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

Aug 2021

Project Reference Number

NIA2_NGET0001

Project Registration

Project Title

Impedance Scan Methods

Project Reference Number

NIA2_NGET0001

Project Licensee(s)

National Grid Electricity Transmission

Project Start

January 2023

Project Duration

1 year and 2 months

Nominated Project Contact(s)

Atia Adrees (box.NG.ETInnovation@nationalgrid.com)

Project Budget

£359,000.00

Summary

Dynamic stability is a major concern in maintaining the security of power grids with high shares of power electronics-based resources. Stability analysis tools are needed to evaluate the impacts of power electronics converters on system stability at slow and fast time scales. This project will investigate a new impedance scan method, which provides a more accurate impedance representation to investigate stability challenges associated with power electronics connections. If the project is successful, it will enable power engineers to do similar studies in the future and obtain a more accurate impedance representation.

Nominated Contact Email Address(es)

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Problem Being Solved

Dynamic stability is a major concern in maintaining the security of power grids with high shares of power electronics-based resources. Stability analysis tools are needed to evaluate the impacts of power electronics converters on system stability at slow and fast time scales. Impedance responses of power converters at different frequencies can be obtained by performing scans on their PSCAD models. These impedance responses, when obtained properly, can be used for evaluating the impacts of power converters on system. However, the existing impedance scan tool in the PSCAD library, the so-called Z(f) block, is suitable only for analysing subsynchronous resonance (SSR) in Type 3 wind power plants in the presence of series-compensated transmission lines, that too only when the frequency coupling effects are negligible.

This method cannot be used for analysing subsynchronous or low-frequency oscillations (SSO and LFO), harmonic resonance problems, and for evaluating the impact of wind power plants and HVDC on the damping of wide-area system oscillations modes. These deficiencies stem from the inability of the existing tool in measuring frequency coupling effects, limited frequency range and resolution where the impedance responses can be obtained, and inability to obtain dq impedance responses.

Method(s)

Method:

The project will investigate a method to perform comprehensive impedance scans on PSCAD models of any three-phase electrical network. Methods using such impedance responses for grid-level stability studies will also be investigated. In this project, these methods will be applied in GB context; their accuracy, computational requirements, and scalability will be evaluated through this project. The project will also enable National Grid, other Transmission operators and system operator to perform similar studies in the future for power converter integration or for existing interconnections for post-mortem analysis of a stability event.

Data Quality Statement (DQS):

The project will be delivered under the NIA framework in line with OFGEM, ENA and NGET internal policy. Data produced as part of this project will be subject to quality assurance to ensure that the information produced with each deliverable is accurate to the best of our knowledge and sources of information are appropriately documented. All deliverables and project outputs will be stored on our internal SharePoint platform ensuring backup and version management. Relevant project documentation and reports will also be made available on the ENA Smarter Networks Portal and dissemination material will be shared with the relevant stakeholders.

Measurement Quality Statement (MQS):

The methodology used in this project will be subject to supplier's own quality assurance regime and the source of data, measurement process and equipment as well as data processing will be clearly documented and verifiable. The measurements, designs and economic assessments will also be clearly documented in the relevant deliverables and final project report and made available for review.

Risk Assessment and Audit

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

TRL Steps = 1 (1 TRL step)

Cost = 1(£359,000)

Suppliers = 1 (1 suppliers)

Data Assumption = 1 (Data will be gathered using available network model)

Scope

Work package 1 [M1-M6]: Use new impedance scan methods for the analysis of subsynchronous, near-synchronous, and super-synchronous control interactions in power electronics interconnections

Subtask 1.1 [M1-M3]: Perform analysis of subsynchronous, near-synchronous, and super-synchronous control interactions in power electronics interconnection using impedance scan methods. Demonstrate analysis on PSCAD simulation testbeds

Subtask 1.2 [M4-M6]: Compare performance of the investigated impedance scan methods with the impedance scan obtained using Z(f) block in PSCAD library

Subtask 1.3 [M6]: Prepare a report on different types of impedance scan methods, comparison with the PSCAD's Z(f) block, and analysis of control interactions at subsynchronous, near-synchronous, and super-synchronous frequencies.

Go/No-go Deliverable 1 [M6]: Report on the investigated impedance scan methods and algorithm, and PSCAD simulation testbeds used for demonstrating the impedance scan methods and stability analysis. Python and MATLAB scripts implementing the impedance scan methods.

