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.

Network Licensees must publish the required Project Progress information on the Smarter Networks Portal by 31st July 2014 and each year thereafter. The Network Licensee(s) must publish Project Progress information for each NIA Project that has developed new learning in the preceding relevant year.

NIA Project Annual Progress Report Document

Date of Submission

Jul 2024

Project Reference Number

NIA2_NGESO051

Project Progress

Project Title

MinGFM

Project Reference Number

NIA2_NGESO051

Project Start Date

September 2023

Project Duration

1 year and 6 months

Nominated Project Contact(s)

Dechao Kong

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.

Objectives

- 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

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.

Performance Compared to the Original Project Aims, Objectives and Success Criteria

Summary

This progress report provides an update on our ongoing project aimed at enhancing grid stability and fault management through advanced Grid Forming (GFM) technologies. By focusing on wind farms and inverter-based resources (IBRs), the project seeks to address the challenges posed by diminishing inertia in power systems. Structured into three distinct work packages (WPs), this report reviews completed tasks, ongoing efforts, and future plans, aligning them with the project's initial objectives and success criteria.

Work Package 1 (WP1): Development of Wind Farm Models and System Studies

WP1 focused on the development and evaluation of individual wind farm models utilizing Grid Following (GFL), Standard Grid Forming with Energy Storage (GFM+ES), and Minimised Grid Forming (MinGFM) technologies. The primary tasks involved conducting system studies to assess stability and fault levels.

A draft report has been successfully delivered, which includes comprehensive system studies performed using RSCAD simulations. These studies have demonstrated that MinGFM technology can provide inertia support by harnessing the kinetic energy from the rotational mass of wind turbine generators (WTGs). However, the report also highlighted that the inertia support is limited due to the absence of additional energy storage.

Furthermore, the WP1 report covers the theoretical background of MinGFM control technology, along with a literature review of control technologies for various IBR-based plants. A series of GFM compliance simulation tests were conducted, comparing MinGFM against synchronous generators (SG), GFL, and GFM with Battery Energy Storage Systems (BESS). These studies confirmed the feasibility of MinGFM control without additional energy storage investments.

Work Package 2 (WP2): Development of Data-Driven Smart Controllers

WP2 is centred on developing data-driven smart controllers for offshore wind turbines, with and without HVDC systems, employing GFL, standard GFM, and MinGFM technologies. Based on emerging research and evolving industry needs, the scope of WP2 has been revised to include a detailed study of GFM STATCOM performance.

Planned actions for WP2 include evaluating the performance of a GFM STATCOM without internal or external storage, focusing on compliance testing. Sensitivity analysis will be conducted to determine the storage size required for compliance, considering scenarios without minimum inertia requirements. Additionally, efforts will be directed towards developing and testing MinGFM-controlled VSC-HVDC connected offshore wind farms, addressing critical aspects such as inertia support, phase jump, Fault Ride Through (FRT), and islanding capabilities.

Work Package 3 (WP3): Techno-Economic Comparisons

WP3 aims to conduct techno-economic comparisons of GFL, GFM+ES, and MinGFM technologies, as well as their optimized combinations in various trial regional networks. This will involve evaluating their performance in terms of security, economic efficiency, and coordinated system operations.

The planned actions for WP3 include system testing in Real Time Digital Simulation (RTDS) environments. This testing will incorporate best practices from the NIA 'D3' (NIA2_NGESO009) project and adhere to international standards such as those from IEEE and CIGRE. Additionally, the outputs of this project will be validated against an in-house model library co-developed with National Grid, with

further development based on IEEE publications and input from international experts.
Current Deliverables and Future Plans
The project has made substantial progress, particularly in WP1, where foundational models and system studies have been completed. The WP1 report provides detailed analysis and simulation results of MinGFM technology, including its inertia support capabilities and theoretical background. This report serves as a key milestone, demonstrating the feasibility and potential of MinGFM control technology.
Ongoing efforts in WP2 are focused on initiating the performance studies of GFM STATCOM and developing smart controllers for offshore wind turbines. This phase will build on the insights gained from WP1, aiming to unlock further control capabilities of IBRs. In WP3, preparations are underway for techno-economic comparisons and system testing in RTDS environments, which will provide critical data for optimizing GFM technology implementations.
Conclusions
To date, the project has successfully achieved its initial milestones, particularly in WP1, where key models and system studies have been completed. As we advance into WP2, the focus will shift to performance evaluation and smart controller development, followed by comprehensive techno-economic assessments in WP3.
The project continues to align with its original goals, progressively working towards innovative solutions for grid stability and fault management without the need for extensive energy storage investments. The forthcoming phases will build on these foundations, providing valuable insights and practical solutions to support the industry’s transition to a more stable and efficient power grid. Future efforts will concentrate on refining these technologies and validating their performance in real-world scenarios, ultimately contributing to the broader goal of achieving net-zero energy targets.

