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NIA Project Registration and PEA Document

Date of Submission

Apr 2023

Project Reference Number

NGET0036

Project Registration

Project Title

Grid forming modelling and stability

Project Reference Number

NGET0036

Project Licensee(s)

National Grid Electricity Transmission

Project Start

April 2023

Project Duration

3 years and 1 month

Nominated Project Contact(s)

Xiaolin Ding

Project Budget

£585,000.00

Summary

To meet the needs of energy transition to renewables, and address the challenges posed by declining system inertia and strength, a significant number of converters with grid forming capabilities will be necessary to ensure future power grid security. This project seeks to tackle the complexity arising from the various models, configurations, and control modes of grid forming converters by developing generic converter models. The project will also aim to assess and identify any potential instability risks associated with deploying grid forming converters and develop mitigation measures to address any identified risks.

Third Party Collaborators

Cardiff University

ESO

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Problem Being Solved

To ensure the future security of power systems and enable high penetration of renewables, a significant number of Grid Forming Plants with grid forming capability will be necessary. However, the complexity arises due to different models, configurations, and control modes of grid forming converters and currently there is no suitable generic models available. This complexity makes it challenging for system analysis, plan and operation. To address this, a generic grid forming converter model in simulation tools is required to conduct comprehensive analyses and configure the model according to different applications.

With the increase in grid forming converters, the dynamic response of power systems is likely to be significantly affected by power-electronic characteristics like fast response and limited current withstanding. This situation may introduce new instabilities in the

system, causing oscillations in a wide range of frequencies. Moreover, the dynamics of a grid forming converter vary concerning different control modes and applications like non-synchronous renewable generation, HVDCs, and DC converters. Therefore, a broad range of stability analyses and relevant mitigation measures are crucial to mitigate the risks associated with these dynamics.

Method(s)

The project aims to address the complexity arising from different models, configurations, and control modes of grid forming converters. To achieve this, generic models of the grid forming converter will be developed for both RMS and EMT simulations such as DIgSILENT/Power Factory and PSCAD/EMTDC, respectively. The models will include all possible grid forming control modes applicable to non-synchronous renewable generation, HVDCs, and DC converters. To validate the generic models, a real-time simulator in the lab will be employed.

Furthermore, the project will specify the instability risks comprehensively using small disturbance analysis, large disturbance analysis, and non-linear stability analysis. Effective measures to mitigate these instability risks will also be developed.

Scope

The scope of the work will include 7 work packages (WP):

WP1. Literature review of grid forming converters including all feasible control configurations and stability analysis methods

- Review all feasible controls of a grid forming converters and assess these controls' potential for future industrial adoption.
- Review feasible grid forming functions to fulfill the requirements of different applications such as HVDCs, non-synchronous generator and DC converters.
- Review stability criteria of converter stability from the grid code, industries and recent research outcomes of academia.
- Survey study to identify appropriate methodologies to model and analysis the grid forming converters in an accurate and efficient way.
- Define suitable models including RMS, EMT and small-signal modelling to evaluate grid forming functions and potential instability risks.

WP2. Develop the generic models of grid forming converter in both RMS and EMT simulation

- Develop all feasible variants of grid forming control modes to fit different applications such as HVDCs, non-synchronous generators and DC converters.
- Develop all feasible grid forming capabilities and operation modes for grid requirements.
- Develop well-designed interfaces for both RMS and EMT models to flexibly select control modes, grid forming capabilities and operation modes.

WP3. Validation of the developed generic models via Real Time Digital Simulators (RTDS)

- Validate the accuracy of the developed generic models under normal grid forming operation.
- Validate the accuracy of the developed generic models under transient situations.
- Validate the accuracy of the developed generic models under oscillation situations.

WP4. Performance assessment on grid forming capability

- Assess the performances of grid forming capabilities including voltage and frequency support, island operation, and black start capability.
- Assess the transient performances including inertia and damping capabilities, transient current handling capability, and fault-ride-through capability.
- Assess the impact of low current withstand capability of converters on grid forming capabilities.

WP5. Comprehensive stability analysis to identify any instability risks introduced by grid forming converters

- Analyse the control interaction with power systems via small signal modelling.
- Identify causes of instability risks from converter control.
- Identify causes of instability risks from power systems.

WP6. Specify and classify the converter related power system instabilities

- Specify all types of power system stabilities due to grid forming converters.
- Classify the relevant power system instabilities and assess the associated risks of the instability.

WP7. Innovative mitigation measures to reduce instability risks

- Develop control solutions to avoid potential oscillation risks identified in WP6. Specify grid requirements and overall control consideration for grid forming converters to reduce instability risks.
- Produce a final project report with recommendation for future work.

