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.
Network Licensees must publish the required Project Progress information on the Smarter Networks Portal by 31st July 2014 and each year thereafter. The Network Licensee(s) must publish Project Progress information for each NIA Project that has developed new learning in the preceding relevant year.

NIA Project Close Down Report Document

Date of Submission

Jun 2025

Project Reference Number

NIA2_NGESO045

Project Progress

Project Title

RealSim: Real-Time Phasor-EMT Simulations

Project Reference Number

NIA2_NGESO045

Project Start Date

June 2023

Project Duration

1 year and 6 months

Nominated Project Contact(s)

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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.

Objectives

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

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

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

Establishing ePHASORSIM and HYPERSIM models of the South Coast power system:
Initial Focus: The project originally targeted the creation of a hybrid RMS-EMT co-simulation framework using the South Coast segment of the GB power system from NESO's PowerFactory model. The plan was to convert this into an ePHASORSIM RMS-compatible model and subsequently develop an EMT equivalent in HYPERSIM. This approach aimed to utilise the strengths of RMS simulations for assessing overall system behaviour while employing EMT simulations for detailed transient dynamics analysis. However, the development of an ePHASORSIM RMS model was not pursued due to the presence of NESO’s commercially sensitive data in PowerFactory, which posed potential delays if such data needed complete removal.
New approach and what was done: The research team began by evaluating the integration capabilities of PowerFactory with other simulation tools. The PSCAD model was derived from the PowerFactory model, ensuring that commercially sensitive data was removed in the process. Since PSCAD is not compatible with ePHASORSIM, the team focused on high-fidelity modelling using the PSCAD model as a basis. They converted it from the equivalent PowerFactory RMS model representation into an EMT analysis-compatible model suitable for HYPERSIM. This process involved adding detailed plant models and control system architectures for Type 3 and Type 4 wind farms, as well as HVDC links, to accurately capture the fast-switching dynamics of these inverter-based resources (IBRs), enabling both EMT and real-time analysis to be conducted. Overall, this approach provided enhanced accuracy for transient phenomena, which is essential for analysing dynamic interactions within the power system.
Outcome: Even though an ePHASORSIM model was not pursued, the project successfully developed and validated detailed EMT models using HYPERSIM, including components such as Type 3 and Type 4 wind farms, which required precise parameterisation and validation against known benchmarks. HVDC links were also included, with models carefully calibrated to reflect real-world operational behaviours under various scenarios
Real-time transient stability assessment of ePHASORSIM and HYPERSIM models:
Approach: The project conducted real-time transient stability assessments using HYPERSIM, focusing on EMT-based analysis. The research team set up simulations to run in real-time, mimicking the operational conditions of the South Coast power system. This approach allowed for the observation of immediate system responses to dynamic events, particularly the loss of interconnector links and the impact on frequency response in the region. Although the project did not use ePHASORSIM, due to reasons earlier discussed, the use of HYPERSIM provided valuable insights into dynamic interactions and stability issues.

Insights Gained: The project yielded critical insights into the transient behaviour of inverter-based resources (IBRs), particularly how they respond to rapid changes in the system. The project also examined the impact of interconnector tripping on frequency stability, revealing how such events could affect the broader network. Additionally, the study of commutation failures in HVDC systems highlighted areas where system design could be improved to enhance stability, demonstrating the value of EMT analysis in understanding complex dynamic phenomena.

A framework to identify when and where each phasor and EMT simulation tools should be used:

Framework Development: Despite moving away from RMS integration, the project developed guidelines for creating RMS-EMT co-simulation frameworks. This involved a detailed analysis of the capabilities and limitations of RMS and EMT simulations. The project proposed scenarios and conditions under which each type of simulation would be most effective, considering factors like the level of detail required and the specific stability concerns being addressed. The framework aimed to guide the application of real-time and faster-than-real-time simulations, providing a structured approach for selecting the appropriate tool based on the analysis needs.

Guidelines and Suggestions: The project outlined criteria for when to prefer EMT simulations over phasor simulations, particularly for stability analysis. This included evaluating the complexity of the system dynamics involved and the importance of capturing transient phenomena in detail. These guidelines support future operational decision-making by providing a reference for selecting the most suitable simulation approach for different scenarios.

Overall Evaluation:

The RealSim project successfully adapted its focus to EMT-based analysis, achieving significant insights and model validations aligned with its objectives.

The decision not to use ePHASORSIM was due to the potential delays associated with removing NESO's commercially sensitive data from RMS models. Instead, the project effectively leveraged HYPERSIM and PSCAD for comprehensive EMT analysis, providing a robust foundation for understanding system stability.

The project contributed valuable understanding of transient stability in the South East Coast network and established groundwork for future simulation frameworks.

