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 2023

Project Reference Number

NIA2_NGESO045

Project Registration

Project Title

RealSim: Real-Time Phasor-EMT Simulations

Project Reference Number

NIA2_NGESO045

Project Licensee(s)

National Energy System Operator

Project Start

June 2023

Project Duration

1 year and 6 months

Nominated Project Contact(s)

Mostafa Nick (NGESO), Xiaowei Zhao (Warwick University)

Project Budget

£450,000.00

Summary

The increasing penetration of inverter-based resources and HVDC interconnections have created unfavourable dynamic interactions, oscillations and low inertia related stability issues. With the planned continuous growth of inverter-based resources into the system, it is essential to develop real-time modelling and simulation studies for fundamental understanding and mitigation strategies of various types of oscillations.

This project aims to develop a real-time simulation of a region of GB power system in both phasor and EMT modes for transient stability assessments. It investigates when and where to use the phasor mode and EMT mode simulations for a given system condition and provide real-time simulation of the grid in that region for system stability and security and identification of stability risks.

Preceding Projects

NIA_SHET_0035 - TOTEM (Transmission Owner Tools for EMT Modelling) Extension

NIA_NGSO0007 - Investigation & Modelling of Fast Frequency Phenomena (“F2P”)

Third Party Collaborators

University of Warwick

Nominated Contact Email Address(es)

box.so.innovation@nationalgrid.com

Problem Being Solved

The increasing penetration of inverter-based resources and HVDC interconnections have created unfavourable dynamic interactions, oscillations and low inertia related stability issues. For example, oscillations at 9 Hz were detected 10 minutes before the Aug. 2019 GB power outage. Also, in Aug. 2021, 8-Hz oscillations in RMS voltage in Scotland were appeared in two occasions. With the planned continuous growth of inverter-based resources into the system, it is therefore essential to develop real-time modelling and simulation studies for fundamental understanding and mitigation strategies of various types of oscillations.

The GB power system has been modelled in PowerFactory, suitable for phasor mode studies. The phasor domain studies excel at simulating large mixed networks with fast computations. However, there are limitations to the existing phasor-domain power system models to identify electromagnetic transients and oscillatory interaction issues occurring in the GB power grid. For example, a phasor-domain model does not predict sustained commutation failure and subsequent disconnection of LCC HVDC link, and it does not predict sustained oscillations following a credible contingency in an inverter-dominated network area. With recent national and international experiences, conventional power system stability analysis tools have frequently failed to foresee these occurrences due to the simplifications inherent in these approaches.

EMT-based modelling addresses these deficiencies. However, detailed whole-system modelling has had little applicability in large-scale power system research to date, due to the computational burden associated with such models as well as the difficulty of obtaining the original equipment models from manufacturers. In addition, there is no standard in facilitating the transfer of power system models between the simulation tools. Therefore, as an innovative approach, emerging both modes together and operate in real-time can increase the model reliability and system security.

This project aims to develop a real-time simulation of a region of GB power system (e.g., South Coast) in both phasor and EMT modes for transient stability assessments. It investigates when and where to use the phasor mode and EMT mode simulations for a given system condition and provide real-time simulation of the grid in that region for system stability & security and identification of stability risks.

Method(s)

The project will be delivered in four work packages:

WP1 – Integration of power system model of a part of GB grid into ePHASORSIM
This will provide an ePHASORSIM-ready model of South Coast region for real-time applications and studies.

- **Task 1.1.** PowerFactory model adjustment of the South Coast power system for integration into real-time simulator.
Deliverables (D1): Adjusted DGS format version of South Coast power system model for use in ePHASORSIM environment.
- **Task 1.2.** Establishing pin data file containing input/output signals and monitoring signals.
Deliverables (D2): South Coast power system input/output pin data file for offline, HIL, and real-time simulation purposes.
- **Task 1.3.** Establishing ePHASORSIM model of the South Coast power system model.
Deliverables (D3): ePHASORSIM simulation model of South Coast power system for offline, HIL, and real-time simulation purpose.
- **Task 1.4.** Offline Execution of ePHASORSIM model for transient stability assessment.
Deliverables (D4): Report on offline simulation of ePHASORSIM model and PowerFactory model of South Coast power system.
- **Task 1.5.** HIL Execution of ePHASORSIM model for transient stability assessment.
Deliverables (D5): Report on feasibility study of HIL-based experiments of ePHASORSIM model of South Coast power system.

WP2 – Integration of power system model of a part of GB grid into HYPERSIM
This WP provides a HYPERSIM model of South Coast region suitable for real-time simulations.

