NIA Project Annual Progress Report Document

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Date of Submission

Jul 2024

Project Reference Number

NIA2_NGESO018

Project Progress

Project Title

Automated Identification of Sub-Synchronous Oscillations (SSO) Events

Project Reference Number

NIA2_NGESO018

Funding Licensee(s)

NG ESO - National Grid ESO

Project Start Date

September 2022

Project Duration

1 year and 7 months

Nominated Project Contact(s)

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Scope

New transmission network connections are checked for Sub-synchronous Oscillations (SSO) based on a few future network conditions. Due to the inherent uncertainties in the network and forthcoming reinforcements, scenarios other than those currently considered could materialise. These uncertainties, and the possibility of more frequent controller interactions, are due to the changing nature of the future system with a more significant proportion of converter interfaced generation (of different technology types) coupled with declining short circuit level.

As the SSO identification requires Electromagnetic Transient (EMT) analysis, which is very time-consuming, there is a need to develop an analytical framework that will allow screening of scenarios without running EMT simulations and reduce the total number of scenarios that need to be investigated further. This will ensure that EMT simulations are used only for scenarios of potential concern, and system engineers can focus on root cause analysis. Due to the volume of studies, the process' complexity and the amount of data generated, it is crucial to automat this process as much as possible.

Objectives

The project aims to apply a few advanced techniques borrowed from mathematics, statistics, and machine learning to solve the complex problem of identifying and managing SSOs in future power systems. The project will aim to deliver the following objectives:

- A primary objective of this project is to represent the black box models by a grey box approach which will allow for the identification of state variables which participate and contribute to the poorly damped oscillations. This is crucial to facilitate root cause analysis of controller interaction events.
- Develop a methodology to filter from an extensive a pool of scenarios with the possibility of SSO events based on impedance scans techniques.
- Develop a tool combining automation and machine learning techniques to run EMT simulations unattended and to identify SSO events automatically.
- Provide study cases to evaluate the performance and accuracy of the tools by testing historical event data or synthetic data created by simulation.

Success Criteria

- A framework to reduce the overall time and effort required to investigate a wide range of scenarios for potential SSO threats arising from new transmission connections.
- The ability to incorporate different sources of uncertainty in the scenario analysis.
- An approach for root cause analysis of SSO events in networks with proprietary controllers.
- An automated SSO identification process using time-domain results from PSCAD.
- Dissemination and training for the learnings and tools 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 Automated Identification of Sub-Synchronous Oscillations (SSO) Events, NIA2_NGESO018 ("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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The project will be delivered in four work packages. At this stage of the project WP1, WP2 and WP3 have been delivered. The scope of WP1, WP2 and WP3 tasks are shown below:

WP1 - Review of methods
Assess strengths and weaknesses of existing frequency domain analysis techniques including implementation challenges and compatibility with large practical networks.
Develop novel methodologies for frequency domain analysis of controller interactions specifically focusing on approaches to deal with proprietary black box models. Explore different screening approaches for priority ranking of critical uncertain parameters.
Compare machine learning techniques to find a suitable classification algorithm for the automated identification of SSO events from time domain simulation results.
Review existing (time-domain) modelling tools for operational stability margin, inputs and assumptions for controller interaction studies and the associated business processes (engagement with ESO/NGET subject matter experts)
Review learning from other ESO and industry innovation projects

WP2 - Development and testing of methods
Define appropriate case studies and test networks (and operational scenarios) to test the performance of the developed methods of frequency scanning, uncertainty sensitivities and classification of SSO scenarios.
Develop and trial the most promising methods from WP1 on test networks in PSCAD, explore sensitivity and automation techniques to reduce computational resource. Algorithms will be implemented in Python and linked to PSCAD.
Compare and verify the method results e.g., based on available measurements of events or published results from other research and networks events

WP3 – SSO Tool Demonstration
Adapt the automation code for a ESO submitted network model (South East coast) with no User EMT models.
Test the performance of SSO tool including grey box approach on the South East coast network with proprietary models
Demonstrate SSO tool performance in Cigre Benchmark test system
Validate and compare the performance of SSO tool (Beta version) with another scan tool from MHI

In WP1, a literature review report was delivered, including collecting all documented SSO events from around the world that are publicly available. Also, in WP1, a comparison between classification techniques was undertaken and the most promising classifier in terms of performance measures was selected and further developed to classify SSO events from synthetic data.
In WP2, a Cigre Benchmark test system was acquired from the relevant Cigre working group and migrated from MATLAB Simulink into PSCAD. The modelled SSO events were validated and compared to the published Cigre data from the MATLAB benchmark

system. A frequency scan tool was developed in PSCAD and tested in the Cigre Benchmark. The Grey Box technique was developed in python and incorporated in the main tool. A PSCAD automation module is developed in Python to interface with the PSCAD API. This automation module enables users to define several operational scenarios through the interactive user interface and apply the changes to the network model in PSCAD.
In WP3, the SSO tool was adapted for proprietary models on South East Coast (SEC) network. Grey box method was tested on the network with multiple proprietary models nearby. The Beta version of the SSO tool was submitted to ESO for validation and testing on ESO network models. First, the performance of the SSO tool was validated in a network with known resonant frequency. The SSO tool was then compared with another frequency scan tool from Manitoba Hydro International (developer of PSCAD) to validate performance on other networks and models. Lastly, the SSO tool was tested in the ESO SEC network. The installation details and steps required to use the front end of the SSO tool was described in WP3 report along with validation and compariosn results. A WP3 workshop was conducted to showcase the highlights and work done so far.

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:

- To ensure the availability of required measurement data or the possibility of generating synthetic data that can accurately reflect the field measurements
- The availability of the test systems in the required tools and format
- The ongoing testing in the ESO systems of the tools while being developed allowed for the early identification of any IT requirements issues, which will facilitate the final delivery and handover of the tools by the end of the project

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

WP1 report covers the theoretical background of the SSO phenomena and a literature review for all documented cases recorded.

WP2 report covers the developed tools and the user guidance of how to use them.

The Beta versions of the SSO classification tool, the impedance scan tool and the Grey Box implementation tool were delivered and tested. A workshop was delivered to the ESO, and user feedback was collected and will be incorporated in the further development of the tools under WP3 and WP4.

Also, for the wider dissemination purposes, a synopsis was submitted for Cigre Paris Session 2024.

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

Extended literature review report including all documented SSO events worldwide
A python-based tool automating the PSCAD scenario creation and simulation. The current version of the tool includes:

- Frequency scan screening tool
- Grey box implementation
- Multi scenario runs results visualization