Gas NIC Final Report

VECTOR

Variable Envelope Compressor: Trial, Optimisation and Review

Project Reference: NGGT GN 01

REPORT from RUNE ASSOCIATES LTD

(Confidential)

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1. EXPLANATORY NOTES

This report is based on:

1. The Initial Screening Submission submitted on 29th April 2013
2. The Full Submission, submitted on 9th August 2013
3. Responses to Questions
4. Dialogue between the Rune Consultant and the Project Team on 3rd September 2013
5. Further information provided following the Project team meeting
6. Dialogue between the Project Team and the Expert Panel on 30th August and 23rd September 2013.
7. Dialogue between the Rune Consultants and the Expert Panel on 13th September 2013.
8. A Re-Submission of the proposal on 10th October 2013
9. The basis of the content of this report is as follows:
    - The text of Sections 2 through 11 is that in the Interim Report dated 18th September 2013.
    - The colour ratings shown in Sections 3 through 11 reflect an assessment of the Interim Report information, against the NIC Gas evaluation criteria.
    - Section 12 addresses the implications of the changes set out in the Re-Submission.
    - The colour ratings shown in Section 12 reflect an assessment of the total information provided in the Full Submission and Re-Submission, against the NIC Gas evaluation criteria.

2. SUMMARY OF PROJECT INFORMATION

2.1. SUMMARY DETAILS

Basic Project Information	
Project name	Variable Envelope Compressors: Trial, Optimisation and Review
Project Short Name	VECTOR
The Funding Licensee	National Grid Gas Plc (Transmission) (NGGT)
Total Project Cost (Cell I13[1])	£9,253k
External Funding. (Cell I25)	Nil
Network Licensee Compulsory Contribution. (Cell I66)	£925k
Network Licensee Extra Contribution. (Cell I37)	Nil
Gas NIC Funding Request. (Cell I85)	£7.913k
Direct Benefits.	Nil
Requested threshold for the funding of cost over-runs if different to the default.	5%
Requested protection on Direct Benefits, if different to the default.	0%

2.2. SYNOPSIS

Synopsis of Project Submission	
Description of the problem	The flow of gas on the National Gas Transmission System (NTS) is facilitated by a fleet of 68 compressors at 24 compressor sites. Compressors enable onward transmission of gas and are also used to boost gas pressure for delivery to distribution networks and other directly connected loads such as gas fired power stations. Because of the changing demands on the NTS many of these compressors are now operating outside the range of flow and pressure increase conditions (envelope) for which they were designed and where they work most efficiently. This problem is particularly relevant to networks that need to cope with significant variations in input quantities and locations, brought about by choices made by the supply market, and with changes in demand pattern.
Description of the proposed method	The most common way of changing the performance of gas compressors is to run at different rotational speeds. The operating envelope is limited at low flow by a 'surge' line, at high flow by 'choke' and by the maximum and minimum speed curves. The most efficient operating range is generally in

[1] Cell references relate to the NIC Funding request tab of the Financial workbook

Synopsis of Project Submission	
	the middle of this envelope. Besides speed variation there are two other methods for varying the output of a gas compressor, variable inlet guide vane (VIGV) control – effective but less efficient than speed control on its own, usually used for non-explosive gas processes, and Suction throttle which is effective but much less efficient than either speed or VIGV control. Neither of these on their own offer sufficient operational flexibility and further variation of the compressor's performance has historically been achieved through an extensive and expensive redesign (referred to as re-wheeling), which permanently changes aerodynamic performance. To address the problem NGGT intends to develop and demonstrate a solution using variable inlet guide vane technology in combination with variable speed control to enable compressors to operate stably and more efficiently over a wider range flow and pressure conditions than is currently possible.
Description of proposed Trial(s)	NGGT indicates that the following specific developments are needed: Technology development & risk evaluation: There are two possible ways of introducing variable vane guides into an existing compressor; both have different risk and benefit profiles. In partnership with an Original Equipment Manufacturer (OEM), the project team will evaluate the theoretical performance and risk issues for both options. At the end of the initial design phase the option with the greatest potential benefit will be taken forward to prototype manufacture and off line testing. Demonstration: As there are no examples of this solution being used elsewhere on the natural gas networks in the world that are comparable to the NTS, there is no information available to validate how much the operational envelope is increased in practice, what set of flow and pressure requirements would justify its use from an economic perspective and what the practical installation issues could be. To generate this knowledge to give an investment level of confidence to consider roll out across the network, NGGT will undertake a full demonstration on one of the operational compressors. Optimisation: If successfully demonstrated, roll-out of the variable envelope technology across the Gas Transmission System fleet would inevitably be phased. New control systems and operating strategies that deal with a combination of fixed and variable vane compressors on the same site will need to be developed, tested and optimised.
Intended outcomes (solutions)	NGGT indicates that it expects that successful rollout of this technology across key compressors on the NTS will result in: • Greater flexibility to deal with short term changes in gas transport requirement as a result of variation in gas supply and demand patterns. • More effective resilience to manage fast ramp-up or ramp-down of network demands e.g. Combined Cycle Gas Turbine power generation needed to provide fast response for fluctuations in wind generation. • More efficient operation of compressors as a result of efficiency improvements when operating closer to optimum regions of the compressor envelope.

