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NIA Project Registration and PEA Document

Date of Submission

Jul 2023

Project Reference Number

NIA2_NGET0044

Project Registration

Project Title

Improving the determination of safety and induced effects in earthing systems

Project Reference Number

NIA2_NGET0044

Project Licensee(s)

National Grid Electricity Transmission

Project Start

September 2023

Project Duration

2 years and 7 months

Nominated Project Contact(s)

Muhammad Shaban

Project Budget

£775,000.00

Summary

This project aims to examine three different problems associated with the earthing of the T-pylon assets. The project will investigate the earthing performance of innovative T-pylons and the induced effects of the T-pylons and the associated energised lines. Induced voltages and induced currents will be measured and compared with the computational results to establish recommendations on earthing and induced effects. In addition, the project will examine the most recent computational (XGSLab) and measurement techniques to compare the computations with the existing techniques (CDEGs). Comparative computations of software will be conducted under variable frequency and transient currents will be injected into ground. Conducrete will also be explored to improve the earthing performance. Such low resistance materials will reduce the earth impedance and materials will act as an enlarged earth electrode size increasing the ability to dissipate more earth fault currents.

Third Party Collaborators

Cardiff University

Nominated Contact Email Address(es)

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Problem Being Solved

Earthing systems play a key role in the operation of electrical networks. They are used for the safe operation of high voltage equipment and the safety of operating personnel as well as people in the vicinity of electrical installations. Earthing systems are designed to perform both under steady state and fault/surge conditions. It is important that the impedance of the earthing system is sufficiently low so that, when fault current flows to earth, it does not cause a hazardous rise of earth potential. Any rise of earth potential beyond the safety limits or body tolerance will constitute a real danger to people in contact or in the vicinity of the fault current injection point. The accidental circuit used to estimate the body current helps to estimate scenarios of electrocution due to touch and step voltages. It is, therefore, important to determine the earthing impedance as well as the safety voltages to dimension the earthing system for safety

purposes.

T-pylons are the new innovative assets National Grid (NG) has energised recently. The design of earthing systems were studied thoroughly for T-pylons, but the operational earthing studies and the safety are still to be understood, including the potential coupling effect and induced voltages and currents. In addition to earthing safety of the T-pylon, the computational methods (software and measurement techniques) used have not been updated for a couple of decades. Computational earthing techniques need an investigation to explore recent technological advancements. In addition to these, soil and clay are used as earthing backfill and as NG build more assets in urban areas, it is hard to find virgin soil. There is still a lack of understanding on how new earthing backfill alternatives will interact with earthing safety especially in UK (United Kingdom) weather and conditions.

Method(s)

In this project, we propose to examine the most recent computational and measurements techniques as well as the enhancement material to improve earthing systems performance. In addition, we will examine the earthing performance and induced effects of the T-Pylons and associated lines.

This project aims to develop technical underpinning knowledge on the earthing performance and induced effects of the T-pylons. It will focus on developing safety instructions for energised T-pylon lines with a suitable condition monitoring system. The project will focus on the applicability of the latest earthing techniques and critically assess their suitability to give asset managers the information required for safe operation of T-pylon lines on the transmission network.

The project will be delivered in five parts: (1) T-pylon lines performance assessment which will investigate earthing of T-pylons, T-pylon earthing measurements, induced effects on T-pylon overhead lines, and measurement of induced current on T-pylon lines. (2) Analysis of earthing systems and comparative evaluations using experimental and computational techniques exploring evaluation of software and comparative computations and comparative measurements. (3) Evaluation of enhanced materials for earthing systems with focus on material properties, experimental applications for earthing systems and evaluation of Conducrete performance on practical earthing systems. (4) Investigation of capacitive coupling effects within transmission substation environments while exploring induced capacitive voltages on floating plant and modelling approach for induced capacitive voltages in substation environments. (5) Conditions monitoring of earthing systems and feasibility of condition monitoring for earthing systems. With successful investigations, computational and experimental results, the trials at energised lines will be conducted.

Scope

New T-pylon lines are energised in the Southwest of England, generating operational data available for earthing, this project will develop a greater understanding of the T-pylons earthing requirements. It will underpin efforts to develop safer requirements for T-pylons and determine the working conditions with one line energised through coupling studies. The benefit of these studies, where this is possible, is to achieve reliable asset management to reduce safety concerns and therefore risk of unplanned outages.

