



Indication of Dynamic Model Validation Process

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Foreword

This Document has been prepared by EirGrid to provide an indicative note on the process for validation of dynamic models required by the TSO in proposed Grid Code modification MPID 239. Following discussions at the Grid Code Review Panel (GCRP) EirGrid was requested to produce a document to outline the validation requirements outlined in MPID 239. This document has been prepared to inform the GCRP members of likely validation requirements and aims to supplement the proposed modification MPID 239. The document is purely indicative and should be considered for informative purposes only. The document should not be considered as being a definitive process.

The Grid Code modification MPID 239 has proposed the updating of requirements for Users of the Transmission System. Clause PC.A8.6 of the proposed modification specifies validation of models of the Users Plant. This document aims to outline the specific areas to be considered when validating the Users model. The document is intended to be read in conjunction with the Grid Code, proposed modification MPID 239, and the EirGrid commissioning and testing procedure documents. Terms used in the document are in line with those specified in the Grid Code.

The document has been prepared, solely, for the assistance of Users connecting of the Transmission System. This document may be modified from time to time to reflect changes in Grid Code or testing procedures.

For any queries in relation to Grid Code compliance, commissioning and testing or specific questions in relation to modelling please contact the TSO at info@eirgrid.com.



Guidelines for Dynamic Model Validation

This document sets out the validation process that shall be followed by Users to demonstrate compliance of the User models in relation to clause PC.A8.6. It is intended that the process outlined in this document be used in conjunction with the existing commissioning and testing procedure documents. The process described in this document involves a combination of simulation studies and results from the commissioning and testing process to demonstrate how the Users model adequately represents the performance of the Users Plant.

Each User shall supply a report clearly demonstrating how the simulation studies performed using the submitted model adequately demonstrates the performance of the Plant for each of the commissioning tests. Reports may include detail including but not limited to:

- test traces of unit responses to specific tests
- simulated traces of the Plant response to simulations replicating each test
- engineering analysis of the test and simulated results
- a list of approved model parameters to be utilised in the software model.

The report shall be presented in a clear and structured manner that allows for the TSO to assess the compliance of the Users model. The report format shall be defined by the TSO.

The TSOs shall provide a clear description of the simulations to be performed by the User. The TSO shall provide system information including system strength at the connection point for a range of operational scenarios.

Models that do not adequately reflect the performance of the Users Plant shall be revised and updated by the User until the performance satisfactorily reflects the performance of the Plant. It is intended that the specific simulation studies described in this document are sufficient to demonstrate Grid Code compliance however the TSO may require further studies in some cases. The User shall refer to the TSOs 'Dynamic Model Specifications for Users' document to ensure the model meets all usability guidelines specified by the TSO.

Post-commissioning, the TSO intends to monitor all User models and may contact the User in relation to the performance of the model. In this event the User may need to resubmit the model or associated data to more accurately reflect the performance of the Users Plant. It is the responsibility of the User to submit and where required update the model of the User Plant to ensure that it accurately reflects the performance of the Plant.

The document is split into individual sections to describe the specific processes of each generator type. The sections are divided as follows: Generator, Wind Farm Power Station (WFPS) and Interconnector.



1. Generator

Background

This section outlines the on load tests (Phase C) from the commissioning phase that shall be replicated through software simulations. The User shall demonstrate for each of the tests that the model submitted by the User to the TSO adequately reflects the performance of the Users Plant. The areas of interest can be broken up into fault ride through, frequency control, voltage control and power system stabiliser response. The sections this report refers to are based on the test numbers defined in the Phase C testing procedure.

