



Grid Code Compliance Test Procedure

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1 INTRODUCTION

Grid Code section **WFPS1** outlines the technical rules with which Controllable Wind Farm Power Stations (WFPS) connected to the Transmission System are required to comply. This document is intended to clarify and improve understanding of the **Grid Code** compliance testing procedure for wind farms.

The test procedure document is divided into three categories:

- Section A: Active Power Management
- Section B: Transmission System Voltage Requirements
- Section C: Signals, Communications and Control

Each section has a number of tests included. All wind farms are required to go through full testing of all three of these sections unless given formal indication from the TSO to the contrary. The test procedures outlined in this document are a template and must be agreed upon by the IPP and the TSO prior to commencing **Grid Code** compliance testing. Furthermore, the tests are intended to be carried out in the order as outlined in this document. However, on agreement with the TSO, this order may be modified. It must be noted that Test #3: Active Power Control of Section A must be carried out and successfully passed before any other test is performed.

2 SCHEDULING OF GRID CODE COMPLIANCE TESTING:

Contact details are to be exchanged between the designated contacts from EirGrid and the IPP prior to the scheduling of **Grid Code** compliance testing. These designated contacts will be the primary points of contact between the IPP and EirGrid throughout the **Grid Code** compliance process, from scheduling of testing to the carrying out of testing, unless otherwise indicated by either party.

When the IPP is satisfied that the wind farm is fully compliant with the **Grid Code** with the exception of any derogations approved by the CER, a request should be sent to EirGrid to schedule a date for **Grid Code** compliance testing of their wind farm. This should be sent no later than 10 days prior to the proposed test date.

Along with the test request, the following information should be provided by the IPP:

- Overall single line diagram for the wind farm
- Technical data including reactive power capability curve for the wind turbine
- Directions to the wind farm
- Site map for the wind farm
- Contact details of appropriate personnel on site (if different from designated IPP contact)

EirGrid will consult with the relevant parties to ensure that the personnel required for testing will be available on the date requested. However, if the necessary personnel are not available on the date requested by the IPP, EirGrid will endeavour to arrange a more appropriate date which is convenient to all parties. A testing start time is to be agreed with EirGrid 3 days prior to the scheduled day of testing.

A check of the wind conditions a week prior to, and 3 days prior to the scheduled date of **Grid Code** compliance testing is required to be carried out and discussed by the designated IPP and EirGrid contacts. Insufficient wind conditions as per the TSO wind forecast tool may lead to the cancellation of testing up to 1 day prior to testing. At any time prior to, or during **Grid Code** compliance testing, EirGrid reserve the right to cancel/postpone testing for system security reasons at the judgement of the NCC.

Day of Grid Code Compliance Testing:

The IPP should contact the EirGrid designated contact at least 30 minutes prior to the agreed start time to confirm that personnel on site will be ready to begin testing. An EirGrid representative will witness testing on site on EirGrid's behalf, unless otherwise stated. The EirGrid designated contact will liaise with the NCC operators and personnel on site to co-ordinate testing.

Results of the tests consisting of data and graphs should be provided by the IPP test co-ordinator to the EirGrid representative in both hard copy and electronic file format. Conversion of the data into graphical form shall be the responsibility of the IPP test co-ordinator and shall be included in the documentation provided.

In addition to this, the IPP is required to prepare a report for tests on the wind farm which shall include all tests carried out and the data results collected during testing, along with the raw data from which the data results were extracted. The necessary instrumentation required by the IPP to gather data during testing is outlined in this document for each test. The accuracy standard and resolution required of instrumentation to confirm compliance is also outlined. The absence of required instrumentation, or the inaccuracy of instrumentation to the stated standards, will result in the automatic failing of **Grid Code** compliance testing. A copy of the IPP's report shall be made available to Eirgrid at which point EirGrid will assess compliance in a timely manner.

3 SECTION A: ACTIVE POWER MANAGEMENT

3.1 Introduction:

On the day of testing, suitably qualified technical personnel will be needed at the wind farm to assist in undertaking the tests. Such personnel shall have the ability to fully understand the function of the wind farm and its relationship to the network to which the wind farm is connected. Furthermore, such personnel shall have the ability to set up the control system of the wind farm so as to enable **Grid Code** compliance test to be correctly undertaken. In addition the function of the technical personnel will be to liaise with NCC in carrying out the test who will decide:

- If network conditions allow the testing to proceed
- Which tests will be carried out
- When the tests will be carried out.

In addition, the availability of personnel at NCC will be necessary in order to initiate the necessary instructions for the test.

3.2 Pre-conditions:

All wind turbines should be available for Section A tests. If on the day of the testing all wind turbines are not available, then the test may proceed where one wind turbine is unavailable for a wind farm of registered capacity of up to 75 MW or two wind turbines are unavailable for a wind farm of registered capacity in excess of 75 MW. Wind conditions need to be sufficient and at a relatively constant level in order adequately perform the test. The required wind capacity for this test is detailed in Table 1. NCC shall approve the proposed the sequence of applied values of dispatched power set-points and the period of time that each set-point value of power is maintained.

3.3 General:

The grid voltage at the high voltage side of the grid connected transformer should be automatically maintained to a value specified at the time by NCC, taking account of AVR voltage droop, regulation of the grid connected transformer and the reactive capability of the wind farm. In this regard, consideration may be given to undertaking the 'Ramp Rate Tests' while the Active Power Control Tests are being carried out.

3.4 Test #3: Active Power Control

3.4.1 Purpose of the Test:

The purpose of this test is to confirm the ability of the wind farm to respond to active power control signals issued by NCC.

3.4.2 Instrumentation:

Recorded data that will be required for the test will consist of the following:

- Available active power from the prevailing wind in MW, derived by algorithm in the wind farm control system
- Actual active power from the wind farm connection point in MW
- Grid voltage measured at the high voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Z).
- Wind farm voltage measured at the low voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Y)
- Reactive power measured at the low voltage side of the grid connected transformer, (Figure **WFPS1.3**, Point Y)

Measuring instrumentation to accuracy Class 0.5S or better is required. The time resolution is required to 0.25 seconds.

3.4.3 Procedure:

The wind farm should be producing least 75% of its MEC prior to starting the active power control test.

