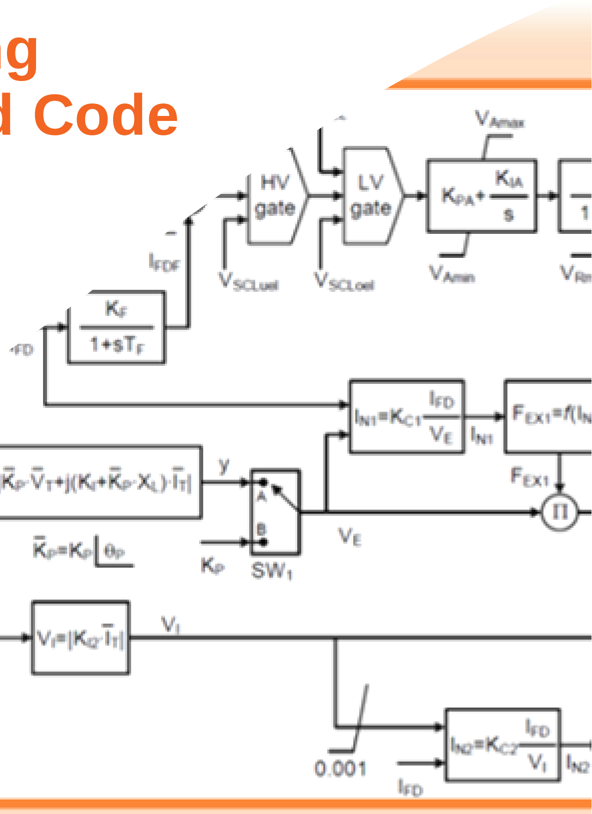
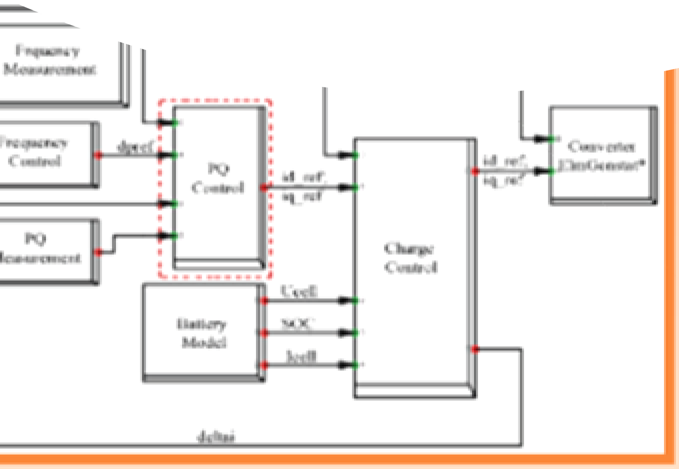
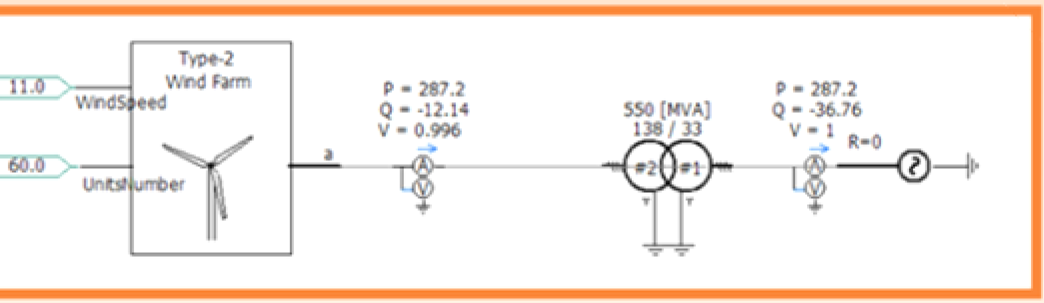
Guidance Notes on Modelling Requirements - GC0141 Grid Code Modification

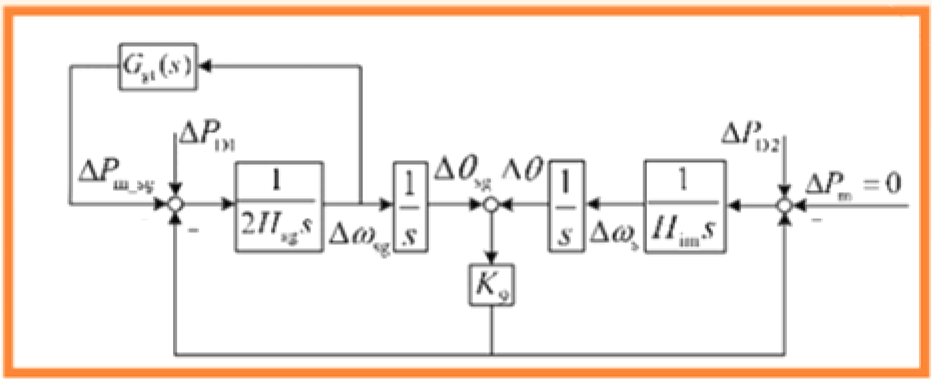
EU Code Users - Issue 1

March 2024









Foreword

These Guidance Notes have been prepared by the National Grid Electricity System Operator (NGESO) to describe to Generators and other Users on the system how the Grid Code Compliance Processes is intended to work in relation to model(s) submissions. Throughout this document National Grid refers to National Grid ESO (NGESO) unless explicitly stated otherwise.

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

Small and Medium Embedded Power Stations should also contact the relevant Distribution Network Operator (DNO) for guidance.

These Guidance Notes are based on the Grid Code, Issue 6, Revision 21, effective from the 04 March 2024 and GC0141: Compliance Processes and Modelling amendments following 9th August Power Disruption

Definitions for the terminology used in this document can be also found in the Grid Code.

The Engineering Compliance Manager (see contact details) will be happy to provide clarification and assistance required in relation to these notes and on Grid Code compliance issues.