Fault Ride Through

The User shall demonstrate that they are compliant with the fault ride through requirements of Grid Code clause CC.7.3.1.1 (h). The User shall apply faults to achieve the retained voltage specified in the Grid Code and report the fault ride through time for the Unit for various operating conditions. The simulation shall be carried out on a test network that has a system short-circuit MVA level as defined by the TSO. The following operating conditions shall be considered for the fault ride through simulations:

Table 1: Fault Ride through simulation cases

Voltage Magnitude Dip	Fault Ride Through Times (ms)				Grid Code FRT times
	Max MW, 0.85 lagging pf	Max MW, 0.93 leading pf	35% MW, 0.7 lagging pf	35% MW, 0.4 leading pf	
95%					150
50%					450

In each case the User shall record and provide traces of variables including:

- active power
- reactive power
- HV voltage
- Terminal voltage



Frequency Response

Governor droop response (Test 48)

The Generator shall be capable of operating with a Governor Droop i.e. it shall be able to adjust its active power output in response to frequency deviations. The Governor Droop shall be defined by the TSO and is tested as part of the commissioning and testing process. The User shall demonstrate that the model it has provided for the Plant is capable of representing the Governor Droop as tested. Governor Droop is defined by the following equation:

$$Droop \% = \frac{\Delta f / f_{nom}}{\Delta P / P_{nom}} \times 100$$

Equation 1: Governor Droop definition

Where,

Δf is the change in frequency

f_{nom} is the nominal system frequency

ΔP is the change in active power

P_{nom} is the Registered Capacity of the unit

The User shall inject a series of simulated frequency steps into the Governor model for a range of droop settings and load levels on the Unit. The settings to be simulated are as follows:

Table 2: Settings for the governor droop simulations

Governor Droop Setting	Frequency Step	Generator Loading
2%	+/-0.1 Hz	35%
4%	+/-0.2 Hz	50%
6%	+/-0.4 Hz	75%

In each case the User shall demonstrate that the Unit responds to the step in a manner that replicates the actual test response of the Unit. The User shall record and provide traces of variables including:

- active power
- reactive power
- HV voltage
- system frequency
- Unit rotational speed.



Ramp rate (Test 51)

The Generator shall be capable of ramping at a defined percentage of its registered capacity per minute. The ramp rate can be assumed to be 1.5% per minute unless otherwise defined by the TSO. The User shall demonstrate that the model of the Plant is capable of responding to the ramp rates defined in the testing period. The User shall perform the simulations to demonstrate the ramp rate of the unit for a range of steps in active power set point at the specified load levels. The settings to be simulated are as follows:

Table 3: Settings for ramp rate simulations of the Generator model

Ramp Rate Setting	Active Power Set Point Step	Generator Loading
1.5% per min.	+/-5%	35%
3% per min.	+/-10%	50%
5% per min.	+/-20%	75%

The User shall record and provide traces of variables including:

- active power
- active power set point
- HV voltage
- system frequency



Voltage Control

AVR droop (Test 59)

The Generator Exciter shall operate with an AVR droop i.e. it shall be able to adjust its reactive power output in response to voltage deviations. The AVR Droop shall be defined by the TSO and is tested as part of the on load testing under Test 59. The User shall demonstrate that the model it has provided for the Plant is capable of representing the AVR Droop as tested. AVR Droop is defined by the following equation:

$$AVR\ Droop\ \% = \frac{\Delta U / U_{nom}}{\Delta Q / S_{base}} \times 100$$

Equation 2: AVR Droop definition

Where,

ΔU is the change in voltage

U_{nom} is the nominal terminal voltage

ΔQ is the change in reactive power

S_{base} is the base apparent power of the unit

The User shall inject a simulated voltage step into the exciter model and demonstrate that the Unit responds to the step in a manner that replicates the actual response of the Unit.

The User shall repeat the simulations for a range of load and reactive power levels for the Unit. This may include the unit operating at the maximum leading and lagging Reactive Power limits. The settings to be simulated are as follows:

Table 4: Settings for the AVR droop simulations

AVR Droop Setting	Voltage Step	Generator Loading	Generator Power Factor
2%	+/-2%	35%	Unity, Max lag., Max lead.
4%	+/-5%	50%	Unity, Max lag., Max lead.
6%	+/-10%	75%	Unity, Max lag., Max lead.

