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

Sep 2018

Project Reference Number

NIA_NGTO022

Project Registration

Project Title

High Frequency Earthing and its Impact on the Transmission System

Project Reference Number

NIA_NGTO022

Project Licensee(s)

National Grid Electricity Transmission

Project Start

November 2018

Project Duration

2 years and 9 months

Nominated Project Contact(s)

Linwei Chen

Project Budget

£411,000.00

Summary

Given that High Frequency (HF) rods are more susceptible to installation difficulties and higher costs, there would be strong saving benefits if the need for HF rods can be avoided. Furthermore, early research at Cardiff demonstrated the superiority of HF performance of partially insulated electrode configurations overlaid on existing earth grids. Such a solution, if adopted, can help mitigate the effect of high frequency and surge currents more effectively and with associated cost savings on installation and maintenance. This project will involve extensive modelling and experimental testing to investigate the safety issues and the effectiveness of high frequency earth electrodes with various earthing methods.

Nominated Contact Email Address(es)

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Problem Being Solved

The use of High Frequency (HF) earthing (particularly HF rod electrodes) has been assumed to be the default/common earthing design practice for all electricity supply asset owners, for both transmission and distribution systems. From previous modelling experience, it is known that the frequency responses of rod and grid electrodes are different, and this feature has been the main driver and argument for choosing rods for HF earthing. However, practical field experiences have led to questions to be raised on the comparison between the performances (i.e. frequency dependence) of rods and large grids.

Given that HF rods are more susceptible to installation difficulties and higher costs, there are strong cost-saving benefits if the need for HF rods can be avoided. Furthermore, early research has demonstrated the superiority of HF performance of partially insulated electrode configurations overlaid on existing earth grids. Such a solution, if adopted, can help mitigate the effect of high frequency and surge currents more effectively and with associated cost savings on installation and maintenance.

Related to this high frequency performance, a validation/development opportunity has emerged recently with a large earth-tester instrument manufacturer, and the accuracy and suitability of basic earth testers for the measurement/assessment of high frequency

performance earth electrodes has been questioned. This investigation seeks to further improve the measurement of high frequency performance of various earth electrodes: vertical, horizontal, grids and tower bases. The high frequency performance and measurement questions are also common to distribution networks.

Method(s)

The project will involve extensive modelling and experimental testing in the HV laboratory at Cardiff University and at the university's outdoor earthing test site in Llanrumney. Furthermore, measurements and tests at selected sites where high frequency rods are installed will be performed.

Modelling investigations will include test electrodes at Llanrumney and practical high frequency electrodes installed at selected National Grid substation sites. CDEGS-HIFREQ software will be utilised to construct the electrode geometries and analyse their performance. Such numerical modelling predictions will be compared to measurements at the test sites. Furthermore, the comparative performance of overlaid insulated conductors will be introduced to evaluate its merits compared to HF rods.
The experimental work will involve (i) preparatory and calibration laboratory tests for measurement equipment, (ii) establishing earth grid with vertical rods and insulated overlaid horizontal conductors at Llanrumney test site, and carrying full characterisation of the various electrodes: grid, and vertical and horizontal electrodes and their combinations. The tests will involve variable frequency sources as well as impulse injections. In addition to the electrodes, above ground arrangements of down leads will be set up and investigated. In particular, the effect of bends will be quantified, and testing equipment will be purchased for this part of the project, (iii) on-site testing of existing HF electrodes.

Scope

This project will address the safety issues and the effectiveness of high frequency earth electrodes with particular emphasis on high frequency rods when subjected to fault and surge conditions. Alternative high frequency/surge mitigations will be investigated and trialled to ascertain their effectiveness and potential cost-efficiency. Collaboration with a world-leading manufacturer of earth measurement apparatus will allow a better assessment of the performance of such electrodes under injected high frequency and surge currents.

Objective(s)

The main objectives of this project are to:

- Fully quantify any added benefit of the so-called High Frequency rod and assess its cost benefits.
- Fully quantify the earthing down lead geometries and arrangements on the effectiveness of the earth electrode and earth potential rise under high frequency fault currents and surges on the system.
- Further develop, refine and quantify the benefits of the Cardiff University proposed alternative method of overlaid insulated horizontal conductors for reducing earth impedance, improving the effective area of earthing systems and enhancing the high frequency earthing performance. Furthermore, establish the relative merit of this technique compared to HF rods.
- Trial and validate test new techniques for earth impedance measurements under high frequency and surge conditions.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

A complete final assessment of high frequency rods and their perceived benefits. A successfully trialled new method for enhancing earthing performance and a comparison of its merits to high frequency rods.

Project Partners and External Funding

N/A

Potential for New Learning

Further knowledge will be generated on the impact of high frequency rods on earthing systems. Development of a more-performant, cost-effective technique for enhancing earthing systems at higher frequencies and under surge conditions.

Scale of Project

This project will involve desktop simulations, laboratory work, test site work and on-site testing of earthing electrodes.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL4 Bench Scale Research

Geographical Area

The work will be undertaken at the Cardiff University's high voltage laboratory, Llanrumney earthing outdoor test site, and selected National Grid substations and towers in the UK.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£411,000

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)

For a typical green-field substation site, by omitting the need for high frequency rods, the saving could be in the range of £50-100k over the life-cycle, e.g. 20 years. For existing sites undergoing refurbishment and/or uprating work, the saving would easily double due to site restrictions and complications.

Please provide a calculation of the expected benefits the Solution

It is difficult to quantify this yet as this is early research, and the potential degree of application depends on the outcomes.

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

If proven successful, the outcomes of this project can be rolled out at all network installations that are subject to high frequency faults and surges conditions.

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

No cost is needed for rolling out the new findings resulted from this innovation work.

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

All utilities will benefit from the assessment of the high frequency rods and the new insulated conductor method for enhancing earthing and safety of their network/assets.

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 fits within the Managing Assets value area of the Electricity Innovation Strategy.

☑ 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.

There are no known projects being undertaken for this scope of work. The review has included the ENA smart portal, and supply base (including Universities and EPRI).

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

The project will ask the important question of its necessity to have high frequency rods at transmission substations, which has always been taken for granted and not challenged. In addition, the very innovative high frequency electrode configuration will greatly improve the cost effectiveness of electrode materials when high frequency earthing is needed. Both themes have never been addressed before this project

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

The nature of a research programme means it inherently carries a risk that the research may be unsuccessful and/or identify unforeseen barriers to implementation and National Grid is unable to consider the research of this scale as business-as-usual. The NIA funding offers the most appropriate route for the National Grid Electricity Transmission to assess the necessity of using high frequency rods and to evaluate alternative earthing methods.

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

Given the innovation nature of the proposed work and necessary collaboration with university partners, NIA is considered the perfect funding mechanism.

This project has been approved by a senior member of staff

☑ Yes