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

Jun 2020

Project Reference Number

NIA_NGTO055

Project Registration

Project Title

Feasibility Study on Upgrading Transmission Network Capability for Renewable Connection

Project Reference Number

NIA_NGTO055

Project Licensee(s)

National Grid Electricity Transmission

Project Start

July 2020

Project Duration

1 year and 1 month

Nominated Project Contact(s)

Xiaolin Ding

Project Budget

£296,000.00

Summary

The GB electricity network is setting a fast pace for the transition towards a net-zero carbon energy system. Effective integration of renewable energy sources into the electricity transmission network in an economic and efficient manner is crucial in achieving the UK net-zero carbon target. The aim of this project is to investigate efficient network reinforcement solutions to upgrade the transmission network transfer capability without the need for constructing new lines. The project will examine the feasibility of using transformative six-phase technology and/or voltage upgrades to increase the power transfer capability of the existing transmission line in the GB network.

Nominated Contact Email Address(es)

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Problem Being Solved

In future, renewables will become the dominate energy source in the UK. The transmission network must be able to transfer renewable energy from where it is generated to where it is demanded in an efficient, economic, reliable and resilient manner. To satisfy all these conditions can be challenging, especially when considering the constraints of the legacy network. Currently the existing transmission network capacity in certain areas, such as the East Anglia boundary is becomingconstrained, and in the near future, the power transfer capabilities from other “low-carbon generation rich” areas to city regions may be economically difficult. The conventional solution of constructing new overhead lines can be a challenge for environmental, aesthetic and planning reasons and consequently may not be an efficient solution in the future. Innovative technologies to enable more power transfer through the existing transmission network without building new lines are both needed and worthy of investigation.

Method(s)

To address the above problem, the project will examine the techno-economic feasibility of converting selected three-phase (3ϕ) transmission lines (e.g. East Anglia) in the National Grid network to a six-phase (6ϕ) system that utilises the capabilities of power

transformers to convert from 3ϕ phasors, 120° apart, to 6ϕ phasors, 60° apart. This will enable the increase in the power transfer capability of the network by a factor of 1.73.
The project will also carry out the techno-economic feasibility analysis of increasing the nominal voltage of an existing double-circuit 3ϕ 400kVLL line in the selected network area to 550kV.

Scope

The scope of the work includes the following:
Work Package 1: - Feasibility study on using transformative six-phase technology to increase the transmission power transfer capability in the GB network taking into the consideration of economic, technology and network impacts

- Conduct literature review on six phase systems
- Investigate the opportunity of converting the existing transmission line in selected GB network (e.g. EC5 boundarie) to facilitate efficient renewable connection
- Assess the technical feasibility includes capability and availability of transformers, overhead lines and tower technology. This includes investigating required transformer solutions to enable double circuit lines to operate as six phase system and study related to charging current, ferroresonance, switching transient,etc.
- Conduct economics and lifetime cost analysis including losses, power transfer, substation and lines, transformers, tower retrofit, etc.
- Investigate network impact on short circuit faults and protection, operation under normal & depleted conditions, auto-reclosure.
- Identify future work required to advance to a next stage study into the full implications of the transformative 6ϕ technology.

Work Package 2:- Feasibility study of upgrading the existing 400 kV network to 550kV taking into the consideration of economic, technology and network impacts.Investigate the viability of operating the existing transmission lines to higher voltage up to 550kV in selected parts of the GB network (e.g. EC5 boundary) to facilitate efficient renewable connection.

- Assess the technical feasibility of voltage upgrading of the selected part of GB network

o Review clearance requirements against a range of conditions, investigate the key challenges (e.g. insulator), and identify changes needed to enable the network operation of the existing network to higher voltage level to 550kV (alternative insulation system will be considered where would be necessary).
o Asses environmental impacts (e.g. noise) and the impacts on electric and magnetic fields using the CDEGS software.
o Review the impact of voltage upgrades on short sections of cable included within an overhead line and assess if existing conductors can operate at a higher voltage level up to 550kV.
o Investigate the required transformer solution necessary for higher voltage line operation.

- Conduct a high-level cost analysis considering technical modification requirements based on a length unit of OHL system operating at higher voltage level
- Recommend future work required to deploy the technology

Work Package 3:- Assessment on system security

- Assess the impacts on system security, including thermal performance and stability, of increasing transmission network transfer capability in selected area using 6ϕ technology and 3ϕ voltage upgrades.