Required Modifications to the Planned Approach During the Course of the Project

During the project, several modifications to the planned approach were necessitated by emerging insights and evolving industry requirements. One significant change involved the scope of WP2, which is currently ongoing. Originally focused on developing data-driven smart controllers for offshore wind turbines, the focus of WP2 has been expanded to include a detailed study of Grid Forming STATCOM (GFM STATCOM) performance. This shift was driven by the need to better understand the compliance capabilities of GFM technologies without relying on internal or external energy storage, just utilizing the typical capacitor size. This adjustment is expected to provide critical insights into determining the minimum requirements for storage size and converter capabilities to meet compliance standards.

Furthermore, sensitivity analyses have been introduced as part of WP2 to explore the impact of increasing storage sizes on compliance performance. This modification aims to pinpoint the exact storage thresholds required for optimal GFM operation under various conditions. These changes are essential to align the project's outcomes with the future plans of the ESO and to ensure the developed technologies are both practical and efficient in the real-world applications. By adapting our approach, we are better positioned to address the industry's needs and contribute to the stability and efficiency of the power grid.

Lessons Learnt for Future Projects

Throughout the ongoing project, several key lessons have emerged that will benefit future projects. One important lesson is the need for flexibility in project planning. Initially, WP2 was focused on developing smart controllers for offshore wind turbines. However, as new insights emerged, we had to expand our scope to include a detailed study of Grid Forming STATCOM (GFM STATCOM) performance. This change was necessary to address the evolving needs of the industry and highlights the importance of being adaptable in project planning.

Another lesson is the value of conducting comprehensive sensitivity analyses in system studies. During WP2, we introduced sensitivity analyses to determine the storage size required for compliance with GFM technology standards. This approach has been crucial in understanding the exact requirements for optimal GFM operation. Future projects should consider incorporating similar analyses early on to better anticipate varying conditions and requirements.
Additionally, the availability and compatibility of test systems have proven to be critical. Ensuring that test systems were available in the required tools and formats has been essential for the progress of WP2. Future projects should prioritise securing and validating these resources in the early stages to avoid delays and ensure all necessary tools and systems are in place.

These lessons highlight the importance of flexibility, thorough planning, and resource availability. By applying these insights, future projects can be better prepared to navigate challenges and achieve their goals more efficiently.

Note: The following sections are only required for those projects which have been completed since 1st April 2013, or since the previous Project Progress information was reported.

The Outcomes of the Project

The project has made significant progress, particularly in WP1, where foundational models and system studies have been successfully completed. The WP1 report detailed the development and evaluation of wind farm models using Grid Following (GFL), Standard Grid Forming with Energy Storage (GFM+ES), and Minimised Grid Forming (MinGFM) technologies. Through RSCAD simulations, we demonstrated that MinGFM technology can provide inertia support by harnessing the kinetic energy from wind turbine generators. However, the study also noted that this support is limited without additional energy storage.

Additionally, the theoretical groundwork for MinGFM control technology has been laid out, accompanied by a comprehensive literature review of various control technologies for inverter-based resources. The WP1 report included successful GFM compliance tests and comparisons between MinGFM, synchronous generators, and GFM with Battery Energy Storage Systems (BESS). These findings confirm the feasibility and potential of MinGFM control without the need for extra energy storage, setting a strong foundation for ongoing and future work in WP2 and WP3.

Data Access

Details on how network or consumption data arising in the course of NIA funded projects can be requested by interested parties, and the terms on which such data will be made available by National Grid can be found in our publicly available “Data sharing policy related to NIC/NIA projects” and www.nationalgrideso.com/innovation.

National Grid Electricity System Operator already publishes much of the data arising from our NIC/NIA projects at www.smarternetworks.org. You may wish to check this website before making an application under this policy, in case the data which you are seeking has already been published.

Foreground IPR

The following Foreground IPR will be generated from the project:

- A RSCAD based MinGFM model and simulation. (The current model is in RSCAD, however, we have been requesting an extra PSCAD model.)
- An innovation report/paper regarding MinGFM control technology.

All documentation will be uploaded to the Smarter Networks Portal.