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

The RealSim project was designed to investigate the application of real time EMT simulations for GB grid. It developed a high-fidelity EMT model for a key region of the GB grid — the South East Coast — and investigated how these models could be integrated with RMS simulations for comprehensive stability analysis. The original project scope included developing a hybrid RMS-EMT co-simulation framework using a PowerFactory model. However, later the project was adjusted to focus entirely on EMT-based analysis using PSCAD and HYPERSIM platforms.

Despite this change in scope, the RealSim project achieved success in building and validating detailed EMT models of Type 3 and Type 4 wind farms, LCC and VSC HVDC links, and their dynamic interactions within the South East Coast network. The project provided valuable insights into the transient behaviour of IBRs, the impact of interconnector tripping on frequency stability, and the challenges of commutation failures in HVDC systems. The project also provided suggestions for RMS-EMT co-simulation and proposed guidelines for the future use of real-time and faster-than-real-time simulations to support operational decision-making.

Lessons Learnt for Future Projects

Platform Validation and Benchmarking: The project identified discrepancies between offline PSCAD and real-time simulations, particularly for complex components like wind farms and HVDC links. This underscores the importance of platform validation and the need for standardized benchmarking practices to ensure consistent and reliable simulation results across different platforms.

Hybrid Simulation Framework: Developing a hybrid simulation framework that combines RMS and EMT models can provide a comprehensive approach to grid stability analysis. This framework would enable a more detailed understanding of both system-wide and local dynamic behaviours under normal and faulted conditions

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Advanced Control Strategies for IBRs: Future research should focus on advancing control strategies for inverter-based resources (IBRs), such as synthetic inertia and grid-forming inverter technology. These approaches could help stabilize frequency in low-inertia conditions and provide enhanced system resilience

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

Frequency Stability in Low-Inertia Systems: Maintaining frequency stability in low-inertia grids is a critical challenge. The project demonstrated that droop-based frequency support from wind farms and VSC-HVDC links can significantly improve frequency recovery rates and reduce the severity of frequency nadirs. However, the effectiveness of these ancillary services depends on the tuning of control parameters and the speed of response from inverters and HVDC converters

Commutation Failures in LCC-HVDC Systems: The vulnerability of LCC-HVDC systems to commutation failures during AC-side faults was highlighted. Coordinated control strategies between LCC and VSC converters can improve fault recovery and prevent cascading failures. Enhanced fault-ride-through capabilities in LCC-HVDC systems are essential for grid stability during disturbances

Platform Performance and Scalability: HYPERSIM showed faster execution speed compared to PSCAD, but PSCAD retained an edge in precision for detailed component-level analysis. Scalability remains a challenge for both platforms, particularly when simulating large-scale systems with microsecond-level time steps. Parallel processing techniques and modular hardware configurations were identified as potential solutions to this challenge

Intellectual Property Details

1. Conversion Methodology

Description:
The project developed a unique methodology for converting models from PowerFactory to PSCAD and subsequently to HYPERSIM. This process involved ensuring the removal of commercially sensitive data while maintaining high fidelity in simulations.
Key Features:
Efficient removal of sensitive data during conversion.
Maintenance of model integrity and fidelity throughout the conversion process.
Enhanced interoperability between different simulation platforms.
Potential Applications:
Can be applied in other projects requiring model conversion between different simulation tools.
Useful for NESO looking to protect sensitive data while conducting detailed simulations.

2. Insights into Inverter-Based Resources and HVDC System Impacts

Description:
The project provided significant insights into the transient behaviour of inverter-based resources (IBRs) and the impact of HVDC links on system stability. These insights contribute to a deeper understanding of dynamic interactions and stability issues.
Key Findings:
Identification of critical transient behaviours in IBRs.
Analysis of the impact of HVDC system commutation failures on frequency stability.
Detailed understanding of interconnector tripping effects.
Potential Applications:
Informing future research and development in power system stability.
Enhancing operational decision-making processes.
Consideration for using these insights to develop new analysis techniques or tools.

Conclusion

The project has successfully generated valuable intellectual property that can contribute to advancements in power system modelling and analysis. We can evaluate potential collaborations or partnerships to further develop the IP

Data Access

Details on how network or consumption data arising in the course of NIA funded projects can be requested by interested parties, and the terms on which such data will be made available by NESO can be found in our publicly available “Data sharing policy related to NIA projects (and formerly NIC)” and Innovation | National Energy System Operator.

National Energy System Operator already publishes much of the data arising from our NIA projects at www.smarternetworks.org. You may wish to check this website before making an application under this policy, in case the data which you are seeking has already been published.

Foreground IPR

This section summarises the intellectual property generated because of the project.

