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NIA Project Registration and PEA Document

Date of Submission

Oct 2023

Project Reference Number

NIA2_NGESO051

Project Registration

Project Title

MinGFM

Project Reference Number

NIA2_NGESO051

Project Licensee(s)

National Energy System Operator

Project Start

September 2023

Project Duration

1 year and 6 months

Nominated Project Contact(s)

Dechao Kong

Project Budget

£415,000.00

Summary

The UK Government has set ambitious targets of 50GW of offshore wind installed on the GB transmission system by 2030. Increasing these inverter-based resources provides new opportunities for stability services via grid forming control (GFM) of power electronic converters. The GFM control can help deal with issues synonymous with future electricity systems, such as low inertia and low fault levels. However, while using a GFM approach has benefits, significant energy storage investment is needed.

This project will investigate new methods and control strategies for when additional energy storage is not needed. In particular, this project will help develop an understanding of the potential for data-driven intelligent control of wind turbines while delivering a techno-economic comparison of various control strategies.

Third Party Collaborators

University of Birmingham

Nominated Contact Email Address(es)

Innovation@neso.energy

Problem Being Solved

A substantial volume of onshore wind farms has already been deployed, and an additional 50GW of offshore wind farms are projected to be installed into the GB transmission system by 2030. Both onshore wind farms and offshore HVDC-integrated wind farms possess

significant untapped control capabilities. Consequently, there is tremendous potential to harness these control capabilities to bolster system stability (inertia) and fault level services.

Inverter-based resources (IBRs), such as onshore/offshore wind farms and interconnectors, possess substantial latent control capabilities. The nascent concept of Grid Forming (GFM) control for IBRs is widely regarded as a promising approach to counteract the diminishing inertia and fault level challenges posed by an increasingly -IBR dominated electricity system. However, conventional GFM control implementation requires significant investment in energy storage capacity, and such solutions are severely constrained by both the financial costs and spatial requirements associated with offshore wind turbines.

In recent years, advancements in research have suggested that, with an appropriate smart control strategy, wind turbines can be feasible to incorporate grid forming capabilities without the need for additional energy storage. Consequently, this project presents a valuable opportunity to unlock the control potential of offshore wind turbines in providing inertia and fault level services. This can be achieved by implementing a minimised GFM (MinGFM) approach that reduces the need for additional investment in energy storage infrastructure.

Method(s)

The project will be delivered in three work packages:

WP1: Development of individual wind farm models using Grid Following (GFL), Standard GFM with Energy Storage (ES) and MinGFM (without ES) as proposed, as well as system studies including stability and fault level assessment (6 months)

WP2: Development of data-driven smart controller for offshore wind turbines (with/without HVDC systems) using GFL, standard GFM, MinGFM as well as system studies including stability and fault level assessment (9 months).

In WP2, a data-driven intelligent smart controller will be developed to unlock IBRs MinGFM control capabilities. Drawing upon recent research findings, it has been demonstrated that the implementation of a MinGFM approach is feasible without the need for additional investments in energy storage.

WP3: Techno-economic comparisons of those IBRs with Grid Following Control GFL, GFM+ES, MinGFM and their optimised combinations in different trial regional networks for secure, economic and coordinated system operations (3 months)

System testing will be carried out in Real Time Digital Simulation (RTDS) across WP1-3. This approach will utilise best practice techniques identified in the NIA project 'D3' - Data-driven Network Dynamic Representation for Derisking the HVDC and Offshore Wind, in addition to International open-sourced best practices e.g. Institute of Electrical and Electronics Engineers (IEEE) and the International Council on Large Electric Systems (CIGRE). The approach will also be informed by in-house best practices for IEEE R&D publications and other study results for existing publications. The ESO will not share any non-public data with the University of Birmingham as per the approach adopted in the D3 project.

The outputs of the project will be validated against an in-house model library co-developed by the University of Birmingham and National Grid in 2017. Some emerging models will be further developed based on the existing outcomes of IEEE publication as well recognised by international experts. Model performances will be further validated from knowledge collected from the ESO's engagement with international associations and organisations e.g. CIGRE and the Global Power System Transformation Consortium (ESIG/G-PST) and internal capability developed during the MinGFM project.

Project deliverables include:

1. Report on wind turbine models with stability control capability using GFL, Standard GFM and MinGFM (Month 6), based on WP1
2. Report on assessment of data-driven smart controller for offshore wind turbines using GFL, Standard GFM and MinGFM (Month 15), based on WP2
3. A comprehensive report on the techno-economic comparisons of Grid Following Control (GFL), standard Grid Forming (GFM), MinGFM (without energy storage) along with recommendations (due at Month 18). This report will be based on the insights and findings derived from Work Package 3 (WP3).