Party	Instruction	Value	Note
NCC	Switch APC status 'on'		<i>WF to automatically confirm status by feedback to the NCC</i>
NCC	Send active power setpoints as follows:		<i>Ensure setpoint is within the available active power from wind at time of test</i>
NCC	75% MEC		<i>WF to respond appropriately and operate at each setpoint for 5 mins.</i>
NCC	50% MEC		
NCC	25% MEC		
NCC	5% MEC		
NCC	0% MEC		
NCC	15 % MEC		
NCC	25% MEC		
NCC	75% MEC		
NCC	Send active power setpoint in line with the available active power of the wind farm		
NCC	Switch APC status 'off'		

Five active power set-points should be selected as agreed with TSO, in sequence in descending order and five set-points should be selected in ascending order, depending upon the available active power from wind conditions at the time of testing.

The grid voltage at the high voltage side of the grid connected transformer should be automatically maintained to a value specified at the time by the NCC. (The ability to maintain set-point voltage is dependent upon the voltage regulator voltage droop setting, the impedance of the grid connected transformer and short circuit level at the point of common coupling). Manual intervention by the wind farm operator should not be required over the duration of the active power control tests.

3.4.4 Pass Criteria:

On completion of the tests, the results should confirm or otherwise compliance with the relevant section of the **Grid Code** including as follows:

Grid Code Clause (V3.4)	Description	Pass Criteria
WFPS 1.5.2.1	Ability to respond to active power setpoints	Average value of power to be within $\pm 2.5\%$ of set-point value, averaged over the length of time from when the unit should have implemented the setpoint to when the setpoint was changed; or over 10 minutes, whichever is less
WFPS 1.5.2.1	Implementation of active power setpoint on receipt of signal from NCC	Response required in 10 s or less
WFPS 1.5.2.1	Rate of change of power should be bound by the maximum ramp rate settings advised by TSO. (Refer to WFPS1.5.3).	Rate of change of active power no less than the 1 min and 10 min averaged ramp rates as defined by the TSO.

3.5 Test #4: Frequency Response

3.5.1 Purpose of the Test

The purpose of this test is to confirm the ability of the wind farm to respond to changes in grid frequency. As the grid frequency cannot be changed at will, the test will require to be simulated by means of injection of a frequency signal into the wind farm controller to simulate appropriate changes of frequency. When the Frequency Response System is 'on' the wind farm is required to respond to one or other of two different power-frequency response curves, Power Frequency Response Curve 1 and Power Frequency Response Curve 2, as selected by NCC. The wind farm should respond by regulating its power output in proportion to the grid frequency. This relationship is different for each of the two characteristic curves, as outlined in the Customer Pack.

3.5.2 Pre-condition:

- Active Power Control system must be proven to function correctly before performing this test.
- Wind conditions must be sufficient to provide at least 60% of registered capacity of the wind farm.

3.5.3 Instrumentation

Recorded data that will be required for the test will consist of the following:

- Available active power from the prevailing wind in MW
- Actual active power from the wind farm connection point in MW
- Simulated test frequency in Hz
- Grid frequency in Hz
- Grid voltage measured at the high voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Z).
- Active Power Control Setpoint in MW as received from NCC
- Active Power Control Setpoint Feedback as sent to the NCC
- Frequency Response system 'on'/'off'
- Curve 1/Curve 2 Selected

Measuring instrumentation to accuracy Class 0.5S or better is required. The time resolution is required to 0.25 seconds.

3.5.4 Test Procedure

The tests for power frequency response come under the following conditions:

1. Frequency Response system On/Off and changes between Curve 1 and Curve 2
2. Response with Curve 1 and Curve 2 with Active Power Control 'on':
3. Response with Curve 1 and Curve 2 with Active Power Control 'off'

1. Curve Settings:

Party	Instruction	Note
NCC	Switch Frequency Response system 'on'	<i>Should activate within 1 second. WF to automatically confirm status by feedback to the NCC</i>
NCC	Select Curve 1	
	Select Curve 2	<i>Should activate within 1 minute</i>
	Select Curve 1	<i>Should activate within 1 minute</i>
	Switch Frequency Response system 'off'	<i>WF to automatically confirm status by feedback to the NCC</i>

2. Frequency Response with APC 'on':

Injected signals shall consist of step changes in frequency applied sequentially in ascending order followed by sequential setpoint changes in descending order

Party	Instruction	Note
Curve 1		
NCC	Switch Frequency Response system 'on'	<i>Should activate within 1 second. WF to automatically confirm status by feedback to the NCC</i>
NCC	Select Curve 1	
NCC	Switch Active Power Control 'on'	<i>WF to automatically confirm status by feedback to the NCC</i>
NCC	Sent active power setpoint within Available Power and low enough to reduce output deviation due to wind variation as much as possible	<i>Typically 50% of Available Power</i>
WF	Inject frequency signals into wind farm controller as follows:	<i>Response shall be a minimum of 1% of rated capacity per second</i>
	48 Hz	
	49.8 Hz	
	50.2 Hz	
	52 Hz	
	52.2 Hz	
WF	Return WF to system frequency	
NCC	Switch Frequency Response 'off'	
NCC	Send active power setpoint equal to the available active power	<i>Allow WF to reach setpoint</i>
NCC	Switch Active Power Control 'off'	<i>WF to automatically confirm status by feedback to the NCC</i>

Party	Instruction	Note
Curve 2		
NCC	Switch Frequency Response system 'on'	<i>Should activate within 1 second. WF to automatically confirm status by feedback to the NCC</i>
NCC	Select Curve 2	
NCC	Switch Active Power Control 'on'	<i>WF to automatically confirm status by feedback to the NCC</i>
NCC	Sent active power setpoint within Available Power and low enough to reduce output deviation due to wind variation as much as possible	<i>Typically 50% of Available Power</i>
WF	Inject frequency signals into wind farm controller as follows:	<i>Response shall be a minimum of 1% of rated capacity per second</i>
	48 Hz	
	50 Hz	
	52.2 Hz	
WF	Return WF to system frequency	
NCC	Switch Frequency Response 'off'	
NCC	Send active power setpoint equal to the available active power	<i>Allow WF to reach setpoint</i>
NCC	Switch Active Power Control 'off'	<i>WF to automatically confirm status by feedback to the NCC</i>

3. Frequency Response with APC 'off':

Party	Instruction	Note
Curve 1 Response		
NCC	Switch Active Power Control 'off'	
NCC	Select Curve 1	
WF	Inject frequency signals into the wind farm controller as follows:	<i>Response shall be a minimum of 1% of rated capacity per second</i>
	48 Hz	
	50 Hz	
	52.2 Hz	
WF	Return WF to system frequency	
NCC	Switch Frequency Response 'off'	<i>Allow WF to reach setpoint</i>
NCC	Send active power setpoint equal to the available active power	<i>WF to automatically confirm status by feedback to the NCC</i>
NCC	Switch Active Power Control 'off'	<i>WF to automatically confirm status by feedback to the NCC</i>

