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

Mar 2026

Project Reference Number

NIA2_NESO125

Project Registration

Project Title

Hybrid Frequency Domain Assessment for Networks with IBRs

Project Reference Number

NIA2_NESO125

Project Licensee(s)

National Energy System Operator

Project Start

March 2026

Project Duration

1 year and 1 month

Nominated Project Contact(s)

Innovation@neso.energy

Project Budget

£400,000.00

Summary

This project aims to evaluate and verify a hybrid frequency domain methodology for power system stability analysis, assessing its suitability for networks with high penetrations of inverter-based resources. The work involves reviewing existing impedance scanning practices, applying device level impedance scans and grid frequency sweeps using a hybrid approach, comparing results against established EMT (Electromagnetic Transient) based methods, and validating frequency domain findings through time domain simulations. The project will be delivered over a 12-month period, progressing from initial scoping and review through application, comparison, verification, and final reporting. Expected outcomes include a validated hybrid stability assessment method, comparative evidence of accuracy and efficiency, and documented results to support future stability studies.

Preceding Projects

NIA2_NGESO018 - Automated Identification of Sub-Synchronous Oscillations (SSO) Events

NIA2_NGESO009 - 'D3' - Data-driven Network Dynamic Representation for Derisking the HVDC and Offshore Wind

Third Party Collaborators

Siemens

Nominated Contact Email Address(es)

Innovation@neso.energy

Problem Being Solved

The increasing connection of inverter-based technologies in power systems has introduced new stability challenges, which have led to a recategorisation of power system stability. Existing methodologies for assessment do rely heavily on detailed Electromagnetic Transient (EMT) based time domain simulations and grid perturbation techniques, which can be computationally intensive, time consuming, and difficult to scale for large or complex networks. There are limited validation and confidence in the evolving frequency domain approaches, particularly hybrid methods that perform assessment in the frequency domain, relying on frequency domain models, combining device level impedance scanning and analytical grid frequency representation. The lack of a verified, efficient, and scalable methodology, using different software platforms, creates uncertainty in stability assessments and restricts the ability to perform timely and consistent studies for future network scenarios.

Method(s)

The project will use a technical, model-based methodology to evaluate and verify a hybrid frequency domain stability assessment approach. This combines device level impedance scanning using EMT tools with grid-level frequency sweeps with frequency domain simulation environments. The method includes review of existing NESO practices, alignment on model scope and assumptions, comparative analysis against established EMT based techniques, and validation of results through targeted time domain EMT simulations. Knowledge transfer will be delivered through regular engagement and presentations to support future application by NESO

Work Package 1: Scoping and Review (2 months)

Following the kick off of the project the activities during this work package will include:

· At the outset of the project, this work package will focus on establishing a clear understanding of existing impedance scanning activities and defining the modelling scope for the work ahead. The team will review and gather information on current impedance scanning projects and methodologies used across industry to identify where hybrid methods may offer technical advantages. The review of current projects and relevant research will be carried out through a structured desktop study. Key assessment parameters will include underlying method (e.g., frequency sweep, adaptive scanning, hybrid scanning), computational performance and execution speed, model assumptions, data requirements, accuracy and repeatability, and suitability for system level or component level studies. The work package will also confirm and document the required scope for both the RMS model in PowerFactory and the dynamic EMT model in PSCAD.

· Deliverable: A report covering the findings from this work package.

Work Package 2: Device Scanning and Grid Frequency Sweep (3 months)

· This work package focuses on completing the first phase of model analysis. Impedance scans will be conducted on individual IBRs and synchronous machines using PSCAD. In parallel, grid level frequency sweeps will be performed at selected nodes within the PowerFactory model. These activities will generate the initial dataset that forms the foundation for cross tool comparison and hybrid method assessment.

· Deliverable: A report covering the findings from this work package.

Work Package 3: Comparison with Existing Approach (3 months)

· Here, the project evaluates how the emerging hybrid approach compares with current impedance scanning practices. Grid perturbation based impedance scans will be performed in PSCAD, and the resulting outputs will be compared with frequency sweep results obtained from PowerFactory. Frequency domain stability assessments will also be carried out to quantify the accuracy, efficiency, and insights offered by each method.

