# NIA Project Registration and PEA Document

### Date of Submission

Nov 2023

### Project Reference Number

NIA2_NGESO050

## Project Registration

### Project Title

Enhanced RMS (e-RMS) models for stability assurance

### Project Reference Number

NIA2_NGESO050

### Project Licensee(s)

National Energy System Operator

### Project Start

October 2023

### Project Duration

1 year and 10 months

### Nominated Project Contact(s)

Dr Lily Yang (NGESO)

### Project Budget

£400,000.00

### Summary

Threats of instabilities posed by high fractions of inverter-based resources (IBRs) force the system operators to operate conservatively by curtailing wind or limiting interconnector flows, for example. System studies with existing RMS models (e.g., 'GB master') or EMT simulation can't necessarily foresee or replicate such stability problems. The aim of this project is to develop an enhanced RMS (e-RMS) modelling framework that can provide dynamic stability assurance in planning studies and at operation timescale without carrying the cost of being overly conservative. This would be achieved by an e-RMS model of IBRs as a digital twin with modelling adequacy of both IBRs and the network in the sub-synchronous frequency range. The e-RMS model will provide early warning of any incipient instability and identify its root cause allowing targeted intervention and effective mitigation.

### Third Party Collaborators

Imperial College London

### Nominated Contact Email Address(es)

Innovation@neso.energy

### Problem Being Solved

Unforeseeable instabilities caused by high fractions of inverter-based resources (IBRs) force the system operators to operate conservatively by curtailing wind or limiting interconnector flows, for example to ensure security of supply. System studies with existing

RMS models (e.g., 'GB master') or EMT simulation can't necessarily foresee such stability problems. It is difficult to replicate and analyse these stability problems in post-event EMT or RMS studies. A systematic way to analyse such IBR-driven instabilities, develop early warning system for incipient instability problems and decision support on mitigation is necessary at both planning and operational level.

## Method(s)

The project outcome will be delivered through five work packages (WP):

- WP1 - Develop EMT simulation model (in PSCAD) of a reduced equivalent GB system with generic EMT models of IBRs. The EMT simulation model is meant to mimic the real system for benchmarking.

- WP2 - Obtain an 'enhanced RMS' (e-RMS) model by updating the IBR model parameters to match the response from the EMT benchmark model.

- WP3 - Study modelling adequacy of e-RMS model in terms of the role of network dynamics, different IBR control loops and subsystems (e.g., detailed current control) by benchmarking against EMT simulation

- WP4 - Replicate event response from EMT model using the e-RMS model. These events would be triggered by re-dispatch, grid strength, incorrect control settings etc.

- WP5 - Validate the root cause of instability through modal analysis on e-RMS model against the known trigger in the EMT model and demonstrate effective mitigation through targeted interventions based on the identified root cause. The simulated data from an EMT model (mimicking the real system) of a 'GB-like' grid will be used to update the e-RMS model which will be further utilised for stability and root-cause analysis. Validation of stability and root cause analysis would then be based on the alignment between what happens in EMT model and what's reflected in the e-RMS models.

In line with the ENA's ENIP document, the risk rating is scored Low.
TRL Steps = 1 (2 TRL steps)
Cost = 1 (£400k)
Suppliers = 1 (1 supplier)
Data Assumptions = 2
Total = 5 (Low)

## Scope

System-wide simulation with existing RMS models (e.g. 'GB-master') or localised EMT simulation often do not foresee IBR-driven instability problems. System-wide EMT simulation or co-simulation with vendor specific IBR models is an option but could be prohibitively slow and is unable to readily identify the root cause of the instabilities. In principle, an RMS model with adequate modelling detail and parameters tuned for the prevailing operating condition should capture instability problems within a certain frequency range, allow root cause analysis and hence, effective mitigation. In the context, this project would develop e-RMS model of IBRs as Digital Twin of a high-fidelity IBR model (in EMT) mimicking a real one. This way the operating point dependency of the RMS model of an IBR can be captured while addressing modelling adequacy in the sub-synchronous frequency range.

This project will enable the ESO to:

- Analyse stability of IBR-dominated systems with enhanced RMS modelling in PowerFactory

- Perform system wide studies for a much larger number of scenarios than what is possible with EMT simulation

- Use e-RMS models for planning and operational studies including near-real time applications

- Utilise root cause analysis to develop early warning systems and effective mitigation of potential instability problems.

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

## Objective(s)

The specific objectives of the project are to develop:

- an e-RMS model of the equivalent GB test system with Digital Twins of IBRs driven by the EMT simulation model (as benchmark) mimicking the real system

- a methodology for validating the modelling adequacy and accuracy of the e-RMS model by replicating event response

- software tool for stability analysis, identification of the root cause of instability and early warning system – all based on the e-RMS model.

## 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 below.

## Success Criteria

The project will be deemed successful if the following criteria are met :

- Benchmarking the event response from e-RMS model against the EMT model
- Validation of root cause from e-RMS model against known disturbance trigger in EMT model
- Accuracy of early warning system, optimality of mitigation measure against IBR-driven instability

## Project Partners and External Funding

Imperial College will be carrying out the work. No external funding required.

