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

Jan 2014

Project Reference Number

NIA_SPT_1309

Project Registration

Project Title

Low Frequency Electricity Transmission Technology Evaluation

Project Reference Number

NIA_SPT_1309

Project Licensee(s)

SP Energy Networks Transmission

Project Start

December 2013

Project Duration

2 years and 4 months

Nominated Project Contact(s)

James Yu (Future Networks Manager)

Project Budget

£175,000.00

Summary

This proposal aims to structure research work in the related areas, in order to establish a comprehensive and objective appraisal of the concept of a low frequency a.c. network as compared to the multi-terminal VSC-HVDC concept that is being pursued by industry. If successful, this will establish an opportunity for some manufacturers to overtake in this fast growing and severely competitive arena, and accelerate the deployment of offshore wind power. The technology will be generally beneficial to the exploitation of offshore wind and other forms of marine renewables. The research will reference to the on-going development in the traditional direction of VSC-HVDC concept and may achieve understanding to reveal the fundamental difficulties and solutions in that direction, but is conceptually transformative targeting the hidden simplicity in a totally different direction by means of fundamental scientific investigation.

Third Party Collaborators

University of Warwick

Newcastle University

Nominated Contact Email Address(es)

innovate@spenergynetworks.co.uk

Problem Being Solved

The main attraction of VSC-HVDC, as compared to conventional HVDC using line-commutated converters, is the relatively small space requirement for the filters which could be difficult to accommodate offshore [3,4]. But a multi-terminal d.c. network requires d.c. circuit breakers which are not economically available in spite of escalated efforts in the last few years [5]. Effort is also being made to develop VSCs which can block/limit the current infeed upon the occurrence of pole-pole faults on the d.c. side [6]. This would be useful

but cannot eliminate the need of d.c. circuit breakers and further challenges are yet to be addressed to provide the 'selectivity' in fault clearance. Point-to-point, two-terminal VSC-HVDC systems have been commissioned. Faults on the d.c. side can be cleared from the a.c. sides using a.c. circuit breakers on natural arc-extinction as the fault current crosses zero. In a multi-terminal HVDC system, this method is not applicable and, without d.c. circuit breakers, the entire system needs to be shut-down and then re-started later. Future d.c. circuit breakers may also need to handle the large discharging current from the capacitors inherent in the VSCs. Another major issue is the reliability of high voltage d.c. cables based on XLPE technology which has made VSC-HVDC economically competitive. XLPE cables are subject to the adverse effect of space charge accumulation and the water treeing problem associated with it and the humidity that can penetrate into the cable insulation structure [7]. There is strong evidence that such a problem is much exacerbated in the case of d.c. as compared to a.c., while without a complicated switchgear arrangement and coordination between terminals the d.c. voltage polarity of a VSC-HVDC system cannot be easily reversed. There is only very limited experience regarding the operational reliability of XLPE HVDC cables, whilst condition monitoring and preventive maintenance in the offshore environment will be difficult [8].

Method(s)

The reason that prevents a standard a.c. network from being used in this target offshore application is the large charging/discharging reactive power associated with the subsea cable, which depends on the transmission distance, power level and hence the required voltage. For instance the charging reactive power for a 100 km, 50 Hz and 400 kV cable reaches 1500 MVAr, exceeding the natural power for such a three-phase cable circuit [9]. This proposal envisages that the charging reactive power can be reduced by adopting an operational frequency much lower than 50 Hz. Another claimed advantage of a.c. against a.c. is that fewer conductors are required for the same power level [10]. The difference is however less significant as the cost of deployment, rather than the additional material and manufacturing cost, will dominate. Adopting a lower a.c. frequency (e.g. in the range of 0.5 to 5 Hz, to limit the charging reactive power to 1~10%) but still high voltage (e.g. 400 kV), would allow the use of a.c. circuit breakers and the cable will work under alternating electric field without accelerated space charge accumulation. However some challenges have to be faced in order to make this a reality. The utmost challenge is that the size of the low frequency transformers would at first glance be prohibitively large [11]. This is addressed in the proposal next while other secondary challenges will be described later.

Scope

This proposal aims to structure research work in the related areas, in order to establish a comprehensive and objective appraisal of the concept of a low frequency a.c. network as compared to the multi-terminal VSC-HVDC concept that is being pursued by industry. If successful, this will establish an opportunity for some manufacturers to overtake in this fast growing and severely competitive arena, and accelerate the deployment of offshore wind power. The technology will be generally beneficial to the exploitation of offshore wind and other forms of marine renewables. The research will reference to the on-going development in the traditional direction of VSC-HVDC concept and may achieve understanding to reveal the fundamental difficulties and solutions in that direction, but is conceptually transformative targeting the hidden simplicity in a totally different direction by means of fundamental scientific investigation.

Objective(s)

To comprehensively literature review, model and evaluate the low frequency ac transmission technology and its potential in transmission business

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

A report with tangible scientific evidence, and clear recommendation on a further demonstration project

Project Partners and External Funding

n/a

Potential for New Learning

n/a

Scale of Project

- Establish the operational (control and protection feasibilities) of the low frequency a.c. network concept, under different wind farm scenarios and transients, satisfying all the grid code requirements.
- Quantification of the benefits and the limitations of the low frequency a.c. network concept, giving a comparative evaluation against the VSC-HVDC. Differences in converters, cables and circuit breakers are to be evaluated based on their predicted stresses during

operation.

- Define criteria under which the low frequency a.c. network concept would be a more attractive design option, with respect to variables such as transmission distance, voltage level and number of terminals.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL6 Large Scale

Geographical Area

Applicable to UK and international transmission networks through technical expert interaction.

Revenue Allowed for the RIIO Settlement

Not applicable.

Indicative Total NIA Project Expenditure

Total expenditure for the full proposal development is £175,000 or less in line with the NIA governance document

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)

- Facilitate the offshore wind interconnection into offshore transmission network
- The initial estimation of the potential saving can easily reach £6m, taking £40/MWH*500MW*8760H*25year*0.005probability*0.3 diversity

Please provide a calculation of the expected benefits the Solution

Research therefore N/A

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

Learning has been agreed to be disseminated in conjunction with Ofgem website, ENA website, Scottish Power Website and annual conferences (including LCNF).

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

N/A, learning via business as usual.

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 control and communication philosophy developed under this project will be applicable to any transmission network boundaries with dynamic constraint.

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