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Guidance Notes for Model Exchange for Converter Based Plant Interaction Studies

January 2023

ESO

Foreword

These Guidance Notes have been prepared by the Electricity System Operator (ESO) to describe to Generators and other Users on the system the model sharing process for interaction studies.

These Guidance Notes are prepared, solely, for the assistance of prospective Users connecting directly to the National Electricity Transmission System. In the event of dispute, the Grid Code and Bilateral Agreement documents will take precedence over these notes.

The Operability Policy Manager (see contact details) will be happy to provide clarification and assistance required in relation to these notes.

ESO welcomes comments including ideas to reduce the compliance effort while maintaining the level of confidence. Feedback should be directed to the ESO Customer Technical Policy Team at:

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Contents

Abbreviations

This section includes a list of the abbreviations that appear in this document.

Abbreviation	Description
AVR	Automatic Voltage Regulator
CI	Control Interaction
DRC	Data Registration Code
ETYS	Electricity Ten Year Statement
HVDC	High Voltage Direct Current
MIIF	Multi-Infeed Interaction Factor
NDA	Non-Disclosure Agreement
NETS	National Electricity Transmission System
ESO	Electricity System Operator
PE	Power Electronic
POC	Point of Connection
PSS	Power System Stabiliser
SSO	Sub-synchronous Oscillations
SSTI	Sub-synchronous Torsional Interaction
TO	Transmission Owner
TOV	Temporary Over Voltage

1. Introduction

Poorly damped or unstable oscillations can occur in the power system due to interactions between different devices.

Sub-synchronous Torsional Interaction (SSTI) refers to interactions between power electronic devices and torsional oscillations of turbine-generator shafts. Interactions between multiple power electronic devices can also lead to poorly damped or unstable oscillations. This is referred to as Control Interaction (CI)

Grid Code ECC.6.1.9 requires ESO shall ensure that Users' Plant and Apparatus will not be subject to unacceptable Sub-Synchronous Oscillation conditions as specified in the relevant License Standards.

Grid Code ECC.6.1.10 requires ESO shall ensure where necessary, and in consultation with Relevant Transmission Licensees where required, that any relevant site specific conditions applicable at a User's Connection Site, including a description of the Sub-Synchronous Oscillation conditions considered in the application of the relevant License Standards, are set out in the User's Bilateral Agreement.

The Grid Code (ECC.6.3.17) requires the User to ensure its HVDC converters (including controllers) within the HVDC System do not cause negatively or lightly damped resonances or interactions on the NETS. Adequate damping control facilities are to be installed if there is a risk of the following phenomena:

- SSO due to interactions between the User’s Plant and Apparatus and the NETS. For clarity, sub-synchronous torsional oscillation with other User’s Plant and Apparatus shall be included in the SSTI study.
- CI due to interactions between the User’s Plant and Apparatus, network and/or any plant directly or indirectly connected to the NETS. For clarity, CI with the network and other User’s Plant and Apparatus shall be studied in the sub-synchronous and super-synchronous frequency ranges where the User’s Plant and Apparatus is identified to be responsive.

This document provides a guidance to users on the provision of data and models to enable the User to carry out SSTI and CI studies.

ESO will provide a PowerFactory RMS (Root Mean Squared) dynamic model of the system area appropriate to the User’s connection (refer to Section 3).

Following the screening studies the user may require additional detailed models for plant that have a risk of interaction with the User’s plant.

2. Non-Disclosure Agreement (NDA)

A Non-Disclosure Agreement is required between ESO and the User, and any other party that will have access to the model data, e.g., consultant or developer. The model cannot be provided before the NDA’s have been signed.

3. Short Circuit Data

The TO will provide short circuit data for the Point of Connection (POC) and the connection date. the fault levels provided are the best estimate available at the time with a forward-looking view of network development, but that changes on the network in future may mean that fault levels end up being higher or lower than those provided.

Table 1 below shows the format of the data and the values recommended for different studies.

The ESO will provide two RMS models to represent the maximum and minimum fault levels system condition. As a result, the fault level data need to be agreed before the work on producing the RMS model can start.