The User shall record and provide traces of variables including:

- active power
- reactive power
- HV voltage
- terminal voltage
- field current
- field voltage



Power System Stabiliser Response

Power System Stabiliser response (Test 68)

This test investigates the performance of the Power System Stabiliser (PSS) and its effect on the Unit stability. There are three distinct criteria to be analysed in the tests and simulations. Initially the test investigates the response of the Unit with and without the PSS activated. The User shall then perform a 'Gain search' to determine the gain of the PSS that results in spontaneous oscillation from the unit. Finally, the User shall demonstrate that the PSS and the Under-Excitation Limiter (UEL) do not adversely interact. The User shall perform a series of simulations to illustrate that the model of the PSS replicates the response seen in the onsite testing of the Unit.

The User shall inject a simulated voltage step into the AVR model and record the response of the Unit. Initially this should be performed without the PSS and then subsequently with the PSS in service. The User shall demonstrate that the simulated results adequately represent the test records for the Plant. The User shall then activate the UEL model and demonstrate in the simulation that there are no adverse interactions between the UEL and PSS. The settings to be simulated are as follows:

Table 5: Settings for the PSS simulations

PSS status	UEL status	Voltage Step	Generator Loading	Generator Power Factor
ON, OFF	ON, OFF	+/-2%	35%	Unity, Max lag., Max lead.
ON, OFF	ON, OFF	+/-5%	50%	Unity, Max lag., Max lead.
ON, OFF	ON, OFF	+/-10%	75%	Unity, Max lag., Max lead.

The User shall also demonstrate in simulation that the gains for the PSS that result in spontaneous oscillation is representative of the gain observed in the Plant testing.

In all simulations the User shall record and provide traces of variables including:

- active power
- reactive power
- system frequency
- HV voltage
- terminal voltage
- field current
- field voltage

This simulation shall confirm the test results obtained during Test 68. In the event that the PSS was modified on-site the new parameters shall be implemented in the model simulations.



2. Wind Farm Power Station

Background

This section outlines the tests from on load tests of the commissioning phase that shall be replicated through software simulation studies of the Wind Farm Power Station (WFPS). The User shall demonstrate for each of the tests that the model submitted by the User to the TSO adequately reflects the performance of the WFPS. The areas of interest can be broken up into fault ride through, frequency control and voltage control. The sections this report refers to are based on the test numbers defined in the Phase C testing procedure.

Fault Ride Through

The User shall demonstrate that they are compliant with the fault ride through requirements of Grid Code clause WFPS.1.4.1. The User shall simulate a fault resulting in a voltage dip of 95% at the WFPS connection point and duration of 140 ms. The User shall demonstrate that the model predicts an Active Power recovery that is in line with the response defined in WFPS1.4.1. In addition to this the WFPS shall demonstrate the reactive current response of the WFPS. The reactive current response shall be in line with the specifications defined in WFPS 1.4.2. Unit. The simulation shall be carried out on a test network that has a system short-circuit MVA level as defined by the TSO.

The User shall record and provide traces of variables including:

- active power
- reactive power
- HV voltage
- direct and quadrature axis currents
- direct and quadrature axis voltages



Frequency Response

Governor droop response and Governor deadband (Test 48,49)

The WFPS shall be capable of operating with a “Governor Droop” i.e. it shall be capable of adjusting its active power to deviations in system frequency. The Governor Droop shall be defined by the TSO in the form of a droop setting and based on the Curve 1 and Curve 2 frequency settings defined in Grid Code clause WFPS1.5.3. These responses are illustrated in Figure 1.