Scope

To harness the substantial potential control capabilities of IBRs such as offshore wind farms and interconnectors, and to advance the emerging concept of GFM control for IBRs as a solution for declining inertia and fault level challenges, it is crucial to develop new mathematical models and tools. These tools will help to unlock the control potential of renewable energy sources without requiring additional investment in energy storage. Investigating data-driven smart controller design methods will enable the realisation of grid forming control capabilities. A techno-economic framework will be employed to devise optimised combinations of control strategies in various trial regional networks to ensure secure, cost-efficient, and coordinated system operation.

This project will yield the following benefits:

- By negating the need for additional energy storage investments particularly in offshore wind farms where space is limited, the constraints associated with these investments will be reduced.
- The implementation of MinGFM stability services, which will rely on software upgrades rather than additional hardware (energy storage) installations, can significantly reduce associated costs.
- Unlike standard GFM, which requires substantial investment in energy storage, MinGFM stability services are expected to become basic grid connection requirements for wind farms, thus greatly reducing the associated service costs.
- The outcomes will also help shape new ESO policies and strategies for creating a portfolio of stability control services utilising GFM, thereby supporting the industry in achieving net-zero targets.
- Increased competition in the offshore wind market through the facilitation of appropriate entry requirements will benefit both generators and consumers through reduced costs.
- Appropriately setting market entry requirements will help capture value for all participants in the value chain.
- The contribution to incentives will significantly accelerate the net-zero energy transition in the UK.

Objective(s)

- Investigating the stability service capability of wind farms employing MinGFM control through the sole upgrade of wind farm control systems (primarily software updates) without the need for additional energy storage investment.
- Defining the implementation of GFM control by unlocking the control capabilities of IBRs, allowing them to release certain amounts of stored energy within wind turbines through data-driven smart control strategies.
- Conducting economic comparisons between Grid Following Control (GFL), standard GFM (with energy storage), and MinGFM (without energy storage), subsequently proposing a roadmap for implementing MinGFM services under electricity market environments and recommending changes to the Grid Code

Consumer Vulnerability Impact Assessment

N/A

Success Criteria

1. The capability of minimised control of IBRs Type 4 Wind Turbine (WT with Full-scale Converter) Power System Management Group Type 4 Wind Turbines + High Voltage Direct Current can be fully assessed, and the economic values can be quantified.
2. Recommendations and a developed roadmap on the implementation of the MinGFM can be provided to show market development routes.

Project Partners and External Funding

University of Birmingham will be carrying out the work, no external funding required.

Potential for New Learning

The main findings will help influence key internal stakeholders including ESO Networks, Markets, Strategy and Regulation as well as external stakeholders (e.g. GB TOs, Developers, and OEMs) to define/update relevant industrial codes for future rollouts of GB Grid Forming applications based on:

- Verbal/written communications for purpose of project progress reporting;
- This project's own knowledge dissemination events for wider internal/external stakeholders;
- Knowlege sharing in global/regional industrial forums e.g. G-PST, CIGRE.

The learning will be also captured as appropriate into a Technical Report in public version (if possible) and conference/journal papers for wider awareness and knowledge sharing.

Scale of Project

The project spans 18 months with one project partner. The project consists of desk-based research, stakeholder engagement with various network licensees and international TO's. At the end of each work package internal dissemination events will be held to ensure that the results align with the wider business.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL5 Pilot Scale

Geographical Area

The project will be conducted in the GB area of operations.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£415,000

Project Eligibility Assessment Part 1

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

This project aims to enable the widespread adoption of emerging GFM applications in the UK by carefully considering the technical requirements and business models of all relevant stakeholders in the nascent GFM markets. By doing so, this project has the potential to yield significant benefits, including the increased deployment and eventual dominance of IBRs for green energy, which will support the acceleration of the net zero energy transition in the UK's energy system.

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

N/A

Please provide a calculation and/or description of the expected benefits of the solution

- Benefit 1: The limitations of costs and space imposed by additional energy storage investment for offshore wind farms can be reduced.
- Benefit 2: Rolling out of the MinGFM stability services based on software upgrading rather than additional hardware (energy storage) installation, will greatly reduce costs.
- Benefit 3: MinGFM stability services are expected to be the basic grid connection requirements of wind farms and hence the services costs would be significantly reduced compared to traditional GFM with energy storage.
- Benefit 4: The outcome of the project will contribute to the ESO's development of policy and help to accelerate the transition to net-zero.