## Potential for New Learning

The knowhow of e-RMS model with Digital Twins of could be leveraged to integrate stability assurance with operational decisions in the control room, for example. Learnings could be incorporated into the development of the Virtual Energy System common framework.  Moreover, the e-RMS modelling framework would complement the whole system EMT model under development in NIA_SHET_0035 TOTEM and NIA2_NGET0020 Co-simulation projects and provide clarity on the specific application domain for each approach.

## Scale of Project

The project spans 21 months with 1 project partner. The project consists of desk-based research and workshops with the relevant ESO teams (including network and wider teams).

## Technology Readiness at Start

TRL3 Proof of Concept

## Technology Readiness at End

TRL4 Bench Scale Research

## Geographical Area

This project will be based upon the GB ESO area of operations.

## Revenue Allowed for the RIIO Settlement

None

## Indicative Total NIA Project Expenditure

£400,000

# 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 will develop an enhanced RMS modelling framework to analyse and mitigate potential instability threats posed by high fractions of IBRs on the grid. With threats of unforeseen instabilities mitigated, higher fractions of renewables can be accommodated without compromising the security of supply. This will facilitate the net zero transition while ensuring secure and affordable supply for consumers.

### 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

As this is research project, a calculation of the expected benefits would not be appropriate, however a high-level summary of the benefits is included below.

Currently, existing simulation models struggle to anticipate instability issues caused by inverter-based resources (IBRs), leading operators to limit renewable generation from IBRs to ensure grid security. The project's development of an enhanced RMS (e-RMS) model for IBRs, functioning as digital twins of high-fidelity IBR models, addresses these challenges. It enables a more thorough analysis of IBR-dominated systems, allowing for greater renewable integration without compromising grid stability. The e-RMS model facilitates advanced stability studies, real-time applications, and root cause analysis, ultimately ensuring a reliable and affordable power supply during the transition to net zero emissions.

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

The project will use a reduced equivalent of GB transmission system model for validating the e-RMS model and stability analysis and mitigation. The next step would be to scale this up to the GB master model in Powerfactory. Also, the generic IBR models to be used in the EMT benchmark model in this project would have to be replaced by vendor-specific IBR models as and when those are mandated through the Grid Code.

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

The cost of rolling out the method is estimated to be £100,000.

## 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 outcomes of the project will include:

- an e-RMS model of the equivalent GB test system with Digital Twinss of IBRs driven by the EMT simulation model (as benchmark) mimicking the real system
- a methodology for validating the modelling adequacy and accuracy of the e-RMS model by replicating event responses
- a software tool for stability analysis, identification of the root cause of instability and early warning system – all based on the e-RMS model.

The next step is to implement in DIgSILENT PowerFactory with recorded data to carry out studies (stability or otherwise) on the GB-master model. Eventually, the IBR Digital Twins will be implemented with real-time measurements from the IBRs in operation to inform decisions at the control room. This methodology can be used in any network with high fraction of IBR-interfaced renewable generation to enable an efficient stability analysis.

## 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.

Several research and development projects are underway internally at the ESO and externally at the Australian Energy Market Operator (AEMO), focusing on enhancing EMT models for comprehensive system-wide studies using efficient methods like co-simulation. However, there needs to be more attention towards adapting RMS models for analysing the stability of systems dominated by IBRs, which motivates our proposal.

Additionally, there is ongoing work in creating Digital Twins for various energy system components. For example, the ESO is developing a [Virtual Energy System programme](#), to enable an ecosystem of connected digital twins of the GB energy system. This will be a real-time digital replica of GB's entire energy landscape working in parallel to the physical system, to improve simulation, forecasting abilities and visibility of the whole energy system.

This e-RMS project is driven by the need for more clarity surrounding vendor-specific IBR models. Developing Digital Twins for IBRs would enable comprehensive system-wide studies, including stability analysis. Nevertheless, several other power system components, including distribution networks and demand profiles, also need more transparency, necessitating the creation of their Digital Twins to fill the gaps in the overall model.

The e-RMS models developed in this project could form a key input to an integrated digital representation of Great Britain's energy system, facilitated through the Virtual Energy System.

## 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 core innovation in this project is to capture the operating point dependency of the RMS model of an IBR using a Digital Twins of the real one making it an 'enhanced RMS' or e-RMS model. This enables stability and root cause analysis of IBR-dominated systems using the well-established and computationally efficient RMS modelling. Without e-RMS models, system-wide EMT simulation with vendor specific IBR models is the only way to check stability. But the latter is a) slow to run limiting the scenarios that can be studied, b) not suited for near real time applications (e.g., early earning of incipient problems) and c) cannot identify the root cause of the problem for effective mitigation. All these could potentially be overcome with e-RMS models.

## Relevant Foreground IPR

The following Foreground IPR is expected to be generated in the course of the project:

- e-RMS model of the equivalent GB test system with Digital Twins of IBRs driven by the EMT simulation model (as benchmark) mimicking the real system
- methodology for validating the modelling adequacy and accuracy of the e-RMS model by replicating event response
- software tool for stability analysis, identification of the root cause of instability and early warning system – all based on the e-RMS model.

## 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](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](https://www.nationalgrideso.com/future-energy/innovation)
3. Via our managed mailbox [innovation@nationalgrideso.com](mailto: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](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 low TRL 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.

- 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.

- There are risks associated with acceptable performance of the methods when applied to the detailed GB network model.

## This project has been approved by a senior member of staff

☑ Yes