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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

Jul 2022

Project Reference Number

NIA_NGSO0031

Project Progress

Project Title

DETECTS - Developing Enhanced Techniques to Evaluate Converter-dominated Transmission System Operability

Project Reference Number

NIA_NGSO0031

Funding Licensee(s)

NG ESO - National Grid ESO

Project Start Date

May 2020

Project Duration

1 year and 1 month

Nominated Project Contact(s)

Djaved Rostom

Scope

The work is to comprise:

1. Obtaining suitable high-fidelity models of converters in the area of interest and integrating these into a suitable advanced model for stability simulations. Drawing conclusions regarding the implications for future grid security and grid modelling.
2. Providing “guidance notes” for ESO on the use of advanced models and techniques for conducting detailed stability analysis.
3. Investigating tools that would give “early warning” of situations on the grid where advanced modelling techniques and detailed analysis might be required to ensure stability.
4. Investigating whether the representation of grid demand needs to be upgraded.

Objectives

- Validating the conclusions of NIA_NGET0187 regarding grid stability.
- Research into practical tools for the application of advanced grid modelling for system operations.

Success Criteria

- A report on the stability of the part of the grid examined, including lessons learnt in obtaining high-fidelity (“black box”) models of converters.
- A report providing guidance on the practical use of advanced grid models.
- Reports describing research into tools to help identify situations where advanced stability models and more detailed analyses are

needed, and research into the representation of grid demand.

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

Project Overview

The project is a continuation of a previous NIA Project titled "Transient Voltage Stability of Inverter Dominated Grids and Options to Improve Stability" (NIA_NGET0187) which identified that under the high penetration of converter-based generation, the transmission system may be subject to forms of system instability which cannot be accurately detected using traditional RMS (Root Mean Square) dynamic simulations and that more detailed Electromagnetic Transient (EMT) studies are instead required. The reports from this project can be found here.
This project set out to get a better understanding of the scenarios where EMT studies would be required, the best practices for setting up and conducting such studies and the modelling considerations that need to be made. As EMT studies are computationally intensive and require a long run times, the project also sought to understand whether alternative techniques can be adopted instead of the EMT studies. Finally as the previous project was based on generic EMT models of converters and implemented a high-level presentation of the network, it was deemed useful to repeat the previous analyses using actual manufacturer EMT models and a more detailed representation of the network in order to verify whether the previous conclusions were valid.

Project Plan

The project was split into 4 work packages:

Work Package 1 (WP1)

- Provision of manufacturer models for converters on South East Coast (or similar converters elsewhere) - May 2020
- Report into stability of the South East Coast. Studies to use available manufacturers' model and also generic models which (where possible) have been validated using manufacturers' models -Sept 2020

Work Package 1B

Update of report into the stability of the South East Coast, with the addition of all manufacturer's models that have subsequently become available -March 2021

Work Package 2 (WP2)

- A set of guidance notes for use by ESO employees seeking to identify scenarios at risk of inverter instability and a report describing the studies that were undertaken to support the guidance provided - Feb 2021

Work Package 3 (WP3)

- A report comparing alternative techniques for providing a warning of inverter instability without needing to use EMT simulation. Interim report - Dec 2020, Final report - March 2021

Work Package 4 (WP4)

- A report comparing the impact on the South East Coast's stability of active and passive demand models, along with recommendations on the demand model that should be used. Interim report Oct 2020, Final report: Jan 2021

The project was officially started in July 2020.NGESO already has access to most EMT models required for the project, however obtaining the necessary approval from relevant manufacturers to share these models with a third-party consultancy i.e. Power Nova proved to be more complex than anticipated. Substantial progress has been made after lengthy negotiations with providers for the provisions of manufacturer models. NGESO have managed to share most of the necessary models apart from the 1 DIFG wind turbine, 1 OFTO statcom and 1 full converter models. Workaround models were developed and tested to make sure they are fit for the purpose of this study. At of end of May 2022, all 4 WPs have been completed by PowerNova.

Project Activities

Work Package 1 (WP1)

The first step was to seek actual manufacturer black box EMT models. As mentioned above, EMT models for relevant interconnectors and Transmission Owner (TO) STATCOMs in the South East Coast were already available to NGESO. However, most wind farm models and their associated STATCOMs were not available. Letters were sent out to various project owners in order to explain the nature of the project and for the projects where NGESO already had the models, permission was requested to enable NGESO to share the models with the consultants. Where the models were not available, the project owners were requested to provide an EMT model of their equipment, and the modelling specification implemented by the Australian Energy Market Operator (AEMO) was referenced in case new models had to be produced or amended. The AEMO Model guidelines can be found here.