- **Task 2.1**. Establishing HYPERSIM model of the South Coast power system model.
Deliverable (D6): To facilitate the model transfer, the PSCAD model is transferred to a unified data-base and then it is imported into the HYPERSIM.
- **Task 2.2**. HYPERSIM model adjustment of the South Coast power system for integration into real-time simulator.
Deliverables (D7): HYPERSIM simulation model of South Coast power system with different technologies (LCC and VSC-HVDC lines) for offline, HIL, and real-time simulation purpose.
- **Task 2.3.** Offline Execution of HYPERSIM model for transient stability assessment.
Deliverables (D8): Report on offline simulation of HYPERRSIM model and PSCAD model of South Coast power system.

- **Task 2.4.** HIL Execution of HYPERSIM model for transient stability assessment.

Deliverables (D9): Report on feasibility study of HIL-based experiments of HYPERSIM model of South Coast power system.

WP3 – Real-time operation of integrated models for transient stability assessments and controllers' impacts

This WP investigates that given a system condition, when and where the phasor and EMT simulations should be used. So far, there is no clear standard on allocating the type of simulation studies on a power system model.

- **Task 3.1.** EMT and phasor models steady-state analysis.

Deliverables (D10): The states of the model are transferred for each busbar and the same power flow is established with HYPERSIM-PSCAD model to ensure the steady state responses are valid and error free

- **Task 3.2.** Real-time EMT and phasor modes operation.

Deliverables (D11): Real-time simulation model of the South Coast power system model in EMT and phasor modes

WP4 –Developing Frameworks standards for application of real-time EMT and phasor simulations for GB power system

This WP provides the guidelines to the operators to implement the EMT and phasor models of power system according to the given conditions of the system.

- **Task 4.1.** Standards and frameworks for real-time EMT, phasor simulations.

Deliverables (D13): Report is delivered on the completion of WP4 containing application of EMT and phasor models in real-time according to system conditions and roadmaps to ESO for real-time simulations platforms.

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

- TRL Steps = 1 (2 TRL steps)
- Cost = 1 (£450k)
- Suppliers = 1 (1 supplier)
- Data Assumptions = 2
- Total = 5 (Low)

Scope

The penetration of inverter-based resources and HVDC interconnections are rapidly growing into the GB power system in line with the integration of more renewable resources. Phasor-domain power system models excel at simulating large mixed networks with fast computations, however there are limitations to identifying electromagnetic transients and oscillatory interaction issues occurring in the GB power grid.

This project aims to develop a real-time simulation of a region of GB power system (e.g., South Coast) in both phasor and EMT modes for transient stability assessments. It investigates when and where to use the phasor mode and EMT mode simulations for a given system condition and provide real-time simulation of the grid in that region for system stability & security and identification of stability risks.

Full implementation of the project outcomes could reduce the costs associated with the early-stage identification of control interaction issues, and proper parameter tuning, which would result in more secure and reliable system operation. It would help identify the stability issues that may not have been identified using phasor mode-only models. The grid reinforcement required to solve the control interaction between inverter-based resources may cost hundreds of millions in the future if the correct technical measures are not introduced.

The outputs of the project could also benefit consumers by reducing the risk of major power disruptions. It would enable a smooth transition to a decarbonised electricity network with greater renewable integration, improved planning and reduced energy bills for consumers.

Objective(s)

The project will deliver the following objectives through the four linked work packages:

1. Conduct the phasor-domain and EMT models of a part of GB power system suitable for real-time simulation studies
2. Understanding the differences between phasor and EMT models for power system stability issues
3. Develop a standard to identify when and where each phasor and EMT model of a region should be used, given a system condition
4. Stability analysis based on real-time simulations e.g., for understanding the impact of controllers and their interactions on transient stability of the power system, and contingencies

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 considered a success if it meets the following success criteria:

- Establishing ePHASORSIM model of the South Coast power system
- Establishing HYPERSIM model of the South Coast power system
- Real-time transient stability assessment of ePHASORSIM and HYPERSIM models
- A framework to identify when and where each phasor and EMT simulation tools should be used

Project Partners and External Funding

Warwick University will be carrying out the work, no external funding required.

Potential for New Learning

This innovation project is expected to deliver new learning by investigating real-time simulation of a part of GB power system in both phasor and EMT modes and identifying the transient stability issues using the right tool at the right time and region. Given that several steps of the work will be the first examples being tested for the GB system and that a part of GB power system will be used, the success of this project can be extended to the whole GB grid. NIA funding will allow the ESO to disseminate the learnings from the project to the energy sector and GB network licensees. This will directly contribute to enhancing the knowledge and capabilities of the ESO for controller adjustments in the GB power system as well as opening a new roadmap and direction for future R&D activities at the ESO, wider energy sector and academic community.