NGESO welcomes comments including ideas to reduce the compliance effort while maintaining the level of confidence. Feedback should be directed to the NGESO Engineering Compliance 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
BCA	Bilateral Connection Agreement
BEGA	Bilateral Embedded Generation Agreement
BEIS	Department for Business, Energy & Industrial Strategy
BELLA	Bilateral Embedded License Exemptible Large Power Station Agreement
DNO	Distribution Network Operator
DFIG	Double Fed Induction Generator
ECP	European Compliance Process
EMT	Electromagnetic Transient
FAT	Factory Acceptance Tests
FFCI	Fast Fault Current Injection
FON	Final Operational Notification
FRT	Fault Ride Through
FSM	Frequency Sensitive Mode
GB	Great Britain
GC0141	Grid Code Modification 0141
HVDC	High Voltage Direct Current
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ION	Interim Operational Notification
LEMPS	License Exemptible Medium Power Stations
LFSM – U	Limited Frequency Sensitive Mode Under Frequency
LFSM – O	Limited Frequency Sensitive Mode Over Frequency
LON	Limited Operational Notification
NGESO	National Grid Electricity System Operator
OEM	Original Equipment Manufacturer
OGEP	Offshore Grid Entry Point
OFGEM	Office of Gas and Electricity Markets
PoC	Point of Connection

PSS	Power System Stabiliser
RMS	Root Mean Square
SSTI	Sub-Synchronous Torsional Interaction
SSCI	Sub-Synchronous Control Interaction
UDFS	User Data File Structure
WECC	Western Electricity Coordinating Council

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Guidance Notes

1 Introduction

The GC0141 Grid Code modification was proposed by the Company in response to the actions and concerns raised by both the Office of Gas and Electricity Markets (Ofgem) and the Government's Department for Business, Energy & Industrial Strategy (BEIS) following the review on 9th August 2019 power outage, when over 1 million customers lost their electricity supply as a consequence of unexpected losses of generation for a correctly cleared fault event on the Transmission System.

The GC0141 Grid Code modification proposed changes to the Grid Code with regards to the following areas: Grid Code compliance, the robustness of the modelling process, and Fault Ride Through requirements.

This document focuses solely on the modelling requirements included in the PC.A.9 of the Grid Code approved by Ofgem on 5th January 2023.

2 Objective

The aim of this Guidance Notes is to assist Users of the GB Electricity System with the interpretation of the GC0141 modelling requirements detailed under PC.A.9 planning code section of the Grid Code to achieve the following specific objectives:

- To ensure all users of the GB Electricity System have a clear understanding of their obligations under PC.A.9.
- Ensure the RMS and EMT models to be submitted to the Electricity System Operator (the Company) represent the actual plant measured dynamic response and behaviour.

3 Model Submission Requirements on Users

The Grid Code PC.A.9.2 specifies to users the type of models required by the Company. The table below summarize the model requirement per user type.

User Connection Type	Technology	RMS Model	EMT model
Directly Connected	*Non- Synchronous Generator*	*Yes*	*Yes*
	Synchronous Generator	*Yes*	*Yes (1)*
Bilateral Embedded Generator Agreement (BEGA) - Large	*Non- Synchronous Generator*	*Yes*	*Yes*
	Synchronous Generator	*Yes*	*Yes (1)*
Bilateral Embedded Generator Agreement (BEGA) - Medium	*Non-Synchronous Generator*	*Yes*	*No*
	Synchronous Generator	*Yes*	*No*
Bilateral Embedded Generator Agreement (BEGA) - Small	*Non-Synchronous Generator*	*No (2)*	*No*
	Synchronous Generator	*No (2)*	*No*
Bilateral Embedded Licence Exemptible Large Power Station Agreement (BELLA)	*Non - Synchronous Generator*	*Yes*	*Yes*
	Synchronous Generator	*Yes*	*Yes (1)*
Licence Exemptible Embedded Medium Power Stations (LEMPS)	*Non-Synchronous Generator*	*Yes*	*No*
	Synchronous Generator	*Yes*	*No*

Table 1 - Models to be submitted directly to the Company.

NOTE (1): The company has identified the need for modelling Synchronous Generators in an EMT environment to be able to perform the detailed studies specified in the Company Website. Unless the requirement is in the Bilateral Connection Agreement (BCA), synchronous generators users as identified in table 1 will not be expected to provide an EMT model as a requirement to obtain an ION. However, these users are expected to provide an EMT model to the Company within 6 months of the request being made and will be required to submit a plan to the Company detailing how the delivery date will be achieved.

NOTE (2): The Company does not require Small Embedded Synchronous Generators with Bilateral Embedded Connection Agreement to provide RMS models during the compliance process, it will not be a requirement for the user to obtain an ION. However, the Company might approach the user if the need for more detailed modelling of these small generators arises.

4 Model Platform and Version

The Grid Code specifies in PC.A.9.3.3 and PC.A.9.8.1 that all RMS models shall come implemented in the Software and version required by the Company. The Company requires users to submit the RMS models implemented in DIgSILENT PowerFactory.

The Grid Code specifies in PC.A.9.4.2 and PC.A.9.9.1 that all EMT models shall come implemented in the Software and version required by the Company. The Company requires users to submit the EMT models implemented in PSCAD.

The RMS and EMT models shall be developed in the versions used by the Company at the time the submission is due; these versions currently are 2023 for DIgSILENT PowerFactory and version 5 for PSCAD. The user is advised to approach the Company to confirm the version(s) required as the Company upgrade the software' versions from time to time.

5 Process for Model submission and Timing

The connection models are requirements from the planning code, as such the Company requires users to upload them to the SharePoint site as any other planning data part of the UDFS submission.

Models submitted via email followed by subsequent emails containing password to download them will not be accepted.

The models shall be submitted according to the time scales detailed in the Grid Code PC.A.9.6.1.4 and PC.A.9.6.2.5 for the RMS model and EMT model respectively.

For avoidance of doubt, this is 3 months ahead of the date required for the Interim Operational Notification (ION) and 1 month ahead of the date required for the Limited Operational Notification (LON).

For offshore connections the models shall be submitted 3 months ahead of the date required for the Interim Operational Notification A (ION A).