Party	Instruction	Note
Curve 2 Response		
NCC	Switch Active Power Control 'off'	
NCC	Select Curve 2	
WF	Inject frequency signals into the wind farm controller as follows:	<i>Response shall be a minimum of 1% of rated capacity per second</i>
	48 Hz	
	50 Hz	
	52.2 Hz	
WF	Return WF to system frequency	
NCC	Switch Frequency Response 'off'	<i>Allow WF to reach setpoint</i>
NCC	Send active power setpoint equal to the available active power	<i>WF to automatically confirm status by feedback to the NCC</i>
NCC	Switch Active Power Control 'off'	<i>WF to automatically confirm status by feedback to the NCC</i>

3.5.5 Pass Criteria:

On completion of the tests, the results should confirm or otherwise compliance with the relevant section of the **Grid Code** including as follows:

Grid Code Clause (V3.4)	Purpose of Test and Description	Pass Criteria
WSPS 1.5.2.2	Confirm that settings for Curve 1 are implemented.	Curve 1 implementation required within 1 minute of receiving signal from NCC
WSPS 1.5.2.2	Frequency Response to Curve 1 with Active Power Control 'Off'.	Rate of response required minimum 1% of rated capacity per second.
WSPS 1.5.2.2	Frequency Response to Curve 1 with Active Power Control 'On'.	Rate of response required minimum 1% of rated capacity per second.
WSPS 1.5.2.2	Confirm that settings for Curve 2 are implemented.	Curve 2 implementation required within 1 minute of receiving signal from NCC
WSPS 1.5.2.2	Frequency Response to Curve 2 with Active Power Control 'Off'.	Rate of response required minimum 1% of rated capacity per second.
WSPS 1.5.2.2	Frequency Response to Curve 2 with Active Power Control 'On'.	Rate of response required minimum 1% of rated capacity per second.

3.6 Test #5: Ramp Rates and Start-Up Test

3.6.1 Purpose of the Test

The purpose of this test is to confirm the ability of the wind farm to ramp up and ramp down according to certain rates, as defined by the TSO. In addition, this test is to demonstrate the ability of the wind farm to start-up from a stopped condition. The two ramp rates issued by the TSO detail the maximum ramp rate average over a period of one minute and a second ramp rate average over a period of ten minutes. These are ramp rates for increasing load from a stopped condition to normal operating output and also for decreasing output following initiation of a stop command, (not Black Start Shutdown). It should be noted that these ramp rates do not apply for changes in active power as part of the Frequency Response system or, in the case of downward ramping alone, the sudden decrease in wind speed.

3.6.2 Instrumentation

Recorded data that will be required for the test will consist of the following:

- Available active power from the prevailing wind in MW, derived by algorithm in the wind farm control system
- Actual active power from the wind farm connection point in MW
- Grid voltage measured at the high voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Z).
- Wind farm voltage measured at the low voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Y)
- Reactive power measured at the low voltage side of the grid connected transformer, (Figure **WFPS1.3**, Point Y)

Measuring instrumentation to accuracy Class 0.5S or better is required. The time resolution is required to 0.25 seconds.

3.6.3 Test Procedure

Party	Instruction	Value	Note
Without Active Power Control			
NCC	Switch APC 'off'.		
WF	Local initiation to 'stop'.		<i>Remain for 5 mins.</i>
WF	Local initiation to 'start' to a setpoint in excess of available power.		<i>Remain for 5 mins.</i>
With Active Power Control			
NCC	Switch APC 'on'.		<i>WF should b operating at 75% MEC or greater.</i>
NCC	Send active power setpoint of 10% MEC.		<i>Remain for 5 mins.</i>
NCC	Send active power setpoint of 60% MEC *.		<i>Remain for 5 mins.</i>
NCC	Send active power setpoint equal to the available active power.		<i>WF to automatically confirm status by feedback to the NCC.</i>
NCC	Switch Active Power Control 'off'.		<i>WF to automatically confirm status by feedback to the NCC.</i>

* This is on the basis that wind conditions provide 75% MEC or greater without active power control.

3.6.4 Pass Criteria:

On completion of the tests, the results should confirm or otherwise compliance with the relevant section of the **Grid Code** including as follows:

Grid Code Clause (V3.4)	Purpose of Test and Description	Pass Criteria
WFPS 1.5.3	Confirm the ability of the wind farm to start-up and ramp up to available wind capacity and ramp down **	The rate of change of active power no greater than the 1 min and 10 min averaged ramp rates as defined by the TSO.

***It is acknowledged that falling wind speed or Frequency Response may cause either of the maximum ramp rates to be exceeded. On occurrence of either of these conditions, the wind farm may be retested.*

4 SECTION B: TRANSMISSION SYSTEM VOLTAGE REQUIREMENTS

4.1 Pre-Conditions:

All wind turbines should be available for the test. If on the day of the test all wind turbines are not available, then the test may proceed where two wind turbines are unavailable for a wind farm of registered capacity of up to 75 MW or three wind turbines are unavailable for a wind farm of registered capacity in excess of 75 MW. Wind conditions need to be sufficient and at a relatively constant level in order adequately test this facility. The required wind capacity for this test is detailed in the table.

Mandatory trends to be logged are as noted under each heading 'Instrumentation'.

4.2 General:

On the day of the tests, suitably qualified technical personnel will be needed at the wind farm to assist in undertaking the tests. Such personnel shall have the ability to fully understand the function of the wind farm and its relationship to the grid to which the wind farm is connected. Furthermore, such personnel shall have the ability to set up the control system of the wind farm so as to enable this grid compliance test to be correctly undertaken. In addition, the function of the technical personnel will be to facilitate undertaking the tests which shall be carried out in conjunction with NCC. The availability of personnel at NCC will be necessary in order to initiate the necessary signals for the test.

4.3 Test #7: Automatic Voltage Regulation

4.3.1 Purpose of the Test:

The purpose of this test is to confirm the ability of the wind farm to regulate the grid voltage at the connection point to a value set by NCC. Such regulation shall be within the capability of the wind farm to regulate the voltage at this point taking account of the short circuit level at the connection point, regulation of the grid connected transformer, the voltage slope (droop) applied to the wind farm and the reactive capability of the wind farm.

