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

Feb 2026

Project Reference Number

NIA2_NESO121

Project Registration

Project Title

Early Signs of Oscillations

Project Reference Number

NIA2_NESO121

Project Licensee(s)

National Energy System Operator

Project Start

March 2026

Project Duration

1 year and 7 months

Nominated Project Contact(s)

Innovation@neso.energy

Project Budget

£500,000.00

Summary

The project aims to develop a real-time sub-synchronous oscillation (SSO) monitoring system to detect and analyse early signs of SSO events, enabling preventive actions. The project will span two years and include three main stages:

- Stage 1: Analyse historical data to build an event database.
- Stage 2: Develop a software prototype of early-warning system to detect and track SSO early signs.
- Stage 3: Test and validate the tool with simulated and real-world data.

Expected outcomes include a prototype software tool for detecting SSO risks and aiding in mitigation. Challenges involve identifying early signs accurately and managing data-sharing complexities among partners, which could affect project progress.

Preceding Projects

UKRI10079053 - INSIGHT - Innovative Network Status Intelligence Gathered by Holistic use of Telemetry

NIA_SHET_0051 - SETTLE

NIA2_NGESO049 - Data-Driven Online Monitoring and Early Warning for GB System Stability (DOME)

Third Party Collaborators

University of Strathclyde

Nominated Contact Email Address(es)

Innovation@neso.energy

Problem Being Solved

Since 2021, Sub-Synchronous Oscillation (SSO) events have been increasingly observed in both Great Britain (GB) and other countries, posing a significant risk to power system security. Collaborative efforts between NESO, the TSO, and network users have led to progress in understanding and managing such SSO events, with key lessons incorporated into industry practices. However, recent reoccurrences of SSO events highlight the need for more effective systems and tools to enable real-time monitoring and mitigation of SSO events, thereby safeguarding system security during the decarbonisation process.

Method(s)

This project is based on a real-world phenomenon observed using high-resolution real-world measurements recorded at Strathclyde over 4 years, where SSO events were found to be typically preceded by identifiable precursory patterns minutes to hours in advance. These precursors (referred to as “early signs”) can be characterised by features such as frequency spectrum patterns and damping ratios. When properly processed and analysed, these indicators hold strong potential for enabling early warning of SSO, offering a powerful tool for system SSO monitoring and risk mitigation.

The project will apply advanced signal processing and feature extraction techniques, along with machine learning methods, to identify patterns within historical events data. These patterns will be used to uncover dependencies between specific measurement signals, system states, and the early signs of SSO events. This will then inform the development of a real-time early warning system that interprets incoming measurements and system conditions to assess the current SSO risk level and inform potential mitigating actions with sufficient time before SSO happens, thus safeguarding the system security.

The project identifies three groups of data sources. The first group includes historical PMU data from SPEN and SSEN and the University of Strathclyde. This data requires TOs to sign data-sharing agreements to provide access from multiple key locations as determined by the project team. The second group consists of open-source system operational data, including generation connection status and output levels, particularly in Scotland. The third group involves open-source information on network configuration, such as line outages for maintenance, available from TOs SCADA system.

- **Work Package 1: Historical PMU/system data gathering and processing**

This work package will apply advanced signal processing and feature extraction techniques, along with machine learning methods, to identify patterns within historical events data. The data used here will involve historical synchronised measurements and system operational data. The identified patterns will be used to uncover dependencies between specific measurement signals, system states, and the early signs of SSO events.

- **Work Package 2: Development of SSO monitoring and analysis system based on early signs**

This work package is to develop a prototype early warning system based on the identified patterns in WP1, which can detect oscillations risks in real time, monitor their progression, and inform mitigating actions to prevent such instabilities in advance. The software system will have the following functionalities: real time classification of system states, and detection of early warning signs of oscillations; evaluation and tracking of the evolving risks of oscillations; identification of similar historical observed events for decision support with past experiences; correlating oscillations/early signs with specific triggering resources/operational actions; informing proactive actions to mitigate oscillation risks.

- **Work Package 3: Test and validation**

This work package will test and validate the prototype tool developed by WP2 using both simulated and real-time data. The test and validation start using PMU/Elexon data and then move on to wider network tests using historical data from multiple PMUs and detailed system operating conditions. The criteria of the validation are whether the tool can provide insights of potential SSO events, evaluate and track the evolving risks of SSO. A report should be delivered covering the findings of the correlation analysis and testing and validation activity around the early warning system.

In line with the ENA's ENIP document, the risk rating is scored Low.