System Condition	3-phase Sub-Transient		1-phase sub-transient		Purpose (It is recommended the relevant fault levels are used for the following purposes)
	Sub-Transient Current (kA)	Make X/R Ratio Break X/R Ratio	Sub-Transient Current (kA)	Make X/R Ratio Break X/R Ratio	
Minimum fault level (N-1 condition)					1- Protection settings with additional appropriate safety margins. 2- Electromagnetic transient study in relation to CC.6.1.7(a) and (b) and TOV (TGN 288). 3- Any study in relation to unbalance.
Post fault minimum fault level (N-1-D condition)					1- Fault ride through 2- Transient active and reactive power exchange studies 3- For SSTI and control interaction studies the part of network around the point-of-interest is usually modelled. Post fault minimum fault level, which represent a N-1-D condition on a summer minimum scenario should be included in the study cases.
Maximum fault level					1- Protection studies. 2- Controller tuning.

Table 1: Fault Data Template

4. Defining Study Area

The RMS model will cover the area of the system relevant to the User's connection. The main objective of defining the study area is to cover all generators and devices that have a potential to interact with the User's equipment. The area should be sufficient for both SSTI and CI studies.

The ESO will initially define the area using Multi-Infeed Interaction Factor (MIIF) which is recommended by CIGRE [1] for finding HVDC converters at risk of CI interaction. MIIF is defined as:

$$MIIF_{e,n} = \frac{\Delta V_e}{\Delta V_n}$$

Where ΔV_e is the observed voltage change at bus e for a voltage change at bus n.

The study area is initially based on the CIGRE recommended MIIF threshold of 0.15. Our experience is that the study area defined by MIIF is sufficiently large to cover generators with SSTI risk as determined by the Unit Interaction Factor (UIF) method. The area is then reviewed and may be expanded if there are large generators or interconnectors close to the boundary of the area. This initial study area is then proposed to the User.

The User should review the proposed area and ensure that they are satisfied with the study area before agreeing the boundaries of the study area with ESO.

5. RMS Dynamic Model

ESO will provide the user with two RMS dynamic models of the agreed system study area. The model will be derived from the ETYS model close to the User's connection date. For projects with multiple stages, the model date will be agreed with the user taking into account the major future network developments within the study area.

5.1. Pre-Requisites

Before starting the work on providing the model, the fault levels and study area must be agreed with the User. Changes to the study area, connection date, or fault level could result in re-starting the model reduction work from scratch.

5.2. Third Party Data

The model will contain third party data (TOs and other generator owners), if the permission to share the information has been obtained from the data owner. ESO will write to the data owners, asking for permission to share their data with the User. Where permission is granted, the plant model will be included in the dynamic model provided to the user. Detailed information on the third party data can be found in section 6.

5.3. Model Setup

The model will be derived from the Electricity Ten Year Statement (ETYS) model suitable for the connection year of the User.

The generation and demand profile will be based on Future Energy Scenarios (FES) data used for ETYS model. The model will be setup for winter peak (maximum fault level) and summer minimum (minimum fault level) system condition.

5.4. Reduction of Model

In the ETYS model, after setting up the winter peak and summer minimum condition, the model will be reduced according to the agreed study area. The parts of the network outside of the study area will be reduced and represented by equivalent voltage sources with corresponding fault levels. These equivalent voltage sources do not have detailed dynamic representation for other parts of the system.

The reduced network will represent 400kV and 275kV networks in detail. Networks on or below 132kV will be reduced unless they are deemed essential to the study, e.g., if the lower voltage networks include plant that has a risk of interaction with the new connection. The fault levels for the reduced model will be closely matched to the fault levels provided by the TO.

5.5. Power System Analysis Tools

These models will be produced with DIgSILENT PowerFactory (PF). The PF version information will be provided as part of model release. The winter maximum and summer minimum system condition will be produced as separate project files (.pfd).

With the produced model, it will be possible to carry out load flow analysis, fault level analysis and RMS dynamic analysis. The reduced model will be able to perform RMS simulation with a 1ms time step.

6. Plant Models

The main dynamic plant types are as discussed in the sections below (6.1 to 6.4). ESO will share these models subject to data owner's explicit permission if required as detailed below. Users should make their own assessment on the suitability and level of detail required to carry out their assessment. ESO, where possible can facilitate the user to obtain any additional data that would be required to complete their assessment. Please note that some data owners might only be willing to share an encrypted model.