The test shall demonstrate that the wind farm can:

- apply selected voltage slope settings at any value between 1% and 10%
- implement the change in voltage regulation set-point within 20 seconds of receipt of the signal from NCC
- achieve 90% of its steady state reactive power response within 1 second
- show that the actual droop voltage droop concurs with the applied voltage droop setting.

4.3.2 Pre-conditions:

It is required that wind conditions provide at least 60% of rated capacity of the wind farm for this test to be carried out.

4.3.3 Instrumentation:

Recorded data that will be required for the test will consist of the following:

- Available active power from the prevailing wind in MW, derived by algorithm in the WFCS
- Actual active power from the wind farm in MW
- Grid voltage measured at the high voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Z)
- Reactive power measured at the high voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Z)
- Wind farm voltage measured at the low voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Y)
- Reactive power measured at the low voltage side of the grid connected transformer, (Figure **WFPS1.3**, Point Y)
- Grid transformer tap position.
- Automatic Voltage Regulator (AVR) set-point
- AVR set-point feedback

Measuring instrumentation to accuracy Class 0.5S or better is required. The time resolution is required to 0.25 seconds.

4.3.4 Procedure:

1. Test with Voltage Slope Setting of 1%:

Party	Instruction	Note
1% AVR Upwards:		
NCC	Select voltage slope setting of 1%	
NCC	Select setpoint voltage to grid voltage	<i>Ensure no reactive power imported/exported at HV (Note reactive power at LV)</i>
NCC	Increase setpoint voltage by a step of 0.5 kV on 110 kV (or 1 kV on 220 kV)	<i>Incremental step voltage setpoints of approx 0.5% of nominal grid voltage (note V and Q at HV and Q at LV)</i>
	<i>Confirm voltage and reactive limits of WF are not reached</i>	<i>220 kV system: 200 kV to 245 kV 110 kV system: 99 kV to 123 kV</i>
NCC	If HV system and reactive capability of WF are within limits, increase set point voltage by a further step	<i>Incremental step voltage setpoints of approx 0.5% of nominal grid voltage (note V and Q at HV and Q at LV)</i>
	<i>Confirm voltage and reactive limits of WF are not reached</i>	<i>220 kV system: 200 kV to 245 kV 110 kV system: 99 kV to 123 kV</i>
NCC	If HV system and reactive capability of WF are within limits, increase set point voltage by a further step	<i>Incremental step voltage setpoints of approx 0.5% of nominal grid voltage (note V and Q at HV and Q at LV)</i>
	<i>Confirm voltage and reactive limits of WF are not reached</i>	<i>220 kV system: 200 kV to 245 kV 110 kV system: 99 kV to 123 kV</i>
1% AVR Downwards:		
NCC	Return the setpoint voltage in steps of 0.5 % of nominal grid voltage towards the original starting position	<i>i.e. Virtually zero reactive power at HV (Note reactive power at LV)</i>
NCC	Decrease setpoint voltage by a step of 0.5 kV on 110 kV (or 1 kV on 220 kV)	<i>Decremental step voltage setpoints of approx 0.5% of nominal grid voltage (note V and Q at HV and Q at LV)</i>
	<i>Confirm voltage and reactive limits of WF are not reached</i>	
NCC	If HV system and reactive capability of WF are within limits, decrease set point voltage by a further step	<i>Decremental step voltage setpoints of approx 0.5% of nominal grid voltage (note V and Q at HV and Q at LV)</i>
	<i>Confirm voltage and reactive limits of WF are not reached</i>	
NCC	If HV system and reactive capability of WF are within limits, decrease set point voltage by a further step	<i>Decremental step voltage setpoints of approx 0.5% of nominal grid voltage (note V and Q at HV and Q at LV)</i>
	<i>Confirm voltage and reactive limits of WF are not reached</i>	
NCC	Return the setpoint voltage in steps of 0.5 % of nominal grid voltage towards the original starting position	<i>i.e. Virtually zero reactive power at HV (Note reactive power at LV)</i>

2. Test with Voltage Slope Setting of 4%:

Party	Instruction	Note
4% AVR Upwards:		
NCC	Select voltage slope setting of 4%	
NCC	Select setpoint voltage to grid voltage	<i>Ensure no reactive power imported/exported at HV (Note reactive power at LV)</i>
NCC	Increase setpoint voltage by a step of 0.5 kV on 110 kV (or 1 kV on 220 kV)	<i>Incremental step voltage setpoints of approx 0.5% of nominal grid voltage (note V and Q at HV and Q at LV)</i>
	<i>Confirm voltage and reactive limits of WF are not reached</i>	<i>220 kV system: 200 kV to 245 kV 110 kV system: 99 kV to 123 kV</i>
NCC	If HV system and reactive capability of WF are within limits, increase set point voltage by a further step	<i>Incremental step voltage setpoints of approx 0.5% of nominal grid voltage (note V and Q at HV and Q at LV)</i>
	<i>Confirm voltage and reactive limits of WF are not reached</i>	<i>220 kV system: 200 kV to 245 kV 110 kV system: 99 kV to 123 kV</i>
NCC	If HV system and reactive capability of WF are within limits, increase set point voltage by a further step	<i>Incremental step voltage setpoints of approx 0.5% of nominal grid voltage (note V and Q at HV and Q at LV)</i>
	<i>Confirm voltage and reactive limits of WF are not reached</i>	<i>220 kV system: 200 kV to 245 kV 110 kV system: 99 kV to 123 kV</i>
NCC	Return the setpoint voltage in steps of 0.5% of nominal grid voltage towards the original starting position	<i>i.e. Virtually zero reactive power at HV (Note reactive power at LV)</i>
4% AVR Downwards:		
NCC	Return the setpoint voltage in steps of 0.5% of nominal grid voltage towards the original starting position	<i>i.e. Virtually zero reactive power at HV (Note reactive power at LV)</i>
NCC	Decrease setpoint voltage by a step of 0.5 kV on 110 kV (or 1 kV on 220 kV)	<i>Decremental step voltage setpoints of approx 0.5% of nominal grid voltage (note V and Q at HV and Q at LV)</i>
	<i>Confirm voltage and reactive limits of WF are not reached</i>	<i>220 kV system: 200 kV to 245 kV 110 kV system: 99 kV to 123 kV</i>
NCC	If HV system and reactive capability of WF are within limits, decrease set point voltage by a further step	<i>Decremental step voltage setpoints of approx 0.5% of nominal grid voltage (note V and Q at HV and Q at LV)</i>
	<i>Confirm voltage and reactive limits of WF are not reached</i>	<i>220 kV system: 200 kV to 245 kV 110 kV system: 99 kV to 123 kV</i>
NCC	If HV system and reactive capability of WF are within limits, decrease set point voltage by a further step	<i>Decremental step voltage setpoints of approx 0.5% of nominal grid voltage (note V and Q at HV and Q at LV)</i>
	<i>Confirm voltage and reactive limits of WF are not reached</i>	<i>220 kV system: 200 kV to 245 kV 110 kV system: 99 kV to 123 kV</i>
NCC	Return the setpoint voltage in steps of 0.5% of nominal grid voltage towards the original starting position	<i>i.e. Virtually zero reactive power at HV (Note reactive power at LV)</i>

