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NIA Project Registration and PEA Document

Date of Submission

Aug 2022

Project Reference Number

NIA2_NGESO018

Project Registration

Project Title

Automated Identification of Sub-Synchronous Oscillations (SSO) Events

Project Reference Number

NIA2_NGESO018

Project Licensee(s)

National Grid Electricity System Operator

Project Start

September 2022

Project Duration

1 year and 7 months

Nominated Project Contact(s)

Sami Abdelrahman (NGESO)

Project Budget

£450,000.00

Summary

As the number of large wind and solar connections increases, any potential interaction, due to the differences in their converter control system, will be an important consideration during planning and design studies.

It will be increasingly important to understand the impact of any new connection in terms of unacceptable oscillatory behaviour considering the possible sources of uncertainty (e.g., forecast errors, parameter errors) and variability (e.g., wind speed) that can affect the network condition.

This project will explore, develop, and test a combination of novel frequency domain methodologies and machine learning techniques to identify potential system operating conditions which can lead to Sub-Synchronous Oscillations (SSOs) and implement an automated control interaction studies framework.

Nominated Contact Email Address(es)

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Problem Being Solved

Insufficient damping during and/or following network events can lead to unacceptable Sub-Synchronous Oscillations (SSOs) in network RMS voltage and power. These oscillations can have a negative impact on the generating plants in terms of reduction in the lifetime of the machines and failure of power electronic interfaced devices due to unexpected variations of current and voltages at its terminal, such as the increased risk of commutation failure in LCC HVDC. The report on the 9th August 2019 UK incident suggests growing sub-synchronous oscillations in the reactive power compensation plant during low voltage ride under extreme conditions, undamped oscillations can lead to de-loading of wind farms which might trigger loss of distributed energy resources (DER) in other parts of the network.

The Grid Code and NETS SQSS outline the requirements for assessing system instability regarding electromechanical oscillations of

generating units, pole slipping and fault ride-through capability of wind farms. In addition to that, the GSR018/GC00773 proposal proposed changes to the Grid Code and SQSS to include SSO related provisions for new and existing plants. With the increasing penetration of converter interfaced generation at both transmission and distribution levels, sometimes in close proximity to existing generators (old wind farms having type 2 turbines) with very different control architecture, technology and capability, there is an increasing need to develop efficient and robust methodologies to study and identify any such interactions in the planning timescale to identify appropriate management methods (e.g., through grid code and system services).

Time-critical oscillatory instability (5-20 Hz) is a phenomenon which has gained attention with increasing new converter interfaced devices like STATCOM, Type 4 wind turbines and HVDC converters. In NGESO's NIA project report 'Inverter Dominated Grids', inverter-induced instability can occur on the UK grid and is not captured using current RMS domain models. A study in the Canterbury zone showed that such an instability phenomenon could lead to distorted voltage waveforms with a sudden increase in the Total Harmonic Distortion level.

Method(s)

The project will be delivered in four work packages:

WP1 - Review of methods

- Develop novel methodologies for frequency domain analysis of controller interactions, assess strengths and weaknesses against existing techniques including implementation challenges, filtering methodologies for further exploration.
- Explore local, screening and global sensitivity analysis techniques for priority ranking of critical uncertain parameters.
- Compare machine learning techniques to find a suitable classification algorithm for the automated identification of SSO events.
- Review existing (time-domain) modelling tools for operational stability margin, inputs and assumptions for controller interaction studies and the associated business processes (engagement with ESO/NGET subject matter experts)
- Review learning from complementary ESO and industry innovation projects

WP2 - Development and testing of methods

- Define appropriate case studies and test networks (and operational scenarios) to test the performance of the developed methods of frequency scanning, uncertainty sensitivities and classification of SSO scenarios.
- Develop and trial the most promising methods from WP1 on test networks in PowerFactory/PSCAD, explore sensitivity and automation techniques to reduce computational resource, explore probabilistic techniques to characterise uncertainties. Algorithms will be implemented in Python and linked to PowerFactory/PSCAD.
- Compare and verify the method results e.g., based on available measurements of events or published results from other research and networks events

WP3 - Demonstration

- Demonstrate the developed methods on the GB network
- Adapt the tools developed in WP2 to run on the full network to ensure the practicality of the tool to run in larger networks with reasonable computational resources

WP4 – Roadmap and implementation

- Recommendations on implementation of the SSO analysis framework for assessing operational stability margin in system design and connection studies.
- Recommendations on how this framework can be extended as a data driven online SSO identification and warning tool as more PMU data is available.
- Handover and training on the developed tools

Scope

New transmission network connections are checked for Sub-synchronous Oscillations (SSO) based on a few future network conditions. Due to the inherent uncertainties in the network and forthcoming reinforcements, scenarios other than those currently considered could materialise. These uncertainties, and the possibility of more frequent controller interactions, are due to the changing nature of the future system with a more significant proportion of converter interfaced generation (of different technology types) coupled with declining short circuit level.

As the SSO identification requires Electromagnetic Transient (EMT) analysis, which is very time-consuming, there is a need to develop an analytical framework that will allow screening of scenarios without running EMT simulations and reduce the total number of scenarios that need to be investigated further. This will ensure that EMT simulations are used only for scenarios of potential concern, and system engineers can focus on root cause analysis. Due to the volume of studies, the process' complexity and the amount of data

generated, it is crucial to automat this process as much as possible.