6.1. Synchronous Generators

Synchronous generator models use specific third-party models which contain third party data. ESO requires permission from the plant owners before sharing the models with the User. The models contain the Synchronous Machine model with AVR and PSS models attached to the synchronous machine. Governor models will not be provided due to the following reasons:

- Governor performance is linked to commercial services the generators offer to the grid. Hence they are highly commercially sensitive and it will not be appropriate to share detailed governor models.
- For SSTI/CI and Fault Ride Through (FRT) studies, the governor system response is slow (between 2 seconds and 10 seconds). Hence it will not make any difference compared to using a generic model.
- For frequency response studies, it is not necessary to simulate the frequency response of other users, which would require simulation of the entire GB system. It is sufficient to assume rest of the system complies with Grid Code requirement and demonstrate that the user's system frequency response complies with the Grid Code.

6.2. Windfarms

Wind farms are modelled using ESO developed generic models that are validated against test results. These models are owned by ESO and do not require third party permission for sharing with the user.

6.3. HVDC Interconnectors

HVDC interconnectors are modelled using ESO developed generic models that are validated against test results. These models are owned by ESO and do not require third party permission for sharing with the user.

6.4. Future Plant

The Model will include future generators and interconnectors that are due to connect before User's connection date.

ESO does not have validated models for future connections and so will only supply generic models for future generators and interconnectors. Since this is generic data, it will not require third-party permission.

7. Checks on Models

After creating the reduced model, the following checks will be carried out:

- Load flow converges without an excessive number of iterations.
- RMS initialisation without any errors or warnings (sometimes warnings may appear but will not have any impact on results or performance of the model).
- RMS simulation will be carried out and number of busbar voltages and frequencies will be observed. Similarly, different generators in the Study Area will be selected and their real and reactive power output will be observed. This is to ensure there is stable operation without any fault event.
- For a circuit fault event at the POC of the User, the pre/post fault voltage levels and TOV are within acceptable limits along with stable post fault response, within the capabilities of an RMS model.

8. Detailed Models

The user may carry out screening studies to identify any generators that are at risk of SSTI and power electronic devices that are at risk of CI.

If there are plants that are identified as having a risk of SSTI or CI, the User can request detailed models to investigate any potential SSTI or CI issues.

8.1. Shaft Data

Following a screening study, the user may need to carry out detailed SSTI analysis. This requires modelling the turbine-generator shaft. The shaft is modelled using a multi-mass model with an inertia constant for each mass and a stiffness constant between adjacent masses. Table 2 below shows the data format requested in the DRC.

The Grid Code requires generators to supply the mechanical data to ESO as part of the connection compliance process. However, this only applies to generators connecting after 2015. Generators that were connected before 2015 are required to provide shaft data, if requested by ESOThe generator will need to approach their manufacturer/equipment supplier for the relevant data.

MECHANICAL PARAMETERS *(PC.A.5.3.2(a))*											
The number of turbine generator masses		□		DPD II							
Diagram showing the Inertia and parameters for each turbine generator mass for the complete drive train	Kgm^2	□		DPD II DPD II							
Diagram showing Stiffness constants and parameters between each turbine generator mass for the complete drive train	Nm/rad	□		DPD II DPD II							
Number of poles		□		DPD II							
Relative power applied to different parts of the turbine	%	□		DPD II							
Torsional mode frequencies	Hz	□		DPD II							
Modal damping decrement factors for the different mechanical modes		□		DPD II							

Table 2 Shaft Model Data

8.2. Power Electronic Devices EMT Models

Where a user has identified another Power Electronic (PE) device as having a risk of CI, the user may need to run studies which require a detailed EMT (Electromagnetic Transients) model. Plant with a completion date before 1st September 2022 may not have previously provided their EMT models to ESO. For these plant, NGESO will facilitate tripartite discussions with the third party and the User to help reach an agreement to share the EMT model.

9. Expected Timelines

Figure 1 shows the data sharing process. ESO would normally expect a user to enter model discussion at least 42 months prior to the connection date to agree the scope of the RMS model and the delivery timeline. Recognising the importance and complexity of the process, it is highly recommended to have the discussion as soon as possible once the HVDC contractor/manufacture is appointed, and they should also attend the discussion.