Synopsis of Project Submission	
Customer impact of Project implementation.	NGGT customers are shippers and connected networks (gas distribution and independent gas transporters). Proposals for engagement with these customers are presented although there will be no direct interaction during the trial nor any effect on contractual or charging arrangements. There is a risk that an unplanned interruption of gas supply to customers may occur if there were simultaneous problems with the trial compressor unit and standby unit; this is unlikely and contingency arrangements will be in place.
Key strengths of the proposal	• Has potential to provide an extended `real time` flexibility to compressor operations, beyond that provided by speed variation. • Has the potential to provide `real time` flexibility at a lower cost than operating multiple smaller compressors. • Will assist in meeting rapidly changing supply demands placed on NGG by CCGT units. • Has potential to reduce frequency of re-wheeling compressors, thus reducing expenditure. • Has potential to raise overall efficiency of compressor operations by retro fit to other units. • Has potential to be incorporated into future `new build` compressors, extending their effectiveness, and reducing their operating costs.
Key weaknesses of the proposal	• There already appears to be international experience of incorporating VIGVs on both new build and retrofit natural gas compressors • IPR issue with Rolls Royce (RR), if not successfully resolved, may impact retro-fitting of VIGV to other OEMs machines. • Trial performance recorded on one aerodynamic configuration of VIGV and compressor design, may not be repeatable with alternative designs • VIGV presence causes some aerodynamic drag, reducing efficiency that must be evaluated, including any impacts when VIGV is in the `neutral` position (which could potentially be most of the compressor operating period). • Current partnership with only one OEM may impact on tendered costs. • Current partnership with only one OEM may indicate other OEMs do not consider their plant suitable for retro fitting VIGV.
Project management structure and related information.	A satisfactory, comprehensive detailed project management structure is set out clearly in the submission, with related governance, risk mitigation and contingency plans
Derogations/ Exemptions that the Project would/may require.	None
The key learning outcomes which the Project aims to deliver.	• A functional design for a retrofit variable guide vane unit for the demonstration compressor. • The design issues and philosophy for a retrofit solution that will be suitable for other compressor types and for other OEM compressors.

Synopsis of Project Submission	
	• The requirements of, and interactions between, control systems in order to manage variable vane and rotation speed control. • The costs and benefits of rolling out the technology across the GB fleet of Gas compressors.

3. SUMMARY OF ASSESSMENT - INTERIM REPORT

3.1. OVERALL ASSESSMENT

Overall summary
The flow of gas on the National Gas Transmission System (NTS) is facilitated by a fleet of 68 compressors at 24 compressor sites. Because of the changing demands on the NTS many of these compressors are now operating outside the range of flow and pressure increase conditions (envelope) for which they were designed and where they work most efficiently. To address the problem NGGT intends to develop and demonstrate a solution using variable inlet guide vane (VIGV) technology in combination with variable speed control to enable compressors to operate stably and more efficiently over a wider range flow and pressure conditions than is currently possible. Successful implementation of this project, and subsequent roll-out of VECTOR technology, will contribute to the more efficient use of Compressors, in meeting the increasingly flexible and intermittent demands placed on the Gas Transmission Network. This will result in lower carbon usage. The project will generate new knowledge regarding the variation achieved in extending the stable and efficient operating envelope of in line Gas Compressors in the NTS by the employment of VIGV Technology in conjunction with variable speed Compressors. It will also generate knowledge to support retro-fitting the technology to existing Compressor units. The submission indicates that there is no known implementation of VIGV technology with variable speed compressors nor is there experience of retro fitting VIGV in natural gas applications. However it has become clear that Rolls Royce do have experience of incorporating VIGVs on both new build and retrofit natural gas compressors NGGT has subsequently indicated a '5 of the same design of equipment installed and operational in similar applications anywhere the world' criteria to justify why the project should not be conducted as business as usual. It is questionable whether this is appropriate in a trial of this nature. The partners involved in the Project are appropriate, and they bring complementary knowledge and experience to the project but an additional OEM would provide competition in tendering for the detailed design and manufacture of components.

3.2. SUMMARY OF ASSESSMENT AGAINST INDIVIDUAL EVALUATION CRITERIA

Key to ratings		• Seems to be generally in line with the objectives and requirements of the NIC Gas evaluation criteria, • Whilst there are some areas where additional information would be useful, that provided is generally comprehensive and provides no immediate cause for concern.
		• Some indication that the project is in line with the objectives and requirements of the NIC Gas evaluation criteria. However further scrutiny is required to ensure this, • There are some gaps in the information provided, • Further assurance is needed to confirm that the project is viable and that risks are appropriately managed
		• Significantly more assurance is required that the project is in line with the objectives and requirements of the NIC Gas evaluation criteria, • There are some major gaps in the information provided, • Considerable scrutiny is needed to confirm that the project is viable and that risks are appropriately managed, • Potential major risks to the viability of the project.

Evaluation Criteria[2]	Rating	Overall assessment
Criterion A: Low carbon and benefits		A successful implementation of this project and subsequent roll-out of the VECTOR technology, will contribute to the more efficient use of Compressors in meeting the increasingly flexible and intermittent demands placed on the Gas Transmission Network. This will result in lower carbon usage. The flexibility offered by the combination of NIGV and variable speed control is indicated as potentially increasing the range of flow conditions over which the compressor can operate by 10% and 30%. However, without changing the power of the compressor driver, this may affect the range of pressure increase that can be delivered, one of the main reasons for operating the compressor. The robustness of the financial benefits claimed is questionable due to a lack of clarity over re-wheeling costs and as the future mode of operation required from the compressors is difficult to predict, although more flexibility is likely to be required.