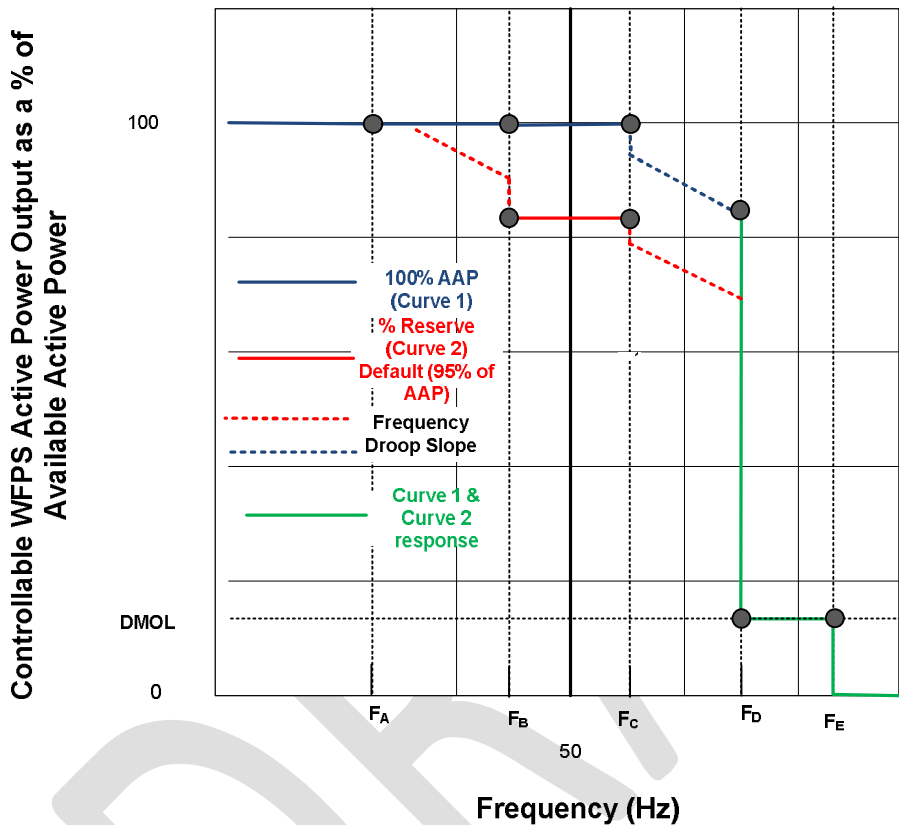


Figure 1: Frequency response curves for WFPS

The response of the WFPS when operating in both frequency curve settings and for a defined droop shall be tested and simulated by the User to demonstrate compliance. The simulation studies shall demonstrate that the model adequately represents the response of the WFPS for all modes of operation. The TSO shall specify the droop settings, the Frequency Response Ramp Rate and the frequency settings for points A-E on the frequency curve settings. This shall define the active power response of the WFPS over the range of operational frequencies. The Governor dead-band shall also implicitly be defined by these settings.

The tests performed for WFPS ramp rates and frequency response are likely to be performed over a longer period of time than is usually considered in a dynamic simulation therefore simulations shall be performed to replicate the WFPS response in a shorter timeframe than is tested. An example of a frequency response for a WFPS under Curve 2 settings and active power dispatch mode is shown in Figure 2.