The Company is required to incorporate the user's model into the GB transmission system planning tool to assess in a timely manner the impact of the connection on the wider system performance. Hence, Users shall be aware the not meeting the timeframes specified in the code might result in the Company not being able to release the ION for the requested date, potentially delaying the project.

Appendix A and B show high level flow charts depicting the timeline users and manufacturers are expected to follow.

6 Model Submission Scope

The user shall submit the models accompanied by all the relevant documentation required by the Grid Code for the Company to be able to release the ION/LON. The documentation must include:

- The model(s) user guide.
- The model(s) supporting documentation.
- The model(s) performance and validation report.

6.1 Models' User Guide

RMS Models

The user guide shall allow the user to:

- Understand the hierarchical structure of the control and protection system model.
- Familiarize with the operational modes implemented in the model.
- Understand how to set up the model for different operational modes and the parameter changes required to that effect (i.e. LFSM, FSM).

EMT Models

The user guide shall allow the user to:

- Install the model, including the links to the library so it is ready to use.
- Understand the overall structure of the control and protection system model.
- Understand how to set up the model for different operational modes and the parameter changes required to that effect (i.e. LFSM, FSM)

6.2 Models' supporting documentation.

RMS Models

The Grid Code requires the models to be submitted with supporting documentation. The documentation needed is specified in the Grid Code clauses: PC.A.9.3.4.1, PC.A.9.3.4.2, PC.A.9.3.5, PC.A.9.8.2.1 and PC.A.9.8.2.3

The supporting documentation shall comprise the following:

- Transfer function block diagrams.
- Tables containing all the parameters and values required by the model.
- Operational range for the model which must be consistent with the actual plant.
- A description of the controllers' logic implemented for meeting the voltage control, frequency response, fault ride through and Fast Fault Current Injection (FFCI) requirements. The description shall include an explanation of the purpose for the main control loops depicted in the controllers' transfer functions associated to these services.
- An explanation for the purpose and logic of any user defined block definitions developed using DSL language to deliver functionalities not possible using standard library block definitions.

EMT Models

The Grid Code specifies in PC.A.9.9.2 that the EMT model for representing the user system might be encrypted, and the documentation required if the user does opt for submitting encrypted models.

Users submitting encrypted EMT models shall provide a minimum level of documentation to allow the Company to:

- Identify the functional blocks involved in the provision of mandatory services.
- Understand the expected behaviour of the functional blocks and control loops, so that the Company can discriminate where potential performance issues within the model might be coming from.

6.3 Model(s) Performance and Validation Report

The model performance and validation report(s) shall contain all the relevant simulations showing the level of validation carried out on the models for demonstrating they adequately represent the actual user system performance at the point of connection. Further details on the scope of model validation are provided under section 9 and 10.

7 User System Models Structure and Representation

To meet the Grid Code PC.A.9.1.2 and PC.A.9.7.7 the user shall submit models to the Company representing the entire user system following the project single line diagram.

It shall be the user responsibility to manage how the user system models are assembled. This point is especially important for projects where there might be more than one Original Equipment Manufacturer (OEM) providing main plant of equipment designed to control the user system response at the point of connection to meet the relevant Grid Code requirements, i.e. AC and DC offshore wind farm projects.

All the main plant of equipment within the user system shall be modelled to the appropriate level of detail to ensure an adequate and representative performance.

The models shall:

- Be numerically stable for the full operating range of the user's plant and the system strength levels where the user system will be connecting.
- Include any relevant non-linearities, such as limits, mathematical functions, dead-bands, saturation, etc.
- Represent the delays between plant of equipment that has an impact on the models' dynamic performance at the point of connection.
- Contain all the relevant protection functions applicable to the technology being modelled to ensure an adequate user system response to disturbances on the transmission system.
- Be representative of plant design and provide an adequate response from any level of active power within its operational range, and for set-point changes on active power, voltage, and frequency, including ramp rates.
- Contain adequate modelling of relevant electrical and mechanical phenomena affecting the plant response at the plant of connection..
- Initialise correctly from any setpoint within the plant operational range.

RMS Models

These models are balanced, root mean-square, positive sequence control and protection system models, therefore they shall not fail to solve balanced load flows. Furthermore, the models must be capable of adequately representing the changes in the user system state variables in response to changes in voltage and system frequency at the point of connection to meet PC.A.9.3.1.

PowerFactory vendor specific models are required to be open source to meet the Grid Code PC.A.9.8.2.1 and PC.A.9.8.2.2. This requirement means that the Company, as user of the model, shall be able to display the following diagrams in PowerFactory:

- Power system arrangement in single line diagram format showing how the actual user system has been represented in PowerFactory.
- All frames' diagrams required by the model depicting how plant, associated controllers and measurement devices are interconnected, clearly showing the signals names for connecting the slots shown in the frame diagram.
- All Laplace Transfer function block diagrams used, for every controller required by the model to deliver a performance representative of the actual user system at the point of connection.

7.1 Protection

The PC.A.9 refers to control and protection system models, as such all the protection functions required to ensure the models remain representative of the user system behaviour when responding to FRT events, providing voltage control and frequency response services must be adequately modelled (i.e. if the actual plant is set up to trip for an FRT event lasting beyond the times specified in the Grid Code, then so should the model setting the flag indicating that the unit has tripped)

The user shall be aware that protection modelling was a requirement on RMS models before GC0141 came into force as specified in PC.A.5.4.2 (a) (ii) and PC.A.5.4.2 (f), and that remains the case as detailed in PC.A..9.8.4.3 and PC.A.9.8.4.4. The user shall discriminate the level of protection modelling required to ensure RMS model remain representative of the actual user system.

7.2 Use of Generic Models.

RMS Models

Generic models such as IEEE, WECC or IEC might be used to meet the Grid Code PC.A.9.8.2.2 requirement for the provision of open-source RMS model.

The Grid Code under PC.A.9.3.4 specifies that when generic models are used the user is required to submit an unambiguous refence to the models with an appropriate set of parameters.