[2] Further information on evaluation criteria can be found in the Gas Network Innovation Competition Governance Document

Evaluation Criteria[2]	Rating	Overall assessment
Criterion B: Value for money		It is uncertain that there will be competition between Compressor OEMs tendering for the initial design phase. There are doubts arising from Intellectual Property Rights and dissemination of project findings to other OEMs. There is an assumption that the Project results will be transferable to other OEM's compressor designs. That will depend on the IPR issues being satisfactorily resolved. However, notwithstanding the above points, the importance of finding a way to operate the NGGT grid more flexibly, means that the potential gains exceed the risks. Overcoming the IPR issue should be possible early in the process, at which time a more firm view of Value for Money should be assessed. Providing flexibility in the performance of NGGT transmission is clearly of strategic importance.
Criterion C: Generates new knowledge		The project will generate new knowledge regarding the variation achieved in extending the stable and efficient operating envelope of in line Gas Compressors by the employment of VIGV in conjunction with variable speed control. It will also generate knowledge in the design of VIGV as a retro-fit facility to existing Compressor units.
Criterion D: Innovative and unproven business case		The submission indicates that there is no known implementation of VIGV technology with variable speed compressors; nor is there experience of retro fitting VIGV in natural gas applications. However the Frazer Nash report 'Research into Variable Envelope Compressors', indicates Rolls Royce do have experience of incorporating VIGVs on both new build and retrofit natural gas compressors. NGGT has indicated that to allow new technology to be introduced on the UK gas transmission system and fulfil "Best Available Technique" requirements they require the OEMs to demonstrate that a minimum of 5 of the same design of equipment should have been installed and operational in similar applications anywhere the world. This is elaborated in Section 7 on page 19. It is questionable whether this approach is appropriate in a trial of this nature.
Criterion E: Involvement of other partners & external funding		There are no external funding partners. The participants involved in the Project are appropriate, and they bring complementary knowledge and experience to the project. An additional OEM would provide competition in tendering for the detailed design and manufacture of components. There is no confirmed external funding although the Carbon Trust has offered to provide financial support to this project by way of an efficiency discount if National Grid is successful in securing funding for both its NIC projects.

Evaluation Criteria[2]	Rating	Overall assessment
Criterion F: Relevance and timing		The flexibility of operation now seen as a requirement for NGGT national gas transmission system and associated Compressor operation is unprecedented, and appears to be unique. If successful, the project will contribute to more efficiently meeting customer and shipper requirements.
Criterion G: Demonstration of robust methodology		The methodology appears robust, the Project Plan encompasses those processes which will be required to safely implement VIGV in the NGGT environment, including prior intensive maintenance on standby compression to ensure uninterrupted service from the chosen site. There should be no adverse effects on NGGT customers during the trial.
Criterion: Appropriateness of the SDRC definitions, timing and adequacy of links to key project milestones		NGGT has identified five criteria, which are clearly defined. They are tied to project milestones and include learning outputs as well as project process measures.

4. CRITERION A: LOW CARBON AND BENEFITS

Criteria	Rating	Overall assessment
Criterion A: Accelerates the development of a low carbon energy sector and/0r environmental benefits & has the potential to deliver net financial benefits to existing and/or future customers Credibility of the carbon, environmental and financial benefits claimed for the project.		A successful implementation of this project and subsequent roll-out of VECTOR technology will contribute to the more efficient use of Compressors, in meeting the increasingly flexible and intermittent demands placed on the Gas Transmission Network. This will result in lower carbon usage. The flexibility offered by the combination of NIGV and variable speed control is indicated as potentially increasing the range of flow conditions over which the compressor can operate by 10% and 30%. However, without changing the power of the compressor driver, this may affect the range of pressure increase that can be delivered, one of the main reasons for operating the compressor. The robustness of the financial benefits claimed is questionable due to a lack of clarity over re-wheeling costs and as the future mode of operation required from the compressors is difficult to predict, although more flexibility is likely to be required than hitherto.

Sub-Criteria	Assessment and material document references
* contribution to what part of the DECC Plan?	The strategy to achieve carbon budgets in the Carbon Plan indicates 'The transition to low carbon power will not happen overnight. Over the next two decades, gas-fired power plants will provide the flexibility that we will need to meet peak demand and manage intermittent generation from some renewables, as well as baseload generation capacity' (Section 2.152). The project aims to provide greater flexibility for NTS compressors to respond to rapid changes in supply and demand, which will facilitate flexible operation of gas fired power plant. Section 4.1
* carbon benefits claimed & assumptions	The specific level of carbon benefits are not stated, but the role of the gas transmission system as an enabler to supply CCGT used to balance variations in renewable generating capacity are highlighted, together with the increasing requirement of flexibility from the performance of compressors. Section 4.1
* environmental benefits & assumptions	NGGT indicates an anticipated reduction in compressor fuel consumption, fuel cost and carbon emissions directly associated with the operation of the network but these are not quantified. Section 4.1