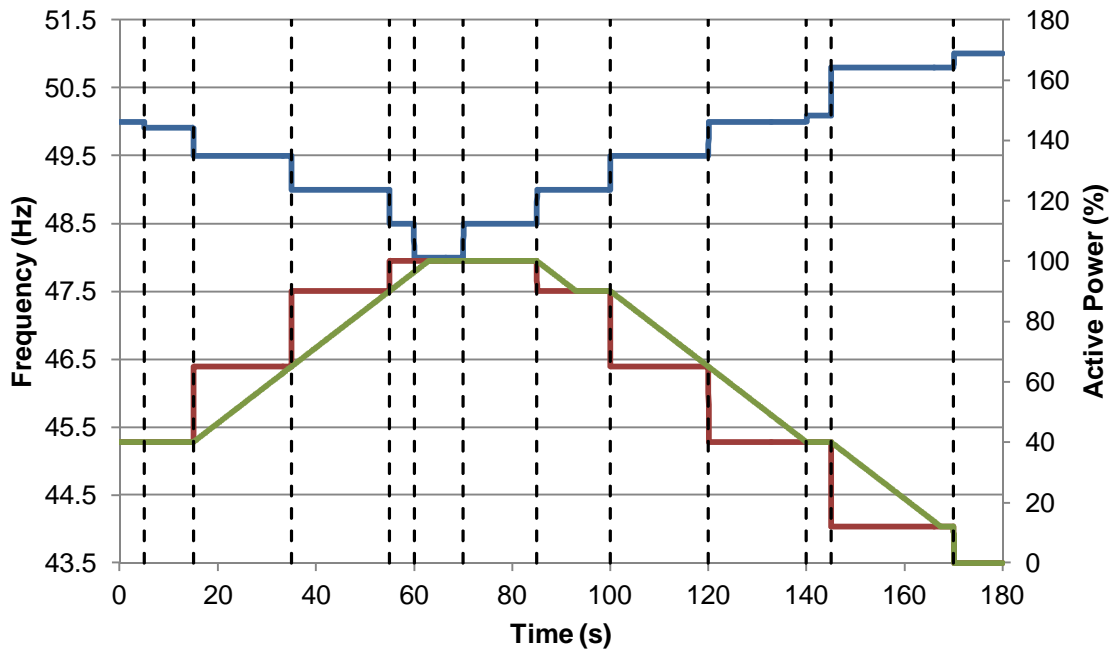


Figure 2: WFPS response under Curve 2 and active power control mode for a range of step changes from 48 - 51 Hz with frequency (blue), active power set point (red) and active power response (green) shown in each case

The assumptions used to generate this plot are given in Table 1. It should be noted that these assumed parameters are used for illustrative purposes and should not be taken as typical settings for WFPS on the system of Ireland and Northern Ireland. The table assumes that the WFPS is dispatched to 40% initially. It is also assumed that the Frequency Response Ramp Rate is 75% per minute.

Table 6: Assumed parameters for frequency response graph of WFPS

F_A (Hz)	48
F_B (Hz)	49.9
F_C (Hz)	50.1
F_D (Hz)	50.8
F_E (Hz)	51
Droop (%)	4
DMOL (%)	12
$P_{Dispatch}$ (%)	40
P_{ramp} (%/min)	75



Figure 2 illustrates that the active power set point (red trace) changes with the step changes in frequency and that the active power required from the WFPS is in line with the droop setting of the WFPS. The WFPS active power response (green trace) follows the set point at a ramp rate defined by the Frequency Response Ramp Rate. The frequency step changes (blue curve) are applied as follows:

Table 7: Frequency step changes utilised for profile in Figure 2

Time (s)	Frequency (Hz)
5	49.9
15	49.5
35	49.0
55	48.5
60	48.0
70	48.5
85	49.0
100	49.5
120	50
140	50.1
145	50.8
170	51.0

The simulations shall therefore confirm that the WFPS responds correctly to the frequency curve settings defined in Tables WFPS 1.1 and WFPS 1.2 in the Grid Code. The simulations shall also confirm the Governor droop setting for the WFPS and the Frequency Response Ramp Rate for the WFPS. The User shall repeat the simulations for each frequency curve setting and a range of droop and dispatch levels for the WFPS. The following cases shall be considered:

Table 8: Settings for WFPS Governor Droop simulations

Governor Droop	WFPS Dispatch of Available Power	Active
2%,4%,6%	40%	
2%,4%,6%	50%	
2%,4%,6%	100%	

The User shall record and provide traces of variables including:

- active power set point
- active power
- system frequency

Ramp rates (Test 51)

The WFPS shall be capable of ramping at a defined percentage of its registered capacity per minute in one of three ramp rates defined in Grid Code clause WFPS1.5.4. This test is performed to determine the response of the WFPS when in Active Power Control mode or Wind Following mode. These ramp rates shall be defined by the TSO. The User shall demonstrate that the model of the WFPS is capable of responding to the ramp rates defined in the testing period.

