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 2018

Project Reference Number

NIA_SHET_0024

Project Registration

Project Title

Partial Discharge in HVDC Cables

Project Reference Number

NIA_SHET_0024

Project Licensee(s)

Scottish and Southern Electricity Networks Transmission

Project Start

August 2018

Project Duration

0 years and 7 months

Nominated Project Contact(s)

Joe McNeil

Project Budget

£50,000.00

Summary

Partial discharge (PD) is the breakdown of a small part of insulation on equipment that is under high voltage (HV) stress. It is one of the major causes of catastrophic failures in HV equipment. PD mechanisms in HV Alternating Current (AC) systems are well understood and there is a growing body of knowledge around effective detection, monitoring and mitigation techniques under these conditions. However, there is a lack of knowledge and experience in the industry relating to PD under High Voltage Direct Current (HVDC) conditions. SSEN is investing significantly in HVDC cables, a trend replicated by the rest of the GB industry where there is proliferation of interconnectors and connections to offshore renewable sources of energy. To better prepare for the growth in use of HVDC, there is recognition for the imperative to know more about the mechanisms and characteristics of PD under these conditions.

Third Party Collaborators

University of Strathclyde

Imperial College London

Engineering and Physical Sciences Research Council

Nominated Contact Email Address(es)

transmissioninnovation@sse.com

Problem Being Solved

Partial discharge (PD) is the breakdown of a small part of insulation on equipment that is under high voltage (HV) stress. It is one of the major causes of catastrophic failures in HV equipment. PD mechanisms in HV Alternating Current (AC) systems are well understood and there is a growing body of knowledge around effective detection, monitoring and mitigation techniques under these conditions. However, there is a lack of knowledge and experience in the industry relating to PD under High Voltage Direct Current (HVDC) conditions. SSEN is investing significantly in HVDC cables, a trend replicated by the rest of the GB industry where there is proliferation of interconnectors and connections to offshore renewable sources of energy. To better prepare for the growth in use of HVDC, there is recognition for the imperative to know more about the mechanisms and characteristics of PD under these conditions.

Method(s)

This project proposes a technical method delivered through PhD studies. Knowledge pertinent to partial discharge inception voltage, magnitude and frequency of discharges, pulse characteristics, and frequency domain profile will be established by applying positive and negative DC stresses to polymer samples. AC stresses will also be recorded for reference.

The samples to be tested are:
1. Spherical voids in epoxy resin
a. 2 void sample
b. 3 void sample
c. 4 void sample
d. 5 void sample

2. Cylindrical voids in low-density polyethylene (LDPE) and polypropylene (PP) films
a. Single void samples
b. 2 void samples (voids in parallel)
c. 2 void samples (voids in series)

3. Cylindrical void in cross-linked polyethylene (XLPE) Cable
a. Single void

The above knowledge will be captured under laboratory conditions using commercial equipment including: Doble PDS200, LeCroy Waverunner 104Xi, Lemke LDIC LDS-6, and HVPD high-frequency current transformer (HFCT).
Analysis is performed using Mathworks Matlab and Microsoft Excel.
Detection of the above will be attempted at longer distances, by the use of longer cables between the HFCT and measurement devices to investigate the attenuation of these signals.

Scope

The scope of the project is limited to laboratory experimentation and does not include on-site testing, although cables will be procured from on-site.
The project aims to better facilitate the detection of PD under HVDC conditions but does not involve designing a new monitoring method.

Objective(s)

To determine
1. Partial discharge inception voltages, magnitude and frequency of discharges, pulse characteristics, and frequency domain profiles of the samples mentioned above
2. To investigate and consider technologies for the detection of partial discharges in longer length (tens of kilometres) HVDC cables by investigating the attenuation of signals in both the time and frequency domains

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

The project will be successful if:
1. An open-access database (published in Nature's Scientific Data) of the aforementioned partial discharge characteristics is created and made available
2. An additional journal paper is published on the knowledge generated by obtaining this data.
3. The work forms the basis for a successful PhD thesis on the topic.

Information can be shared within networks industry

Project Partners and External Funding

University of Strathclyde
Imperial College London
EPSRC CDT in Future Power Networks and Smart Girds (EP/L015471/1)

Potential for New Learning

The learning from this project has potential to provide GB network licensees with the fundamental knowledge needed to gain insight into how to better detect and protect their HVDC equipment from PD induced failures.
Knowledge generated will be shared within the networks industry and published in peer-reviewed academic journal and conference papers, as well be submitted as a PhD thesis.

Scale of Project

The project is at laboratory scale, but learning is scalable to on/off-shore cables of tens of kilometres in length.

Technology Readiness at Start

Technology Readiness at End

TRL2 Invention and Research	TRL3 Proof of Concept

Geographical Area

Project is undertaken within the SHE Transmission license area of SSEN

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£50,000, 90% (£45,000) of which is allowable NIA expenditure

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)

A greater understanding of the mechanism of PD in HVDC cables will provide a basis for the development of effective mitigation in the future. It is expected that this will result in deployment of detection or monitoring systems such as the ones currently implemented in AC systems thereby enabling pre-emptive intervention and operational longevity of HVDC cables.

Please provide a calculation of the expected benefits the Solution

At this stage this is a research project

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

Research and development resultant from the project are applicable to any transmission or distribution operator, or generator using HVDC cables.

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

The outputs from this project are not expected to be fully rolled out. However, the learning is envisaged to provide a starting point for future work which will develop technologies for detecting and mitigating PD in HVDC systems. As such, rollout costs cannot be stated at this point.

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 learning from this project has potential to provide GB network licensees with the fundamental knowledge needed to gain insight into how to better detect and protect their HVDC equipment from PD induced failures.
Knowledge generated will be shared within the networks industry and published in peer-reviewed academic journal and conference papers, as well be submitted as a PhD thesis.

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.

A study of the market and the learning portal has shown that this particular focus area has not yet been researched. Work will be submitted to peer-reviewed journals and conferences and published as PhD thesis, therefore novelty is a requirement. The subject is of academic interest and therefore other projects exist which are examining different aspects of the issue. A review of the other initiatives shows that this methodology is exploring different measurement techniques on different cable defects in different cable types.

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

HVDC cable systems and AC partial discharge monitoring have been utilized in the transmission of energy for some time, however the used of PD monitoring in cables under HVDC conditions is not well understood.

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

There is a lack of technical expertise and equipment/software within SSEN to undertake the project as part of business as usual. There is also no knowledge within industry to inform work of this nature.

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

The work involved is of an exploratory nature and is aimed at investigating the problem from the fundamentals. As such, the work is still at very low levels of technology readiness which poses commercial risk if funding is provided through business as usual. However, if the outcome is successful, use of NIA funding provides a mechanism for knowledge sharing and replication which can deliver value to all GB network customers.

This project has been approved by a senior member of staff

☑ Yes