NIA Project Annual Progress Report Document

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Date of Submission

Jul 2024

Project Reference Number

NIA2_NGESO035

Project Progress

Project Title

Practical Transition into wider EMT GB Modelling

Project Reference Number

NIA2_NGESO035

Project Start Date

July 2023

Project Duration

1 year and 9 months

Nominated Project Contact(s)

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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.

Objectives

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.

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.

Performance Compared to the Original Project Aims, Objectives and Success Criteria

National Grid Electricity System Operator (“NGESO”) has endeavoured to prepare the published report (“Report”) in respect of the Practical Transition into Wider EMT GB Modelling NIA2_NGESO035 (“Project”) in a manner which is, as far as possible, objective, using information collected and compiled by NG and its Project partners (“Publishers”). Any intellectual property rights developed in the course of the Project and used in the Report shall be owned by the Publishers (as agreed between NG and the Project partners).

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Project Summary

The project aims to improve the efficiency and applicability of Electromagnetic Transient (EMT) simulations for analyzing the dynamic behavior of the GB power system, especially under high penetration of Inverter Based Resources (IBRs). As traditional Root Mean Square (RMS) simulations become insufficient in capturing the nuances of systems dominated by power electronics, this project focuses on developing an enhanced EMT model of the GB network to address these challenges. The project is divided into two main objectives: enhancing EMT simulation efficiency and producing technical guidance for scenarios necessitating EMT analysis.

Work Package Overview

The project is being delivered in two work packages:

- **WP1: Research & Development to Improve EMT Simulation Run Time**
- **WP2: Technical Guide to Determine When EMT Simulations Are Necessary**

Objectives and Achievements:

- Improving Simulation Efficiency: The primary objective is to reduce the run time of EMT simulations for the National Grid (England & Wales) electricity network model in PSCAD (Power Systems Computer-Aided Design)
- Enhanced GB EMT Model: Developed an improved model with validation reports and supporting tools for efficient testing and review.

Key Measures Implemented:

- Identification of Bottlenecks: Conducted extensive analysis to identify specific PSCAD cases requiring substantial computational resources. The network associated with these cases was divided to enhance parallelization.
- Optimization Techniques: Reduced the tolerance for converting small resistances into ideal branches in PSCAD, and disabled runtime debugging information to eliminate slow performance caused by static ideal elements.

- Parallel Processing: Investigated innovative methods for partitioning the network matrix to facilitate parallel processing in Electromagnetic Transients including DC (EMTDC), PSCAD's backend simulation engine.

Progress and Results:

- Successfully divided complex network cases to optimize simulation times.
- Implemented key measures leading to significant performance improvements.
- Delivered an optimized E&W PSCAD network model to the ESO, which successfully ran a 30-second simulation within a 20-minute timeframe.
- Currently integrating IBR generic models into the E&W network to evaluate performance under the new configurations.

Outcomes:

- Enhanced Performance: Achieved practical run time targets for the E&W network model in PSCAD through parallel computing techniques and algorithm optimization.
- Optimized EMT Methods: Incorporated improved methods into the EMTDC back-end, allowing for efficient full-scale model simulations.

WP2: Technical Guide to Determine When EMT Simulations Are Necessary
Objectives:

- Technical Guidance: Develop guidelines to determine when EMT simulations are required under critical system conditions.
- Scenario Verification: Perform simulations and verify guidelines based on both RMS and EMT results on the GB network.

Planned Tasks:

- Preparation of Guidelines: Outline scenarios necessitating EMT simulations.
Simulation and Verification: Conduct simulations to verify the technical guidance and ensure accuracy.
- Conclusion and Next Steps

Work Completed to Date:

- Successfully completed WP1, enhancing the efficiency of EMT simulations and developing an optimized E&W network model.
- Implemented significant measures to improve simulation run times and validated the model with initial tests.
- Integrated parallel processing techniques to facilitate more efficient EMT simulations.

Next Steps:

- Complete the integration of IBR models into the E&W network and evaluate performance.
- Develop and finalize the technical guidance in WP2, outlining scenarios where EMT simulations are necessary.
- Continue to improve simulation techniques and incorporate advancements in High-Performance Computing (HPC) to support practical run times for large system studies.

Overall Progress: The project is on track to achieve its aims, supporting ESO's transition to a zero-carbon energy system and enhancing the capability to conduct efficient operational studies. Through innovative methods and advanced computing techniques, the project will provide valuable insights and tools for future power system stability analyses.

Required Modifications to the Planned Approach During the Course of the Project

No modifications required to the planned approach.

Lessons Learnt for Future Projects

The lessons learnt at this stage are:

- Different methods in PSCAD to improve the efficiency of EMT simulations will enable extensive analysis with a feasible computational process time.
- Leveraging parallel computing techniques has significantly improved efficiency, which is a valuable lesson for future projects

Note: The following sections are only required for those projects which have been completed since 1st April 2013, or since the

previous Project Progress information was reported.

The Outcomes of the Project

A major outcome has been the successful reduction in EMT simulation run times through parallel computing techniques and algorithm optimization, meeting the practical run time targets for the E&W network model in PSCAD.
Improved EMT methods have been incorporated into the EMTDC back-end, allowing the full-scale model to run more efficiently. This integration enables flexible transient studies without the need for specialized hardware.
While the project is ongoing, the goal is to ensure the model can run in practical times, making large system studies a norm for engineers. All the methods applied here, combined with advancements in High-Performance Computing (HPC), will help run the model in practical run times. Once the model supports significant amounts of IBRs adhering to UK Grid codes, the project will focus on producing technical guidance outlining scenarios where EMT simulations are necessary under critical system conditions.
Overall, the project is on track to achieve its aims, supporting ESO's transition to a zero-carbon energy system and enhancing the capability to conduct efficient operational studies.

Data Access

Details on how network or consumption data arising in the course of NIA funded projects can be requested by interested

Foreground IPR

The following is expected to be generated:

- Optimisation techniques and an optimised PSCAD Network model