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

Dec 2024

Project Reference Number

NIA2_NESO059

Project Registration

Project Title

Power System Oscillation Characterisation using Wavelets and Trilateration

Project Reference Number

NIA2_NESO059

Project Licensee(s)

National Energy System Operator

Project Start

May 2024

Project Duration

1 year and 7 months

Nominated Project Contact(s)

innovation@nationalenergyso.com

Project Budget

£450,000.00

Summary

Sources of oscillations on the transmission system can be determined by investigating the transfer of oscillation energy in the network. Following the direction of the energy flow on the system allows the source of the oscillations to be traced.
These methods have limitations: it requires good coverage of power management units (PMUs) across the system, determining the time period for calculating the energy flow requires some manual intervention and some oscillation source will absorb energy at certain frequencies, meaning that the energy method cannot be used.
This project aims to explore potential improvements to energy methods, investigating the application of signal processing techniques to improve accuracy with limited PMU coverage, remove the need for manual intervention and to replace the energy flow direction calculation.

Nominated Contact Email Address(es)

box.so.innovation@nationalgrid.com

Problem Being Solved

Forced oscillations can occur, undetected, on the transmission system, with no information available concerning their source. As a worst case, they can cause cascading outages and present a risk to the stable and secure operation of the system. Due to the increasing penetration of Inverter Based Resource (IBR) connecting to the transmission system over the coming years, their prevalence is likely to increase.
Detection and source location methods have been proposed, though require extensive Phasor Measurement Unit (PMU) coverage,

and they have limitations.

Method(s)

The approach to solving the problems will be delivered through three work packages:

- WP1 (Technical) will investigate existing energy based methods for oscillation source detection and the use of the dissipating energy flow (DEF) method on the GB Transmission System. This work package will also look at the use of trilateration to minimize the use of PMUs and an automatic method for calculating the energy using time-frequency plots of PMU data
- WP2 (Technical) will derive a new method of oscillation source localisation using the wavelet arrival time of the mode of interest
- WP3 (Technical) tests the use of the new methods derived in WP1 and WP2 in different models and the GB network. It will also compile the final report of the project and prepares slides/videos for dissemination

In line with the ENA's ENIP document, the risk rating is scored Low.
TRL Steps = 1 (2 TRL steps)
Cost = 1 (£500k)
Suppliers = 1 (1 supplier)
Data Assumptions = 2
Total = 5 (Low)

Scope

The project outcomes will allow NESO to :
1) accurately and actively identify sources of oscillations in real time;
2) make better use of limited PMU coverage to locate oscillation sources, and reduce need for additional PMU installation;
3) reduce reliance on stakeholder data to locate oscillation sources
4) have improved accuracy and reliability of location methods through use of data processing techniques

With threats of unforeseen instabilities mitigated, higher fractions of renewables can be accommodated without compromising the security of supply. This will facilitate net zero transition while ensuring secure and affordable supply for the customers.

The project is desktop assessment based, and will implement three work packages covering:

- Review of existing methods, their applicability to the GB Transmision System and the design of new energy methods and PMU trilateration
- Derivation of new method based on wavelet arrival time of mode of interest
- Testing of new methods in different models and GB network, plus final reporting

Objective(s)

The final outputs should include:

- Guidance and details on fast and accurate localisation of forced oscillation events in the UK network
- A demonstration of using the developed methods to localise forced oscillation events using simulated data on the two-area and IEEE 30-bus systems and real event data from the UK network.

The next steps will be determined by the trajectory of the project, though could include:

- Further adaptation and development of the methods to close gap between outcome and implementation
- Further development and deployment of the method in NESO to allow real time detection and mitigation of oscillations
- Development of an automatic detection, location and disconnection scheme based on the method.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

The NESO 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 above.

Success Criteria

The following will be considered when assessing the success of the project

- Improvements to the accuracy of the application of the DEF method where there is limited PMU availability

- A new method of oscillation source identification using wavelet arrival time of the mode of interest
- Guidance on the use of the methods investigated and developed, including demonstrations of their application to the GB transmission system

Project Partners and External Funding

Durham University will be carrying out the work. No external funding required.

Potential for New Learning

This project applies the energy method to localise forced oscillation for the first time in GB, and will further develop new energy methods that are custom-designed for the GB network using as few PMUs as possible and automatic oscillation period recognition for high accuracy.
It also aims to improve reliability and generality of source detection with new methods using the arrival time of the mode of interest. These new methods will allow the network operator to identify what and who has caused the forced oscillation completely from the network side without any extra information or report from third parties.

Learnings from the project will be disseminated through the publication of academic papers, and also through presentation material developed in WP4.

Scale of Project

The project spans six months with one project partner. The project consists of desk-based research, tool development and workshops with the relevant NESO teams (including network and wider 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:

The project is meant to develop methods of locating sources of forced oscillations on the GB transmission system. Occurrences of oscillations in the system will increase due to the energy system transition, driven by the increase in IBR on the system. By developing methods to understand how oscillations occur and their sources, higher fractions of renewables can be accommodated without compromising the security of supply – to manage oscillations in realtime, typically renewable energy sources need to be curtailed. This will facilitate net zero transition while ensuring secure and affordable supply for the customers.

