes occur during startup and shutdown. As such when new Customers wish to connect to the NTS, they are assigned, default, 50 MW/minute as the maximum rate at which they can increase or decrease their flow rate, i.e. the default “Ramp Rate”.

Where a Customer wishes to have a Ramp Rate higher than the default value, a feasibility study, that includes Fast Transient Analysis,

is carried out to investigate whether a requested Ramp Rate would create a large disturbance in the local pipe flows which could have undesirable effect on the local and/or neighbouring pipework and plant equipment.

National Grid has identified the need to decrease requirements for ramp rate studies using an adjusted default value, along with a reduction in the time currently required to carry out a Fast Transient Analysis, while maintaining, or even improving, the quality of the output forms. A need has also been intensified to increase knowledge and appreciation of the impact of fast transient on the local transmission system; define and standardise fast transient analysis outputs; and to extend/compliment the capability of existing network modeling tools.

This project will look at comprehensive fast transient models using computational fluid dynamics (CFD) methods to allow a fuller understanding of the expected impact of quick flow changes on the system. This work will allow for validation of default 50 MW/minute ramp rate.

Method(s)

In this collaborative project between National Grid and the University of Manchester, a recently developed technique known as Embedded Large Eddy Simulation (ELES), coupled with the Large Eddy Simulation (LES), will be applied in conjunction with the Reynolds-averaged Navier-Stokes (RANS) equation model. It is anticipated that this approach will enable a breakthrough in the Reynolds-number range accessible with high-accuracy flow, noise and vibration simulations.

Deliverable 1: Validation of Method

· Development and application of the ELES approach to examine in detail the impact of an unsteady flow (i.e. surge) through precise representation of local pipework and specific equipment.

· Benchmarking exercise with existing results, for external CFD reports or internal network modeling.

· Performing a sensitivity analysis, by studying a range of flow parameters around those typically assumed, in order to quantifiably assess the sensitivity and likely bounds of error.

Deliverable 2: Reassessment of the 50MW/min trigger point

· Perform simulations with ELES to enable a high level of detail to be obtained about the flow physics during a surge situation for the first time.

· Scenario analysis to examine in detail the flow associated with a range of different ramp-up rates, in order to investigate the hypothesis that the current trigger is too conservative.

· Detailed study will be undertaken of regions of unsteady separated flow in order to link to potential modes of structural vibration.

· Provide a framework for the calibration of the reduced order modeling employed in network-scale analysis. In this way the accuracy of 1-D or 2-D network models can be improved for specific junctions, configurations.

Deliverable 3: Integration of tool into NG workflow

· Developed ELES method further, with potential to automating the workflow further.

· Identify trigger points arising from low order modeling that indicate the need for more detailed simulation.

· Generation of the mesh, the definition of the limits of the embedded region, the initialization of the unsteady flow and the time-averaging will all be automated, in order to establish a reliable, repeatable prediction tool.

Deliverable 4: Knowledge transfer

The software used will be open-source to enable knowledge transfer within National Grid for future scenarios to be run in-house once the research is complete, and to provide learnings to other licensees.

Scope

Dynamic operation of the National Transmission System (NTS), where users are starting up (ramp-up), shutting down, and/or changing flow rates quickly, can produce challenging scenarios on the gas transmission network. At a wider network level, the manifestation of this behavior is a quick changing flow pattern which calls for a rapid reconfiguration of the system. Where as on a local subsystem the result can be fast transient effects which may have an adverse impact on the compressors and other equipment which momentarily

impose high stresses on pipe walls and high velocities, among other issues. This collaboration research project with the University of Manchester has been established to investigate novel methods used to determine a new, more accurate ramp rate model.