3. Test of Voltage Slope Setting:

Test of the voltage slope setting should be undertaken at 4% slope setting and is undertaken by manual initiation of a tap change on the grid connected transformer. Control of the transformer tap changer needs to be in manual control for this test.

- Request NCC to alter the voltage set-point so that there is a small amount of reactive power being exported as measured at the low voltage side of the grid connected transformer.
- Note the value of voltage at the low voltage side of the grid connected transformer, the reactive power at the low voltage side of the grid connected transformer.
- Manually initiate one tap change on the grid connected transformer in the direction that increases the export of reactive power from the wind farm
- Note the value of voltage at the low voltage side of the grid connected transformer, the reactive power at the low voltage side of the grid connected transformer.
- Confirm that the magnitude of increase in export of reactive power is within the limits of the capability of the wind farm
- After the elapse of about two minutes, manually initiate one tap change back to the initial position again.

The voltage at the low voltage side of the grid transformer measured before and after the tap change and the reactive power measured at the low voltage side of the grid transformer before and after the tap change are used in the calculation of the voltage slope of the voltage regulation system of the wind farm.

Voltage Slope (Droop) in percent =

$$\frac{\frac{\Delta kV}{kV}}{\frac{\Delta MVar}{MVar}} \times 100$$

Where:

- ΔkV = Step change in voltage at low voltage side of grid connected transformer as a result of transformer tap change.
- kV = Nominal voltage of low voltage side of grid connected transformer.
- $\Delta MVar$ = Step change in reactive power at low voltage side of grid connected transformer.
- $MVar$ = Value of reactive capability of wind farm at low voltage side of grid connected transformer as used by the wind turbine manufacturer for calculation of Voltage Slope (Droop).

4.3.5 Test Results

On completion of the tests, the results should confirm or otherwise compliance with the relevant section of the **Grid Code** as follows:

Grid Code Clause (V3.4)	Description	Pass Criteria
WFPS 1.6.2	Confirm the ability of wind farm to respond to dispatch voltage set-points from NCC.	Voltage regulation for given droop setting to be within limits set out in contractor's voltage study that will have been approved by Eirgrid.
	Confirm that actual voltage slope settings concur with selected voltage slope settings of 1% and 4%.	Actual voltage slope per applied voltage slope setting.
	Confirm that change in voltage regulation set-point is implemented by the wind farm within 20 seconds of receipt of the signal from NCC.	Response implemented within 20 seconds or less
	Confirm that 90% of the steady state reactive power response occurs within 1 second.	Response of 90% of steady state reactive power required within 1 second

4.4 Test #8: Reactive Power Capability

4.4.1 Purpose of the Test:

The purpose of this test is to confirm the ability of the wind farm to operate to the limits of the reactive power capability curve for Controllable Wind Farm Power Stations as indicated in Figure WFPS1.4 of the **Grid Code** and also to establish the limits of the wind farms reactive power capability for the purposes of Ancillary Services agreements. The test is undertaken for both the export of reactive power from the wind farm and for the import of reactive power to the wind farm. The measured reactive power is at wind farm voltage, (Point Y) adjacent to the grid connected transformer. This test should be undertaken at different levels of active power to confirm that the range is within the capability characteristic at the given level of power. The test should be undertaken at the Voltage Slope setting 4%. The grid voltage set-point should be under the control of NCC.

4.4.2 Pre-Conditions:

Wind conditions to provide at least 60% of rated output.

4.4.3 Instrumentation

Instrumentation that will be required for the test will consist of the following:

- Available active power from the prevailing wind in MW, derived by algorithm in the WFCS.
- Actual active power from the wind farm in MW
- Grid voltage measured at the high voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Z)
- Reactive power measured at the low voltage side of the grid connected transformer, (Figure **WFPS1.3**, Point Y)
- Reactive power measured at the high voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Z)
- Wind farm voltage measured at the low voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Y)
- Grid transformer tap position.
- Automatic Voltage Regulation system (AVR) set-point
- AVR set-point feedback

Measuring instrumentation to accuracy Class 0.5S or better is required. The time resolution is required to 0.25 seconds.

4.4.4 Procedure:

Party	Instruction	Note
Capacitive Capability		
NCC	Switch Active Power Control 'off'	
NCC	Select voltage setpoint approx equal to system voltage	<i>PF = 1</i>
WF	Enable AVR system	
NCC	Select voltage slope setting to 4%	
NCC	Select voltage setpoint to allow WF to reach its capacitive side maximum limit in increments of 0.5 kV on 110 kV (Or 1 kV on 220 kV)	<i>Continue in step wise manner until full reactive capability is reached to match reactive power capability curve**. Allow 1 min. per setpoint (or until system is stable)</i>
NCC & WF	Record MVAR at grid transformer LV terminals for each of the following MW active:	<i>Compare with expected -MVAR at those points</i>
	10%	
	20%	
	30%	
	40%	
	50%	
	60%	
	70%	<i>If wind conditions allow</i>
	80%	<i>If wind conditions allow</i>
	90%	<i>If wind conditions allow</i>
Inductive Capability:		
NCC	Select voltage setpoint approx equal to system voltage	<i>PF = 1</i>
NCC	Select voltage setpoint to allow WF to reach its inductive side maximum limit in decrements of 0.5 kV on 110 kV (Or 1 kV on 220 kV)	<i>Continue in step wise manner until full reactive capability is reached to match reactive power capability curve. Allow 1 min. per setpoint (or until system is stable)</i>
NCC/WF	Record MVAR at grid transformer LV terminals for each of the following MW active:	<i>Compare with expected +MVAR at those points</i>
	10%	
	20%	
	30%	
	40%	
	50%	
	60%	
	70%	<i>If wind conditions allow</i>
	80%	<i>If wind conditions allow</i>
	90%	<i>If wind conditions allow</i>

** In the event that it is not possible to reach the full reactive power capability of the wind farm due to displacement between AVR set-point and actual voltage achieved, control of Q may be set in manual in order to increase exported (Q lagging) to the grid. In doing so, the grid voltage will gradually increase towards the AVR set-point. (Such voltage displacement may be due to the regulation of the grid transformer which would be in addition to the Voltage Slope of the voltage regulator). Such manual control shall be undertaken in consultation and with the agreement of NCC.