For the avoidance of doubt, The Company requires users to submit a PowerFactory model of the entire user system detailing in the supporting documentation all the parameters of the tuned generic models' controllers, and including in the model performance and validation report all the simulations evidence that the model meet the accuracy requirements of this guidance notes to show that the model is representative of the actual plant performance as required by PC.A.9.1.2 and PC.A.9.8.3.3.

Furthermore, The Company recognizes that generic models might not be as accurate as vendor specific ones which have been developed to replicate specific features of the plant control design. However, for the same reason, vendor specific models tend to be more complex requiring longer simulation times.

The GB transmission system model has several hundreds of user models; therefore, to keep simulation times low the Company encourages users to submit WECC models provided the accuracy requirements specified under section 14 can be met.

8 System Quantities and Signals from User System Models

8.1 User System Quantities at Point of Connection

The user system quantities required at the Point of Connection (PoC) (and OGEP if applicable) to assess the models' dynamic responses are:

- Active Power.
- Reactive Power.
- Voltage Magnitude.
- Voltage Phase Angle (RMS only).
- Measured frequency.

8.2 Plant level quantities and control system variables.

The models shall also permit the display of plant level quantities and control system variables:

RMS Model

All the variables shown in the transfer function block diagrams associated to the RMS control and protection model shall be available for the duration of the simulation as required by PC.A.9.8.4.2. These includes inputs, outputs, state variables and internal variables.

EMT Model

EMT models must provide access to the generators LV terminals as well as controllers inputs and outputs.

8.2.1 Synchronous Generators and Condensers

- Generator Active and Reactive Power, and terminal voltage
- Generator Rotor angle and speed.
- Automatic Voltage Regulator (AVR) inputs and outputs.
- Power System Stabilizer (PSS) inputs and output.
- Excitation System Limiters inputs and outputs.
- Governor Inputs and Outputs
- Controllers adjustable setpoints.

8.2.2 Wind Farms

- Wind Turbine Generator Active and Reactive Power.
- Wind Turbine HV and LV terminal voltage
- Wind Turbine Generator Active and Reactive Current.
- Wind Turbine Generator Drive Train quantities (DFIG only).
- Power Park Controller adjustable setpoints (Active Power, Voltage, etc).

8.2.3 HVDC Links and Batteries

- Convertors Active and Reactive Power
- Convertors Active and Reactive Current.
- DC link Voltage
- HVDC System adjustable setpoints (Active Power, Reactive Power, Voltage, etc..)

9 Model(s) Performance and Validation Requirements for ION

To meet PC.A.9.7 the user shall submit evidence to the Company that the model(s) provided achieve the following:

- Meet the performance requirements specified under PC.A.9.8 and PC.A.9.9
- Represent the user system dynamic performance at the point of connection meeting PC.A.9.1.

9.1 Model(s) Performance

9.1.1 Initialization

RMS Model

The user shall demonstrate that the RMS model meets the requirements detailed in the Grid Code PC.A.9.8.2.4 as well as the initialization requirements under PC.A.9.8.3.

A flat start time domain simulation (no disturbances) lasting at least 50 seconds shall be carried out to demonstrate the numerical stability of the model. The simulation shall be carried out with an integration step size of 10ms.

The RMS model shall initialise correctly with no errors and minimal warnings. The model shall require only the steady state condition delivered by the load flow to initialise correctly, external software or automation routines shall not be used to integrate and/or initialise the model. The RMS model flat start shall not deviate from the load flow solution for the entire simulation.

The model shall calculate correctly all the state variable derivatives on initialization and be within the range which DIgSILENT PowerFactory considers equivalent to zero.

The model shall initialise correctly from any setpoint within the plant operational range for active power, reactive power, and voltage.

EMT Model

The EMT model shall initialise from user defined terminal conditions within 4 seconds of the simulation time when connected to an equivalent Thevenin source while using a 10us time step to meet PC.A.9.9.3.x). For large more complex models .i.e. HVDC links, 6 seconds is acceptable for a 10us time step.

The user shall carry out an initialisation run lasting 20 seconds to demonstrate the model run without errors and it is numerical stable. The user shall specify the model initialisation time in the model's user guide.

The model shall initialise correctly from any setpoint within the plant operational range for active power, reactive power, and voltage.

The EMT models shall be able to run simulations from a snapshot of network conditions to meet PC.A.9.9.3.xii) Grid Code requirement. Further details on specific requirements applicable to EMT models can be found in the "Guidance Notes for Electromagnetic Transient (EMT) Models". A link to this guidance notes can be found in Appendix D.

9.1.2 Voltage Control

The user is required by ECP.A.3.7.4 to simulate a +2% voltage reference step change into the controller of the plant of equipment responsible for delivering the voltage control capabilities at the point of connection to show that the model(s) predicts that the user system will deliver a dynamic response compliant with ECC.A.7.2.3.

The user shall include the time domain simulation required by ECP.A.3.7.4 in the RMS and the EMT model performance and validation reports to facilitate the following:

- Demonstrate the model dynamic performance ahead of tests.
- Comparison in dynamic performance with the user system measured response and the updated model following the successful completion of the voltage control tests.

9.1.3 Frequency Response

Limited Frequency Sensitive Model (LFSM – O)

The user is required by ECP.A.3.6.6 to carry out a time domain simulation and show the user system model active power output at the point of connection in response to a +2Hz step frequency deviation.

Limited Frequency Sensitive Mode (LFSM – U)

The user is required by ECP.A.3.6.8 to carry out a time domain simulation and show the user system model active power output at the point of connection in response to the system frequency deviation depicted by the frequency profile detailed in Figure ECP.A.3.6.1.

For Electricity storage modules the low frequency deviation profile to be used is shown in Figure ECP.A.3.6.5.

FSM

The user is required by ECP.A.3.7.2 to carry out a time domain simulation and show the user system model active power output at the point of connection in response to the system frequency deviation depicted by the frequency profile detailed in Figure ECP.A.3.7.2

The user shall include the time domain simulations required by ECP.A.3.6.6, ECP.A.3.6.8 and ECP.A.3.7.2 in the RMS and the EMT model performance and validation reports to facilitate the following:

- Demonstrate the model dynamic performance ahead of tests.
- Comparison in dynamic performance with the user system measured response and the updated model following the successful completion of the voltage control tests.