The science behind the Ramp Rate Model

Computational Fluid Dynamics can be a valuable tool in the detailed analysis of flow phenomena, for example when one needs to understand the complex flow of a ramp-up scenario. In cases where transient flow phenomena result from complex geometry it is necessary to undertake 3D Computational Fluid Dynamics (CFD) for either a range of piecewise components or larger combined scenarios (e.g. bends, valves, compressors, etc.). The most difficult challenge in the accurate prediction of unsteady flow arises from turbulence, which spans a wide range of length and time scales. For most industrial applications, it is too computationally expensive to resolve all the scales of turbulence as required in direct numerical simulation (DNS). Hence, recourse must be sought in turbulence modelling. In Large Eddy Simulation (LES) only the less influential small scales are modeled, however, the use of LES is also prohibitively expensive when applied to complex geometries.

In order to review the relevance of current supply network threshold levels with any certainty, an innovative solution is required to reduce the cost while retaining high accuracy.

The default prediction method currently used in industry is based on the Reynolds-averaged Navier-Stokes (RANS) equations, which is completed by statistical turbulence models. However, in many cases, RANS models are not sufficiently accurate. In particular, they systematically fail in regions where complex features such as flow separation or transition occur, which can have a strong effect on the overall flow. RANS predictions lack the broad frequency content required for the faithful computation of aerodynamically generated noise, fluctuating wall temperatures, or flow induced vibrations, which can only be obtained with higher fidelity LES or DNS methods. Therefore, there is a clear need for a novel and innovative method(s) to allow zones of LES to be flexibly embedded within the overall flow domain treated with lower-order RANS methods.

Innovative methods

These innovative new methods will produce models with precise representation of local pipework and equipment that provide a more realistic inference of results for system wide simulations. This will lead to more precise and quicker decisions related to ramp rates. This improvement has the potential to significantly reduce the number of Ramp Rate Studies carried out, thereby saving time and cost to National Grid customers.

Further, it is anticipated that the models will be used to assess other flow / structural interaction issues, with application in determining whether to extend life or replace an asset.

Objective(s)

This project aims to create comprehensive fast transient models (using computational fluid dynamics (CFD) methods) of National Transmission System (NTS) components to enable a fuller understanding of the expected impact of quick flow changes on the system. This will also facilitate validation of the default 50 MW/minute ramp rate.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

- Publication of a technical paper / thesis on the work with discussions on the findings, recommendations and suggestions for further work.
- Production of detailed models of local NTS components.
- Proposal of a new default ramp rate or provision of analysis data to justify the existing value.
- Integration of existing network modeling software with CFD models.

Project Partners and External Funding

n/a

Potential for New Learning

n/a

Scale of Project

The project will focus on the development of a model that is suitable for the full rang of ramp rate scenarios encountered on the Gas Transmission Network.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL4 Bench Scale Research

Geographical Area

Work on this project will take place at the University of Manchester and is predominantly desk based.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£100k of NIA expenditure

EPSRC are providing £68,648 through the i- case award.

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)

ere are number of different aspects to the potential savings associated with this work:

1. Detailed modeling of effects of expected fast transients due to rapid customer flow changes on NTS assets will ensure that the ramp rate limits set are appropriate and therefore prevent damage to assets. For example, the cost of replacing large diameter valves, damaged by extreme ramp rates would be over £100K.

2. If a new higher (than the current 50 MW/min) default ramp rate is proposed and validated by the project, a number of customers' connections and associated flow rate change proposals will be accepted without requiring detailed fast transient studies for the local AGI. Thus saving the customer both time and money. Cost saving to the customer would be about £50k per avoided study.

3. The project will assist in enabling more operational flexibility to the customer, allowing quick responses to market signals.

Please provide a calculation of the expected benefits the Solution

n/a – research project

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

This project will develop a new model/tool that will be used on the full range of ramp rate scenarios.

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

There will be training on tools and methods for the relevant National Grid staff. This may involve two days of training for 5 members of staff costing ~ £5K.

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 methods developed and knowledge gained within this research project has the potential to be applied to the Gas Distribution Networks.

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

This project sits within National Grid's Reliability theme under capacity and capability; utilising operation, commercial and asset solutions along with supply and demand patterns to enable the NTS to remain flexible into the future and capable of accommodating network user requirements.

☑ 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.

n/a

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

n/a

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

n/a

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

n/a

This project has been approved by a senior member of staff

☑ Yes