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 2022

Project Reference Number

NIA2_NGET027

Project Registration

Project Title

Enhance Power Flow Control Capability of GB Network

Project Reference Number

NIA2_NGET027

Project Licensee(s)

National Grid Electricity Transmission

Project Start

September 2022

Project Duration

3 years and 1 month

Nominated Project Contact(s)

Xiaolin Ding (box.NG.ETInnovation@nationalgrid.com)

Project Budget

£590,000.00

Summary

The Enhance Power Flow Control Capability (EPFCC) project will investigate the operating performance of existing Quadrature Boosters and use the resulting knowledge to better understand if new control strategies will allow more effective power flow control and help manage future network constraints. It will also explore how innovative solutions in phase shift transformer designs could deliver transportable modular solutions sufficiently flexible to cope with future demand and the power flow changes during the energy transition. It will also investigate how numerous suitably sized and optimally placed power flow devices can be effectively coordinated to maximise the power transfer capabilities of critical transmission boundaries, whilst minimising risk and ensuring resilience and reliability.

Third Party Collaborators

University of Exeter

Nominated Contact Email Address(es)

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Problem Being Solved

The transition to a Net Zero clean energy future, requires a significant increase in the network transfer capabilities of critical electrical transmission boundaries. Government's commitment to 50 GW offshore wind by 2030 further stretches the network and accelerates the needs for increased power transfer capacities. Technological solutions, such as the construction of new HVDC links or OHL lines, might need to be considered, but more effective and advanced power flow control capability should also be explored to optimise load flow and maximise the boundary transfer capability in the network.

Conventional power flow control devices, such as Quadrature Boosters (QBs), are already used within the GB network and have been proved to be highly effective in shifting power along the network. However, these devices are restricted to limited tap moving range

and thus cannot fully utilise their capability. In addition, lack of mobility and inflexibility restricts their wider application in the network. Furthermore, these devices are controlled individually and coordinated control is not available between them. It is critically important to investigate and understand the physical and technical limitation of these devices, then explore solutions to unlock their power flow control capabilities, and further enhance the flexibility and mobility of these devices.

Method(s)

The project will first investigate the capabilities of the existing QBs and use the results to better understand if new control strategies will allow more effective power flow control and help manage network constraints. It will then explore how innovative solutions in phase shift transformer designs could deliver transportable modular solutions sufficiently flexible to cope with future demand and the power flow changes expected during the energy transition. It will also investigate how numerous suitably sized and optimally placed power flow devices (e.g., QBs) can be effectively coordinated to maximise the transmission boundaries capabilities as well as minimise risk and ensure resilience and reliability.

Data Quality Statement (DQS):

- The project will be delivered under the NIA framework in line with OFGEM, ENA and NGGT / NGET internal policy. Data produced as part of this project will be subject to quality assurance to ensure that the information produced with each deliverable is accurate to the best of our knowledge and sources of information are appropriately documented. All deliverables and project outputs will be stored on our internal sharepoint platform ensuring access control, backup and version management. Relevant project documentation and reports will also be made available on the ENA Smarter Networks Portal and dissemination material will be shared with the relevant stakeholders.

Measurement Quality Statement (MQS):

- The methodology used in this project will be subject to the supplier's own quality assurance regime. Quality assurance processes and the source of data, measurement processes and equipment as well as data processing will be clearly documented and verifiable. The measurements, designs and economic assessments will also be clearly documented in the relevant deliverables and final project report and will be made available for review.

Risk Assessment: TRL=1

Cost=2

Supplier=1

Data=2

Total risk score =6 Low (L)

Scope

The scope of the project includes the following work packages:

WP1 Maximising power control capability of the existing QBs

- Literature review on global experience of QBs & Phase Shifting Transformers (PSTs).
- Assess advantages and disadvantages of QBs & PSTs vs other types of power flow control devices.
- Evaluate capabilities and limitations of existing QBs from a plant perspective (e.g. single/dual core designs, core saturation at extreme taps, OLTC current limiting resistor thermal capability and tap ranges & controls).
- Investigate viability of using QBs & PSTs with fast power electronic tap changers.
- Identify root cause of the existing QB tap operating constraints & recommend solutions
- Evaluate benefits of utilising a full tap range for existing QBs (e.g. power flow capability).

WP2 Development of coordinated control of multiple QBs.