· Deliverable: A report covering the findings from this work package.

Work Package 4: Time-Domain Validation (3 months)

· This work package validates the frequency domain observations by running a series of targeted time domain simulations. These simulations help verify whether the impedance based assessments reliably reflect system behaviour under dynamic conditions. All validation outcomes will be integrated into the ongoing reporting to build a consistent story between frequency domain and time domain results.

· Deliverable: A report covering the findings from this work package. An automated toolbox that executes the full hybrid impedance‐scanning process end‐to‐end.

Work Package 5: Finalisation and Knowledge Transfer (1 month)

· The final stage of the project focuses on consolidating outcomes and ensuring full visibility and ownership of the methodologies. A knowledge‐sharing workshop will be delivered to transfer capability on tools, processes, and analytical techniques.

· Deliverable: A final project report and an NIA closure report.

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

- TRL Steps = 2 (3 TRL Steps)
- Cost = 1 (£400k)
- Suppliers = 1 (1 supplier)
- Data Assumptions = 2 (Medium)

Total = 6 (Low)

Scope

The scope for this project is limited to:

· Reviewing existing industry practices to understand current impedance‐scanning methods, their assumptions, and where hybrid approaches may offer measurable improvements.

· Applying the proposed hybrid approach to device‐level impedance scans and frequency sweeps to demonstrate feasibility and performance.

· Comparing hybrid‐method outputs against established PSCAD‐based techniques to assess accuracy, alignment, and computational efficiency.

· Conducting stability assessments and verification using time‐domain simulations to ensure that impedance‐based conclusions reflect real dynamic behaviour.

· Providing usable knowledge transfer, the methods, tools, and interpretation frameworks can be applied independently.

The project excludes changes to network codes or standards, development of operational tools, and full system-wide deployment, which would be subject to follow-on work.

Objective(s)

The objectives of this project are to:

· Benchmark hybrid approach against existing methods (e.g., PSCAD-based impedance scanning and time-domain simulations) to validate accuracy and efficiency.

· Perform device-level impedance scans and grid frequency sweeps on inverter-based resources (IBRs) and synchronous machines and compare results across tools (PSCAD and PowerFactory).

· Create and deliver a toolbox to implement hybrid scanning for stability analysis.

· Reduce computational time compared to the conventional impedance scan method that may take days, and improve scalability for large network studies, enabling analysis over broad frequency ranges.

· Develop and deliver knowledge transfer and training materials for NESO engineers.

Consumer Vulnerability Impact Assessment

This project has been assessed as having a neutral impact on customers in vulnerable situations because the outputs of this project are focused on providing improvements to the stability of the GB electricity system.

Success Criteria

The project can be deemed successful if:

· Completion of impedance scan and frequency sweep results using the hybrid approach which meets accuracy, repeatability and execution speed criteria.

· Demonstrated alignment within defined tolerance between hybrid method and the existing approach.

· Completion of validated comparison between hybrid method and time domain simulations.

· Delivery of reusable models, an automated toolbox, and all appropriate supporting manuals.

· Delivery of usable training and workshops that provide practical, actionable knowledge transfer on the methods, tools, and results.

Project Partners and External Funding

One external partner: Siemens.

No external funding.

Potential for New Learning

The project will generate new learning on the applicability, benefits, and limitations of a hybrid frequency domain stability assessment methodology for networks with high penetrations of inverter-based resources. Key outcomes include improved understanding of device level impedance scanning, grid level frequency sweeps, and the consistency to EMT-based stability assessments. Learning will be disseminated through technical presentations, workshops, and the model usage with developments during the project, enabling wider industry understanding and uptake. At project completion, all findings, lessons learned, and recommended next steps will be made available.

Scale of Project

The project will be delivered over a 12-month period, progressing from initial scoping and review through application, comparison, verification, and final reporting

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL5 Pilot Scale

Geographical Area

The project will be based upon the GB National Electricity Transmission System (NETS).