9.2 Model(s) Validation at ION

9.2.1 Fault Ride Through

The Company acknowledges that there might not be substantial user system performance data available to validate the model(s) response at the ION/LON stage.

Therefore, to demonstrate to the Company as required by the Grid Code PC.A.9.1.2, PC.A.9.1.3 and PC.A.9.7 that the model(s) represent the actual plant performance under fault ride through scenarios the user shall:

- Validate the Power Park unit model(s) Fault Ride Through (FRT) performance by overlaying the models' simulated responses to balanced and unbalanced faults on the corresponding measured data from the identical unit to be installed on site as obtained by the OEM during field tests as required by ECP.A.6.7.

- Validate the HVDC system model(s) Fault Ride Through (FRT) performance by overlaying the models simulated responses to balanced and unbalanced faults on the Factory Acceptance Test (FAT) results (the user shall schedule these tests well in advance of the ION/LON date to ensure the model(s) are submitted in the time required by the Grid Code)

9.3 Model(s) Performance and Validation Report

The user shall submit a model(s) performance and validation report containing all the simulations specified under section 9 of this Guidance Notes. The user shall submit the model(s) performance and validation report along with the model(s) and all the other required documentation as detailed in section 6 to obtain an ION/LON.

The model(s) performance and validation report(s) simulations shall display all the quantities specified under section 8.1 of this guidance notes.

10 Model(s) Performance and Validation Requirements for FON

10.1 Model(s) Validation

10.1.1 Voltage Control

Following the successful commissioning of the user system and acceptance by the Company of the 100% voltage control tests results, the user shall validate the user system model(s) voltage control performance, as required by ECP.A.3.7.5 and PC.A.9.7.3, by repeating the simulation in section 9.1.2 in the updated model(s) and overlaying the response at the point of connection on:

- The user system measured response to the equivalent test accepted by the Company.
- The model(s) response shown by the model(s) when submitted to obtain and ION.

10.1.2 Frequency Response

Following the successful commissioning of the user system and acceptance by the Company of the 100% frequency response tests results, the user shall validate the user system model(s) frequency response performance, as required by ECP.A.3.7.6 and PC.A.9.7.3, by repeating the simulations in section 9.1.3 in the updated model(s) and overlaying the response at the point of connection on:

- The user system measured response to the equivalent test accepted by the Company.
- The model(s) response shown by the model(s) when submitted to obtain and ION.

10.2 Model(s) Performance and Validation Report

The user shall update the model(s) performance and validation report submitted to obtain an ION/LON with the latest model validation plots required to cover the requirements detailed under section 10.1. of this Guidance Notes.

The model(s) performance and validation report(s) simulations shall display all the quantities specified under section 8.1 of this guidance notes.

The user shall submit the updated model(s) and model(s) performance and validation report(s) within 3 month following the successful completion of the compliance tests as show in Appendices A and B.

11 Grid Code Simulation Requirements

The simulations to be included in the model(s) performance and validation report(s), as detailed in this Guidance Notes, are proposed as a way for the user to demonstrate to the Company that the model(s) submitted during the compliance process to obtain an ION/LON and later a FON are representative of the actual plant performance as required by PC.A.9.

The user shall be aware that except for the initialization simulations specified under this Guidance Notes section 9.1.1, all the other simulations detailed in this document are existing requirements specified in the Grid Code Appendix 3 of ECP code. The initialization simulations included in this guidance notes are proposed as a method for demonstrating the model(s) numerical stability, as required by PC.A.9.8.3.3 and PC.A.9.9.1.

The simulations requested in this guidance notes for inclusion in the model(s) performance validation report(s) are driven by the Company's need to ensure users submit model(s) with consistent evidence over the level of validation carried out on them. In general, the criteria chosen to discriminate whether the simulation should be part of the model(s) performance and validation reports(s) is based on whether there is benchmark data available to compare the model performance against. Appendix C provides a summary of the simulation studies the user is required to perform to obtain an ION/LON and specifies whether the simulation should be included in the model(s) performance and validation report or whether it should be a separate study to comply with the simulation requirements in the Grid Code.

The methodology suggested under section 9.2 of this Guidance Notes for validating the model(s) for FRT performance at ION stage is extracted from the requirement on users to carry out fault ride through tests as detailed in ECP.7.2.2 (d) and ECP.a.6.7, and the knowledge that HVDC links manufacturers carry out FAT with hardware (controllers) in the loop set ups to confirm system performance.

12 System Strength

All the simulations specified in this document for inclusion in the model(s) performance and validation report(s) shall be carried out using the minimum fault level value the Company specified during the compliance process for that connection so the model(s) performance is evaluated under a weak system strength condition.

13 Sample Network

To meet the requirements PC.A.9.7.7 and PC.A.9.9.3 x) of the Grid Code, the user shall demonstrate that the model(s) remain representative of the user system performance regardless of whether the user system model(s) is connected to a simple representation of the external network (as it is the case of a Thevenin equivalent) or the user system model(s) is connected to a multi node power system network.

To demonstrate the model(s) meet the requirement, the Company proposes the inclusion in the model(s) performance and validation report requested by this guidance notes of a set of simulations overlaying the user system model response when it is connected to a Thevenin equivalent external network model on the equivalent set of simulations run with the external network modelled using the IEEE 9 bus system.

The set of simulations proposed are:

<u>RMS Model</u>

- A close-up three phase balanced fault at the point of connection lasting 140ms.
- A balanced voltage dip with a 30% retained voltage at the point of connection lasting 384ms (non-synchronous).
- A balanced voltage dip with a 50% retained voltage at the point of connection lasting 450ms (synchronous)

EMT Model

- A close-up three phase balanced fault at the point of connection lasting 140ms.
- A single phase to ground fault at the point of connection lasting 140ms.
- A double phase to ground fault at the point of connection lasting 140ms.
- A balanced 80% voltage dip lasting 2.5 seconds.