- Literature review on coordinated control of multiple QBs.
- Compare benefits of coordinated control of multiple QBs vs non-coordinated control of QBs in accordance with existing NG-ESO guidelines (e.g. impacts on constraint management).
- Conceptual design of integrated control algorithm designed to co-ordinate the tapping of multiple QBs at strategic locations within the network.
- Determine impact on overall network performance of proposed coordinated control algorithm, with respect to power flows, voltages, short-circuit faults, dynamic stability, switching transients and network protection.
- Recommend future coordinated control strategy for QBs

WP3 Conceptual design of modular, compact mobile QBs/PSTs

- Investigate how physical size of QBs & PSTs is affected by operational tap range, power and voltage rating, single or dual core, asymmetric or symmetric design, core material, core saturation and losses.
- Detailed study into design of QBs & PSTs using FEM simulation software (COMSOL).
- Initial design of compact mobile QBs & PSTs with associated OLTC or fast power electronic tap changers.
- Simulation studies to assess the performances of compact QBs &PSTs.

WP4 Strategic sizing and location of power flow control devices

- Investigate optimisation of sizing and location of QBs/PSTs in the GB network.
- Preliminary investigation into sizing and location of QBs/PSTs in combination with other type power flow devices (e.g. SSSCs-) in the GB network.
- Produce recommendation for sizing and locating future power flow control devices to maximise transmission boundaries' transfer capability.

Objective(s)

The objectives of the project are as follows:

- Identify solutions to maximise power flow control capability of the existing QBs.
- Develop an algorithm for coordinated control of multiple power flow control devices.
- Develop an innovative modular and compact PSTs/QBs design that enables implementable flexibility and mobility
- Recommend strategic sizing and location of power flow control devices for an evolving future network.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

An assessment of distributional impacts (technical, financial and wellbeing related) for this project has been carried out using a bespoke assessment tool, which assesses the project as having a positive, negative or neutral effect on consumers in vulnerable situations. To help inform the assessment, this tool considers the categories of consumers identified in the Priority Services Register.

This project has been assessed as having an overall positive impact on consumers in vulnerable situations. The assessment has identified that this project will look to enhance power flow control capability of the network which will reduce the costs for households.

Success Criteria

- Identification of solutions that maximise the power flow control capabilities of the existing QBs.
- Design of an algorithm that enables co-ordinated optimal control of multiple QBs and other power flow control devices.
- Development of a modular compact PST/QB design that enables implementable flexibility and mobility.
- Recommendations on the strategic location and sizing of future QBs and other power flow control devices (e.g. SSSCs) within the evolving National Grid network.

Project Partners and External Funding

None

Potential for New Learning

New solutions will be identified to maximise the power flow control capabilities of the existing QBs used in the GB network. These solutions will be used to design a new coordinated control algorithm suitable for operation with multiple power flow control devices and developed to further enhance the power flow control capabilities of the network. The identified solutions and developed algorithm can be applied to the transmission network as it evolves towards a Net Zero future. Knowledge will be acquired on new possibilities for power flow control suitable for present and future transmission network scenarios. The key findings of the projects will be shared with other Transmission Owners and the System Operator via workshops, technical documentation and/or publications.

Scale of Project

The project aims to develop solutions that optimally exploit and maximise the power flow control capabilities of existing QBs and potential new developments in the design and use of QBs/PSTs to improve the flexibility of the devices. To achieve the critical objectives set out in section 2.4, the first stage of the project involves desktop-based research that focuses on the development of an advanced control algorithm that enables tapping to the full capability of the QB. The second stage is also desktop-based research, but is directed to wide-area coordinated control of existing multiple power flow devices to optimise the power flow across critical

boundaries in the network. The third stage involves the innovative design of modular QBs suitable for economic and flexible transportation between substations. The final stage is directed to system level research that focuses on the strategic sizing and location of future power flow control devices.

All stages are strategically linked and designed to deliver a comprehensive optimal solution to enhance the power flow control capability of the networks. Therefore, to deliver all these holistic research benefits, the scale of the project is as specified, since there would be inadequate potential for new learning with a less ambitious and smaller project.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL3 Proof of Concept

Geographical Area

The research which is mainly desk based at the University of Exeter.

Revenue Allowed for the RIIO Settlement

Not applicable

Indicative Total NIA Project Expenditure

£531k

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 transition in a way that will unlock the power flow control capabilities of the existing control devices in the network to allow more renewable energy to be transferred via the existing lines, reducing or delaying the need for network reinforcement. This project will develop an advanced control algorithm for QBs, that incorporates wide-area coordinated control applicable to the simultaneous operation of multiple QBs. The project will also aim to develop an innovative modular flexible design for a QB, which, in conjunction with an optimised approach to strategic sizing and locational placement, will enable the network to have adequate power flow control capability to facilitate the energy transition.