The simulations shall be performed by injecting a specified Active Power set point into the WFPS and the response of the WFPS shall clearly demonstrate that the WFPS is following the specific ramp rate. The simulations shall be performed to demonstrate both the Active Power Set Point Control



Ramp Rate and the Wind Following Ramp Rate. The User shall perform the simulations at specified dispatch and ramping levels as given below:

Table 9: Settings for WFPS Ramp Rate simulations

Ramp Rate Setting	Active Power Set Point Step	WFPS Dispatch of Available Active Power
10% per min.	+/-10%	40%
25% per min.	+/-25%	50%
50% per min.	+/-50%	75%

The User shall record and provide traces of variables including:

- active power set point
- active power
- system frequency. Voltage Control

AVR droop (Test 59)

The WFPS shall be capable of operating in three modes of operation in relation to Voltage Regulation as defined in WFPS1.6.2. These modes of operation are defined as Power Factor control, Reactive Power control and Voltage Regulation Set Point control. The User shall provide simulations confirming that the response of the model accurately reflects the response of the WFPS.

For Power Factor and Reactive Power control modes the User shall inject a step change in the control set point of the WFPS and demonstrate that the response of the model is compliant. The User shall simulate the following cases:

Table 10: Settings for WFPS Reactive Power and Power Factor control simulations

Reactive Power/Power Factor Step	WFPS Dispatch of Available Active Power	WFPS Power Factor
+/-2%	35%	Unity, Max lag., Max lead.
+/-5%	50%	Unity, Max lag., Max lead.
+/-10%	100%	Unity, Max lag., Max lead.

When the WFPS is in Voltage Regulation Set Point control mode the WFPS shall operate with an AVR droop, i.e. it shall be able to adjust its reactive power output in response to voltage deviations. The AVR Droop shall be defined by the TSO. The User shall demonstrate that the model it has provided for the WFPS is capable of representing the AVR Droop as tested. AVR Droop is defined by equation 2.



The User shall inject a simulated voltage step into the WFPS model and demonstrate that the Unit responds to the step in a manner that replicates the actual test response of the WFPS. The simulations shall be performed at various set points which may include the WFPS operating at the maximum leading and lagging Reactive Power limits. The User shall simulate the following cases:

Table 11: Settings for WFPS AVR Droop simulations

AVR Droop Setting	Voltage Step	WFPS Dispatch of Available Power	Active Power	WFPS Power Factor
2%	+/-2%	35%		Unity, Max lag., Max lead.
4%	+/-5%	50%		Unity, Max lag., Max lead.
10%	+/-10%	75%		Unity, Max lag., Max lead.

In all simulations the User shall record and provide traces of variables including:

- active power
- reactive power
- terminal voltage
- direct and quadrature axis currents
- direct and quadrature axis voltages



3. Interconnector

Background

This section outlines the tests from on load tests of the commissioning phase that shall be replicated through software simulations. The User shall demonstrate for each of the tests that the model submitted by the User to the TSO adequately reflects the performance of the Users Plant. The areas of interest can be broken up into fault ride through, frequency control and voltage control. The sections this report refers to are based on the test numbers defined in the Phase C testing procedure.

Fault Ride Through

The User shall demonstrate that they are compliant with the fault ride through requirements of Grid Code clause CC7.3.1.1 (h). The User shall apply faults to achieve the retained voltage specified in the Grid Code and report the fault ride through time for the Interconnector. The simulation shall be carried out on a test network that has a system short-circuit MVA level as defined by the TSO. The User shall simulate the following cases:

Table 12: Settings for Interconnector Fault Ride Through simulations

Voltage Dip	Grid Code FRT time	Interconnector Dispatch	Interconnector Power Factor
50%, 95%	150, 450ms	35%	Unity, Max lag., Max lead.
50%, 95%	150, 450ms	50%	Unity, Max lag., Max lead.
50%, 95%	150, 450ms	75%	Unity, Max lag., Max lead.