4.4.5 Test Results:

The wind farm shall clearly demonstrate that the reactive power capability for both export of reactive power and import of reactive power at wind farm voltage at Point Y, (normally medium voltage), can operate within and up to the limits of the reactive power characteristic as set out in Figure **WFPS1.4** of the **Grid Code**.

Grid Code Clause (V3.4)	Purpose of Test and Description	Pass Criteria
WFPS 1.6.3	Confirm the ability of wind farm to provide reactive power over the full range of the capability diagram Figure WFPS1.4 of the Grid Code .	Detailed above.

4.5 Test #9: Voltage Emissions Test and Harmonics Test

4.5.1 Purpose of the Test

The purpose of this test is to confirm the ability of the wind farm to operate within the limits specified in Table 2 of IEC 61000–3-7 for fluctuating loads and within the limits specified in Section **WFPS 1.6.4** of the **Grid Code** for harmonics. This test shall take place while other **Grid Code** compliance tests are being undertaken which are within the normal operating parameters of the wind farm. Such measurements shall be undertaken at both wind farm voltage and at grid voltage and will be referred to collectively as 'power quality' tests.

4.5.2 Instrumentation

Instrumentation that will be required for the test will consist of the following:

- Actual active power from the wind farm in MW
- Grid voltage measured at the high voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Z)
- Power quality measured at the high voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Z)
- Reactive power measured at the low voltage side of the grid connected transformer, (Figure **WFPS1.3**, Point Y)
- Wind farm voltage measured at the low voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Y)
- Power quality measured at the low voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Y)

Measuring instrumentation to accuracy Class 0.5S or better is required.

Instrumentation for power quality shall measure and record emissions and harmonics at wind farm voltage, (Figure **WFPS1.3**, Point Y) and at grid voltage, (Figure **WFPS1.3**, Point Z) and shall have the ability to:

- Record representative sample of harmonics for each operational test.
- Capture all harmonics that are above the maximum levels referred to in the **Grid Code** as appropriate.
- Capture all voltage incidents.

4.5.3 Procedure

Power quality consisting of step emissions and harmonics shall be recorded during normal operating conditions and these would be represented while the following tests are being undertaken:

- Active Power Control test (**WFPS1.5.2.1**)
- Frequency Response test (**WFPS1.5.2.2**)
- Ramp Rate test (**WFPS1.5.3.1**)
- Transmission System Voltage Range (**WFPS1.6.1**)
- Reactive Power Capability test (**WFPS1.6.3**)
- Black Start Shutdown

In the case of the Reactive Power Capability test, emissions and harmonics would be applicable where reactive power is operating within and as far as the limits of the reactive power characteristic for the wind farm.

4.5.4 Test Results:

Grid Code Clause (V3.4)	Purpose of Test and Description	Instrumentation & Information Output	Pass Criteria
WFPS 1.6.4	Confirm that the wind farm does not produce voltage emissions and harmonics outside the specified limits set out in Table 2 of IEC 61000-3-7 and the Grid Code	Data recording of the following: <ul style="list-style-type: none"> • Active power • Grid voltage • Power quality at grid voltage • Reactive power at wind farm voltage • Wind farm system voltage • Power quality at wind farm voltage. 	Emissions within limits in Table 6 of IEC 61000-3-7. Harmonics within limits referred to in Distribution Code for HV and MV systems

5 SECTION C: SIGNALS, COMMUNICATIONS AND CONTROL

5.1 Purpose and Scope of the Test

The purpose of grid compliance tests of the signals, communications and control systems is to confirm the functionality of each digital and analogue signal between the wind farm and NCC and vice versa. These tests may be carried out without actually influencing the wind farm during the course of the tests. Their actual influence on the wind farm will form part of the individual operational tests such as the Active Power Control test and the Frequency Response test.

The scope of the tests is to confirm the functionality and accuracy of the signals received at the wind farm control system from NCC and also to confirm the functionality and accuracy of the signals received by NCC from the wind farm. These tests are not intended to check intermediate values of the signals, such as the calibration of signal transducers, as these should be completed during commissioning.

5.2 Scope of Signals, Communications and Controls

Signals, communications and controls from controllable wind farm power stations to NCC are set out into five groups in the **Grid Code** as follows:

- Signals List #1: General - applies to all controllable wind farms
- Signals List #2: Meteorological Data – WFPS with MEC in excess of 10 MW
- Signals List #3: Availability Data – all WFPS with MEC in excess of 10 MW
- Signals List #4: Active Power Control Data - all controllable wind farms
- Signals List #5: Frequency Response System Data - all controllable wind farms

Signals from NCC to the controllable wind farm power stations are set out in the **Grid Code** as follows:

- Active Power Control
- Frequency Response
- Voltage Regulation
- Black Start Shutdown Group of Signals

The following procedures apply to testing of all of these listed signals.

5.3 General

On the day of the tests, suitably qualified technical personnel will be needed at the wind farm to assist in undertaking the tests. Their function will be to facilitate undertaking the tests which shall be carried out in conjunction with NCC. Such personnel shall have the ability to fully understand the function of the wind farm and its relationship to the grid to which the wind farm is connected. Furthermore, such personnel shall have the ability to set up the control system of the wind farm so as to enable this grid compliance test to be correctly undertaken. Personnel will be needed at NCC to facilitate the initiation of digital and analogue signals in the test schedule and confirm receipt of feedback signals from the wind farm.

5.4 Instrumentation

Instrumentation is not envisaged to be required except for the ability of the data terminal equipment at the wind farm to display each of the signal values and acknowledge the receipt and transmission of status signals. In the event of there being a problem with the signals, the following additional equipment may be required:

- Volt meter and ammeter to measure digital and analogue signals. The volt meter needs to have the ability to measure a fleeting pulse.