The company proposes the use of the IEEE 9 bus system model because it is available in both power system modelling tools used by the Company, and therefore it is practical way for the user to demonstrate to the company that the model(s) meet the PC.A.9.7.7 requirement at the ION stage.

Furthermore, the PSCAD technical note mentions that future upgrades to the IEEE 9 bus system include replacing voltage sources for detailed machine models and the flexibility to modify fault levels to replicate the system strength condition at the specific point the user will connect to the network.

The requirement to test the model(s) against the IEEE 9 bus system is not applicable to HVDC links connections. HVDC links projects are required by the Grid Code to carry out Sub-Synchronous Control Interaction (SSCI) and Sub-Synchronous Torsional Interaction Studies (SSTI), and the methodology for performing these studies is detailed in " Guidance Notes for Model Exchange for Interaction Studies". A link to this guidance notes can be found in Appendix D.

14 Model(s) Submission Review and Acceptance

The company requires good quality user system model(s) for the ongoing management and assessment of system security, which relies on system studies carried out on a regular basis to complete license activities such as operational planning, system stability assessments, long term network development, connections compliance and system incidents investigations.

To assist users in understanding the quality of the model(s) expected by the Company an acceptance criteria has been included in this guidance notes.

The model(s) accuracy requirement detailed below have been designed to ensure the following:

- The model(s) dynamic response matches to a minimum standard the actual user system measured response data as obtained through FRT type tests, FAT, and compliance tests.
- The model(s) overall behaviour aligns with the actual plant.

14.1 Model(s) Accuracy Requirements

The time phases making up the model(s) dynamic response to simulated event(s) are:

- Pre-event period.
- Transient period.
- Post event period.

14.1.1 Pre-event period model(s) performance criteria.

Pre-event period definition

The time immediately before the application of a reference step change or the application of a disturbance event.

Accuracy Criteria

The difference in values between the model(s) quantities and the corresponding user system measured quantities shall be within 3% of the model pre-event steady state value.

14.1.2 Transient period model(s) performance criteria.

Transient period definition - step responses

The time that elapses between the application of the reference step change and the point in time at which the model response settles within a tolerance band +/- 5% of the final steady state value.

Transient period definition – system disturbances.

The time that elapses between the application of the disturbance and the point in time at which the model(s) response settles within a tolerance band around the final steady state value of +/-5 % of the maximum induced change (the maximum induced change is the difference in the simulated quantity between the pre-event period value and the average value reached during the fault)

Accuracy Criteria 1

For 95% of the samples within the transient period, the difference between the user system model(s) response and the user system measured response shall be contained within an envelope defined by a +/-10% deviation around the model(s) simulated response.

The accuracy criteria 1 applies to the entire transient period, that includes rapid ramps and the size of peaks as well as troughs.

Accuracy Criteria 2

The model(s) dynamic response shall display a similar trend to the measured response. User system model(s) meeting the accuracy criteria 1 above that display oscillatory behaviour not displayed but the actual user system will not be deemed as meeting the accuracy requirements.

14.1.3 Post event period model(s) performance criteria

Post-event period definition

The time commencing 1 second after the completion of the transient period.

Accuracy Criteria

The difference in values between the model(s) quantities and the corresponding user system measured quantities shall be within 3% of the model final steady state value.

14.2 Model Review Process

The Company will check the user system model(s) come complete with all documentation detailed in this guidance notes and review that the model(s) meet the accuracy requirements.

Checking models to ensure they meet the minimum standard is a time-consuming task. Therefore, it is important users adhere to the model(s) submission timescales detailed in this guidance notes.

14.2.1 Model(s) set up.

RMS Model

To expedite the checks and the assessment that the Company will carry out on the models the company requests users to submit RMS models with the required study case and operational scenarios set up as it will ultimately save time and money for both parties.

15 Model Confidentiality and Sharing

The user shall provide the model(s) and the supporting documentation to the Company. However, as specified in PC.A.9.6.1.1 and PC.A.9.6.2.1, the Company is entitled to share these model(s) and associated documentation detailed in these Guidance Notes with the Transmission Licensees to carry out license activities.

The company will accept the model(s) and associated documentation directly from manufacturers provided they agree to sign the company's standard confidentiality agreement. In the event the manufacturer is unable to enter into the standard confidentiality agreement, the user shall be responsible for the model(s) provision and the supporting documentation as detailed in PC.A.9.6.1.2 and PC.A.9.6.2.2.

As detailed in section 5, manufacturers who have signed to the company standard confidentiality agreement to directly submit the model(s) and associated documentation to the Company must follow the same submission process users are required to follow.

15.1 Sharing of User Model(s) with Third Parties

The Company might be required to share an RMS or an EMT model representative of the user system with a third party to carry out license activities. To comply with PC.A.9.6.1.3 and PC.A.9.6.2.3, the user shall notify the company in writing at the time the model(s) and associate documentation are submitted to obtain an ION whether the model(s) can be shared.

In the event the user is unable to authorize sharing the model(s) submitted during the compliance process with third parties, the user shall provide an equivalent encrypted version(s) that can be shared demonstrating that its performance is comparable with the originals.

To comply with PC.A.9.6.2.4 users receiving third party models from the Company shall

- Use the model only for the specific purpose it has been requested for.
- Control access so that only the individuals requiring to use the model in relation to the specific purpose have access to it.
- Set and maintain security measures to avoid the model being used for unauthorised individuals.
- Ensure any publication coming from the work related to the shared model is authorised by the Company.
- Destroy any information relating to the model upon completion of the work requiring the model.

16 User System Model(s) Updates

The user is responsible for ensuring the models work correctly and remain representative of the actual user system dynamic performance for the lifetime of the user system as required by PC.A.9.7.4, PC.A.9.7.5 and PC.A.9.7.6.

The company will endeavour to thoroughly test the model(s) before accepting them. However, there is the possibility that issues with the model(s) are found after the model(s) are accepted during the compliance process as they get extensively used in the company's transmission system model and tested under a much wider range of system operational conditions. Should the company identify and confirm issues with the user's system model(s) the user shall revise the model(s) and provide an updated version that works and meets the accuracy criteria defined in this guidance notes.

