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_NGESO035

Project Registration

Project Title

Practical Transition into wider EMT GB Modelling

Project Reference Number

NIA2_NGESO035

Project Licensee(s)

National Grid Electricity System Operator

Project Start

July 2023

Project Duration

1 year and 9 months

Nominated Project Contact(s)

Jay Ramachandran, Gopi Yericherla

Project Budget

£350,000.00

Summary

As the number of IBR sources in the GB system continues to rise, it becomes essential to conduct numerous Electromagnetic Transient (EMT) simulations across various scenarios and contingency cases to assess system stability. Consequently, there is an escalating demand for the development of the ability to perform multiple EMT analyses to facilitate broader network studies while keeping simulation times manageable and practical.

This project aims to develop innovative approaches for expediting simulation times required to execute the comprehensive GB EMT model. It will also offer technical insights to ascertain the imperative need for EMT simulations during critical system conditions.

Nominated Contact Email Address(es)

box.so.innovation@nationalgrid.com

Problem Being Solved

The conventional approach for large-scale power system stability studies involves Root Mean Square (RMS) simulation, which simplifies the system representation in the phasor domain. RMS simulations have historically provided reliable results, particularly in power systems primarily reliant on synchronous machine-based generation. However, the increasing integration of power electronic (PE) devices into the system is poised to bring substantial changes to system dynamics. These PE-based devices possess characteristics that may not be accurately captured through RMS analyses alone. The classical RMS model may fall short in precisely depicting the network's dynamic behaviour.

Therefore, the necessity arises for Electromagnetic Transient (EMT) analysis to comprehensively assess operational risks within the system, such as control interaction and sub-synchronous resonance issues, particularly with the high penetration of Inverter Based Resources (IBR). NGESO collaborates with Transmission Owners (TOs) in the TOTEM innovation project (NIA_SHET_0035) to develop an EMT model that represents the entire GB system.

The EMT simulations usually take a considerably longer time when compared with RMS simulations, even for simple networks. Currently, the developed full GB EMT model takes several hours to run 30 seconds of simulation in PSCAD. Also, with the increasing number of IBR sources in the GB system, EMT simulations must be carried out for many scenarios and several contingency cases to analyse system stability. There is an increasing need to develop a capability to carry out multiple EMT analyses for wider network studies with reduced and practical simulation time.

Method(s)

This project seeks to achieve two main objectives:

- Improve the efficiency of EMT simulations, with the overall objective of running the National Grid (England & Wales) Electricity network model in PSCAD to achieve practical run time.
  - Deliver enhanced GB EMT model with validation reports
  - Deliver supporting tools in PSCAD allowing for testing and review
- Produce technical guidance outlining scenarios where EMT simulations are necessary under system critical conditions.

These objectives will be achieved by breaking down the problem into smaller tasks. To achieve the first objective, some methods that will be investigated are:

- Improved network matrix solution methods to accelerate solution speed of network admittance matrix.
- Improve the efficiency of calculating Y matrix formulation
  - Parallel computing of submodules
  - Identify if complex control systems of generators and inverters contribute to simulation speed and investigate improvements.
  - Investigate if new methods can be adopted to partition the network matrix for parallel processing.
- Computationally efficient yet accurate representation of power electronic inverters models – average representation of switching devices
- Improved computer hardware and lower latency when exchanging information between processors.

These tasks are expected to significantly reduce the simulation time of full GB EMT model while maintaining the accuracy and quality of the results.

To produce the EMT scenarios technical guidance the following tasks can be done:

- Prepare the technical guidelines to determine when EMT simulations are necessary
- Perform the simulations and verify the guidelines based on both RMS and EMT simulation results (simulation performed on the GB network)

The project will be delivered in two work packages:

- WP1 - Research & Development to improve the efficiency of EMT simulations run time
- WP2 - Technical Guide to determine when EMT simulations are necessary

In line with the ENA's ENIP document, the risk rating is scored Low.
TRL Steps = 1 (2 TRL steps)
Cost = 1 (£350k)
Suppliers = 1 (1 supplier)
Data Assumptions = 2
Total = 5 (Low)