Mandatory required test instruments are as follows:

- Display terminal at distributed control system to display the value of each individual signal or status of signal
- Alternatively, temporary display terminal to display the value of each individual signal or status of signal
- Means of measuring time delays as follows:
 - Controllable wind farm to NCC Interface Cabinet – Digital changes within 1 second of the associated change of state event.
 - Controllable wind farm to NCC Interface Cabinet – Analogue changes within 5 seconds of the associated change of state event.
 - NCC to controllable wind farm – Digital commands from the NCC Interface Cabinet to the wind farm controller within 1 second.
 - NCC to controllable wind farm – Set-point signals from the NCC Interface Cabinet to the wind farm controller within 5 seconds.

Measuring instrumentation to accuracy Class 0.5S or better is required. The time resolution is required to 0.25 seconds.

5.5 Pre-Conditions

All signals, communications and control systems between the wind farm and NCC require to be fully commissioned prior to undertaking **Grid Code** compliance testing. These include all digital and analogue signals from the wind farm to NCC and vice versa.

These tests are independent of wind conditions and operating output of the wind farm and can be carried out when wind conditions are unsuitable for other grid compliance tests or if a significant change has been made to the wind farm controller.

5.6 Test #10: Signals, Communications and Control:

5.6.1 Procedure

Digital and analogue signals are set out in 'Test Results' below and the procedure for testing each of these signals is set out in the following paragraphs:

Digital Signals:

Digital signals from NCC to the wind farm shall be tested as follows:

Party	Instruction	Note
NCC	Provide a digital signal 'on' to the WF	
WF	<u>Automatically</u> send feedback to NCC confirming satisfactory receipt of digital 'on' signal from NCC	
WF	Confirm that the digital 'on' signal takes appropriate action in WF control system within required time	Time set out in 'Test Results' below
NCC	Confirm, by voice communication, satisfactory receipt of the digital feedback signal	
NCC	Provide digital 'off' signal to WF	
WF	<u>Automatically</u> send feedback to NCC confirming satisfactory receipt of digital 'off' signal from NCC	
WF	Confirm that the digital 'off' signal takes appropriate action in WF control system within required time	Time set out in 'Test Results' below
NCC	Confirm, by voice communication, satisfactory receipt of digital feedback signal	

Analogue Signals:

Analogue signals from NCC to the wind farm shall be tested as follows:

Party	Instruction	Note
<u>Analogue Signals:</u>		
NCC	Provide an analogue signal of a range of values in percent of full value, as outlined in 'Test Results' below	
WF	<u>Automatically</u> send feedback to NCC confirming receipt of appropriate value from NCC	
WF	Confirm that the control system implements the signal within the required time	Time set out in 'Test Results' below
NCC	Confirm, by voice communication, satisfactory receipt of the analogue feedback signal	Tolerance on signals set out in 'Test Results below'

5.6.2 Test Results:

For all digital signals, on completion of the tests, the results should confirm or otherwise compliance with the relevant section of the **Grid Code**, including:

- Confirmation that each digital signal is received by the wind farm from NCC
- Confirmation that each digital feedback is received by NCC from the wind farm
- Confirmation that each digital signal is received by NCC from the wind farm
- Confirmation that the wind farm takes the required action on the control system within the required time.

For all analogue signals, on completion of the tests, the results should confirm or otherwise compliance with the relevant section of the **Grid Code**, including:

- Confirmation that each analogue signal of the correct magnitude is received by the wind farm from NCC
- Confirmation that each feedback analogue signal of the correct magnitude is received by NCC from the wind farm
- Confirmation that each analogue signal of the correct magnitude is received by NCC from the wind farm

The pass standards as set out in the **Grid Code**, along with the individual tests required for each signal, are outlined below.

5.7 Test # 10.1: Signal List #1 from Controllable WFPS to NCC

This test is to confirm the functionality and accuracy in transmission of signals as outlined in **Grid Code** clause **WFPS1.7.1.1** which refers to signals required at the wind farm's designated TSO Telecommunication Interface Cabinet.

	Purpose of Test and Description:	Pass Criteria:
(a)	Active Power Output (MW) at LV side of grid-connected transformer	
	Simulated MW value: 0%, 5%, 15%, 25%, 50%, 75%, 90%, 100% of rated capacity	<ul style="list-style-type: none"> - Signal received by NCC - Error of 0.5% or less, - Change of status (digital) relayed within 5 s
(b)	Reactive Power output/demand (+/-MVar) at LV side of grid connected transformer	
	Simulated MVar value: 0%, 15%, 25%, 50%, 75%, 100% of reactive power capacity (import and export)	<ul style="list-style-type: none"> - Signal received by NCC - Error of 0.5% or less, - Change of status (digital) relayed within 5 s
(c)	Voltage at lower voltage side of grid connected transformer	
	Simulated wind farm system voltage for 0%, 80%, 90%, 100%, 110% of rated voltage.	<ul style="list-style-type: none"> - Signal received by NCC - Error of 0.5% or less, - Change of status (digital) relayed within 5 s
(d)	Available Active Power (MW)	
	Simulated MW value for available active power at 0%, 5%, 15%, 25%, 50%, 75%, 90%, 100% of rated capacity	<ul style="list-style-type: none"> - Signal received by NCC - Error of 0.5% or less, - Change of status (digital) relayed within 5 s
(e)	Grid connected transformer tap positions	
	Simulated signal for tap position	<ul style="list-style-type: none"> - No error for tap positions, - To be relayed within 1 second
(f)	Voltage Regulation Set-point feedback signal (in kV)	
	Simulated wind farm system voltage for 0%, 80%, 90%, 100%, 110% and 120% of nominal system voltage.	<ul style="list-style-type: none"> - Signal received by NCC - Error of 0.5% or less, - Change of status (digital) relayed within 5 s
(g)	On/off status indications for all Reactive Power devices exceeding 5 MVar	
	Simulated signal for reactive power devices	<ul style="list-style-type: none"> - No error for status, - Response time <1sec
(h)	Circuit breaker and disconnect position indications.	
	Simulated disconnect positions, actual test on one circuit breaker	<ul style="list-style-type: none"> - No error for status, - Response time <1sec
(i)	Normally open potential free auxiliary contacts	
	Test of actual contacts	<ul style="list-style-type: none"> - No error for status, - Response time <1sec
(j)	Eirgrid - Remote Control Enable Switch at Wind Farm	
		<ul style="list-style-type: none"> - No error for status, - Response time <1sec
	Active Power Control – Status ‘Off’	
	Part of test WFPS1.7.2.2	<ul style="list-style-type: none"> - No error for status, - Response time <1sec.
	Active Power Control – Status ‘On’	
	Part of test WFPS1.7.2.2	<ul style="list-style-type: none"> - No error for status, - Response time <1 sec. - Control system to implement within 10 s