Sub-Criteria	Assessment and material document references
* financial benefits claimed, robustness of claims and assumptions	The flexibility offered by the combination of NIGV and variable speed control is indicated as potentially increasing the range of flow conditions over which the compressor can operate by 10% and 30%. However, without changing the power of the compressor driver, this may affect the range of pressure increase that can be delivered, one of the main reasons for operating the compressor. The financial benefits claimed and assumptions are contained in Appendix 2 Cost Assumptions. The savings derive from two sources: Reduction in costs by avoidances of two instances of `re wheeling` over the (approx.) 25 year life of a compressor Reduction in fuel costs through more efficient operation. The robustness of these claims must be viewed as `low`, as the future mode of operation required from the compressors is an imprecise factor, although likely to require more flexibility than hitherto. Section 4.1 and Appendix 2
* quantitative analysis provided	There is no rigorous financial analysis; a Net Benefit over the life of a compressor is provided. There is clarification needed to explain why re-wheeling costs used in the analysis differ from re-wheeling costs used in the RIIO submission. Appendix 2, RIIO T1
* cost, time and speed to implement	The information provided regarding the design and manufacture of components is insufficient to assess those proposals; however, it would be reasonable to assume that NGG estimates of their own work on site should be accepted. Appendix 3
* claims for potential for replication across GB	The outcome of VECTOR, in terms of VIGV retro fit will only be replicated at a limited number (probably no more than 15) sites within NGG network. These sites will contain some compressors from OEMs not involved in the trial. There is an assumption that the tested VIGV technology can be migrated to these compressors. The potential performance of the tested VIGV in all aerodynamic configurations of compressor, may not fully match the VECTOR findings, although there is no evidence to suggest that it may be lesser or greater. The VIGV technology, if proven, may also be appropriate for inclusion in specifications for future `new build` compressors if an economic case exists. Sections 4.3, 4.6
* claimed capacity released and how quickly released, if relevant	NGG state that VECTOR will not provide additional network capacity as capacity is a function of a combination of the diameter of the pipelines; the maximum operating pressure of the pipelines; or the power outlet of the compressor drive unit. Nevertheless the intended outcomes include greater flexibility to deal with short term changes in gas transport requirement as a result of variation in gas supply and demand patterns and more effective resilience to manage fast ramp-up or ramp-down of network demands. It is surprising that these outcomes appear to indicate a need for additional capacity if such solutions are not available.

5. CRITERION B: VALUE FOR MONEY

Criteria	Rating	Overall assessment
Criterion B: Value for money The size of benefits and learning from the project that is applicable to the relevant network		It is uncertain that there will be competition between Compressor OEMs tendering for the initial design phase. There are doubts arising from Intellectual Property Rights and dissemination of project findings to other OEMs. There is an assumption that the Project results will be transferable to other OEMs compressor designs. That will depend on the IPR issues being satisfactorily resolved. However, notwithstanding the above points, the importance of finding a way to operate the NGG grid more flexibly, means that the potential gains exceed the risks. Overcoming the IPR issue should be possible early in the process, at which time a more firm view of Value for Money should be assessed. Providing flexibility in the performance of NGG transmission is of strategic importance.

Sub-Criteria	Assessment and material document references
* Proportion of benefits to customers (the relevant network system) as opposed to elsewhere on the supply chain	Under the Network Code, NGG must fulfil the requirements of Shippers and other customer in providing a resilient gas transportation capacity. Gas customers, and the population of the UK will benefit if the use of renewable energy can be employed to its maximum. Such additional energy sources will result in short term requirements for gas powered electrical generation to compensate when (typically) wind generation falls. This, in turn leads to a need for operational resilience in gas transmission operations. VECTOR offers the potential to contribute to that resilience, to the benefit of all gas customers Appendix 9 Future Gas Network Resilience.
* how the project has a potential direct impact on the network	The project has a direct contribution to providing much needed flexibility to NGG compressor operations. Appendix 9 Future Gas Network Resilience.
* justification that the scale & cost of the Project is appropriate in relation to the learning that is expected.	The project is focused on a single compressor unit; it would not be feasible to scale down the project and it is unnecessary to scale up. The project provides valuable experience and performance evaluation for the introduction of proven technology, into an environment about which there is little or no current knowledge. The learning to be gained is directly and increasingly relevant in the future, to the future successful operation of the NGG grid. The cost is justified and appropriate providing guidance on a topic of strategic importance to energy supply. Section 4.3

Sub-Criteria	Assessment and material document references
* the processes that have been employed to ensure that the Project is delivered at a market competitive cost	The project plan aims to introduce competition into the design and selection of the modification methodology but only one compressor OEM has been engaged. A functional design specification has been prepared in order to evaluate an OEM detailed design specification. Value for money would be best served by acquiring other enthusiastic partners from compressor OEMs, who are willing to undertake the initial design work and who could confirm if retro fitting VIGV to their units was economically feasible. The normal procurement processes have been deployed and personnel have been identified. Sections 4.2, 4.5
* how Project Partners have been identified and selected including details of the process that has been followed and the rationale for selecting Participants and ideas for the Projects	An independent review of current compressor OEMs was commissioned and their views on compressor control and VIGV were sought. RR was established as an OEM partner, having had experience in VIGV at sites in Alberta, and Slovakia. The Carbon Trust was approached to provide an assessment of the performance of VIGV which was independent of NGG or the OEM. A technical partner has been identified to provide detailed expertise in compressor design and fluid dynamics. Section 4.4, 4.5
* the costs associated with protection from reliability or availability incentives and the proportion of these costs compared to the proposed benefits of the Project	The VECTOR project is being planned to reduce the risk of exposure to any availability and reliability incentives to the minimum acceptable, as such the VECTOR project team is not requesting any protection from its incentives. Section 4.2

6. CRITERION C: GENERATES NEW KNOWLEDGE

Criteria	Rating	Overall assessment
Criterion C: Generates new knowledge The potential for new learning to be generated by the project		The project will generate new knowledge regarding the variation achieved in extending the stable and efficient operating envelope of in line Gas Compressors by the employment of VIGV technology in conjunction with variable speed Compressors. It will also generate knowledge in the design of VIGV technology as a retro-fit facility to existing Compressor units.