Scope

With Great Britain's (GB) power system moving towards net zero carbon operation, the number of inverter-based resources (IBR) is expected to increase. The amount of synchronous generation in the grid will decline, reduced system inertia and lower short circuit levels significantly changing the characteristics of the GB network. EMT simulation are particularly required for weak grid locations experience significant voltage variations, especially in phase angle, following system disturbances. Accurate measurement of phase angle changes through the Phase Locked Loop (PLL) is crucial for the grid-following inverter response. Inaccurate tracking by the PLL can result in poor fault recovery or unit tripping, violating grid codes.

Additionally, Voltage control is challenging in weak locations, particularly when multiple nearby inverter-based devices with fast reactive current control interact unstably, leading to various control interaction issues.

Conventional RMS analysis can no longer accurately identify system security risks during these conditions. Therefore, EMT analysis is required to conduct research to determine system operational risks with high penetration of IBRs.

EMT simulations take much longer than RMS simulations, even for simple networks. The currently developed full GB EMT model developed through a separate innovation project takes a few hours to run in PSCAD. Furthermore, with the increasing number of IBR sources in the GB system, EMT simulations must be carried out for many scenarios and several contingency cases to analyse system stability. There is an increasing need to develop a capability to carry out multiple EMT analyses, for a more comprehensive network, with reduced simulation time. Additionally, strategies must be developed to correctly identify scenarios requiring EMT analysis more than RMS analysis, as more effort is required for network modelling for EMT analysis.

The project will aim to enhance the GB network's EMT model by improving the models' computational efficiency, which will help the ESO investigate more scenarios with stability risks while transitioning into zero carbon operation. It will also provide technical guidance outlining scenarios where EMT simulations are necessary under critical system conditions.

Objective(s)

The project has two main objectives:

- Research and development will be performed to improve the efficiency of EMT simulations, with the overall objective of running the National Grid (England & Wales) Electricity network model in PSCAD to achieve practical run time.
- Produce technical guidance outlining scenarios where EMT simulations are necessary under critical system conditions.

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

Success Criteria:

- Developed methods to accelerate EMT simulation time, will be integrated on the full scale EMT GB network model. This will allow the ESO to “speed up” the process when performing simulations and improve the flexibility of performing transient studies.
- The ESO will have the ability to perform operation studies on the full EMT model of GB, without the need for expensive specialised hardware
- The framework and guidelines will significantly help to illustrate through practical and real examples the limitations of RMS vs EMT tools. That will benefit ESO in understanding which simulation tool to use for which purpose as the GB network transitions to a zero-carbon system.
- Provide actionable insight to improve EMT analysis efficiency and improve understanding of transient interactions and events that could be missed with current tools.
- Dissemination and training for learnings and methods developed in the project.

Project Partners and External Funding

Manitoba Hydro International (MHI) will be carrying out the work. No external funding required.

Potential for New Learning

- Applying different innovative methods to improve the efficiency of EMT simulations will enable extensive analysis with a feasible computational process time. This is currently limited to known and prioritised scenarios due to the massive computational time required per scenario.
- This project will allow for a significant understanding of practical and real examples of the limitation of RMS vs EMT tools and which simulation tool to use for which purpose as the GB network transitions to a zero-carbon system (with more complex stability issues becoming of concern in a decarbonised network).
- This project will also benefit the ESO activities in ensuring system stability in building on the learnings already gathered from other innovation projects in EMT modelling.

Scale of Project

The project spans 21 months with one project partner (i.e. MHI). The project consists of desk-based research and workshops with the relevant ESO teams.

Technology Readiness at Start

Technology Readiness at End

TRL5 Pilot Scale

TRL7 Inactive Commissioning

Geographical Area

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

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£350,000

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:

With increased penetration of IBR in the energy transition, more EMT analysis will be required for wider regions in the system. This project will support the ESO processes requiring more EMT analysis and help capture and provide insight into transient interactions and events that could be missed with the current tools. This will directly impact future constraint costs and customer connection processes.