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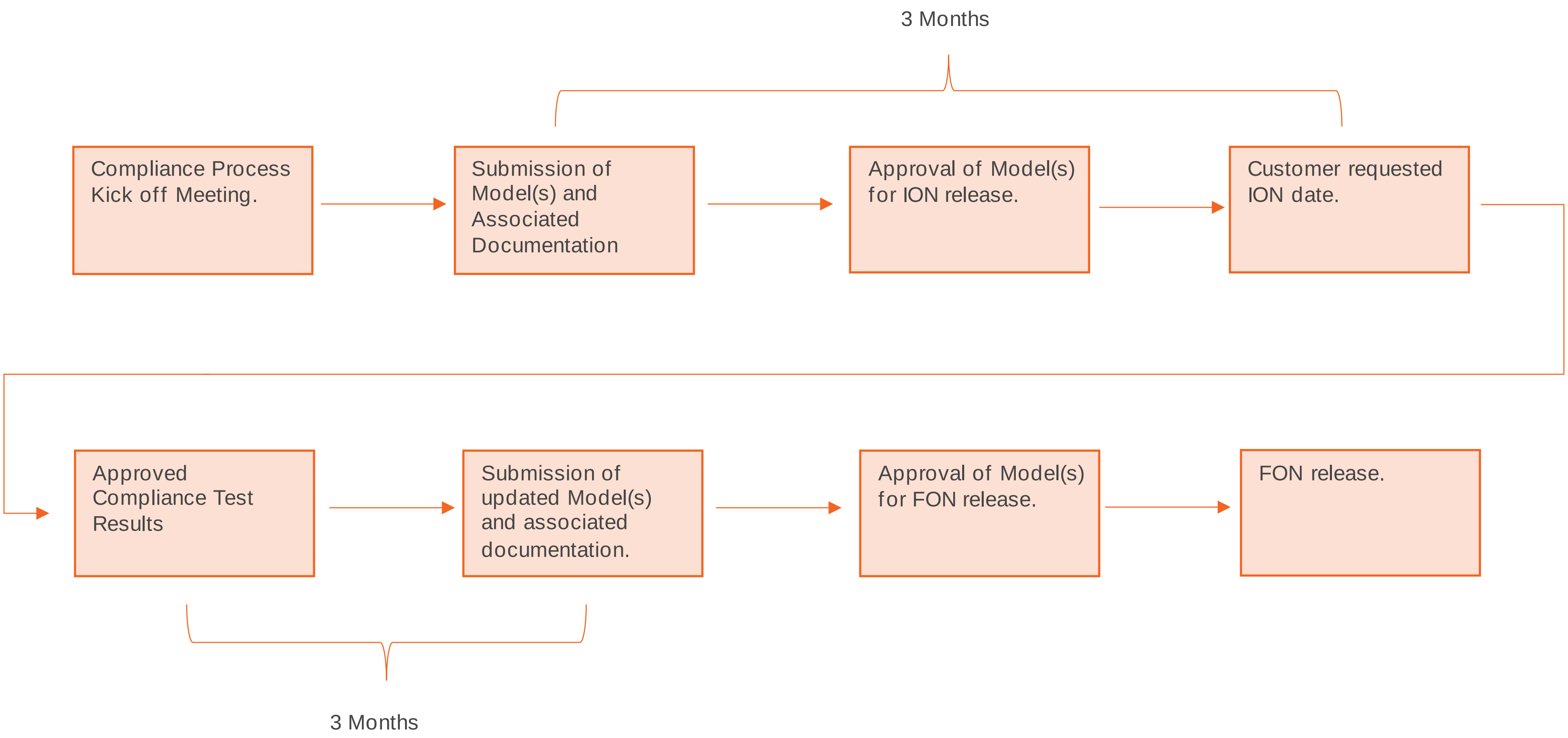
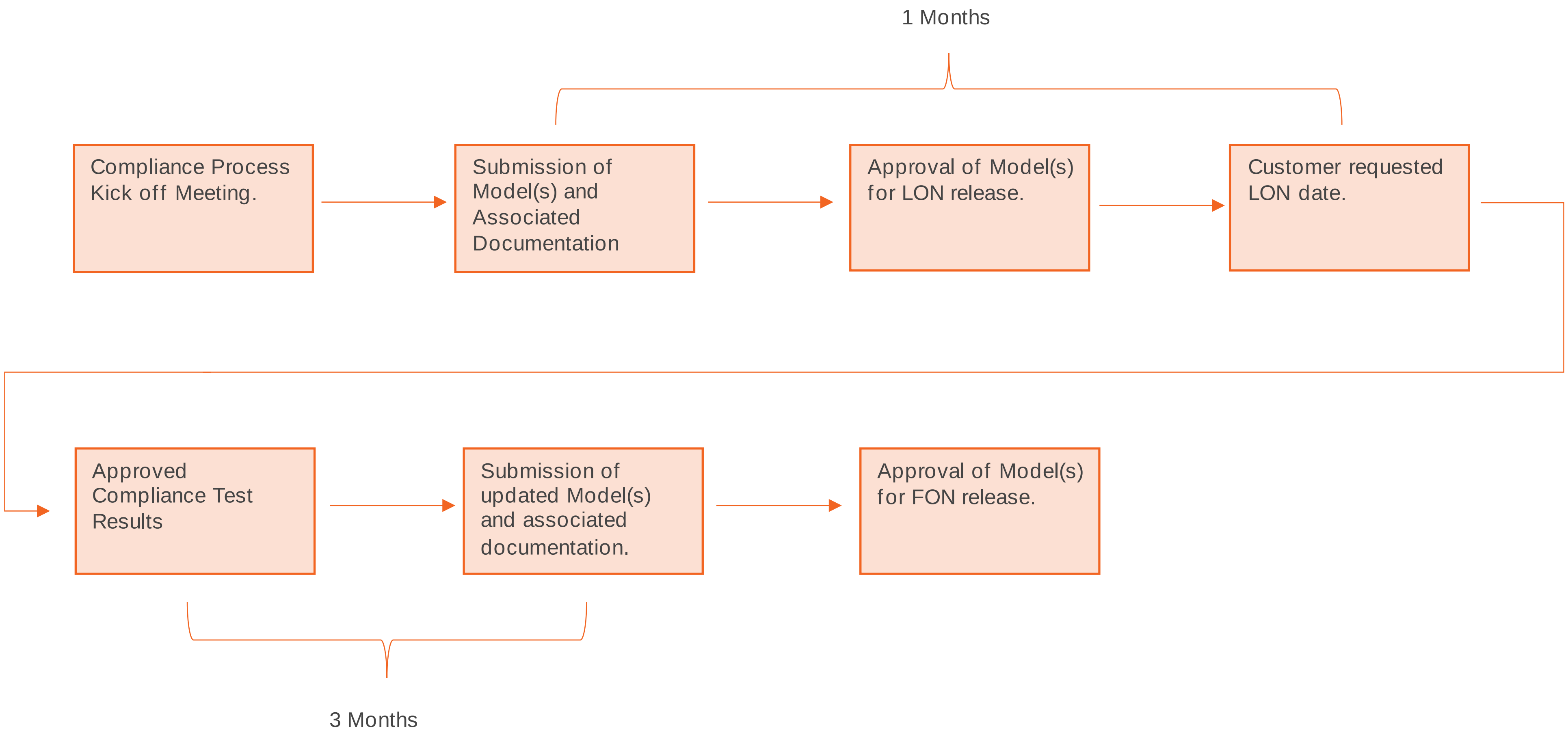
Appendices