The User shall record and provide traces of variables including:

- active power
- reactive power
- HV terminal voltage
- direct and quadrature axis currents
- direct and quadrature axis voltages

Frequency Response

Active power frequency response (Test C43 and C44)

The Interconnector shall be capable of operating with a “Governor Droop” – e.g. it shall be able to adjust its Active Power to deviations in System Frequency. The Governor Droop shall be defined by the TSO in the form of a droop setting. The droop setting is determined by the following equation:

$$Droop \% = \frac{P_{nom}}{Gain} \frac{1}{f_{nom}} \times 100$$

Equation 3: Interconnector Droop definition

Where,

f_{nom} is the nominal system frequency

P_{nom} is the Registered Capacity of the unit

Gain is the Interconnector gain constant



The test involves applying a series of step changes and ramps in frequency to test the droop response of the Interconnector. The simulation studies shall demonstrate that the model adequately represents the response of the Interconnector for all modes of operation. The TSO shall specify the droop settings, the Ramp Rate and the frequency settings for points f_1 - f_4 and Active Power settings P_1 and P_3 as defined in Grid Code clause CC7.5.8. This shall define the Active Power response of the Interconnector over the range of operational frequencies. The frequency dead-band shall also be defined by the TSO.

The tests performed for Interconnector frequency response and ramp rates are likely to be performed over a longer period of time than is usually considered in a dynamic simulation therefore simulations shall be performed to replicate the Interconnector response in a shorter timeframe than is tested. An example of a frequency response for an Interconnector is shown in Figure 3.

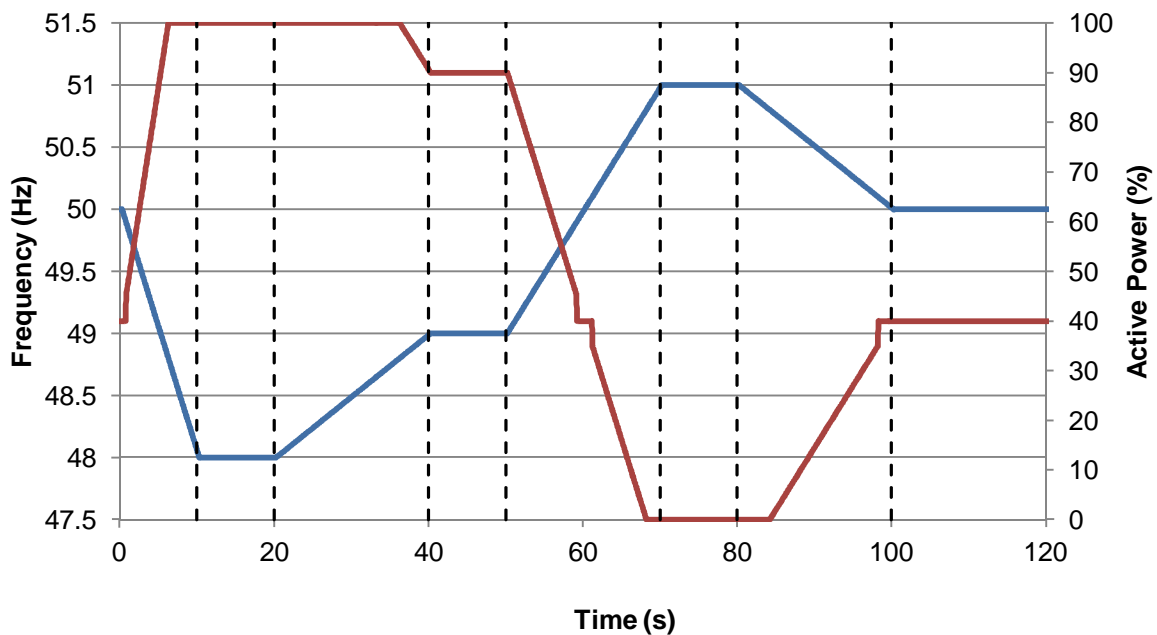


Figure 3: Interconnector active power response for a ramping frequency from 48 - 51 Hz with frequency (blue), active power response (red)

The assumptions used to generate this plot are given in Table 13. It should be noted that these assumed parameters are used for illustrative purposes and should not be taken as typical settings for Interconnector on the system of Ireland and Northern Ireland. The table assumes that the Interconnector is dispatched to 40% import initially. It is also assumed that the Interconnector is at its maximum Ramp Rate per minute.