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 project will enhance the GB network's EMT model by improving the models' computational efficiency, which will help investigate more scenarios with stability risks while transitioning to zero carbon operation. It will also provide technical guidance outlining scenarios where EMT simulations are necessary under critical system conditions.

The learnings from this project will also be beneficial to Transmission Owners (TOs) concerning the run time of their respective EMT networks. The TOs use the same EMT software package, and the developed tool should be able to integrate with their models seamlessly. Furthermore, the second phase of the innovation project will produce technical guideline outlining the scenarios for which EMT simulations are necessary under system-critical conditions for better-informed decisions.

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

The project will initially test its methods in England and Wales to validate their effectiveness. Once proven, these methods will be extended to the entire GB power system. This phased approach minimizes risks and aligns with the goal of improving EMT simulations across GB.

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

The estimated costs of implementing the enhanced EMT simulation methods across GB would primarily involve software integration, potential hardware upgrades, training, testing, and ongoing maintenance. While specific costs may vary, careful planning and cost-benefit analysis will be necessary to ensure the economic feasibility of these enhancements for the GB network. The estimated cost for the necessary software and hardware to run the system is £130,000.

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 learnings from this project can also be beneficial to TOs concerning the run time of their respective EMT networks. The TOs use the same EMT software package, and the developed tool should be able to integrate with their models seamlessly. Furthermore, the second phase of the innovation project will produce a technical guideline outlining the scenarios for which EMT simulations are necessary under system-critical conditions for better-informed decisions.

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.

- TOTEM: NIA project will deliver a validated full GB model – the proposed project will build on that model to provide the enhanced EMT algorithms and support the practical adoption of wider network EMT analysis.
- Co-Simulation: a NIA project led by NGET to deliver a platform to run both RMS and EMT simulations simultaneously. As the proposed project will increase the efficiency of the EMT simulation it will in turn improve the co-simulation outcomes. The proposed technical guidance work will identify the processes which can be delivered with accepted level of accuracy in RMS, EMT or co-simulated environment.
- DETECTS: a NIA project which provided GB South Coast stability analysis based on detailed EMT analysis – the proposed project can be used as a validation for the improved EMT algorithms that will be delivered in this project.

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 project is innovative because it addresses a critical and emerging challenge in the power system domain. As the energy landscape shifts towards net-zero carbon operation, there is a growing penetration of inverter-based resources (IBRs) and a decline in synchronous generation. This transformation fundamentally changes the characteristics of the power network, resulting in reduced system inertia, lower short-circuit levels, and an increased risk of oscillations and control interactions. Conventional RMS simulations, historically reliable for synchronous machine-based generation, may no longer accurately identify system security risks under these new conditions.

To address this gap, the project introduces EMT analysis, which is a more time-consuming but essential approach to evaluate operational risks with high IBR penetration. The innovation lies in improving the computational efficiency of EMT simulations, enabling practical and rapid analyses of the entire GB power system. Additionally, the project aims to provide technical guidance to pinpoint scenarios necessitating EMT simulations under critical system conditions. This project bridges a crucial gap in power system analysis as it adapts to the evolving energy landscape, making it a pioneering initiative in the field. Moreover, the project builds upon the foundation laid by the TOTEM project, which has enabled the full simulation of the entire GB system, enhancing the robustness and comprehensiveness of the proposed innovations.

Relevant Foreground IPR

1. Enhanced full GB EMT model
2. Supporting tool in PSCAD for testing and review the model
3. Technical guidance outlining scenarios where EMT simulations are necessary under system critical 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 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
3. Via the ESO Data Portal at https://data.nationalgrideso.com/
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 is in the complex and new area of EMT analysis for wider networks. The methods to be tested are novel and have yet to be trialled on real networks or other commercial tools. Additionally, there are potential risks associated with the uncertainty of the performance enhancement level that would be achieved by the end of the project and how practical the simulation run time will be for the operational planning. The impact of alternative models on the accuracy of the analysis needs to be tested and evaluated before integration into the whole model.

This project has been approved by a senior member of staff

☑ Yes