Appendix A – Model Submission Timeline for ION



Appendix B – Model Submission Timeline for LON



Appendix C – Grid Code Simulation Requirements Summary

Item	Grid Code Requirement	Study type	Technology	Simulation Objective	Required for	Included in
1	*CP.A.3.2/ECP.A.3.2*	*PSS Tuning*	*Synchronous Generators*	*Establish PSS Parameters for plant excitation system ahead of witness testing*	*ION/LON*	*Simulation study*
2	*CP.A.3.3/ECP.A.3.3*	*Reactive Capability Across Voltage Range*	*All*	*Demonstrate user system model(s) predict the plant will meet the minimum reactive power requirement at the limits of the voltages operational range*	*ION*	*Simulation study*
3	*CP.A.3.4/ECP.A.3.4*	*Voltage Control and Reactive Power Stability*	*Non- Synchronous Generators*	*Demonstrate model(s) predict a Grid Code compliant voltage control performance and stable operation at the limits of reactive capability envelope*	*ION*	*Simulation Study*
4	*CP.A.3.5/ECP.A.3.5*	*Fault Ride Through and Fast Fault Current Injection*	*All*	*Demonstrate user system model(s) predict that the user's plant is capable to ride through specific credible transmission system faults and voltage dips*	*ION*	*Simulation Study*
5	*CP.A.3.6.1 - CP.A.3.6.5/ ECP.A.3.6.1 - ECP.A.3.6.5*	*Load Rejection Study*	*All*	*Demonstrate user system model(s) predict the user's plant will deliver a Grid Code compliant frequency response to system split condition.*	*ION*	*Simulation study*
6	*CP.A.3.6.6/ECP.A.3.6.6*	*LFSM-O*	*All*	*Demonstrate user system model(s) predict the user's plant will deliver a Grid Code compliant response to an +2Hz step rise in system frequency while plant is operating in LFSM mode.*	*ION*	*Model Performance and Validation Report*

7	*ECP.A.3.6.7/ECP.A.3.6.8*	*LFSM-U*	*All*	*Demonstrate user system model(s) predict the user's plant will deliver a Grid Code compliant response to fall in system frequency over a 10s ramp while plant is operating in LFSM mode.*	*ION*	*Model Performance and Validation Report*
8	*CP.A.3.7.2/ECP.A.3.7.2*	*FSM*	*All*	*Demonstrate user system model(s) predict the user's plant will deliver a Grid Code compliant response to a system frequency deviation profile while the plant is operating in FSM*	*ION*	*Model Performance and Validation Report*
9	*CP.A.3.7.3/ECP.A.3.7.3*	*Voltage setpoint step changes*	*Synchronous Generators*	*Demonstrate user system model(s) predict a Grid Code compliant excitation system response to voltage refence step change*	*ION*	*Model Performance and Validation Report*
10	*CP.A.3.7.4/ECP.A.3.7.4*	*Voltage setpoint step changes*	*Non-Synchronous Generators*	*Demonstrate user system model(s) predict a Grid Code compliant voltage controller's response to voltage reference step change*	*ION*	*Model Performance and Validation Report*
11	*CP.A.3.7.5/ECP.A.3.7.5*	*Voltage setpoint step changes*	*All*	*Demonstrate user system model(s) represent the user's plant dynamic performance to equivalent voltage reference step change tests*	*FON*	*Model Performance and Validation Report*
12	*CP.A.3.7.6/ECP.A.3.7.6*	*Frequency setpoint changes (step and ramp)*	*All*	*Demonstrate the user system model(s) represent the user's plant dynamic performance to equivalent frequency response tests.*	*FON*	*Model Performance and Validation Report*

Appendix D – Additional Guidance

(1) Guidance Notes for Model Exchange for Interaction Studies

https://www.nationalgrideso.com/document/192966/download

(2) Guidance Notes for Electro-Magnetic Transient (EMT) Models

https://www.nationalgrideso.com/document/275661/download

Appendix E - Contacting National Grid

There are several different departments within National Grid ESO that will be involved with this connection. The initial point of contact for National Grid 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 box.ECC.Compliance@nationalgrideso.com.

For any correspondence relating to testing on the system following the Grid Code the IET process should be followed with notifications made to the '.Box.Tranreq' email address for England and Wales connections and '.Box.TR.Scotland' for all connections in Scotland.

Contact Address:

National Grid ESO, Faraday House, Warwick Technology Park, Gallows Hill, Warwick CV34 6DA

Faraday House, Warwick Technology Park,
Gallows Hill, Warwick, CV346DA

nationalgrideso.com