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

Dec 2013

Project Reference Number

NIA_NGET0045

Project Registration

Project Title

Multi-terminal VSC HVDC operation, control and ac system integration

Project Reference Number

NIA_NGET0045

Project Licensee(s)

National Grid Electricity Transmission

Project Start

October 2011

Project Duration

4 years and 9 months

Nominated Project Contact(s)

Paul Coventry

Project Budget

£531,000.00

Summary

As a consequence of the European Union Renewable Energy Directive, the UK is committed to a target of more than 30% of electricity to be generated from renewable sources by 2020. The transmission reinforcements necessary to allow the EU 2020 renewable target and longer-term energy goals to be achieved in an effective and efficient manner were studied by the Electricity Networks Strategy Group (ENSG) and detailed in their report 'Our electricity transmission network: A vision for 2020'.

Nominated Contact Email Address(es)

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Problem Being Solved

It was recognised in the report that due to planning constraints and environmental concerns, traditional methods of enhancing system capacity can be difficult to achieve and consideration was given to employing the latest technology, especially where this would yield additional economic and/or environmental benefits. One such technology potentially contributing to the achievement of the above aims is Voltage Sourced Converter (VSC) HVDC transmission. Furthermore, VSC HVDC is, in principle, well suited to multi-terminal applications which would allow optimised designs integrating onshore and offshore networks to be achieved and such solutions are under consideration for the GB transmission system. However, while the technology is believed to be achievable, National Grid has not previously implemented VSC HVDC on the GB transmission system and multi-terminal VSC HVDC has not previously been implemented anywhere. It is essential, therefore that an adequate understanding of the application issues be developed. In order to initiate work in this important and urgent area, it is proposed that National Grid fund three PhD students who are available to start work immediately at the University of Manchester. Each student would address one of the three areas indicated above.

The work is complementary to the simulation of multi-terminal VSC HVDC system by means of real time digital simulator (RTDS) at the University of Birmingham which is the subject of a separate R&D proposal.

Method(s)

The method that has been proposed for this project includes the following;

1. MULTI – TERMINAL VSC HVDC OPERATION

- Familiarisation with VSC HDVC and AC system modelling in DigSILENT.

- Construction of a base case 40terminal generaric VSC HVDC system in DigSILENT – hardware and structure
- Investigation of multi-terminal HVDC and development of a series of multi-terminal scenarios; comparison of methods of ac and dc side control with DigSILENT simulation verification
- Development of lead candidate scenarios into models – RMS AC system representation – detailed dc multi- terminal behaviour. Parameterisation and testing
- First year PhD transfer report
- Investigation of dc control parameterisation for quasi-steady-state operation – local terminal control and multi terminal system control. Development of droop line settings for terminal control over whole operating range
- Fault study for power electronics system and system parameterisation – introduction of the associated non- linearities and the subsequent re-design of control algorithms and other system elements to be capable of dealing with them
- Study and identification of key slower transient phenomena (both ac and dc side), severity assessment and impact on control
- Robustness study identification of controller stability limits and key compensation requirements/controller modifications at both the local and multi-terminal levels
- Develop and test a detailed, more fully parameterised case study for a multi-terminal HVDC system
- Test the detailed case study system fully across the whole operating range of possible operational scenarios identified to help establish design and specification guidelines.

2. AC/DC HVDC INTERACTION - CONTROL

- Familiarisation with VSC HVDC and system modelling in DigSILENT
- Construction of base case VSC HVDC and generic AC network system in DigSILENT – hardware, structure and control
- Scoping study – investigation of a range of probable future scenarios with different level of penetration and technology mix of HVDC lines and series compensation of AC lines. Identification of key dynamics and fidelity of models required, identification of key studies to be performed. Justification of key scenarios to model.
- Implementation of key scenarios and model verification in PSCAD/EMTCD to act as a base case comparison
- First year PhD transfer report
- Implementation of key scenarios and model verification in DigSILENT with PSCAD/EMTDC to act as a comparator
- Investigation of transient control behaviour and parameterisation (RMS/EMT mode) for system in response to candidate scenarios.
- Revised and more realistic system models; thorough testing of detailed fidelity scenarios against published/public performance of system components
- Robustness and sensitivity study; identify potential for controller interactions (FACTS and SVC controllers and conventional, existing POD controllers, i.e. PSSs, series compensation) over pre-determined range of parameter variation and operating scenarios. Identify potential remedial actions required
- Second year PhD transfer report
- Identify minimum additional control requirements for each of probable scenarios. This could include required re-tuning of existing POD controllers (conventional PSSs) and/or application of supplementary WAMS based POD controllers applied at HVDC terminals. Illustrate effectiveness of each of the potential solutions on generic case studies.
- Review of methodologies applied to carefully chosen limited set of particular case study/studies.

