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

May 2024

Project Reference Number

NIA2_NGET0062

Project Registration

Project Title

Compact Substation (CoSub)

Project Reference Number

NIA2_NGET0062

Project Licensee(s)

National Grid Electricity Transmission

Project Start

May 2024

Project Duration

1 year and 11 months

Nominated Project Contact(s)

Muhammad Shaban

Project Budget

£478,128.00

Summary

Conventional 400kV air insulated substations (AIS) require a significant footprint to accommodate the double busbar arrangement with its associated main and reserve busbars, disconnectors, circuit breakers and metering apparatus. This project will explore compact substation designs by introducing surge arrester overvoltage protection to reduce the surge magnitudes and adoption of the innovative transformers with embedded close overvoltage protection, disconnector circuit breakers and optical voltage and current measurements. Moreover, Delta and Vertical busbar configurations (DBC and VBC) will also be explored to reduce the footprint width of the busbars. Project will result in taking this work to the next TRL stage, design and prepare a plan for a full demonstrator compact substation bay, including geometry and new equipment selection.

Third Party Collaborators

Cardiff University

Nominated Contact Email Address(es)

box.NG.ETInnovation@nationalgrid.com

Problem Being Solved

AIS has significant footprint due to busbars and other equipment which add clearance space to the substation dimensions. Furthermore, surge arresters and transformers add a further ground space demand. The key factor that controls the size and separation of such components is related to the physical air clearance around the high voltage terminals for adequate insulation with respect to earth terminals. Such clearances need to be sufficient to allow withstand of steady state and transient overvoltages, switching and lightning surges. Moreover, safety distances from the earthed terminal of high voltage insulated equipment such as insulators, surge arresters, bushings etc., add a further constraint to the design, size and installation of equipment. Thus, the safety distance requirement is also important to fully satisfy while carrying condition monitoring, maintenance and any refurbishment, upgrade or expansion work that may be required at the substation.

The clearance distances are defined by standards and technical specifications, which are derived from the statistical breakdown voltages of air gaps under steady state and transients surge voltages. The atmospheric and weather conditions as well as the geometry of the terminal electrodes are important for such breakdown voltages. Corrections factors were derived to account for such variability.
IEC 60071 gives recommendations for such clearances for various transmission system voltages. For each voltage level, e.g., 400kV system, there are several recommended air clearance distances to choose from, depending on the adopted withstand insulation level for switching and lightning surges (LIWL and SIWL). The highest levels for SIWL and LIWL recommended for 400kV systems are 1050kV and 1425kV respectively. National Grid Electricity Transmission (NGET) has adopted these highest levels in its technical specifications. As such, the air clearances are generous given the use of overvoltage control measures and surge protection using modern Zinc Oxide (ZnO) surge arresters. Hence the benefit of new equipment should be explored which includes ZnO arresters to reduce the phase-to-phase and phase-to-ground clearances.

Method(s)

This study is broken down into different phases and milestones. To achieve a full design and equipment specification for the proposed compact AIS bay, we will work with National Grid engineers (innovation, assets and maintenance) along with a key contractor to ensure that both installation and maintenance key aspects are considered.

The following work Tasks will be addressed in the project:

1. Revisit and verify compaction principles including assessing previous proposals.
2. Review and explore new innovative developments in compact substation equipment.
3. Use surge arresters to explore optimised overvoltage protection.
4. Review and investigate relevant aspects of safety and maintenance implications.
5. Identify site for installation.
6. Finalise a design for consideration, discussion and feedback from NGET and contractor/s.
7. Identify suppliers of equipment and discuss suitability for compact substation design.
8. Prepare installation requirements with contractor/s.
9. Finalise design and equipment selection and forward plan.

Scope

This is a research project to understand the carbon footprint of AIS substation. Over the 21-month project with Cardiff University, we will perform different tasks with the help of research institute, the internal NGET experts, and manufacturers in the field. This proposal addresses the application of new compact solutions in substation design with the aim of reducing the footprint of 400kV air insulated substations (AIS).
A 400kV compact substation design will be proposed by adopting a lower IEC Basic Insulation Level and Switching Impulse Level, and consequently reduced clearances, taking advantage of modern overvoltage protective devices. A new configuration will be proposed with the adoption of minimum clearance and alternative geometric arrangement of the busbar. Furthermore, manufacturers like Siemens/GE will be engaged in research to develop integrated high voltage plant and to use non-conventional instrument transformers (e.g. using fiber-optic transducers). The introduction of innovative high voltage equipment permits a further significant footprint reduction.
The overall area occupied by an air insulated substation is a function of the number of incoming lines to the substation and of the layout adopted (e.g. double busbar). In this proposal, the area required by a single switch bay is selected as a parameter for comparison of different possible designs to assess the overall space reduction using compact AIS solutions for 400kV substations. A preliminary evaluation on the percentage space saving achieved with some of the illustrated compact solutions is also presented. At the end of the project, we intend to redesign the substation bay with reduced emissions meeting the technical and regulatory standards/targets. Key findings across all deliverables will be presented in a workshop with NGET staff.