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

Not applicable

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)

Not applicable

Please provide a calculation of the expected benefits the Solution

Not applicable. This is a research focused project with low TRL.

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

The research outcomes and the developed method are of generic nature and are applicable to the same power flow control devices in all transmission networks across GB.

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

The project is a research project and if successful the methods can be further developed to roll out across GB. The estimated cost will be reviewed at the completion of the 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

One of the key project outcomes will be a new coordinated control algorithm which enables the optimal control of multiple power flow control devices in the GB network. The key learning will be shared with other Network Licenses. The developed method is applicable to all GB electricity transmission network.

The second key project outcome will be a new modular design of QB, which is smaller in size, economic in cost and easy for transportation. The derived outcome will enable wider application of the devices to enhance the power flow control capability of the network. The third key project outcome will be a strategic sizing and location scheme that ensures future power flow control devices can maximise the transmission capabilities of network boundaries. This will be particularly helpful in mitigating boundary constraints and enhancing network security in a future power network, where bulk energy generation and demand profiles will continue to change as the energy transition gains pace. The key learning will be shared with other Network Licenses. The developed sizing and location strategy is applicable to all GB electricity transmission network.

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

Not applicable

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 a number of projects which might be relevant from power flow control perspective. These projects are NIA_NGTO017 'Voltage source converter based series controlled impedance technology' and NIA_NGET0211 'Controllable Series Impedance at 275 and 400kV (CSI)', which both investigated the feasibility of inserting serious impedance to the transmission line via power electronic control devices to provide power flow control. UKPNT202 'Flexible Plug and Play Low Carbon Networks' innovation project might be also relevant, which investigated the deployment of smart devices (including QBs), dynamic rating of overhead lines and an Active Network Management system, onto the distribution network to best utilise the capacity of the existing distribution electricity network and allow real-time management of network constraints.

However, none of these projects focused on the optimised and coordinated control of existing QBs to enhance the power flow control capability of the transmission network, and the development of innovative solutions in QBs designs to deliver transportable modular

solutions to improve the flexibility of the devices. There is seen to be no duplication or overlapping between these projects.

If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

Not applicable

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

The innovation of this project is related to enhancing network transfer capability by advanced and coordinated control of multiple power flow control devices like QBs. There is no coordinated control between multiple QBs available, which limits the utilisation of its full capability in the network. This project will develop an advanced wide-area coordinated control algorithm for QBs to maximise the power flow control capability in the network. In addition, current QBs are big in size and lack of mobility, which restricts their wider application in the network. The project will deliver an innovative flexible modular design for QBs/PSTs, which makes the device smaller in size and easier for transportation between substations as the power system evolves. No similar developments have been done or attempted before.

Relevant Foreground IPR

The expected Foreground IPR for the project includes an advanced wide-area coordinated control algorithm for the operation of multiple QBs in the transmission network, an innovative modular and compact design for PST/QBs which enables implementable flexibility and mobility of the devices, and the recommendation for strategic location and sizing of power flow control devices for further network. The Foreground IPR also includes any models, technical reports developed for the projects and any publications associated.

It is expected that the development will use the know-hows of partners in phase shifting transformer design. The University of Exeter owns the background IP on these know-hows.

Any and all results created, acquired or otherwise developed during the project belong to National Grid and will be made available through the publication of the progress and completion reports on the ENA portal.

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

This project is in the early research stage and initially involves the design of a new modular and compact QB suitable for mobile and flexible operation, and the development of a coordinated QB control algorithm to maximise the power flow control capability in the network. No such similar developments have been carried out and implemented in the transmission network. This is not a business as usual activity and there is considerable risk associated with the development of an innovative coordinated control algorithm and a design concept based on modularity and minimisation of size. There is no guarantee the development of the algorithm and the design concept will be successful.

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 project contains high technical and commercial risk in developing coordinated control algorithm for optimal operation of multiple power flow control devices, and the design of modular and compact PSTs /QBs that enhance the mobility and flexibility of these devices. The proposed methodology and design need to be verified and the risk of failure is high. Therefore, it can only be undertaken with the support of NIA.

This project has been approved by a senior member of staff

☑ Yes