Table 13: Assumed parameters for frequency response graph of Interconnector

F_1 (Hz)	48
F_2 (Hz)	50
Deadband (Hz)	+/-0.1
Droop (%)	4
$P_{Dispatch}$ (%)	40
P_{ramp} (%/min)	75

Figure 3 illustrates that the active power required from the Interconnector is in line with the droop setting of the Interconnector. The Interconnector does not show an active power response within the deadband defined in Table 2.



The simulations shall therefore confirm that the Interconnector responds correctly to the frequency response settings defined in CC.7.5.8 in the Grid Code. The simulations shall also confirm the Governor droop setting for the Interconnector, the Frequency Deadbands and the Interconnector Ramp Rate. The Frequency Deadband is +/- 0.015 Hz unless otherwise stated by the TSO. The frequency profile to be simulated shall be defined by the TSO. The simulations shall consider the following cases:

Table 14: Settings for Interconnector Droop simulations

Governor Droop	Interconnector Dispatch
2%,4%,6%	40%
2%,4%,6%	50%
2%,4%,6%	100%

Ramp rate (Test C45)

The Interconnector shall be capable of ramping at a defined percentage of its registered capacity per minute. This test is performed to determine the response of the Interconnector when in Active Power Control mode. The ramp rate shall be defined by the TSO and tested during Phase C of the testing process. The User shall demonstrate that the model of the Interconnector is capable of responding to the ramp rates demonstrated in the testing period.

The simulations shall be performed by injecting a specified Active Power set point into the Interconnector and the response of the Interconnector shall clearly demonstrate that the Interconnector is following the specific ramp rate. The User shall perform the simulations at the specified load levels and ramping rates defined as follows:

Table 15: Settings for Interconnector Ramp Rate simulations

Ramp Rate Setting	Active Power Set Point Step	Interconnector Dispatch
10% per min.	+/-10%	40%
25% per min.	+/-25%	50%
50% per min.	+/-50%	100%

The User shall record and provide traces of variables including:

- Active Power set point
- Active Power
- system Frequency.



Voltage Control

AVR droop (Test C52)

When the Interconnector is in Voltage Control mode the Interconnector shall operate with an AVR Droop i.e. it shall be able to adjust its reactive power output in response to voltage deviations. The AVR Droop shall be defined by the TSO and is tested as part of the on load tests under Test C52 (Phase C). The User shall demonstrate that the model it has provided for the Interconnector is capable of representing the AVR Droop as tested. AVR Droop is defined by equation 2.

The User shall inject a simulated voltage step into the Interconnector model and demonstrate that the Unit responds to the step in a manner that replicates the actual test response of the Interconnector. The simulations shall be performed at various set points which may include the Interconnector operating at the maximum leading and lagging Reactive Power limits. The User shall perform the simulations for specified cases as follows:

Table 16: Settings for Interconnector AVR Droop simulations

AVR Droop Setting	Voltage Step	Interconnector Dispatch	Interconnector Power Factor
2%	+/-2%	35%	Unity, Max lag., Max lead.
4%	+/-5%	50%	Unity, Max lag., Max lead.
6%	+/-10%	75%	Unity, Max lag., Max lead.

In all simulations the User shall record and provide traces of variables including:

- active power
- reactive power
- HV terminal voltage
- direct and quadrature axis currents
- direct and quadrature axis voltages

Voltage Control variations (Test C53)

The Interconnector shall be capable of operating in Reactive Power control mode. For Reactive Power control mode the User shall inject a step change in the control set point into the Interconnector and demonstrate that the response of the model is compliant. The User shall perform the simulations for specified cases as follows:

Table 17: Settings for WFPS Reactive Power control simulations

Reactive Power	Interconnector Dispatch	Interconnector Power Factor
+/-2%	35%	Unity, Max lag., Max lead.
+/-5%	50%	Unity, Max lag., Max lead.
+/-10%	100%	Unity, Max lag., Max lead.

The User shall record and provide traces of variables including:

- active power
- reactive power
- HV terminal voltage
- direct and quadrature axis currents
- direct and quadrature axis voltages



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