TRL Steps = 1

Cost = 1

Suppliers = 1

Data Assumptions = 2

Total = 5

Scope

This project aims to develop a real-time SSO monitoring system prototype capable of detecting, analysing, and tracking precursory signs of SSO events using historical PMU data and open-source operational data, thus informing mitigating and preventive actions in advance.

In Scope:

· Processing and analysing data from PMUs installed at Strathclyde and partner TOs.

· Prototyping a software system for SSO monitoring and mitigation.

· Testing and demonstrating the prototype system in a realistic environment.

Out of Scope:

· Directly taking measurements from actual system PMUs.

· Industrialising and integrating the early warning system within existing Wide Area Monitoring platforms.

Objective(s)

The objective of this project is to develop a real-time SSO monitoring system capable of detecting, analysing, and tracking precursory signs of SSO events (referred to as early signs) before they occur, thus informing mitigating and preventive actions in advance.

· Identify patterns and features for early sign of SSO events by assessing the historical synchronised measurements and system operational data.

· Develop a set of data driven analysers for SSO events and their early signs' similarity, causality and correlation analysis in real time, thus informing SSO risk levels and mitigating actions.

· Prototype the SSO monitoring and mitigating system and demonstrate its feasibility and effectiveness.

· Develop a plan and recommendations for rolling out the developed prototype for practical implementation.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

Not Applicable

Success Criteria

The project can be deemed successful if:

· Successfully identify and document key patterns and features indicative of early signs of SSO events using historical synchronised measurements and system operational data. Create a comprehensive set of data-driven analysers capable of real-time similarity, causality, and correlation analysis of SSO events and their early signs.

· Successfully develop the prototype of early warning system, based on identified features and patterns. Conduct demonstrations showcasing the feasibility and effectiveness of the prototype under various operational scenarios. Gather and analyse feedback from stakeholders and experts to validate the system's performance and areas for improvement.

· Get final report delivered and approved covering the findings of the correlation analysis and testing and validation activity around

the early warning system.

Project Partners and External Funding

University of Strathclyde is the partner for this project. No external funding.

Potential for New Learning

The project will, for the first time, demonstrate that early precursory signs of oscillations can be detected and featured using real-time measurements minutes to hours before they occur, enabling effective early warning and mitigation of oscillation risks. It is based on real-world phenomenon with evidence in extensive recorded events, reflecting actual system behaviours. It eliminates the need for complex and potentially inaccurate modelling and does not require active injection of disturbances. The early signs can be detected well before the oscillations occur, providing system operators sufficient time to pre-emptively act and assess the real-time impact of their actions. With the data required readily available from existing systems, the proposed approach represents a practical and promising solution for addressing the growing oscillation challenge.

The tool and findings will be shared among SSO Taskforce members for future possible tool implementation and operational procedure changes. A demonstration workshop will be setup to showcase its functionality and performance in detecting early signs, tracking SSO risks, and enabling mitigating actions.

At the end of a project, the project learning, including recommended next steps will be available on the ENA Smarter Network Portal.

Scale of Project

The project spans 18 months with one project partner.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL5 Pilot Scale

Geographical Area

This project will be conducted within GB.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

The total project cost is £500,000.

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 has the potential to greatly facilitate the energy system transition by addressing the significant risks posed by SSO events, which have been increasingly observed in Great Britain and other countries. Current offline methods, which rely on physics-based modelling, fall short due to the complexity of system modelling, proprietary information limitations, and challenges in supporting real-time operations. Similarly, existing online methods often necessitate active disturbance injections, which are both costly and difficult to implement.

This project aims to overcome these challenges by providing NESO and Transmission Operators (TOs) with a real-time SSO monitoring and mitigation system that leverages existing data sources and infrastructures. This approach offers a realistic and powerful solution to manage SSO challenges during the energy transition. Specifically, the benefits include:

· Early Identification of Risks: The system will enable the early detection of SSO precursory signs and risks, allowing for timely responses before events occur.

· Enhanced Operational Understanding: It will improve understanding of how operational actions, such as variations in wind farm outputs or line outages, impact system behaviour and stability.

· Preventive Action Enablement: The system will facilitate preventive actions by providing real-time feedback on how implemented actions affect SSO risks.

· Cost Reduction: By minimising the need for expensive defensive measures that may be unnecessary, the project can reduce the overall cost of system operation.

Through these benefits, the project supports the seamless integration of renewable energy sources and enhances the security and stability of the power system during the energy transition to Net Zero.

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 is a research project. Not Applicable.

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

The method can be implemented in future TO and NESO control room software if the methodology has been proven in this project.

