NIA Project Annual Progress Report Document

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Date of Submission

Jul 2024

Project Reference Number

NIA2_NGESO050

Project Progress

Project Title

Enhanced RMS (e-RMS) models for stability assurance

Project Reference Number

NIA2_NGESO050

Project Start Date

October 2023

Project Duration

1 year and 10 months

Nominated Project Contact(s)

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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.

Objectives

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.

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

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 Enhanced RMS (e-RMS) models for stability assurance NIA2_NGESO050("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 ongoing project aims to mitigate the instability threats posed by high fractions of inverter-based resources (IBRs) in the power grid. Traditional RMS models and EMT simulations fall short in predicting these stability issues, necessitating conservative operational measures like wind curtailment and limiting interconnector flows. The project's objective is to develop an enhanced RMS (e-RMS) modeling framework that provides dynamic stability assurance during planning and operational timescales, without the need for such conservatism. This is achieved by creating a digital twin of IBRs within the e-RMS model, capable of providing early warnings of instability and identifying their root causes for effective intervention and mitigation.

The project has been divided into five key work packages:

- Work Package 1: Development of EMT Simulation Model
- Work Package 2: Development of e-RMS Model
- Work Package 3: Modelling Adequacy Studies
- Work Package 4: Event Response Replication
- Work Package 5: Root Cause Validation and Mitigation

As part of the ongoing work, there are three key activities:
An advanced 'GB-like' test system is being developed as a benchmark to replicate the behavior of the real GB power system. This system is a 36-bus reduced equivalent of the GB system, as published on the ESO website, with all synchronous generators (SGs) substituted by inverter-based resources (IBRs). A generic model of an aggregated IBR is connected at each bus (zone). For small-signal studies in the sub-synchronous oscillation (SSO) frequency range, necessary simplifications such as a stiff DC link are incorporated. The system considers various mixes and distributions of grid-following (GFL) and grid-forming (GFM) inverters. Simultaneously, the potential of utilizing the network in northern Scotland is being explored. This approach is based on network data from the Electricity Ten Year Statement (ETYS) and generation and demand data from actual scenarios where SSO was observed in Scotland during the summer of 2023. ESO's modeling team is providing a set of power flow cases for this purpose.
A closed-loop system identification method is being developed to estimate the parameters of each IBR based on their perturbed reference inputs and outputs at the network connection points. The study examines the effectiveness of various perturbation signals and the appropriate model order selection for both GFL and GFM inverters to enhance estimation accuracy. These estimated IBR models, combined with the known network model, will form the overall state-space model of the power system, enabling the analysis of SSO problems and identification of their root causes.
The role of network dynamics in RMS studies of SSO in an IBR-dominated power system is being investigated. Initial findings indicate that neglecting network dynamics in RMS simulations (as done in most commercial RMS tools) can lead to misleading SSO analysis, particularly in the presence of GFMs. Although the issue is less pronounced with GFL inverters, it still exists. Therefore, it is crucial to consider network dynamics in RMS studies of SSO in an IBR-dominated power system to ensure accurate analysis.

Next Steps:

- **Implementation in DIgSILENT PowerFactory:** Integrating the e-RMS modeling framework with real-world data for comprehensive stability studies on the GB-master model.
- **IBR Digital Twins:** Incorporating real-time measurements from operational IBRs to enhance the accuracy and responsiveness of the digital twins.

Conclusion: Significant progress has been made in developing and validating the e-RMS model framework. The EMT simulation model serves as a robust benchmark, and ongoing studies are fine-tuning the parameters and dynamics within the e-RMS framework. Upcoming phases will focus on real-world implementation, integrating real-time data, and ensuring practical applicability of the developed models. This project promises to mitigate unforeseen instabilities, thereby accommodating higher fractions of renewables without compromising supply security, which is crucial for the net-zero transition.

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

The 'GB-like' test case utilised in this project may transition from the 36-bus reduced equivalent to a North Scotland test system, which more accurately reflects real-world SSO issues. This adjustment is contingent upon the availability of necessary information from the ESO modeling team.

Lessons Learnt for Future Projects

The lessons learnt at this stage include:

- Choosing a suitable reduced model;
- Ensuring the availability of required data can reflect the real issues on the GB network.

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

The outcomes at this stage include: #

- Developing a ‘GB-like’ test case for EMT benchmark
- EMT modelling of IBR-dominated power systems
- Studying IBR model parameterisation
- Modelling adequacy – role of network dynamics
- Studying the feasibility of the root cause using participation factor

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 National Grid can be found in our publicly available “Data sharing policy related to NIC/NIA projects” and www.nationalgrideso.com/innovation.

National Grid Electricity System Operator already publishes much of the data arising from our NIC/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

The following is expected to be generated:

- The methodology for developing a ‘GB-like’ test case for EMT benchmarking