Work Package 4:- Recommendation and Future work

- Propose future work required to take either the 3ϕ voltage upgrade aspects of this projects or the 6ϕ transformative technology into a full site trial where it is appropriate.
- Completion of a final report that summarises all aspects of the work completed within this project and provides clear recommendations on how to move forward to effectively increase transmission capability that will allow economic and efficient integration of significant renewable energy resources and deliver the UK net-zero energy future

Objective(s)

The objective of the project is to investigate the feasibility of using either innovative six-phase technology or voltage upgrading of existing three-phase overhead lines to increase the power transfer capacity of the transmission corridors for renewable integration.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

The project will be deemed a success if it meets the following criteria:

- Provide a good understanding on technical feasibility and cost effectiveness of the innovative six-phase technology based soluiton and voltage upgrade solution in the seclected GB network.
- Identfy the impacts of the above six-phase and voltage upgrade soluiotns on system security.
- Recommend optimal reinforcement solution to upgrade network transfer capability for renewable integration and the application of the technology in the GB network.
- Identify future work required to advance to a next stage and into full site trial of either taking the 3ϕ voltage upgrade aspects of this projects or the 6ϕ transformative technology where it is appropriate.

Project Partners and External Funding

n/a

Potential for New Learning

The outcome of the project will benefit all the network licencees. The technology proposed in the project and assessment results will offer the network licencees an insight on the techno-economic feasibility of six phase transmission network and upgrading operating voltage of the exisiting networks.

Scale of Project

The study will focus on the network in East Anglia where large capacity of renewables will be connected and transferred. This scale of project is chosen to investigate the techno-economic feasibility of six phase technology and voltage upgrade of the existing transmission networks.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL4 Bench Scale Research

Geographical Area

The project will be carried out through a desk-based simulation study.

Revenue Allowed for the RIIO Settlement

None.

Indicative Total NIA Project Expenditure

£296,000

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)

The project has the potential to deliver cost savings to customers via offering the following benefits:

- Significant increase in transmission flow transfer capability without the construction of new lines and major infrastructure investment.
- Reducing the UK's carbon footprint by increasing power transfer capability from renewable-rich regions to high-demand city regions.

The detailed CBA of these technological solution will be carried out as a part of this project

Please provide a calculation of the expected benefits the Solution

Not applicable.

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

The methods used to assess the feasibility of voltage upgrades to existing three-phase lines or the use of six-phase technology is replicable across the GB network and the key findings are applicable to all GB network licensees and will be disseminated with all key stakeholders.

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

As this is a research project at an early stage of development, estimates are difficult to make and it depends on the application in specific areas and transmission boundaries. The cost to roll out the solution in the East Anglia region will be carried out as a part of this project.

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 outcome of the project can offer network licencees insights on the economic benefit on the innovative six-phase technology and/or voltage upgrade and its potential application in the transmission network to help effectively integrate renewable connection whilst reducing carbon impacts and driving more values to end consumers. The findings of the project are applicable to the whole GB network licenses due to the coherence of the issues that are under investigation.

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

Efficient Build - Building new assets faster and at lower capital and whole-life costs

☑ 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.

Based on our literature review, there is no similar projects found in the ENA portal on using either voltage upgrades to existing three-phase lines or the innovative six-phase technology to unlock the existing transmission network power flower capability significantly without constructing a new line.

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 proposes an investigation into the benefits of voltage upgrades on existing three-phase lines or the use of six-phase transmission technology. Both the solutions have potential to enable a significant increase in the power flow transfer capability of the existing tranmsision network without any major infrastructure changes. No similar project has been found on the GB network that

involves the examination of the feasibility of significant voltage upgrades on 3ϕ lines or the transformation of an existing double circuit 3ϕ overhead transmission line into a 6ϕ transmission corridor.

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 innovative ideas and technology required to implement this project have not been carried out previously on the GB EHV tansmission network and consequently the risks, challenges and impact on the existing three-phase network are not thourougly understood. Therefore the project is associated with a higher risk than would typically be carried by BAU activities and cannot be carried out directly at NGET.

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 problems investigated in this work are common to all network licensees. The new insights gained in this project will benefit all electricity transmission networks to understand the opportunity and risk of applying voltage upgrades to existing three-phase lines and the use of innovative six-phase technology within the GB network. In addition to the risk mentioned above, NGET feels NIA is the right funding route for this project.

This project has been approved by a senior member of staff

☑ Yes