Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

NIA Project Registration and PEA Document

Date of Submission

Aug 2015

Project Reference Number

NIA_NGET0166

Project Registration

Project Title

VSC-HVDC Model Validation and Improvement (iCASE)

Project Reference Number

NIA_NGET0166

Project Licensee(s)

National Grid Electricity Transmission

Project Start

September 2015

Project Duration

4 years and 1 month

Nominated Project Contact(s)

Robin Gupta

Project Budget

£230,670.00

Summary

If VSC-HVDC links and networks are to be best used, i.e. the most cost-effective investment solution is to be correctly specified, the complete operational capabilities of the AC/DC converter stations need to be understood. Good progress is being made in understanding the implications of different forms of converter hardware. Very good progress is being made on understanding the station control & power control. However the intermediate stages of station operation and control have received scant attention and are less well understood. Given that these are vital to defining the operational limits and capabilities of the station, this is a glaring omission, and a serious weakness and risk in present VSC-HVDC power system models. As a result overly (or even insufficiently) conservative investment choices in future VSC-HVDC investment choices may result without further research into system operational capabilities. Likewise AC plant may not be correctly specified for optimum usage with such systems. The research will also derisk on-going investment in new VSC-HVDC links and allow better informed specification and operational requirements to be formulated.

Key elements include how the central station control communicates with sub-modules, selects which modules to use, sets ramp rates, manages auxiliary functions and avoids DC injection into the AC system. This project will address this knowledge gap, the constraints these stages impose on the station control, operation and protection, and will investigate necessary algorithms for improving system performance to make station control more robust and reliable as seen from the AC network, and consequently appropriate selection and specification of equipment (AC and DC) to be more readily made. Initial simulation will be validated on a highly reduced-scale prototype converter.

Key stages include the following:

1. Formulation of sub-module performance limits and telecommunications
2. Adding presently unmodelled internal converter systems to station hardware model
3. Converter perfomance benchmarking
4. Comparison of simulation models and hardware for a variety of contingencies.

Nominated Contact Email Address(es)

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Problem Being Solved

Present modelling of the impact of Voltage Source Converters for High Voltage Direct Current transmission (VSC-HVDC) are idealised and do not account for the physical environment in which the equipment is operating. For example they use simplified representations of the converter which do not take into account the effect of telecommunications, some of the internal control loops for the output voltage control and measurement delays from the many sub-modules in 4th generation converters. The suitability of existing models need to be verified and possible solutions/model updates identified to de-risk future and reduce costs in future VSC-HVDC deployment and operation and in the AC equipment it is connected to.

Method(s)

A reduced scale hardware model will be built in the laboratory in order to test the software simulations under conditions more closely resembling an operational environment. The hardware model will incorporate signalling, control hardware and measurement delays. The outcomes will be evaluated and used to assess the impact of full scale VSC-HVDC converters on operation of the transmission system.

Scope

If VSC-HVDC links and networks are to be best used, i.e. the most cost-effective investment solution is to be correctly specified, the complete operational capabilities of the AC/DC converter stations need to be understood. Good progress is being made in understanding the implications of different forms of converter hardware. Very good progress is being made on understanding the station control & power control. However the intermediate stages of station operation and control have received scant attention and are less well understood. Given that these are vital to defining the operational limits and capabilities of the station, this is a glaring omission, and a serious weakness and risk in present VSC-HVDC power system models. As a result overly (or even insufficiently) conservative investment choices in future VSC-HVDC investment choices may result without further research into system operational capabilities. Likewise AC plant may not be correctly specified for optimum usage with such systems. The research will also derisk on-going investment in new VSC-HVDC links and allow better informed specification and operational requirements to be formulated.

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Objective(s)

The project objectives are twofold:

1. Construction of a highly reduced scale Modular Multi-Level Converter (MMC) VSC-HVDC converter
2. Comparison of hardware vs. software models to assess the impact of telecommunications, internal voltage control loops and measurement on necessary model fidelity

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

The project team anticipate one of the two potential outcomes:

- An updated model for both Detailed Equivalent Model (DEM) and Average Value Model (AVM) models (see Cigre brochure 604, ‘Guide for the Development of Models for HVDC Converters in a HVDC Grid B4-57 working group).

OR

- An assessment that present DEM and AVM models are sufficient and telecommunications/ measurement / internal loops have negligible impact on the model.

Project Partners and External Funding

n/a

Potential for New Learning

n/a

Scale of Project

The project is of the minimum scale possible (one 4 year industrial CASE PhD student) and a very reduced hardware model costing a few thousand pounds only, focusing principally on the control, telecommunications and signaling aspect.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL4 Bench Scale Research

Geographical Area

University of Manchester laboratory.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

Total NIA funding: £150,000

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)

Provision of an enhanced understanding of VSC-HVDC link operation allows improved specification for future plant, and maximisation of operational benefit from existing and future plant, across the industry. An improved, validated model would also facilitate more reliable, robust operation of the plant when procured, and de-risk the potential for unplanned contingencies affecting the network. This applies to both HVDC systems and the AC transmission system that they are connected to.

Additionally, aligned to our commitment to mitigate environmental impacts on our customers, the knowledge gained through this project would allow VSC-HVDC to be considered along with the other options in a greater number of potential applications.

Please provide a calculation of the expected benefits the Solution

Not required for research projects

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

Could be rolled out to all GB Transmission owners and System Operator.

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

Nil – the deliverables of this project is in the form of a software update.

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

Improved/de-risked model fidelity of major component in future UK network (VSC-HVDC converter).

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.

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