Sub-Criteria	Assessment and material document references
* the potential for new learning to be generated by the Project	The following represents the key new learning from the project: • Feasibility of retro fitting VIGV to an existing compressor casing • Operational experience of controlling a compressor with a combination of VIGV and speed control. • Safety issues of gas tight seals at the actuator/casing interface. • Prime mover and compressor joint efficiency over the planned and actual range of operation. • Effectiveness of vane operation to design limits, in extending the satisfactory operational envelope of the compressor. • Efficiency impacts (if any) on prime mover and compressor with VIGV in `neutral` position cf no VIGV installed. (measure of drag effects) • Cost estimates for roll-out of VIGV to other units in NNG where requirements make retro fitting viable. Section 4.3
* how learning relates to the gas transmission system	The learning is directly relevant to the GB national gas transmission system, providing new knowledge about potential control modes for compressor units that may contribute to more flexible and efficient future operation. Sections 1.3, 2.1
* applicability of learning to other network licensees	No other Licensees operate comparable compressor units.
* the proposed IP management strategy and conformance with the default principles	The IPR issue is as yet unresolved with the OEM, but an email from a representative of the OEM, is included in the submission which sounds a positive note regarding the resolution of IPR issues. For it to be resolved it would need to be in conformance with the default NIC governance principles. Appendix 12
* credibility of the proposed methodology for capturing learning from the trial	Much of the learning from the trial is captured in performance statistics. These are verified independently by the Carbon Trust, thus enhancing the credibility of results, and avoiding influence from NGG or the OEM. Section 9

Sub-Criteria	Assessment and material document references
* quality of plans for knowledge sharing	Plans are sound, and thorough, but require IPR agreements with partners. Section 5
* how alternative IP strategy would deliver value for money to customers	It is important that the IP issue is resolved to the satisfaction of NGGT within the default principles. The key issue is that the IPR agreement must ensure that knowledge gained may be applied to retro fitting VIGV to installed units manufactured by other OEMs, The IPR must also permit NGG to include VIGV in specifications for new units by any OEM. Section 5

7. CRITERION D: INNOVATIVE AND UNPROVEN BUSINESS CASE

Criteria	Rating	Overall assessment
Criterion D: Innovative and unproven business case The extent to which projects could not be performed as part of a network licensee's normal course of business.		The submission indicates that there is no known implementation of VIGV technology with variable speed compressors nor is there experience of retro fitting VIGV in natural gas applications. However the Frazer Nash report 'Research into Variable Envelope Compressors', indicates Rolls Royce do have experience of incorporating VIGVs on both new build and retrofit natural gas compressors NGGT has indicated that to allow new technology to be introduced on the UK gas transmission system and fulfil "Best Available Technique" requirements they require the OEMs to demonstrate that a minimum of 5 of the same design of equipment should have been installed and operational in similar applications anywhere the world. It is questionable whether this approach is appropriate in a trial of this nature.

Sub-Criteria	Assessment and material document references
* The justification that the project is truly innovative: how the project is innovative and evidence that it has not been tried before	NGGT indicates in the submission that extensive research has found no knowledge among current OEMs with Compressors operated by NGG, of VIGV being deployed with variable speed compressors. However the full Frazer Nash report 'Research into Variable Envelope Compressors', referenced in the submission and provided in response to a question, indicates Rolls Royce do have experience of incorporating VIGVs on both new build and retrofit natural gas compressors. VIGV has been installed in a natural gas environment by Rolls Royce on two units in Alberta, one as a retro fit and one as new and NGGT acknowledged at the project team meeting that and there is information available on the prevention of gas leakage and safety issues in this case. Rolls Royce is also commissioning new compressor units with VIGV technology in Slovakia. This is contrary to the inference in Section 4.4, that the application of this technology, particularly in a retro fit situation, would be innovative. Section 4.4, and Appendix 8
* the credibility of why the network licensee could not fund such a project through its price control allowance	NGGT has not indicated in its submission why the work should not be funded as business as usual. In response to a question, NGGT indicated that the project aims to develop a new method of providing flexibility on the network, without requiring a re-wheel of a compressor or the construction of a new unit. However, at this time the technology is not proven for gas transmission applications. This argument does not appear to be convincing. Section 4.4, Response to Questions 9