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

NESO does not have a direct connection to consumers, and therefore is unable to differentiate the impact on consumers and those in vulnerable situations. The project's objectives include improving the overall stability and efficiency of the power system by providing advanced tools for identifying oscillations, ultimately leading to a more reliable and cost-effective operation of the system.

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

Currently, oscillations in the GB power system are detected by NESO monitoring the damping ratio on the GridMetrix tool. However, these events cannot be detected in advance, which makes the implementation of defensive actions highly complex when oscillations occur. The cost associated with an oscillation event entirely depends on how quickly and effectively defensive actions are taken in real time. Unfortunately, the current situational awareness of the GB power system does not allow NESO to develop effective and economical defensive strategy to counteract these events. Consequently, some oscillations events may lead to the tripping of generating units, which in turn potentially lead to further cascading tripping of generating units and eventually a blackout if not promptly addressed.
NESO has implemented a defensive strategy to mitigate oscillations based on actions that have proven to be effective in previous events. This defensive strategy incurs a cost of spinning certain generating units during specific system conditions to enhance the robustness of the system when oscillations are more likely to occur. However, the experience points out that there are no specific actions that damp out all oscillations. Therefore, having a more detailed insight of the system's behaviour may help to develop more effective and reliable defensive actions.
The outcome of this project will provide improved detection and source location methods, enabling a better comprehension of the system's behaviour and identification of the root causes of the oscillations studied. These findings will contribute to the establishment of a more effective defensive strategy. This will enable real-time operators to respond to oscillation events more effectively and make informed decisions to maintain the GB power system security.

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

The project will investigate oscillations in standard IEEE reference systems and data from real events on the GB transmission system.

This should ensure that the method is replicable across GB.

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

The output of the project is subject to uncertainty and therefore no cost for GB roll out can be given. If successful a cost of scaling the solution for the whole of GB can be calculated and assessed against other available solutions.

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

- This project applies the energy method to localise forced oscillation for the first time in GB
- It further develops new energy methods that are custom-designed for the GB network using as few PMUs as possible for and automatic oscillation period recognition for high accuracy
- It also aims to improve reliability and generality of source detection with new methods using the arrival time of the mode of interest.
- These new methods will allow the network operator to identify what and who has caused the forced oscillation completely from the network side without any extra information or report from third parties

The next steps will depend on the trajectory of the project, though it is intended that any developments in oscillation localization techniques could allow the development of tools for deployment by the 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.

There are a number of projects addressing this problem at the time of writing. However, the proposed approach to solving the problem is unique and is not being considered by the other projects. It will also help to improve the understanding of the phenomena and techniques that can be used to locate sources of oscillations.
A number of the other projects in this area also require detailed system models to determine oscillation modes and sources and are intended for use in planning the transmission system. The proposed solution will only require measurement data and will be targeted at real time operational use.

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

The problem being addressed by this project is an active area of research and as such is being looked at by a number of network licensees. It is considered appropriate to carry out similar work as it is unclear which method(s) will be most appropriate to address the challenge and therefore investigating multiple approaches is considered to be appropriate.
Here are some of the previous projects with various approach:
Oscillation and regional RoCoF monitoring
Data-Driven Online Monitoring and Early Warning for GB System Stability (DOME)
WI-POD- Wind turbine control Interaction with Power Oscillation Damping control approaches.
Detection and control of inter-area oscillations (DACIAO)
RealSim: Real-Time Phasor-EMT Simulations
Power System Oscillation Damping with HVDC (POD) - Feasibility Study
Smart Grid Oscillation Management for a Changing Generation Mix (Psymetrix)
Automated Identification of Sub-Synchronous Oscillations (SSO) Events

Additional Governance And Document Upload

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

This project applies the energy method to localise forced oscillation for the first time in GB, and further develops new energy methods that are custom-designed for the GB network using as few PMUs as possible and automatic oscillation period recognition for high accuracy.
It also aims to improve reliability and generality of source detection with new methods using the arrival time of the mode of interest.
These new methods will allow the network operator to identify what and who has caused the forced oscillation completely from the network side without any extra information or report from third parties.

Relevant Foreground IPR

The deliverables of the project include:

- Code for new tracing algorithms
- Simulation models
- Reports on the applicability of tracing methods for different oscillation scenarios, and recommendations for data measurement strategy.

The learnings from the project will be disseminated as whitepapers, IEEE/IET/CIGRE conference and transaction papers, and in G-PST and ESIG workshops.

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’. NESO 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 Innovation | National Energy System Operator
Via our managed mailbox innovation@nationalenerygso.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 80797503.1

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 developed or trialled.
- The relationship between the electrical distances of branches and the energy may be difficult to obtain in a practical network. Such relationship exists but depends on other factors as well. This poses risk on the trilateration method aiming to reduce the number of PMUs
- The energy flow may not be monotonically changing with the direction of oscillation energy transfer due to the internal dynamics. This will increase the localisation error for certain frequencies

This project has been approved by a senior member of staff

☑ Yes