Work package 2 [M7-M12]: Use the investigated impedance scan methods for evaluating the stability impacts of wind power plants and HVDC interconnections

This task should demonstrate the superiority of the investigated impedance scan method over traditional method.

Subtask 2.1 [M7-M9]: Using a generic model of a wind power plant and an IEEE 9-bus system in PSCAD, demonstrate the use of the investigated impedance scan methods for evaluating the impact of the wind power plant on the IEEE 9-bus system oscillation modes.

Subtask 2.2 [M10-M12]: Using a generic model of a VSC-HVDC transmission link and a wind power plant in an IEEE 9-bus system, demonstrate the use of the investigated impedance scan methods for evaluating the impact of control interactions.

Subtask 2.3 [M12]: Prepare a report on the application of impedance scans for analyzing the impact of power electronics interconnections on system oscillations modes and control interactions.

Go/No-go Deliverable 2 [M12]:

- Report on the use of impedance responses for analyzing the impacts of power electronics interconnections on the system oscillation modes, and PSCAD simulation testbeds used for demonstrations in this task.
- MATLAB scripts for performing stability studies using impedance scans with clear code description.

Work package 3 [M13]: Knowledge transfer workshop on the investigated impedance scan methodology

Subtask 3.1 [M13]: Organize a four-day hands-on workshop for engineers at National Grid facilities to perform impedance scans on a National Grid PSCAD model and use these scans for analyzing the stability impacts of power electronics interconnectors. The first day of the workshop will focus on the fundamental principles of the impedance-based stability analysis methods and the practical requirements such as frequency range and perturbation magnitude for performing impedance scans. The second day will focus on hands-on training for performing impedance scans and stability studies.

Deliverable 3 [M13]:

A four-day hands-on workshop for engineers on using impedance scans and perform stability analysis. Python and MATLAB codes, presentation slides, and PSCAD case studies used during the workshop will be provided for future reference.

Objective(s)

- Assess the advantage of the impedance scanning method compared to the PSCAD Z(f) tool.
- Assess the advantage of the methodology for evaluating the stability impacts of power electronic devices.
- Validate the methodology on GB or part of GB PSCAD model and organise knowledge transfer workshop.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

Financial distributional impact:

The project is expected to support energy networks for integration of power electronic devices at lower risk and cost. If these benefits are achieved, the financial distributional impact of this project aligns with the simplest case discussed in OFGEM's "Assessing the impact of economic regulation" report. The report confirms that the savings as a percentage of household income are more significant for lower income deciles and therefore the achieved benefits will be particularly valuable to vulnerable consumers. The pricing structure for energy transmission will not be impacted, e.g. benefits delivered as part of this project can be passed on to all consumers including households using a prepayment meter.

Technical and wellbeing impact:

Based on the recommendations and findings in this research, energy networks may start adopting the impedance scanning and stability analysis methodology. It will support the integration of power electronics devices in the network which will benefit vulnerable consumers as a whole.

The consumer impact of any of the methods or solutions developed in this project is not dependent on any of the following factors:

- Dwelling and location (potentially including tenure)
- Readiness for digital technology
- Personal and social factors (for example, households with disabilities and medical conditions, or which speak English as a foreign language)

Success Criteria

- The project will be successful if it achieves the objectives set out at the start of the project. In particular, the following outputs will be important when assessing the success of the project: The advantage of the impedance scanning method and the associated methodology for evaluating the stability impacts of power electronic devices is validated.
- Successful demonstration of the methodology using GB or part of PSCAD model

- Knowledge dissemination workshop is successfully delivered.

Project Partners and External Funding

NGET NIA funding £342,000

NGESO NIA funding £5,000

SSE NIA funding £7,000

SPEN Funding £5,000

No external funding.

Potential for New Learning

The project aims to deliver the following new learning:

- The technical capability and limitations of the impedance scan and stability analysis method, including comparison to PSCAD embedded tool.
- The practical suitability of deploying the methodology in the GB network.

The learning will be disseminated through the reporting via the ENA portal and either ENA, CIGRE dissemination webinars and publications depending on the project outputs.

Scale of Project

This project aims to deliver the key learning to the industry that will enable further development. It is set up as a desktop study with an on-site/virtual knowledge transfer workshop.

Technology Readiness at Start

TRL5 Pilot Scale

Technology Readiness at End

TRL6 Large Scale

Geographical Area

The project will be a desktop study with an on-site/ virtual knowledge transfer workshop.