The latest computational technology will be explored which break the monopoly of CDEGS software which is the only option available for earthing studies nowadays. Soil and clay are currently used as earthing material backfill and can be replaced by a conducting concrete which will provide low resistance path to fault current.

Objective(s)

The work will be delivered in discrete work packages each with a focus on different objectives linked to the overall aim to develop deeper understanding of the earthing performance of newly energised T-pylon lines.

- Report on characterisation of earthing system performance for T-Pylons
- Report on earthing measurements at T-Pylon locations
- Report on computation induced voltages and currents on T-Pylon lines
- Report on measurements of induced currents on T-Pylon lines
- Report on comparative evaluation of earthing software
- Report on comparative evaluation of computed earthing parameters vs measurements on various earth electrodes
- Report on characteristics of low resistive materials under various environmental conditions
- Report on experimental results using earth electrode using Conducrete
- Report on evaluation of Conducrete impact on practical earthing systems
- Report on computation of capacitively coupled voltages onto floating plant in substations
- Model for estimating capacitively induced voltages on floating metallic objects in substations
- Report on practical condition monitoring of earthing systems

- Final report and dissemination event

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

In the short-term, improving the earthing performance of T-pylons will lead to better performance regime and reduce outages. Since operational earthing performance studies data does not exist, the most effective way to develop new learnings is by carrying out field measurements on energised T-pylon lines. Given the expected long asset lives of high voltage equipment like T-pylons, the project aims to develop better understanding of asset and safety management, reduce the risk of failure and increase the network resilience. The project aims to explore other advanced technical computational cost-effective options which will assist in making better investment decisions. Exploring the benefits of Conducrete will help in reducing dependence in hunting virgin soil and clay for earthing backfills and will provide low resistance path to fault currents while improving safety. The intention is, therefore, to achieve safety goals that will benefit all consumers with reduced risk of failure and better asset management. Efficient investment ensures that the cost of technological advancement is not unfair while achieving computational efficiency.

Success Criteria

The project will be considered successful if the objectives are achieved, specifically:

- Characterisation of earthing system performance of T-pylons while performing computational and field measurements on newly energised T-pylon lines
- Experimental results are shared based on using earthing electrode while implementing Conducrete
- Comparative analysis of CDEGs and XGSLab will be presented to break the monopoly and adopt to new computational techniques
- Computation of capacitively coupled voltages onto floating plant in substations

Sufficient knowledge would be gained for overall earthing performance of T-pylons, computational capability of XGSLab and Conducrete characteristics in UK weather & conditions.

Project Partners and External Funding

The following project partners will be supporting the project:
HV laboratories and outdoor test field at Cardiff University will make use of existing generators and recording instrumentation and laboratory general facilities at no extra cost to the project.
NGET is providing all the funding for the project and is the lead project partner.

Potential for New Learning

The following will be new knowledge expected from carrying out the project:

- Development of new learning around T-pylon earthing performance with operational data and conditions
- Results based on the investigation of Conducrete behaviour within UK weather and conditions
- Computational data based on the comparison between XGSLab and CDEGS
- Comprehensive investigation of capacitive coupling effects within transmission substation environments

Scale of Project

Laboratory studies will be undertaken to demonstrate the testing of the equipment and the software. There will be additional field and laboratory work in this project but ahead of moving the research into an activity that would be undertaken at newly energised T-pylon lines in at Hewish, Southwest of England.

Technology Readiness at Start

TRL4 Bench Scale Research

Technology Readiness at End

TRL6 Large Scale

Geographical Area

Laboratory studies to be performed at Cardiff University. Field based measurement and studies to be carried out at Hewish in Southwest of England. The results of the work will impact T-pylons across the network.

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£697,500

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:

This project supports the energy system transition by increasing network resilience and risk of failure. T-pylon is a new innovative asset to NG and, therefore, has its unique characteristics in terms of coupling relationship. Conducting a comprehensive package of coupling studies is crucial in helping to define the safety instructions (e.g., NSI 4 and TGN 313). Induced voltage and current on the T-pylon will establish safety working conditions with one-line energised. The study will develop better understanding of T-pylons, leading to better and safer maintenance regime in addition to reduced outages.
A related study of using new technology like XGSLab will bring safety benefits and due to its reduced cost over the years, we can have better simulation accuracy with more informed investments. Earthing backfill material like Conducrete behavioural analysis with UK weather and conditions will provide low resistance path to fault currents. Overall, the project will improve the asset management of T-pylons, reduce the risk of failure and increase network resilience.