Sub-Criteria	Assessment and material document references
* why the project can only be undertaken with the support of the NIC, including scrutiny of the claimed commercial, technical, or operational risks associated with the project	NGGT has indicated in response to a Question that to allow new technology to be introduced on the UK gas transmission system and fulfil Best Available Technique requirements they require the OEMs to demonstrate that a minimum of 5 of the same design of equipment should have been installed and operational in similar applications anywhere the world. The Best Available Technique relates to environmental regulation and is designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole. Whilst this and equipment reliability are important, the 5 of the same design is NGGT's criteria and it is questionable whether it should apply to a single retro fit trial on one of 68 units, where there is standby. Clearly full design approval would be required as with any plant modification. Section 4.4, Response to Question 11

8. CRITERION E: INVOLVEMENT OF OTHER PARTNERS & EXTERNAL FUNDING

Criteria	Rating	Overall assessment
Criterion E: Involvement of other partners & external funding The level of external funding and appropriateness of collaborators involved in each project submission		The partners involved in the Project are appropriate, and they bring complementary knowledge and experience to the project. An additional OEM would provide competition in tendering for the detailed design and manufacture of components. There is no confirmed external funding although the Carbon Trust has offered to provide financial support to this project by way of an efficiency discount if National Grid is successful in securing funding for both its NIC projects.

Sub-Criteria	Assessment and material document references
* appropriateness and affiliation of project partners	The OEM of the compressor used in the trial is a project participant whose input will be essential for a successful outcome The Carbon Trust will provide independent scrutiny and validation of the Project performance statistics. Giving the results more credibility A Technical Specialist in compressor design and fluid dynamics will provide expert guidance to NGG. Section 4.5
* level of external funding achieved, presented on a comparable basis	No specified external funding for this project. The Carbon Trust as a not for profit organisation, are unable to make a direct contribution, but have offered NGG an efficiency discount if both NGG NIC projects gain approval Section 4.5
* effectiveness of systems & processes to obtain partners and ideas	Although only one OEM has been acquired as a project participant, the processes put in place to obtain participants covered all potential OEMs with an installed compressor base in NGG. Section 4.5
* robustness of contractual arrangements with partners	Details of the contractual arrangements have not been supplied in the submission although it is intended to procure both the OEM and Technical Specialist through competitive tender. It is uncertain however that more than one Compressor OEM will tender for the initial design phase. Section 4.2
* funding and benefits for each partner	Participants are not providing funding although the Carbon Trust has offered to provide financial support to this project by way of an efficiency discount if National Grid is successful in securing funding for both its NIC projects. Direct benefits flow to NGGT and customers. Section 1.4.4, Appendix A

9. CRITERION F: RELEVANCE AND TIMING

Criteria	Rating	Overall assessment
Criterion F: Relevance and timing		The flexibility of operation now seen as a requirement for NGGT national gas transmission system and associated compressor operation is unprecedented, and appears to be unique. If successful, VECTOR will contribute to more efficiently meeting customer and shipper requirements.

Sub-Criteria	Assessment and material document references
* The significance of the project in: Overcoming current obstacles to a future low carbon economy Trialling new technologies that could have a major low carbon impact Demonstrating new system approaches that could have widespread application	Renewable low carbon energy production from intermittent resources such as wind generation will require increasingly large quick reaction response from alternative energy sources to fill supply troughs when wind power drops. Gas powered generation is identified as the prime alternative source. Providing flexibility from the NGG grid to supply the `troughs` is dependent upon varying pressures within the grid, to meet short term changes in demand patterns. This will enable low carbon production from intermittent energy sources to be maximised. Successful completion of this project will provide evidence that will potentially enable the VIGV technology to be operated more widely within the NGG existing and future compressor stations Section 4.3
* why the problem is relevant and warrants funding	Operating the NGG grid more flexibly is a strategic requirement of increasing importance into the future. The application of VIGV could provide a valuable contribution to the quick reaction required. Section 4.3
* how the GDN would use the method in future business planning	The wider efficient operational envelope provided by VIGV where fitted to compressors, would be incorporated as compressor characteristics used in analytical modelling programs for transient analysis. Not referenced from project material
* the appropriateness of the timing of the project	Supply and demand flexibility requirements are building now, and will increase into the future, so the project is timely. Section 4.6

10. CRITERION G: DEMONSTRATION OF ROBUST METHODOLOGY

Criteria	Rating	Overall assessment
Criterion G: Demonstration of robust methodology The feasibility of the project proposals from technical, customer impact and safety perspectives		The methodology appears robust, the Project Plan encompasses those processes which will be required to safely implement VIGV in the NGGT environment, including prior intensive maintenance on standby compression to ensure uninterrupted service from the chosen site. There should be no adverse effects on NGGT customers during the trial.

Sub-Criteria	Assessment and material document references
* the feasibility/quality of the project plan and programme governance, including responsibilities	The project plan is comprehensive and provides clear identification of responsibility and governance. Section 6, Apps3,6 & 7
* All risks, including customer impact, exceeding forecast costs and missing the delivery date	Risks are clearly identified with mitigating actions, and associated responsibilities. All appropriate risks appear to have been identified. Appendix 4
* Whether items within the project budget appear to provide value for money	The project plan identifies processes to ensure that items within the project are correctly defined in terms of their specification, and that procurement terms and conditions meet the criteria under the NIC governance document. Section 4.2
* the quality of the Successful Delivery Reward Criteria	Covered in Section 11.
* whether the proposed resources are sufficient to deliver the project	The resources specified are adequate to deliver the project. The participants identified provide essential skills, and knowledge which suitably complement those within NGG. The establishment of an independent scrutineer to oversee testing and scrutinise results, adds rigour to the credibility of the trial outcome. Section 6