3. AC/DC HVDC INTERACTION - DETAILED MODEL

- Familarisation with VSC HVDC and AC system modelling in PSCAD
- Construction of detailed VSC HVDC model in PSCAD – hardware, structure and control. FAMiliarisation with DigSILENT modelling
- Identification of key system dynamics and fidelity of AC and DC component models required, identification of key studies to be performed. Justification of key scenarios to model
- Implementation of key AC and DC component models in PSCAD and DigSILENT. This will include key primary plant components (power electronics and applicable control, transformers, cable transmission line, circuit- breaker, busbar, current and voltage transformers, filter banks). An assessment will be made of the level of fidelity required in the DigSILENT models to capture key dynamics. A PSCAD model set will be used as a detailed system model comparator. First year PhD transfer report.

- Report writing and documentation for models
- Detailed system model for local AC network model to allow candidate scenarios of AC/DC detailed interaction to be studied
- Second year PhD transfer report
- Scoping of investigation of detailed system interaction behaviour, including harmonics, switching transients, faults and detailed

system electromagnetic interaction. Preliminary validation against published results. The goal is to define which models need further refinement and/or information and to undertake such refinement - Robustness and sensitivity study; identify potential for AC/DC component interactions over a range of parameter and operating scenarios. Identify remedial actions required
- Identify minimal additional requirements for problems identified in robustness and sensitivity study that cannot be resolved by basic remedial actions (such as choosing a different rating or different controller gain). This could include the use of supplementary harmonic filters at HVDC terminals for example.

Scope

As a consequence of the European Union Renewable Energy Directive, the UK is committed to a target of more than 30% of electricity to be generated from renewable sources by 2020. The transmission reinforcements necessary to allow the EU 2020 renewable target and longer-term energy goals to be achieved in an effective and efficient manner were studied by the Electricity Networks Strategy Group (ENSG) and detailed in their report 'Our electricity transmission network: A vision for 2020'.

Objective(s)

The objective of the project is to improve understanding of the problems of Voltage Sourced Converter (VSC) HVDC integration into the existing transmission system. The project aims to make progress in three related areas:

1. Multi-terminal VSC HVDC operation;
2. AC/DCVSCHVDCinteraction–controland
3. AC/DC VSC HVDC interaction – detailed model (fast transients).

These areas have been identified as requiring to be addressed as part of the risk managed introduction of the technology onto the transmission system. The project will deliver reports on the results of studies and a documented set of models for use in National Grid's internal system studies. The work forms an essential step in being able to implement the technology on the transmission system.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

The project is likely to increase understanding of the issues associated with application of a multi-terminal VSC HVDC system on the GB transmission system. There is a high likelihood that such studies will allow application issues to be identified, better understood and enable their mitigation to be evaluated. This is success for the project.

Project Partners and External Funding

n/a

Potential for New Learning

n/a

Scale of Project

The project will be delivered on a laboratory scale.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL5 Pilot Scale

Geographical Area

This project will be delivered in Manchester

Revenue Allowed for the RIIO Settlement

Zero

Indicative Total NIA Project Expenditure

IFI £209,000.

NIA expenditure is £322,000

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)

The proposed work forms part of the risk managed introduction of multi-terminal VSC HVDC onto the transmission system. VSC HVDC has not previously been implemented on the GB transmission system and multi-terminal VSC has not previously been implemented anywhere. It is essential therefore to understand how a multi-terminal VSC HVDC system would interact with the existing transmission system and how control of the different converters of a multi-terminal system would be coordinated. The proposed work is intended to identify application issues associated with the technology and allow control measures to be evaluated. Failure to identify and manage such issues ahead of commissioning might have severe implications for operationofthelink. Ifdelayedcommissioningorunavailabilityofthelinkpendingasolutionweretoresult, the cost would be of the order of millions of pounds per month.

Please provide a calculation of the expected benefits the Solution

Research Project - N/A

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

This will be applied to the whole of the GB transmission system.

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

The project will deliver an indication of what would be needed when VSC DC links are integrated into the system.

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 learning could be used by the relevant network licensees to understand how the use of multi terminal VSC HVDC systems can impact on the the existing AC transmission system

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