Scale of Project

The project spans 18 months with one project partner. The project consists of desk-based research, lab simulation, and workshops with the relevant NGESO and wider network teams.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL5 Pilot Scale

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

£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 GB power system is transforming into a lower inertia system and facing the decline in short circuit level. The ESO needs to ensure that the sophisticated methodologies and simulation models under consideration are accurate and robust before incorporating them into the decision-making when maintaining system stability. Inaccurate simulation model or inappropriate use of a model in the wrong time and region carries tremendous technical risk, as well as significant business risk if making incorrect judgments based on it. This project investigates the real-time simulation phasor-EMT models to utilise the advantages of both simulation modes to increase the stability and reducing the uncertainties involved in the modelling and stability studies.

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

The penetration of inverter-based resources and HVDC interconnections are rapidly growing into the GB power system in line with the integration of more renewable resources. Full implementation of the project could reduce the costs associated with the early-stage identification of control interaction issues, and proper parameter tuning, which results in a more secure and reliable system operation. It also helps identify the stability issues that may not have been identified using phasor mode-only models. The required grid reinforcement to solve the control interaction between inverter-based resources could cost hundreds of millions in the future if the correct technical measures are not introduced.

The project opens innovative research and development stages for future faster than real-time case studies and modelling standards for real-time operation. The conducted project would be applicable to all parts of the GB transmission system, and lessons learnt would provide a roadmap to ESO for the utilisation of real-time simulation technologies for research and development towards having a more secure and stable electricity network. It could also be applied to distribution system modelling.

The output of the project will also benefit the consumers by reducing risk of power disruptions. It allows the smooth transition towards decarbonised electricity network with more renewable sources and better planning, reaching the net zero target, as well as reducing the energy bills.

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

The method is applied to a part of GB power system and the success of this project can be extended to the whole GB grid, and the method replicable at all regions.

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

At this stage, it is too early to understand what the cost of roll out will look like.

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 knowledge gained has the potential to stimulate meaningful discussion for Transmission Owners on application of real-time simulation models, useful for early identification of problems using the right tools, and provide better decision-making during planning, control and operations.

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.

Given the emerging importance of EMT simulations, the project NIA_SHET_0035 builds the full-scale model of the GB Transmission System in EMT PSCAD simulation software. Also, the ESO originally developed a full-scale model of the GB transmission system in DIgSILENT PowerFactory, as an Offline Transmission Analysis tool. The project NIA_NGSO0007 used ePhasorsim solver of OPAL-RT Technologies as a part of their research on the modelling of fast frequency phenomena. Internationally, the Australian Energy market Operator (AEMO) is working towards implementing fast EMT power system simulation platform. AEMO is working with

vendors to improve the speed and capabilities of EMT simulation tools.

This project will consider the valuable learnings generated from the previous projects and international ongoing work related to EMT simulation, to provide real-time simulation studies for a part of GB power system. There will be regular communications and discussions with other teams to avoid duplication.

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 one of the early examples of real-time simulation of a part of GB power system in both phasor and EMT modes, in terms of being a new application of technology, as well as being the first time to test it on the GB power system. The transient stability assessment of GB power system will provide operators with the early identification of oscillatory interactions caused by the controllers and power electronics-based resources, as well as an understanding of the impact of controllers on transient stability of the grid. This project will generate insights and recommendations on using the right tool (EMT and phasor models) at the right time and region, ensuring more informed decision making based on more accurate simulation results.

Relevant Foreground IPR

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

- An ePHASORSIM-ready model of South Coast region for real-time applications and studies.
- Report on feasibility study of HIL-based experiments of ePHASORSIM model of South Coast power system.
- A HYPERSIM model of South Coast region suitable for real-time simulations.
- Report on feasibility study of HIL-based experiments of HYPERSIM model of South Coast power system.
- Real-time simulation model of the South Coast power system model in EMT and phasor modes
- WP4 report containing application of EMT and phasor models in real-time according to system conditions and roadmaps to ESO for real-time simulations platforms.

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 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 the ESO Data Portal https://data.nationalgrideso.com/
3. Via our Innovation website at https://www.nationalgrideso.com/future-energy/innovation
4. Via our managed mailbox 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.

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) 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 involves the study and testing of new technologies in part of the GB power system that, if successful, could be expanded to the whole grid. Delivering this project with the support of the NIA allows the ESO to disseminate the learnings from the project to the GB Network Licensees and wider industry.

This project has been approved by a senior member of staff

☑ Yes