Sub-Criteria	Assessment and material document references
* whether the project can be started in a timely manner	Project readiness in terms of technology and resources is clearly documented. Ideally a second OEM should be engaged to introduce competition in to the design stage, and the IPR issues resolved with the current OEM partner, Rolls Royce. Neither need be seen at present as influencing the planned start date. Section 6
* the robustness of the project methodology, including technical rigour and statistically robust outputs.	The need for the project, and the trial methodology which potentially could contribute a response to that need is clearly established, and set out in the submission. Technical experience is provided by selecting an OEM participant with current experience very closely related to the possible mode of operation of VECTOR in NGG. Technical rigour is provided by engaging a technical specialist in compressor design and fluid dynamics, independent of the OEM.. Using the Carbon Trust as an independent participant , to assist in the planning of testing, and to scrutinise test results will add credibility and quality assurance to the trial outputs. Section 2, 4.5
* the appropriateness of the risk mitigation processes	The processes for identifying risks, mitigating actions, and associated responsibilities appear to be appropriate. Appendix 4
* Clear vision for the project	The vision for the NIC Gas project is clear.
* Value of the project clear	The potential value of the NIC Gas project is clear.
* Impact of the project clear	The potential impact of the NIC Gas project is clear.
* Obstacles and impediments identified	These matters are addressed in the project description, at high level in the risk and contingency plan and in the project team meeting presentation.
* Project outcomes clear	The potential outcomes are set out. A trial recording the successful performance of VIGVs would result in roll out of VIGV technology to other Compressor sites, where economically viable. An unsuccessful performance of VIGV would remove that option from future plans.
* Means to achieve outcomes identified	The proposed methodology is generally both appropriate and credible in terms of delivery of objectives.
* Risks that may prevent outcomes identified and managed	These matters are addressed in the project description, at high level in the risk and contingency plan and in the project team meeting presentation.
* Project well planned	The information provided regarding the planning process appears robust.
* Resources clearly identified	The proposed project team manpower, external support and financial resources are detailed in the submission and appear sufficient to deliver the project.

Sub-Criteria	Assessment and material document references
* Project timeline justified	The project timeline is clearly specified in the Project Plan and Section 6 – Project Readiness.
* Technical standards clear	None are specified, but common technical standards will need to be established between NGG and project partners.
* Performance requirements clear	Idealised performance requirements are established, detailed performance requirements will be refined during initial design phase.
* Evidence of research of existing solutions	The Frazer Nash report provides evidence of research of existing solutions.
* Collaboration options described	Rationale for partnership arrangements and details of Partners are provided.
* Project informed by data	Some use made of data to illustrate the problem and the potential benefits.
* Clear technical governance	Technical governance is incorporated in the project management proposals.
* Clear Project Management	Project management arrangements in terms of resources and governance processes are clear.

11. SUCCESSFUL DELIVERY REWARD CRITERIA

Criteria	Rating	Overall assessment
Criterion: appropriateness of the SDRC definitions and timing and adequacy of links to key project milestones		NGGT has identified five criteria, which are clearly defined. They are tied to project milestones and include learning outputs as well as project process measures.

Detailed comments

The following criteria are proposed in the Full Submission:

1. Initial Design Evaluation and Selection of Preferred Solution
2. Detailed Design and Prototype build and Offline Trial
3. Preparation for and actual Installation of the VECTOR Technology on Live System.
4. Performance Trials and Benchmarking.
5. Verification of Results from Trials, Knowledge Dissemination and Project Close Out.

The definition of these criteria is clear. They are tied to project milestones and include learning outputs as well as project process measures.

12. ADDENDUM: SYNOPSIS OF CHANGES TO THE SUBMISSION

NGGT re-submitted their proposal on 10th October 2013 following meetings and discussions with the Expert Panel and Rune Associates, and after receiving and responding to written questions. The re-submission includes a number of textual amendments, a number of changes to Appendix 1, the cost spreadsheet and the inclusion of 2 new appendices.

12.1. SUMMARY OF CHANGES

The following table provides a summary of the material changes from the original proposal:

<table>
<tr><th>Topic Area</th><th colspan="2">Changes at resubmission</th></tr>
<tr><td rowspan="6">Funding arrangements</td><td colspan="2">NGGT has indicated their intention that OEMs will now be engaged on a collaboration basis. They also indicate that have reached an agreement in principle with one of their OEM partners that they will provide in-kind funding to cover the costs for the initial design and detailed design phases of the project and that they envisage that a second OEM will be engaged on a similar basis.
The revised Full Submission Cost Spreadsheet indicates the following:</td></tr>
<tr><td>Total Project Cost (Cell I13)</td><td>£9,253k (unchanged)</td></tr>
<tr><td>External Funding. (Cell I25)</td><td>£322k (was Nil)</td></tr>
<tr><td>Network Licensee Compulsory Contribution. (Cell I66)</td><td>£893k (was £925k)</td></tr>
<tr><td>Network Licensee Extra Contribution.
(Cell I37)</td><td>Nil (unchanged)</td></tr>
<tr><td>Gas NIC Funding Request. (Cell I85)</td><td>£7,628k (was £7,913k)</td></tr>
<tr><td rowspan="2">Intellectual Property Rights</td><td colspan="2">As a result of the revised collaboration arrangements and the agreement in principle with one of the OEM partners regarding in-kind funding to cover the costs for the initial design and detailed design phases of the project, NGGT has indicated that the foreground IPR from the initial and detailed design phases will be owned by the OEM.
NGGT further indicates that the IPR developed under this project will relate to the installation and performance of the VECTOR technology which NGGT will disseminate in line with default IPR arrangements.</td></tr>
<tr><td colspan="2">As a result of the revised collaboration and IPR arrangements, Risk Number 2 on the VECTOR project risk register, "There is a risk that the default IPR associated with the NIC rules and regulations prevents OEMs participating in the project" has been changed from a rating of 'Medium' to 'Low'. NGGT has indicated the following additional mitigation "One OEM has already indicated that they are willing to agree to the default IPR arrangements and it is envisaged that the</td></tr>
</table>