Revenue Allowed for the RIIO Settlement

Not applicable

Indicative Total NIA Project Expenditure

NGET NIA funding £307,800

NGESO NIA funding £4,500

SSE NIA funding £6,300

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 outputs of this project will support energy networks building more understanding on interaction and instability issues associated with power electronics converters. It will allow the better planning for integration of power electronic devices. It will also help us in taking mitigating actions to avoid unplanned outages resulting from interaction issues. Thus, it will be help the energy system transition to enable more power electronics based connections, which include renewable energy generation, energy storage, electrolysers and HVDC interconnectors.

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

Not applicable

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)

Not applicable

Please provide a calculation of the expected benefits the Solution

For all network companies, the project will introduce a new method to investigate stability issues. It will be an additional process along with EMT simulations to ensure network stability. It is expected that it will result in almost a savings of 30% of engineering efforts to get a similar accuracy in comparison to only running EMT simulation studies.

If the impedance-based design guidelines are introduced, the project can also bring benefits in terms of cost savings in the development of the control system and its performance validation for control stability. If the control instability occurs during the operation of converters, it may cost £2m-£5m to develop the additional control system to resolve it. As in most cases, it will be subjected to a variation order. Physical intervention may also be required in few cases, e.g. additional active devices and filters, which may lead to an even higher cost. Therefore, the solution generated from this project will provide significant savings to the consumer.

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

The method can be readily adopted by all network licensees by adding additional software programmed tool to the existing network simulation

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

There may be a requirement to develop a software from the method tested in this project, which may cost £30k per licensee. The total rolling out cost across GB will be the 50k (including internal time) per licensee.

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 learning from this project will be facilitating the energy transition. The learning can be used to conduct various studies for the power electronic based connections, i.e. and understand different aspects such as how to select frequency range and magnitude of perturbations for doing impedance scans depending on the type of stability problem being studied, what nodes are appropriate in the PSCAD model for performing impedance scans, how to obtain eigenvalues and system modes using impedance responses of the power electronic interconnections and the network at their terminals, whether the analysis should rely on sequence or dq impedance responses, and how to obtain dq impedance response from sequence impedance scans.

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

Not applicable

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.

Some recent work has been carried out to investigate the application of impedance scan and modelling as part of NIA project NIA_NGTO045 "Risk mitigation of power electronics connections", which has focussed on developing methodology to predict control interactions using impedance modelling and measurement. Stability Assessment and Mitigation of Converter Interactions" project undertaken by National HVDC centre has also investigated methods assessing multi-converter interactions, which takes the approach of direct small-signal impedance modelling. Both the projects have demonstrated the advantages of impedance stability method. However, the projects have used the existing impedance scan methods, which may have accuracy limitations. The current project will explore the accuracy limitations of the exiting method and will evaluate the new proposed more accurate method.

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

Network Licensees.

Not applicable

Additional Governance And Document Upload

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

Power electronics converters exhibit complex dynamics including different frequency coupled responses. It is not a trivial problem to perform impedance scans of these devices with frequency coupling effects. Moreover, the use of impedance scans for stability analysis also need to account different aspects such as reference frames of impedance responses and coupling among different power electronics interconnections. The existing methods of impedance scan have shown accuracy limitations The main innovation of this project is to investigate a new analytical platform for estimating impedance more accurately.

Relevant Foreground IPR

Foreground IPR will be created in relation to the test results of the methodology on the NGET network. The supplier will contribute the background IPR in the area of impedance scanning methodology, whilst NGET will contribute background IPR with regards to the relevant electricity transmission domain knowledge and the NGET PSCAD model used in the project.

Data Access Details

Project data will be shared in line with the requirements of the RIIO-2 NIA Governance, specifically sections 2.13 – 2.16.

https://www.ofgem.gov.uk/system/files/docs/2021/01/riio-2_nia_governance_document_-_draft_for_consultation_250121.pdf

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

The nature of research programme means it carries a risk that the research may be unsuccessful or identify unforeseen barriers to implementation and NGET is unable to consider research of this scale as business-as-usual.

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

Impedance scan and modelling methods for power electronics devices have not been developed enough to fully understand the risks associated with the corresponding technical solutions. The method being explored in the project is new and have not been used anywhere commercially. Considering the risk associated with the success of the project, NGET believes NIA funding is the best route for the project.

This project has been approved by a senior member of staff

☑ Yes