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_NGET0054

Project Registration

Project Title

Load cycling and radial flow in mass impregnated HVDC Submarine cables

Project Reference Number

NIA_NGET0054

Project Licensee(s)

National Grid Electricity Transmission

Project Start

October 2011

Project Duration

4 years and 1 month

Nominated Project Contact(s)

Greg Tzemis

Project Budget

£2,200,000.00

Summary

The scope of this research is focussed on HVDC mass impregnated (MI) cables stress processes that are particularly vulnerable in the cooling stages associated with power reductions or emergency shut downs, especially when occurring during the delivery of short term overloads.

Nominated Contact Email Address(es)

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Problem Being Solved

Mass impregnated HVDC subsea cable has for long been, and still remains, the state-of-the-art technology. The electrical insulation of such cables consists of paper impregnated with a high viscosity oil, enclosed by a lead sheath that prevents water ingress.
Recent installations typically operate at 400 - 450 kV and have a continuous power rating per cable of up to 500 MW. Two such HVDC links are presently in operation between Norway and the European continent. In a future pan-European electrical power grid, subsea cables in the North Sea are expected to play a crucial role, both for exchanging power between the UK, Scandinavia and the European continent, and for transferring power generated in large off-shore wind farms.

It is generally accepted that the cooling period after a power reduction or turn-off is the most critical part of the operation of subsea mass impregnated HVDC cable. Consequently, the power rating of such cables, both with regard to short-term overloads and on a continuous basis, is largely set by considering the risk of having a dielectric breakdown during a power reduction or turn-off. However, as will be described in some detail below, the behaviour of the cable insulation under different load conditions, and thereby the risk of having such breakdowns, is far from fully understood. Hence, it is reasonable to assume that the true capacity and operational flexibility this cable technology can offer, are not fully exploited.

Ohmic loss in the conductor is the main source of heat generation in a loaded cable. Hence, the conductor will always be at a higher temperature than the surroundings, and there will always be a heat flow and an associated temperature gradient in the radial direction

through the cable insulation.
The thermal expansion coefficient of the mass impregnation is ten times that of paper

During load increase, the associated thermal expansion causes the volume of the insulation to increase and the lead sheath is inelasticaly deformed. If the elastic properties of the armouring combined with the external water pressure do not compress this volume sufficiently during cooling, cavities will form in the insulation. Moreover, the greater temperature reduction and thus a larger thermal contraction of the inner parts of the cable than of the outer parts, is also expected to contribute to cavity formation.

These cavities greatly reduce the dielectric strength and may cause long breakdown channels extending tens of centimetres and even meters, in the axial direction.

Moreover, thermal cycling may, over time, lead to a lasting and irreversible displacement of the mass impregnation. The inner insulation layers become depleted, while mass accumulates between the outer insulation layers and the lead sheath.

The existing knowledge about the importance and significance of the various factors expected to influence cavity formation and their interaction is limited, even though such relationships essentially determine the power rating and safe operational patterns for a subsea HVDC mass impregnated cable. In other words, subsea transmission systems are presently operated under constraints that potentially are unnecessarily strict.

Method(s)

Research

This project proposes the following method:

The project will be delivered as part of a consortium with TenneT and Statnett who will provide cable samples from the Nor-Ned interconnector for analysis by academics from the University of Trondheim and the Norwegian Sintef Energy research facility.

Research activity is focuses on:

- Load cycling and Partial Discharge measurements of full-scale cables sections in the laboratory
- Parameter estimation and small scale experiments
- Modelling of radial mass flow and Operational Limits

Scope

The scope of this research is focussed on HVDC mass impregnated (MI) cables stress processes that are particularly vulnerable in the cooling stages associated with power reductions or emergency shut downs, especially when occurring during the delivery of short term overloads.

Objective(s)

To determine what load conditions (power ratings and load patterns) typical high voltage direct current (HVDC) mass impregnated paper insulated cables can be subjected to without risking cavity-induced dielectric breakdowns during a cool-down period after a power reduction or turn-off.

To establish an informal North Sea cable working group collaboration on HVDC link projects, potential sharing of spares holding and repair resources.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

- Obtain a detailed physical understanding of the processes that lead to cavity formation and the importance of various operational, environmental and cable design parameters to these processes.
- Develop a numerical model that quantitatively describes the radial mass flow and cavity formation under load cycling.
- Determine the operational constraints for one or more HVDC subsea cables presently in service.

Project Partners and External Funding

n/a

Potential for New Learning

n/a

Scale of Project

European Collaboration Project of laboratory based work.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL5 Pilot Scale

Geographical Area

The research work is being undertaken in Norway.

Revenue Allowed for the RIIO Settlement

None.

Indicative Total NIA Project Expenditure

NIA- £400,000

IFI - £200,000

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)

This research is contributing towards the sounds understanding and operation of the GB transmission system. The 2.2GW western HVDC link connecting the increasing volume of renewable generators in Scotland to England is expected to cost in excess of £1.2bn. Many more subsea HVDC connections are expected to connect Off-shore wind and to the GB stysem and to connect the GB system to those of Ireland and continental Europe overn the coming decades. Ensuring that optimum use is made of these expensives links will ensure that they not operated with uncessarily limitations on power transfer capacity whilst also securing their longevity.

Please provide a calculation of the expected benefits the Solution

Not required - Research Project

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

This learning can be applied to all HVDC subsea MI cables, currently still the most common type of cable in use.

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

The roll out of the learning from this project is primarily related to policy/procedural changes to the operation of HVDC MI cables . The direct cost of making a policy or procedure change could range from as little as ten thousand to hundreds of thousands of pounds depending on the complexity of the change implications. The wider cost implications arising from such changes will be dependent on the specific outcomes generated from the project and typically will be subject to further stages of demonstration prior to roll out. Further information regarding roll out costs can be provided prior to demonstration stage.

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

n/a

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

This project relates to the connections and system operability themes with specific focus on facilitating connections and smarter system operation through transmission assets being efficiently operated to manage the network challenges created by increasing renewable generation - in particular large scale off-shore wind and greater interconnection with European electricity markets.

☑ 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