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

The methodology and tools developed through this project should be further refined and validated in alignment with practical business cases within the GB market.

The following activities are recommended for potential implementation:

- Dissemination of key findings from the project to inform and influence internal stakeholders, shape suitable business models and relevant industry codes for emerging GB GFM applications within the nascent market.
- Engagement in consultations with external stakeholders in the GB GFM value chain to raise awareness and gather feedback on the ESO's future plans for designing business models and grid industry codes relating to the GB GFM markets under consideration. This would include GBTOs, GFM developers/manufacturers, Academia, industrial forums e.g., G-PST, CIGRE.

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

Costs and Level of Effort for Implementation:

- Wider knowledge dissemination, engagement/comms events (Low, ~£2k);
- Contribution to further round(s) of the ESO's Stability Pathfinder Programme (Medium);
- Contribution to further updates of Technical Code/Commercial Codes (Medium) e.g. 2nd round of Grid Code modification for

Technical Specification Required for Provision of GB Grid Forming (GBGF) Capability.

Requirement 3 / 1

Involve Research, Development or Demonstration

Projects 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

Involve Research, Development or Demonstration - Please select all that apply

☐ 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 knowledge gained throughout the project can be disseminated to relevant Network Licensees (RNLs) to promote awareness and provide guidance.
- RNLs will also be invited to participate in knowledge dissemination events throughout the various stages of the project to facilitate knowledge sharing.
- Given that some RNLs may be significant stakeholders in the value chain of the GB GFM markets, further collaboration and communication opportunities may be explored following the project's findings. For instance, the ESO's consultation on Industrial Code modification and other pertinent activities to co-promote GB Grid Forming developments

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. Networks must explicitly mention similar projects that they have considered and how these differ.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

As this project is the first of its kind within the GB system, its results will directly impact all relevant Network Licensees and external stakeholders. Specifically, the project's findings will inform the ESO's industrial code change and update, requiring additional communication and stakeholder engagement for knowledge sharing and change management purposes. This approach aims to prevent any unnecessary duplication of effort resulting from the project.

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 ESO is recognised for spearheading the development of emerging GFM technology. During the early research and development stage, the ESO conducted initial feasibility studies that weighed the benefits and drawbacks of GFM technology. Additionally, certain expert groups were established to facilitate wider consultation. As the world's first TSO to develop market-driven technical specifications for GB Grid Forming Capability, the ESO introduced the GC0137: Minimum Specification Required for Provision of GB Grid Forming (GBGF) Capability (formerly Virtual Synchronous Machine/VSM Capability). This achievement allowed the integration of emerging Grid Forming technological applications into the GB system.

As the next stage of the rollout of GB Grid Forming applications unfolds, this NIA project marks the first innovation project of its kind in the GB System. It continues to demonstrate leadership in global/regional Grid forming technological developments, contributing to establishing technical requirements and designing appropriate business models for significant future opportunities arising from the developing GB Grid Forming markets.

Relevant Foreground IPR

The following foreground IPR is expected to be generated in the course of the project:

- Individual wind farm models using Grid Following (GFL), Standard GFM with Energy Storage (ES) and MinGFM (without ES)
- A data-driven smart controller for offshore wind turbines (with/without HVDC systems) using GFL, standard GFM, MinGFM
- A data-driven intelligent smart controller to unlock IBRs MinGFM control capabilities.
- A comprehensive report on the techno-economic comparisons of Grid Following Control (GFL), standard Grid Forming (GFM), MinGFM (without energy storage) along with recommendations

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:

1. 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 ESO already publishes much of the data arising from our innovation projects here so you may wish to check this website before making an application.
2. Via our Innovation website at https://www.nationalgrideso.com/future-energy/innovation
3. Via our managed mailbox innovation@nationalgrideso.com

Details on the terms on which such data will be made available by National Grid ESO can be found in our publicly available “Data sharing policy relating to NIC/NIA projects” at https://www.nationalgrideso.com/document/168191/download.

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

Due to the nature of the project and that it is researching potential future impacts to the grid based largely on assumptions, this does not fall into current BAU.

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 increased risks associated with the availability of required data and a high level of assumptions, which makes this project better suited to NIA.
- The TRL of the overall framework is relatively low. Therefore, innovation funding is more suitable for exploring the project's potential and increasing the TRL before transferring into BAU activities.
- Conducting this project with NIA funding will ensure that the project findings can be shared more widely with other interested network licensees.

This project has been approved by a senior member of staff

☑ Yes