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

This is an early-stage research project and therefore costs will not be calculable at this stage.

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 enables NESO and TOs with a real time SSO monitoring and mitigating system, purely based on existing data sources and infrastructures, thus providing a realistic and powerful solution to address the SSO challenges during the energy transition process. More specifically, this project can be used for:

· Early identification of SSO precursory signs and risks well before they occur, providing sufficient time to respond.

· Enhancing the understanding of the impact of operational actions (e.g. variation in windfarm outputs, line outages) on the system behaviour and stability.

· Enabling preventive actions with real time feedback on the effect of implemented actions on the changes in SSO risks.

· Reduced cost of system operation by reduced expensive defensive measures that are unnecessary.

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.

A list of existing projects is presented as follows:

· INSIGHT (UKRI10079053): Explored a real-time alert and control system to reduce system stability risks by detecting and mitigating power network oscillations. Focusing on post SSO detecting and a key finding was that current supply chain solutions lack sufficient TRL and adequate functions for Beta phase trials.

· SETTLE (NIA_SHET_0051): Building on INSIGHT by using physics-based modelling to trace and analyse oscillations in complex IBR and network behaviours, it aims to support a future SIF Beta phase. A key challenge is the need for constructing large scale complex physics-based model, which is challenging and might not be fully representative.

· DOME (NIA2_NGESO049): A desktop study assessing whether online impedance spectrum measurements can provide early warnings of oscillations and identify retuning needs. Intentional injection of disturbances might be required which can be costly and difficult to implement in practice.

The proposed project takes a different and more practical approach, grounded by evidence from actual historical measurements, i.e.:

· The method is based on real-world phenomena observed using high-resolution real-world measurements recorded at Strathclyde over 4 years, which reflects actual system behaviour and eliminates the need for complex, potentially inaccurate modelling.

· The required data is already available from existing systems and practices, avoiding the need for additional infrastructure, making it feasible for wider implementation.

Similarity, correlations and causality analysis enables preventive actions (e.g. adjusting windfarm outputs, rescheduling line outages) well before the oscillations occur, providing system operators sufficient time to pre-emptively act and assess the real-time impact of their actions.

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

Since 2021, the GB transmission network has experienced multiple SSO events. Collaborative efforts between NESO, the TSO, and network users have led to progress in understanding and managing such SSO events, with key lessons incorporated into industry practices. However, recent recurrences highlight the need for more effective systems and tools to enable real-time monitoring and mitigation of SSO events, thereby safeguarding system security during the decarbonisation process.

Existing systems and methods typically identify SSO events after initiation, offering limited time for response. Analytical model-based systems are reported to provide early warning, but they are difficult to implement due to the need for active disturbance injections, complex system modelling, and proprietary information constraints.

The proposed approach is different from the existing techniques and offers the following advantages:

· It is based on real-world phenomena, reflecting actual system behaviour and eliminating the need for complex, potentially inaccurate modelling.

· The required data (i.e. PMU and system operational data) is already available from existing systems and practices, avoiding the need for additional infrastructures, making it feasible for wider implementation.

Similarity, correlations and causality analysis enables preventive actions (e.g. adjusting windfarm outputs, rescheduling line outages) well before the SSO occur, providing system operators sufficient time to pre-emptively act and assess the real-time impact of their actions.

Relevant Foreground IPR

· A software prototype of SSO real time monitoring software.

· A project report covering the processed dataset, findings of the correlation analysis and testing and validation activity around the early warning system

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 Energy System Operator 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.neso.energy/about/innovation

3. Via our managed mailbox innovation@neso.energy

Details on the terms on which such data will be made available by National Energy System Operator can be found on our website: Data Sharing Approach | National Energy System Operator.

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

There are uncertainties and significant risks regarding the successful outcomes of the project activities. Initial indicators of SSO are informed by real-world observations, but a thorough understanding of these phenomena remains to be developed. It is also possible that certain SSOs may not display detectable early signs, and some detectable early signs may not develop into SSOs, which will be examined during the project.

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 initial indicators of SSOs are derived from real-world observations. However, a comprehensive understanding needs further development. Some SSOs may not show detectable early signs, and some detectable early signs may not develop into SSOs, which will be investigated in this project.

In addition, complexities in multi-partner innovation projects, especially regarding data sharing with NDAs, pose risks to progress and success.

Due to the high-risk and investigative nature of the project, innovation funding is deemed most suitable. The NIA funding approach is applicable due to the potential benefits to other network licensees such as TOs from the project outputs.

This project has been approved by a senior member of staff

☑ Yes