Over the period from Sept 2020 – October 2021, various calls were arranged with the project owners to discuss the provision of models. As these models were commercially very sensitive, non- disclosure agreements (NDAs) were required between the equipment manufacturers, the project owner, NGESO and Power Nova. These took several months to be drafted and agreed between all parties. As of October 2021, all the NDAs for the interconnector projects were finalised and signed off by all parties. A windfarm model and STATCOM model has also been received. The TO STACOM models available to NGESO are also black-boxed and shared with the consultant.
There were some wind farm models e.g. those based on doubly fed induction generator (DFIG) and some OFTO Wind farm STATCOMs that were not available. The best available models e.g. generic models are used or where the performance of other equipment is similar in nature, the EMT models of such equipment are used as a sensitivity study case even though they are from a different manufacturer.

For WP1, the models obtained and shared with consultant are as follows:

- 3 out of 3 VSC (Voltage Source Converter) interconnector models have been provided.
- 2 out of 2 LCC (Line Commutated Converter) interconnector models have been provided.
- 1 full converter wind farm model out of 2 has been provided. A workaround model which use a similar fully converted turbine model from other manufacturer was developed and tested for the other one.
- 1 DFIG wind turbine model was not available in EMT and the manufacturer has advised that producing one would be time-consuming and complex to validate. A workaround generic DFIG model from Manitoba Hydro was used and special tests was developed and tested.
- The TO- owned STATCOMs have been black-boxed and shared with consultant.
- 2 out of 3 OFTO/ wind farm STATCOM has been provided. The model provided was a generic model as the manufacturer model was not available. The third STATCOM model is from a different equipment manufacturer and NGESO has been advised that an EMT model for the project is not available therefore a workaround model based on other similar manufacture model was developed and tested.

All manufacturers' models came in the form of a self-contained model which included a very simple representation of the British grid. This allowed the model to be tested in isolation to confirm that it was compatible with the installed versions of Fortran, Visual Studio, etc. Tests using the 9 August 2019 real network event that were undertaken to validate the model of the British grid and the integration of the manufacturer-provided models in the South East Coast. Overall, the PSCAD grid model has provided simulated currents and voltages which are very close to those observed on the grid. This suggests that the grid model has passed this verification test though, as noted previously, the absence of major converters close to the fault means that it is hard to say that these have been verified.

Stability studies of the South East Coast were carried out and report has been drafted. The results were compared to the previous findings from project NIA_NGET0187 to understand the impact of using manufacturer models as opposed to generic models. The report has been submitted to NGESO, and is available on the Smarter Networks portal.

Work Package 2 (WP2)

A report has been produced detailing the recommendations of when EMT studies are required and how they need to be carried out. The following topics are explored in greater details with reasonings provided to support the recommended approach:

- Identifying circumstances where EMT tools should be used for stability assessment.
- The tools that should be used.
- The sources of data, in particular manufacturer's models for converters.
- The creation of "base case" datasets for planning and operational studies.
- The setup of suitable scenarios and cases for study.
- The interpretation of the results.

The report has been submitted to NGESO, and is available on the Smarter Networks portal.

Work Package 3 (WP3)

A literature review has been conducted to identify alternative techniques for providing a warning of inverter instability without the use EMT simulation. The report has been submitted to NGESO, and is available on the Smarter Networks portal.

Work Package 4 (WP4)

The work done in WP4 was to determine whether the explicit modelling demand interfaced through converters will have an impact on the results seen at transmission level. Power Nova has collected data on the volume of converter-based plants (predominantly solar) in the South East and developed a methodology to model the equivalent circuits to present the 132kV and 33kV system for a few Grid Supply Points (GSPs) in the South East. The report has been submitted to NGESO, and is available on the Smarter Networks portal.

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

Changes to approach

It was envisaged that, since not all manufacturer models would be readily available at the beginning of the project, the analysis would be carried out in two stages: firstly using models that are readily available and secondly models that would be obtained at a later date. As the provision of EMT models has been substantially delayed, it was decided to wait for all the models in the end rather than to repeat the analysis everytime a new model was received.

Where manufacturer models are not available, it was decided that the best representation available should be used. The preferred alternative is to use the detailed models of similar equipment where these are available even though they may be from different projects and or from different manufacturers. In case these are not available, the alternative, although not preferred, will be to use generic models.

For WP2, it was originally planned that the analysis which is part of WP1 would be used to demonstrate the instances of when EMT studies would be better than RMS studies. However, due to the unavailability of the manufacturer models, WP2 compared the use of generic EMT models versus RMS models.

Changes to cost

There were no changes to the project cost.

Changes to programme

Due to the lengthy process of obtaining the manufacturer Black Box models, the programme has been substantially impacted. The project was completed in May 2022.