Topic Area	Changes at resubmission
	second OEM will follow suit."
Functional Differences between VECTOR and other Related Technology	NGGT has set out its view on what additional knowledge the VECTOR project will generate beyond that of the Variable Inlet Guide Vane technology currently utilised in the Alberta and Slovakia applications. This includes a summary description of functional differences between the VECTOR proposals and these developments.
Quantification of Further Benefits	NGGT has provided further information in relation to the benefits it expects to arise as a result of the VECTOR project and indicates that VECTOR provides a level of flexibility that is currently not achievable by a re-wheel but falls short of new machine installation. NGGT concludes that "the transition to low carbon energy supplies using CCGTs as the carbon plan indicates will require the flexibility provided by either installing VECTOR or multiple units.
Regulatory Requirements for Adoption of Best Available Technique	NGGT has provided further information on its interpretation and application of Best Available Technique (BAT) in the context of EU and UK environmental legislation and regulation. NGGT's concludes that: "VECTOR technology could not be admitted as BAT on the gas transmission fleet under business as usual conditions since the technology required is not yet "available" – there is no known operational design from which sufficient design, operating, maintenance, etc information could be obtained. However, a VECTOR demonstration project on the gas transmission system would prove the technology and make it "available" in the shortest possible timescales."

12.2. REVIEW OF DETAILED CHANGES

The following table indicates how the changes set out in the resubmission, impact on the assessment against the individual evaluation criteria:

Criteria	Rating	Assessment of changes including material document references
A: Low carbon and benefits		The concern expressed earlier in the report regarding the robustness of the financial benefits claimed has not been mitigated by either the responses to the relevant questions nor the re-submission. NGGT has not clearly articulated the benefits which may be realised through the greater operating flexibility potentially offered by the VECTOR technology. Whilst operational flexibility is likely to be required, the value of this has not been quantified. In the re-submission NGGT has suggested that for the provision of ramp rate flexibility to CCGT stations, the costs of VECTOR should be compared to the costs of additional compressor plant rather than the option of re-wheeling existing machines. This is based on a narrow examination of a hypothetical new power station connection. The potential benefits of implementing the VECTOR technology do not appear to have been quantified or demonstrated. Appendix 13
B: Value for money		The funding requirement has been reduced as a result of one OEM partner funding the initial design and detailed design phases of the project however this only represents a reduction of less than 4%. The previously expressed concerns over IPR have been addressed as part of the OEM collaboration arrangements and NGGT report that they now conform to the default requirements. Although NGGT still envisages that a second OEM will be engaged on a similar basis, evidence has not been provided to support this aspiration. Given the continuing reservations over financial benefits expressed against Criterion A and the scale of the funding required, the VECTOR project would not appear to offer good value for money. Sections 1.4, 4.5, Appendix 1, Appendix 4
C: Generates new knowledge		The information provided on the functional differences between the VECTOR project the Variable Inlet Guide Vane technology currently utilised in the Alberta and Slovakia applications indicates some new knowledge can be expected to arise, particularly in relation to remote operation of VIGV and variable speed control but it would appear that many of the issues associated with the installation of VIGV actuation in new and retro fit applications have already been addressed. Appendix 13

Criteria	Rating	Assessment of changes **including material document references**
D: Innovative and unproven business case		NGGT's further information on its approach to BAT is not considered to change the evaluation against this criterion. Indeed, NGGT indicates one definition of 'available' is "A technique that whilst nascent in application can be built and thoroughly tested and assessed on National Grid's gas transmission system as a demonstration project". This appears to apply to the VECTOR technology and enable its demonstration as part of business as usual. Appendix 13
E: Involvement of other partners & external funding		The comments on project funding and the involvement of a second OEM, included above against Criterion B, are not considered to impact on the evaluation against this criterion. Sections 1.4, 4.5, 5, Appendix 1, Appendix 4
F: Relevance and timing		NGGT's lack of clarity in justifying the benefits of VECTOR, in particular the future power station issue raised in the re-submission, suggests that although additional operational flexibility is always likely to be of practical use to the NTS operator, a compelling case for investment in VECTOR at the current time has not been demonstrated. Appendix 13
G: Demonstration of robust methodology		The changes do not impact on the project methodology, which appears robust and to enable safe implementation of the VECTOR technology in the national gas transmission system environment
Successful Delivery Reward Criteria		No changes were proposed by NGGT and hence the evaluation of these criteria is not impacted by the re-submission.