Objective(s)

This project will help us in optimizing the AIS substation with the following objectives:

- Develop an understanding of standard air clearances for transmission voltages and associated empirical expressions.
- Explore recent developments in compaction techniques and voltage uprating.
- Revisit the concepts suggested in the previous report with the aim to optimise the overvoltage protection and the air clearances.
- Ensure as a business we are adequately addressing environmental impacts of our AIS substation designs whilst enabling the transition to Net Zero.
- Create a design implementation roadmap capable of minimising electricity Transmission substations lifecycle carbon.
- Reduce emissions through a review of current design and best practice options.
- Increase circularity in design of substations through the creation of an opportunities register and roadmap

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

Financial distributional impact:

This project ensures that NGET and the UK energy industry are at the forefront of global developments in asset management of transmission system research, enabling the industry to make decisions that could reduce the carbon emissions and thus reduce CAPEX and OPEX expenditure and are supported by comprehensive research and experiments. The scale of Transmission Network development planned is unprecedented and there is concern that the understanding around the carbon footprint of AIS substation is not mature enough for future decisions given that we do not understand the benefits of using latest technology. With access to the latest research development like Compact substation designs related to carbon footprint, NGET will be able to manage the assets more efficiently and effectively which could deliver savings. Furthermore, the leveraged funding mechanism ensures that expensive research can be carried out at subsidised rates, thereby ensuring the best value for consumers' money. The project will not restrict benefits delivered to vulnerable consumers based on any vulnerability class.

Technical and wellbeing impact:

There is uncertainty in the air clearance values due to latest technology and design being available. There are obvious environmental benefits only if we can understand our carbon hotspots and potential workstreams to decarbonise our construction activities. The outcomes from this research will inform and enable the energy industry to take appropriate measures in the best interest of consumers, particularly in the vulnerable category, as the world transitions to a Net Zero future.

Success Criteria

The project will deliver success by meeting the project objectives:

- Create an implementation roadmap capable of minimising electricity Transmission substations lifecycle carbon emissions through a review of current design and best practice options.
- Increase opportunities in design of substations through the creation of opportunities like innovative equipment.
- A better methodology for substation design.
- Delivery of assessment report containing final design and equipment selection.
- Recommendations for future research in this field.

Our overall objective is to develop an understanding of AIS substation design and latest equipment with TO wide guidance on safety clearance distance using the existing standards.

Project Partners and External Funding

The following project partners will be supporting the project:

- Cardiff will provide experience and expertise relating to simulation and the research.
- NGET is providing all the funding for the project and is the lead project partner.

Potential for New Learning

A variety of new learning will be generated by carrying out this project. We will create a design for best practice in 400kV AIS substation design. This will include design and equipment analysis crating a roadmap of the most efficient designs. The project will also learn about opportunities and challenge in the supply chain to delivering materials and products. The final crucial element will be to increase knowledge of any regulatory implications of moving to BAU. Learning will be disseminated through the project partners and through an end of project report and webinar. The work will be valuable resource for National Grid and other TOs.

Scale of Project

The project aims to take a holistic look across a range of topics to produce a design for AIS substation. The project could take any one of the key topics separately i.e., carbon, design, or equipment-based solutions. This project will be delivered via desktop only with no site visits required. Any workshops or meetings will be via Microsoft Teams and these meetings are dependent on the availability of Cardiff and NG staff. As such there is no scope to reduce the scale of the project any further.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL6 Large Scale

Geographical Area

Desktop studies will be performed remotely by Cardiff at various geographical locations.

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£ 430,315.20

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:

- Evolving energy landscapes – which may require significant upgrades across the normal design life of a substation.
- Evolving geopolitical factors – which can interrupt supply chains, disrupting the development of new substations and the refurbishment of existing substations.
- Evolving technical and regulatory standards – which may have significant associated costs and cause operational challenges associates with retrofitting (e.g., net zero targets, etc).

The project facilitates energy system transition by helping NGET to understand and reduce the environmental impact, in terms of CO2e emissions, associated with a typical 400kV air insulated substation (AIS). Project will seek out carbon hotspots like controlling the size and separation of high voltage components and identify several clear opportunities for future focus to assist in commitments to reduce scope 3 emissions.

How the Project has potential to benefit consumer in vulnerable situations:

Developing an understanding regarding carbon footprint is important to reduce the negative impact of carbon dioxide emissions arising from our construction activities. Reduction in emissions, material volume, and asset health maintenance has huge societal benefit.

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

N/A - TRL3 R&D project

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

A roadmap will be created for 400kV AIS Transmission substation sustainable design. Elements of the design could be replicated across all electricity network substations in the UK.

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

N/A

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 opportunities register and sustainable substation implementation roadmap will be published at the end of the project. Other electricity Transmission and Distribution licences will be able to use these documents to make informed decisions to improve the sustainable design of their substations. The learning will be used in the planning and designing of existing and new substation projects influencing the delivery of the major infrastructure projects to reduce the carbon emissions. It is the learning that is directly applied to other networks with similar assets. The disseminated results will be shared with all licensees so that the reasons for the conclusions are well 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.

here is no overlapping between this work focusing on the AIS substation design and any other study. There are no other projects in development looking at substation carbon footprint or its design. 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

Substation design does not currently include holistic sustainability optioneering. There are elements of good practice, but an in-depth critical analysis is required to provide an efficient sustainable design roadmap. This project is innovative in bringing together a range of expertise on carbon, circularity, and design solutions. There are currently no NIA/SIF projects looking at the AIS substation projects within the UK. As a responsible business, NG need to cover the knowledge gap to address the issue and manage the expectation to meet the commitments of reducing the scope 3 emissions. The study will help us in addressing the recommendations provided by consenting process and other stakeholders. There is no overlapping between this work focusing on the substation design and the technical requirements and the work currently under way in different trials and studies.

Relevant Foreground IPR

The foreground IPR will be the knowledge gained about design and equipment of the AIS substation. The learning will be brought together in a report form 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

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 research of this scale as business-as-usual. The NIA funding offers the most appropriate route for NGET to design experiments, review existing techniques, and perform well designs experiments on certain species. As relatively little is known about the technology and its low TRL level, this justifies the use of NIA.

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 technology is a low TRL level and there is currently little information available without carrying out a proper feasibility study. The work has not been undertaken elsewhere before and the results could have significant impact on business planning. The results will benefit other energy networks making NIA the most appropriate route.

This project has been approved by a senior member of staff

☑ Yes