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

The total project cost is £400,000.

Project Eligibility Assessment Part 1

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

This project has the potential to facilitate the energy system transition by enabling more efficient and scalable stability assessment methods for electricity networks with high penetrations of inverter-based resources such as wind, solar, and battery energy storage. As the system transitions toward lower inertia and increased power-electronic interfacing, traditional time domain EMT studies alone become increasingly resource intensive and challenging to apply at scale. By establishing confidence in a hybrid frequency domain methodology, the project could support earlier identification of stability risks, faster connection assessments, and more timely network development decisions. This, in turn, can help reduce barriers to the integration of low-carbon generation and storage, support faster deployment of renewable technologies, and contribute to the secure and economic operation of the future electricity system.

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

N/A

Please provide a calculation and/or description of the expected benefits of the solution

The project aims to develop a novel stability analysis method for NESO to implement the hybrid impedance scan between power factory and PSCAD. The outcome of this project could enable NESO to reduce the efforts and time used in impedance scan for large network. It could thereby enhance the reliability of power supply for consumers, reduce the risks of oscillation, and reduce the operational cost of the system that will be reflected in the electricity price.

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

The proposed method will be applicable for large network, so it is replicable to all size networks and connections across GB.

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

It will provide the methodology, and the tool required to carry out hybrid impedance scan analysis using RMS and EMT models. The developed tool will be deployed using Python software. During the project, the implementation of the tool will be assessed.

Requirement 3 / 1

Involve Research, Development or Demonstration

Projects 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

Involve Research, Development or Demonstration - Please select all that apply

☐ 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 will deliver a validated hybrid frequency domain stability assessment methodology combining device level impedance scanning in PSCAD with network level frequency sweeps in PowerFactory. The approach aims to provide a faster, more scalable alternative to purely EMT based studies while maintaining accuracy through verification against time domain simulations. This would enable earlier and more proportionate identification of stability and resonance risks in high IBR power systems, reducing late-stage design changes, engineering effort, and project risk.

The learning generated will be directly applicable to Network Licensees, including NESO and TOs. It can be used to enhance connection assessments, operability studies, and network planning by supporting consistent, repeatable screening of control interactions and weak grid conditions. The results will inform best practice guidance on when frequency domain methods are sufficient and when EMT validation is required.

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. Networks must explicitly mention similar projects that they have considered and how these differ.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

NESO is leading the way with this development. Currently, the only other network in the world where a similar methodology is tested is in Australia. However, the GB network is more complex with meshed connectivity.

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

This project is innovative because it introduces a validated hybrid stability assessment approach that combines device level impedance scanning with network level frequency sweeps, reducing dependence on computationally intensive grid wide EMT studies.

It goes beyond existing practice by systematically verifying frequency domain results against established EMT time domain simulations, clearly defining where the hybrid method is reliable and where EMT analysis remains necessary. This bridges the gap between research level techniques and operationally usable methods for NESO.

Relevant Foreground IPR

The following Foreground IPR will be generated from the project:

· A hybrid methodology for stability analysis and assessment in the frequency domain, combining impedance scanning and frequency sweeps.

· A report and code/tool for implement the hybrid impedance scan to determine the large network small signal stability.

· A report on performance validation of the stability analysis tool under varying network conditions.

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 a part of it's business and usual activities

The Network Licensee is not funding this project as business as usual because it involves development and validation of an emerging methodology rather than delivery of routine studies. The work includes cross tool benchmarking, uncertainty assessment and knowledge generation that carries technical risk and provides sector wide learning, making it more appropriate for innovation funding than operational or regulatory business as usual (BAU) activities.

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 can only be undertaken with NIA support because it involves non business as usual, high risk innovation activity focused on validating a new stability assessment methodology with uncertain outcomes. The work delivers shared learning rather than immediate operational value, requires cross-tool benchmarking and open dissemination, and would not be justifiable under normal commercial or regulated spend without innovation funding.

This project has been approved by a senior member of staff

☑ Yes