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)

N/A

Please provide a calculation of the expected benefits the Solution

The benefit of this project is based on an assumption that NGET will achieve earthing performance safety of its assets. A new computational software will also be explored which will reduce the capital and the yearly renewal cost as well. If this project is successful, over a 20-year period, we assume that health and safety will be improved for live T-pylon assets and lives of two on field personnel and 10 injuries can be saved resulting in generation of Societal value created with a net benefit of £1.9m.

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

The outcome of the project will determine the safety practices in T-pylons and the future T-pylons will have better asset management. The success of the project will also break the monopoly of CDEGS and open the market for more advanced computation technologies. The technical specifications can be changed to allow usage of different software and the earthing backfill which can be adopted by other TO and DNOs. Other licensees may benefit from employing new computation technique and reduce the overall cost associated with it.

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

Conservative estimates of costs have been made for the purposes of assessing the value of this project, they are based on the cost of XGSLab software that is available commercially but have not be utilised by NGET. There is some cost associated to changing the technical specification to allow the use of such software in the business and across GB.

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 research is being conducted to understand potential for earthing performance of T-pylons. It is, therefore, learning that may be directly applied to other networks with similar assets at similar voltages. The disseminated results will be shared with all licensees so that the reasons for the conclusions may be understood. It will be the responsibility of others to determine to what extent it applies to other equipment types and different voltages but the underlying work from this project is likely to help.

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

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.

This project builds on, but does not duplicate, work that was carried out in design phase of T-pylons. However, the operational earthing performance has never been investigated. The project is supported by Cardiff University who were involved in design phase as well as it sees the work as innovative and of interest to its utility members. There are no other projects in development looking at earthing performance or different software options or alternative earthing backfill materials. The risk of duplication will be addressed through dissemination of progress with other licensees and being open to co-operate with licensees working in this space.

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

NGET has recently energised T-pylon line in the Southwest of England and, since its operation, there has not been any study that investigated the earthing performance of energised lines. Now, since there is operational data of different conditions is available, it is necessary to define the maintenance regimes. Coupling studies, induced voltages, and induced currents are the main investigations planned for T-pylons. Conducrete, a conducting material has never been used in UK or by NGET as earthing backfill, the project intends to explore the behaviour of such material under UK weather. There exists many earthing software, but NGET has not explored others for the past two decades, it is mandatory to update the technology, and, for that, this project will generate comparative studies to make sure we have enough evidence to adopt to new technology.

Relevant Foreground IPR

The foreground IPR will be the knowledge gained about the performance of earthing performance for T-pylons. The learning will be brought together in a decision support tool which will also form part of the foreground IPR.

Data Access Details

Data for this project and all other projects funded under the Network Innovation Allowance (NIA), Network Innovation Competition (NIC) or the new Strategic Innovation Fund (SIF) can be found or requested in a number of ways:

- A request for information via the Smarter Networks Portal at https://smarter.energynetworks.org, to contact select a project and click 'Contact Lead Network'. National Grid already publishes much of the data arising from our innovation projects here so you may wish to check this website before making an application.
- Via our Innovation website at https://www.nationalgrid.com/uk/electricity-transmission/innovation
- Via our managed mailbox box.NG.ETInnovation@nationalgrid.com

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

There is very little financial benefit involved in exploring different software options that is why BAU see no long-term financial benefit. Also, there is a risk factor involved that may be the software does not perform according to standards we have and there is currently no financial or regulatory driver to do so. Not only that but current standards do not allow use of any other software (other than CDEGS) or material (other than soil/clay), hence learning developed by this project will give us a strong case to change the specifications. We recognise that over that period, other technical solutions may be developed that will mean the anticipated benefits are not achieved.

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

There are technical risks associated with any innovation project as the proposed solution may not work. Testing to date suggests that the work will be successful, but it cannot be guaranteed. If the laboratory and computational work proves unsuccessful, the project will not proceed to BAU and technical specifications will not be changed.

The project is anticipated to generate sufficient benefit to justify the expenditure over 20 years. So, the success of the project will only become truly apparent over a longer period. During that time alternative, currently unforeseeable, solutions may arise that provide greater benefit.

This project has been approved by a senior member of staff

☑ Yes