Objective(s)

The project aims to apply a few advanced techniques borrowed from mathematics, statistics, and machine learning to solve the complex problem of identifying and managing SSOs in future power systems. The project will aim to deliver the following objectives:

- A primary objective of this project is to represent the black box models by a grey box approach which will allow for the identification of state variables which participate and contribute to the poorly damped oscillations. This is crucial to facilitate root cause analysis of controller interaction events.
- Develop a methodology to filter from an extensive a pool of scenarios with the possibility of SSO events based on impedance scans techniques.
- Develop a tool combining automation and machine learning techniques to run EMT simulations unattended and to identify SSO events automatically.
- Provide study cases to evaluate the performance and accuracy of the tools by testing historical event data or synthetic data created by simulation.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

The ESO does not have a direct connection to consumers, and therefore is unable to differentiate the impact on consumers and those in vulnerable situations. Benefits to all consumers are detailed in the sections below.

Success Criteria

- A framework to reduce the overall time and effort required to investigate a wide range of scenarios for potential SSO threats arising from new transmission connections.
- The ability to incorporate different sources of uncertainty in the scenario analysis.
- An approach for root cause analysis of SSO events in networks with proprietary controllers.
- An automated SSO identification process using time-domain results from PSCAD.
- Dissemination and training for the learnings and tools developed in the project.

Project Partners and External Funding

TNEI will be carrying out the work, no external funding required.

Potential for New Learning

The project will enable a significantly improved characterisation and management of complex dynamics of the evolving GB electricity transmission system. The project will address and enhance computation time for EMT type studies and the ability to scan a wider pool of scenarios. A significant impediment to an exhaustive search of potential scenarios of concern regarding the SSO phenomenon is the inherent computational burden of EMT simulations.

In addition to this, the huge volume of data generated from the scenarios is difficult to process, navigate and analyse without an automated framework. This project will precisely provide solutions to these challenges by using advanced frequency-domain techniques. Another big challenge in root cause analysis of SSO events is proprietary controllers' 'black box' model. The project would look into techniques such as 'impedance participation factors' to represent such models as 'grey box', a technique recently developed in scientific research.

This project would also benefit the ESO in building on the learnings that have already been gathered from other innovation projects in the area of EMT modelling and taking this forward into improved and automated analysis capabilities. This will allow for many scenarios and uncertainties to be captured while performing EMT types of analysis.

Scale of Project

The project spans 19 months with one project partner. The project consists of desk-based research and workshops with the relevant NGESO and wider network teams.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL5 Pilot Scale

Geographical Area

We will be based upon the GB ESO area of operations.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£450,000

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:

Currently, the ESO is seeing a significant increase in connection applications, primarily convertor-based connections like wind, solar, and HVDC and new requirements to ensure compliance of existing plants to the declining short circuit level. SSO screening studies will be increasingly important in the future. Each study will require a long time to collect data, set up models for different scenarios, and run EMT simulations with the current procedures. The proposed framework will improve the quality of the analysis and potentially reduce the study time significantly through a combination of automation, frequency domain analysis and machine learning techniques. The tools developed in this project will have the potential to speed up the connection studies that might be required in the future and capture more scenarios and uncertainties to reduce the risks of future system events.

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

Not required as research project.

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

Depending on the availability of the models, the project will aim to study different regions in the GB system as case studies, and the method should be replicable at all regions.

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

At this stage, it is too early to understand what the cost of roll out will look like.

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

n/a

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.

As EMT modelling is currently considered an essential requirement for future network analysis by all network licensees, several innovation projects address different subareas in the topic. This project will utilize the PSCAD models and learnings developed in the Transmission Owner Tools for EMT Modelling' TOTEM' (NIA_SHET_0032) to avoid duplication in building PSCAD models. The project will also look to build on the learnings from Impedance Scan Methods (NIA2_NGET0001), which plans to investigate various impedance scan methods and compare them to the inbuilt PSCAD tool. The 'D3' - Data-driven Network Dynamic Representation for Derisking the HVDC and Offshore Wind (NIA2_NGESO009) project can also provide valuable learnings in reduced order frequency dependant system models, which can be crucial to the tool that will be developed in this project, to increase efficiency and reduce complexity.

We have engaged with the various project teams and will continue to have regular catchups to share learnings throughout the project's progression.

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 proposed approach is a collection of several advanced techniques in impedance frequency scanning, ‘grey box’ approximation

and Machine Learning classification. This project will look to utilise a certain combination of these techniques/ methods for a particular application i.e., SSO identification. This has not been tried before in the GB system. The final outcome will be a tool that can run complex runs of EMT simulations to identify SSO fully automated and unattended.

Relevant Foreground IPR

The following Foreground IPR will be generated from the project:

- A framework to reduce the overall time and effort required to investigate a wide range of scenarios for potential SSO threats arising from new transmission connections.
- An approach for root cause analysis of SSO events in networks with proprietary controllers.
- A tool combining automation and machine learning techniques to run EMT simulations unattended and to identify SSO events automatically.

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 apart 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 business as usual (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

- The project is in a complex area of power systems, and the TRL of the overall framework is low. Therefore, innovation funding is more suitable for exploring the project's potential and increasing the TRL before transferring into BAU activities.
- The methods are novel and have not yet been trialled on real networks.
- There are potential risks associated with the availability of required data and the acceptable performance of the methods.
- Standard procedures may also need to change to integrate the developed tool.
- Due to the practicality of the runtime and the need for high computational resources.

This project has been approved by a senior member of staff

☑ Yes