Intellectual Property Summary

Conversion Methodology: The project developed a unique methodology for converting models from PowerFactory to PSCAD and HYPERSIM. This methodology is applicable to projects needing model conversion while safeguarding sensitive data during detailed simulations.
Insight into Inverter-Based Resource (IBR) operation: The project identified critical transient behaviours and analysed commutation failures and interconnector tripping effects. These findings can inform future research, enhance operational decision-making, and aid in developing new analysis techniques or tools.

For more details, please access the final report on the Smarter Networks Portal.

Planned Implementation

Planned Implementation: The project focused on developing detailed EMT models of the South-East Coast power system using PSCAD and HYPERSIM platforms. These models included Type 3 and Type 4 wind farms, LCC and VSC HVDC links, and their dynamic interactions within the network. The integration process involved resolving compatibility issues, tuning control parameters, and ensuring consistent behaviour between the two platforms. Real-time simulations were conducted under various fault and contingency scenarios to provide critical insights into the transient behaviour of the network.

Recommendations: The work provided several recommendations to enhance NESO's simulation and modelling capabilities:
Establish a structured framework for simulation use, clearly defining the appropriate applications of RMS and EMT models.
Improve computational capacity through parallel processing techniques and modular hardware configurations to support larger and more complex EMT models.
Develop faster-than-real-time (FTRT) simulations to enable predictive grid management and enhance contingency planning.
Establish standardized validation protocols to ensure consistent and reliable simulation results across platforms.
Advance control strategies for IBRs, including synthetic inertia and grid-forming inverter technology.

Next Steps: The work outlined several next steps for NESO:
Implement the recommendations to strengthen simulation infrastructure and improve model accuracy.
Develop a hybrid simulation framework to combine RMS and EMT models for comprehensive grid stability analysis.
Explore the potential for FTRT simulations to enable predictive grid management.
Investigate advanced control strategies for IBRs and HVDC links.

By following these recommendations and next steps, NESO can enhance its ability to manage the complexities of a renewable-dominated grid and improve grid resilience.

Net Benefit Statement

The RealSim project introduced the potential of real-time EMT simulations for modelling and stability analysis of the GB power system. The project explored the feasibility and benefits of using real-time EMT simulations to enhance grid stability as the system transitions to a renewable-dominated future.

Through its work packages, RealSim demonstrated the advantages of real-time EMT simulation in capturing fast system dynamics, assessing stability risks, and improving operational decision-making. The findings provide a foundation for future developments in real-time simulations, helping NESO strengthen its modelling capabilities and ensure a secure and resilient power system.

Key Benefits:

Enhanced Grid Stability: Real-time EMT simulations offer a detailed understanding of fast system dynamics, crucial for maintaining

stability in a low-inertia, renewable-dominated environment. By improving the control design of inverter-based resources (IBRs), the project increased flexibility capacity, measurable in megawatts (MW). This enhancement ensures a robust inertial response from remaining IBRs following the loss of a large IBR, contributing to overall grid stability. The increased flexibility allows for better management of grid dynamics, reducing the need for additional reserve and frequency response services, thereby avoiding associated operational costs.
Improved Operational Decision-Making: The ability to capture transient behaviours and assess stability risks in real-time enables operators to make more informed decisions, enhancing the overall reliability of the power system.
Reduction in Greenhouse Gas Emissions: By maximising the use of existing IBRs for inertial response, the project contributes to reducing greenhouse gas (GHG) emissions, supporting a transition to a cleaner, more sustainable power system. The adoption of innovative measures and technologies leads to an overall reduction in carbon emissions, aiding in meeting environmental targets and resulting in avoided costs associated with carbon emissions.
Advanced Modelling Techniques: The project highlighted the need for advanced modelling techniques, hybrid simulation frameworks, and real-time analysis tools to support the evolving power grid.
Foundation for Future Developments: The insights gained from the RealSim project provide a strong foundation for future developments in real-time simulations, helping NESO strengthen its modelling capabilities and ensure a secure and resilient power system.

By improving the inertial response and flexibility of the power system, the project helps avoid operational costs related to reserve and frequency response purchases, resulting in direct financial savings for NESO. Implementing these benefits allows NESO to better manage the complexities of a renewable-dominated grid and improve grid resilience.

Other Comments

The Project outcomes and results contain confidential information and intellectual property rights that cannot be disclosed in this Report due to their proprietary nature. Should the viewer of this Report ("Viewer") require further details this may be provided on a case by case basis following consultation of all Publishers. In the event such further information is provided each and any Publisher that owns such confidential information or intellectual property rights shall be entitled to request the Viewer enter into terms that govern the sharing of such confidential information and/ or intellectual property rights including where appropriate formal licence terms or confidentiality provisions. Dependent upon the nature of such request the Publishers may be entitled to request a fee from the Viewer in respect of such confidential information or intellectual property rights.

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