Objective(s)

- Identify feasible control modes of converters to form grid forming capability and identify feasible methodologies to model and analyse dynamics of grid forming converters when interacting with power systems.
- Develop generic models of grid forming converters for system design and planning.
- Assess performances of grid forming converters and identify potential instability risks.
- Develop solutions for grid forming converters to reduce the instability risks when interacting with power systems

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. This project will identify any potential instability risks associated with deploying grid forming converters and develop mitigation measures to address any identified risks, which will have a positive impact on reducing the costs for households.

Success Criteria

The delivery of the following items will be used to evaluate the success of this project:

- A generic model of grid forming converters is developed and validated for both RMS and EMT simulation tools. This model will comprehensively include all feasible grid forming control modes and grid forming capabilities.
- A stability assessment of grid forming converters is completed, which includes small disturbance stability analysis, large disturbance stability analysis and non-linear stability analysis.
- Mitigation measures are developed to reduce instability risk associated with interactions between grid forming converters and the system, and recommended solutions are provided.

Project Partners and External Funding

This project is in collaboration with NGENSO.

Potential for New Learning

The project aims to develop generic models of grid forming converters with grid firm capabilities required by the code. The project will also conduct comprehensive stability analyses to identify relevant system instability risk and acquire knowledge of the mechanisms behind these instabilities. Corresponding solutions will be developed to mitigate these risks effectively. The project will contribute to a better understanding of the grid forming capabilities of converters against the corresponding grid requirements.

Learnings of this project will be disseminated via workshops of the industry and academia, international conferences and published journals.

Scale of Project

This project is desk based with minimal laboratory testing. As such, there is no scope to reduce the scale of the projects any further.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL5 Pilot Scale

Geographical Area

The project will be a combination of computer-based studies and lab-demonstration. The project will be carried out at the innovation provider's facilities.

Revenue Allowed for the RIIO Settlement

Not applicable.

Indicative Total NIA Project Expenditure

£526,500

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:

To facilitate the energy system transition and enable high penetration level of renewables, there will be a need for grid-forming converters to support the security of future energy system. However, the integration of grid forming converters might also introduce potential instability to the network under certain circumstances, which needs to be thoroughly understood. This project aims to evaluate the potential risks and impacts of introducing grid-forming converters on the network and develop creative solutions to mitigate any instability risks that may arise.

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)

N/A

Please provide a calculation of the expected benefits the Solution

This project is research focused project and therefore the calculation of the expected benefits are not required.

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

The research outcomes and the developed methodology are of generic nature and would be applicable to all electricity network Licensees across GB.

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

The project starts in the research stage, the estimated cost of rolling out the method across GB 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

The key findings of the projects will be shared with other Network Licenses (Transmission Owners and Operator) via workshops, technical documentation and/or publications. The key learnings and methods developed in the projects would be equally applicable to relevant network licensees.

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.

Two projects, which are innovation project "Sub/Near synchronous instability in the GB network" - NIA_NGTO044 and SIF project "INCENTIVE (Innovative control and energy storage for ancillary services in offshore wind)" - 10037143, might be relevant to this project. However, NIA_NGTO044 focused on evaluating the stability risk of future network with grid following converters only; 10037143 focused on investigating if a range of INCENTIVE solutions like synchronous condenser, HVDC terminal, grid forming battery storage systems and STCOM enable offshore wind farm can allow offshore wind farms to provide stability services to the grid. In contrast, this project aims to create generic models of grid forming converters and assess the potential instability risks they pose to future power grids. As a result, there is no overlap in the scope of the work, and each project contributes distinct insights.

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

At present, there are no generic models of grid-forming converters available in the market that meet the criteria set out in the Grid Code's required grid-forming capability for system analysis and planning. The goal of this project is to create generic models for grid-forming converters that incorporate all feasible control modes and applications while meeting the code requirements. Additionally, this project aims to gain insightful understanding of grid-forming converter capabilities and assess the potential instability risks that they

may introduce. Finally, the project will also develop innovative mitigation measures to reduce any identified instability risks.

Relevant Foreground IPR

The expected Foreground IPR for the project includes a grid forming control system for different converter applications, two generic models of grid forming converters for RMS and EMT analysis, proposed stability analysis method for the interaction analysis between converters and power systems, and stability enhancement control design for grid forming converters to reduce the instability risk. The Foreground IPR also includes technical reports developed for the projects and any publications associated.

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 part of it's business and usual activities

The project involves developing generic models for grid-forming converters and creative solutions to mitigate instability risks it might introduce. It is not a business as usual activity, as there are considerable risks involved in developing the generic model and innovative mitigation measures. There is no guarantee that the development 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 nature of a research programme means it inherently carries a high risk that the research may be unsuccessful. Therefore, this project cannot be carried out as business and usual activities.

This project has been approved by a senior member of staff

Yes