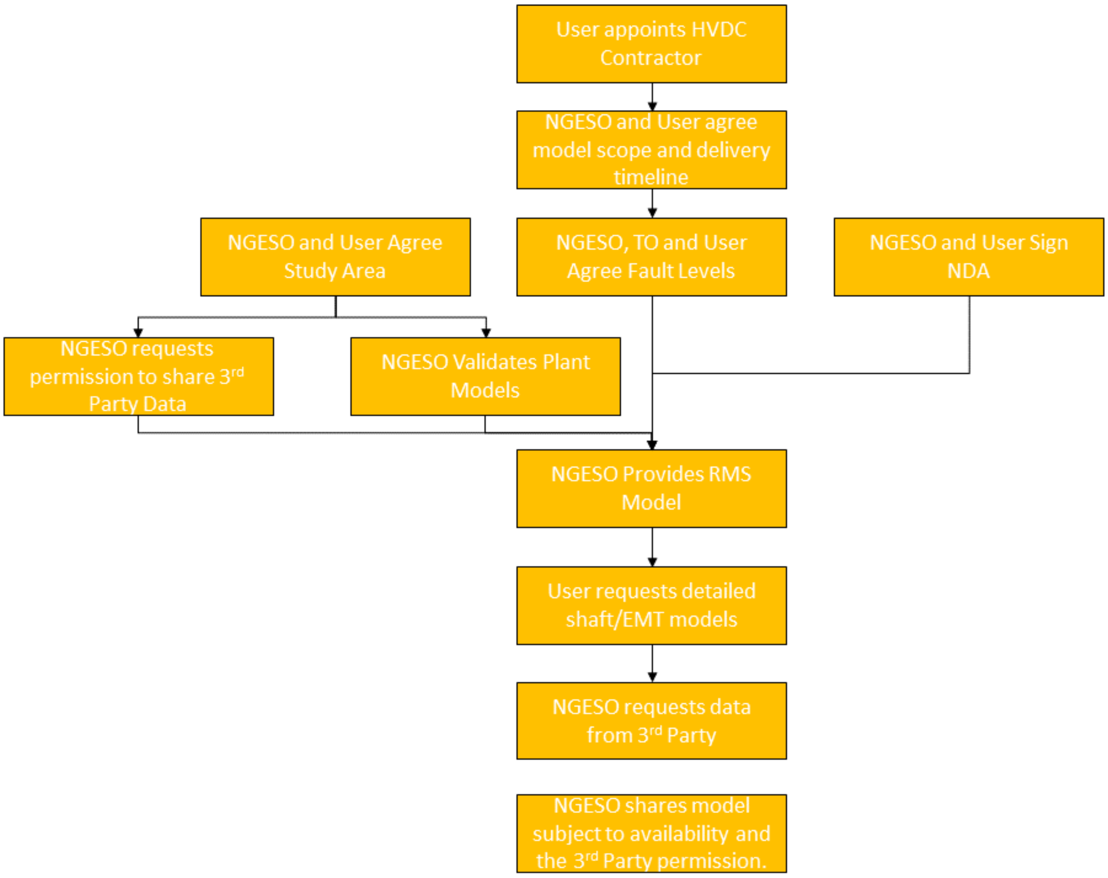

Figure 1 Model data sharing process

Table 3 gives the indicative timelines for provision of models. The estimated time for receiving the RMS model could take around 6 months from the time the model requirements are agreed.

Task	Indicative Timeline
Obtain Permission from Generator Owners	4 weeks
Windfarm, HVDC model validation	8 – 12 weeks
Model Reduction Work and RMS Model Provision	8 weeks
Obtain Turbine-Generator Shaft Data (the timeline can vary depending on whether the data is available and when the permission will be granted)	2 - 8 months
Obtain detailed EMT Model of Power Electronic Device (the timeline can vary depending on whether the data is available and whether permission will be granted)	6-12 months

Table 3 Indicative timelines for the provision of data and models

10.References

[1] “Systems with multiple DC infeed”, Cigre Technical Brochure, Working Group B4.41, 2008.

Appendix A: Contacting ESO

There are a number of different departments within ESO that will be involved with this connection. The initial point of contact for ESO will be your allocated Customer Connection Contract Manager for your Bilateral Agreement. If you are unsure of who your allocated Customer Connection Contract Manager is then the team can be contacted on transmissionconnections@nationalgrideso.com.

Contact Address:

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