Lessons Learnt for Future Projects

Model Provision and sharing

The process of requesting EMT models retrospectively has proven to be quite challenging especially for equipment that has been commissioned a long time ago and for which the appropriate EMT models have not been developed. Manufacturer models require a considerable amount of time and effort to be produced and validated and should ideally be requested at the point of connection to the network. This approach is currently being implemented more regularly as part of the Bilateral Connection Agreement (BCA) during the connections process. The Grid Code Working Group (GC0141) is also progressing a modification that should hopefully allow easier access to EMT models in the future. As the system becomes more complex, there will be a growing need to conduct EMT simulations and having accurate models that have been fully validated to represent the performance of equipment is a key component of the process.

The additional challenge which was faced in this project is that even though some EMT models were available to NGESO, it was not possible to pass these on to a third-party consultant without an agreed NDA in place. Going forward, there may be a greater need to share black-box models across network connectees to verify the interaction between equipment and the use of standard NDAs where possible would help facilitate the process.

In general, we have taken it for granted that the PSCAD model we receive from a manufacturer contains an accurate representation of the control system installed in the field. However, this may not always be the case in some cases: it seems that the software in the actual equipment can be updated (including updates specifically designed to change stability performance) without the PSCAD model being similarly updated. Presumably as the converter gets older the discrepancy between PSCAD and reality will widen. This is a matter of considerable concern and may require grid code changes to ensure the models will be kept up to date. A comparison of modelled converter behaviour to actual measured converter behaviour during faults or other system disturbances would also be desirable.

While the manufacturer models were provided with documentation, the quality of the documentation could be quite variable. Frequently the documentation focused on how the user could get the model to run, but provided little insight into the myriad of user-accessible control settings that could be varied. Where the model is site-specific it is probably reasonable to assume that the settings it is delivered with are appropriate. However, the absence of documentation means that even for generic manufacturer models it is necessary to make the same assumption.

EMT Simulations

The outcome of WP2 provides useful recommendations on when and how to conduct EMT studies. The use of PSCAD has been recommended for conducting EMT simulations mainly due to the fact that most manufacturers have their equipment modelled in the PSCAD environment, that the software package allows simulations to be run using multiple CPU cores in parallel, and is used by at least two TSOs worldwide. This reinforces the need for the TOTEM project (NIA_SHET_0032) which is looking to develop an EMT model of the GB transmission system in PSCAD.

WP2 also recommends the use of short circuit ratio (SCR) to screen when EMT studies are required based on the recommendation from CIGRE TB 671 "*Connection of Wind Farms to Weak AC Networks"* – which sets out the current international consensus on studying converter-dominated grids.

System Instability is more likely to occur under high levels of non-synchronous generation and WP2 recommends the use of automated systems that can run through multiple generation and demand scenarios as well as contingencies. In this project, a script has been developed that allows an automatic dispatch of generation, running of simulations and extraction of results from PSCAD.

Review of benefits case

Valuable lessons shared on model sharing and the best practices for running wider EMT studies are very useful for the ESO and TOs. This is the first time a wide region of the GB system has been modelled in detail with actual users model for stability analysis in EMT environment.

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 project has developed:

- A multi-Party Agreement which enables the ESO and other party to acquire and validate a new system model that will enhance, as well as de-risk the integration of new technologies.
- PowerNova have completed the build of the PSCAD models for South East Coast part of GB network using manufacture provided models.
- A variety of validation tests were undertaken to show the suitability of this model for the assessment of South East Coast converter stability This includes Comparing simulated and actual grid performance during a fault, Comparing a load flow study of the South East Coast undertaken by ESO using DigSilent PowerFactory with the pre-fault steady-state power flows within the PSCAD grid model.
- PowerNova have completed various stability studies assessment of the South East Coast network by applying worst double circuit fault in the region under different scenarios of import level from converter based technologies. Previous studies have shown that this near-instantaneous phase-angle jump can be a challenge for converters with slow PLLs.
- Plan drafted for PowerNova to support NGESO in applying the learnings from stability study and replicate the analysis at another region with high convertors penetration (e.g. East Angelia) and also develop a methodology for root cause analysis and identification of the suspected convertor(s) in cases of instability.
- Work Package 1-4 (WP1-4) Reports have been completed .

Data Access

Details on hownetwork or consumption data arising in the course of a NIC or NIA funded project 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 reports are expected to be released on to the Smarter Networks Portal:

Work Package 1 (WP1) Report
Work Package 2 (WP2) Report
Work Package 3 (WP3) Report
Work Package 4 (WP4) Report

Planned Implementation

To implement the project, an extension of DETECTS project (including training and model transfer) is considered under RIIO-2 mechanism.

Next steps:

- Enhance the DETECTS models and provide knowledge sharing and training within the ESO
- Apply the learnings from DETECTS and replicate the analysis at another region with high convertors penetration (e.g. East Anglia)
- Develop a methodology for root cause analysis and identification of the suspected convertor(s) in cases of instability
- Review and test possible mitigation solutions of invertor instability in the GB network

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.

Standards Documents

No operational type documents have been produced as yet, it is anticipated that they will follow as part of a DETECTS extension Project.