Frequency Response System – Status ‘Off’	
Part of test WFPS1.7.2.3	<ul style="list-style-type: none"> - No error for status, - Response time <1sec.
Frequency Response System – Status ‘On’	
Part of test WFPS1.7.2.3	<ul style="list-style-type: none"> - No error for status, - Response time <1sec
Frequency Response Curve Select – ‘Curve 1’	
Part of test WFPS1.7.2.3	<ul style="list-style-type: none"> - No error for status, - Response time <1sec. - Control system to implement within 1 min.
Frequency Response Curve Select – ‘Curve 2’	
Part of test WFPS1.7.2.3	<ul style="list-style-type: none"> - No error for status, - Response time <1sec. - Control system to implement within 1 min.
Network Operator Initiated Shutdown – Status ‘Off’	
Signal from NCC	<ul style="list-style-type: none"> - No error for status, - Response time <1sec
Network Operator Initiated Shutdown – Status ‘On’	
Signal from NCC	<ul style="list-style-type: none"> - No error for status, - Response time <1sec
Active Power Control Set-Point Enable ‘On’	
Part of test WFPS1.7.2.2	<ul style="list-style-type: none"> - No error for status, - Response time <1sec
Voltage Regulation Set-Point Enable ‘On’	
Part of test WFPS1.7.2.4	<ul style="list-style-type: none"> - No error for status, - Response time <1sec

5.8 Test #10.2: Signals List #2 from Controllable WFPS to NCC

This test is to confirm the accuracy in transmission of analogue signals as outlined in **Grid Code** clause **WFPS1.7.1.2** which refers to meteorological data signals required at the wind farm's designated TSO Telecommunication Interface Cabinet.

	Purpose of Test and Description:	Pass Criteria:
a)	Wind Speed	
	<ul style="list-style-type: none"> - Test at actual wind speed - Test at simulated wind speed of 0, 10, 20, 30, 45, 70 m/s 	<ul style="list-style-type: none"> - Signal received by NCC, - Error of 2.5% or less. - Change of status relayed within 5 s
b)	Wind Direction	
	<ul style="list-style-type: none"> - Test at actual wind direction - Test at simulated wind direction of 0,45, 90, 135, 180, 225, 270, 315 degrees 	<ul style="list-style-type: none"> - Signal received by NCC, - Error of 2.5% or less. - Change of status relayed within 5 s
c)	Air Temperature	
	<ul style="list-style-type: none"> - Test at actual air temperature - Test at simulated air temperature of -40, -10, 0, +10, +20, +30, +70 degrees C. 	<ul style="list-style-type: none"> - Signal received by NCC - Error of 2.5% or less - Change of status relayed within 5 s
d)	Air Pressure	
	<ul style="list-style-type: none"> - Test at actual air pressure - Test at simulated air pressure of 735, 835, 935, 985, 1035, 1060 mBar. 	<ul style="list-style-type: none"> - Signal received by NCC, - Error of 2.5% or less - Change of status relayed within 5 s

5.9 Test #10.3: Signal List #3 from Controllable WFPS to NCC

This test is to confirm the accuracy in transmission of signals as outlined in **Grid Code** clause **WFPS1.7.1.3** which refers to Availability Data signals required at the wind farm's designated TSO Telecommunication Interface Cabinet.

	Purpose of Test and Description:	Pass Criteria:
a)	Controllable WFPS Availability	
	Simulated signal 0%, 25%, 50%, 75%, 100%.	<ul style="list-style-type: none"> - Signal received by NCC - Error of 0.5% or less - Change of status relayed within 5 s
b1)	Percentage of WTG shutdown due to high wind speed	
	Simulated signal 0%, 25%, 50%, 75%, 100%. (Refer also test b2 below)	<ul style="list-style-type: none"> - Signal received by NCC - Error of 0.5% or less - Change of status relayed within 5 s
b2)	Interaction of 'Available Active Power' with 'Percentage of WTG shutdown due to high wind speed'	
	Confirm that Available Active Power signal reduces in proportion to increasing Wind Farm Shutdown signal	<ul style="list-style-type: none"> - Signal received by NCC - Error of 0.5% or less - Change of status relayed within 5 s
c)	Percentage of WTG not generating due to low wind speed	
	Simulated signal 0%, 25%, 50%, 75%, 100%.	<ol style="list-style-type: none"> 1. Signal received by NCC, 2. error of 0.5% or less. 3. Change of status relayed within 5 s.

5.10 Test #10.4: Signal List #4 from Controllable WFPS to NCC

This test is to confirm the functionality and accuracy of analogue and digital signals as outlined in **Grid Code** clause **WFPS1.7.1.4** which refers to Active Power Control Data required at the wind farm's designated TSO Telecommunication Interface Cabinet

	<i>Purpose of Test and Description:</i>	<i>Pass Criteria:</i>
a)	Active Power Control set-point value (MW)	
	Refer to test signal sent by NCC WFPS1.7.2	<ul style="list-style-type: none"> - Signal received by NCC - Error of 0.5% or less - Change of status relayed within 5 s
b)	Active Power Control status (On/Off)	
	Refer to test signal sent by NCC WFPS1.7.2	<ul style="list-style-type: none"> - No error for status - Response time <1sec

5.11 Test #10.5: Signal List #5 from Controllable WFPS to NCC

This test is to confirm the functionality and accuracy of analogue and digital signals as outlined in **Grid Code** clause **WFPS1.7.1.4** which refers to Frequency Response System Data required at the wind farm's designated TSO Telecommunication Interface Cabinet

	<i>Purpose of Test and Description:</i>	<i>Pass Criteria:</i>
a)	Frequency Response Mode signal Curve 1 or Curve 2	
	Refer to test signal sent by NCC WFPS1.7.2	<ul style="list-style-type: none"> - No error for status - Response time <1sec
b)	Frequency Response system status (On/Off)	
	Refer to test signal sent by NCC WFPS1.7.2	<ul style="list-style-type: none"> - No error for status - Response time <1sec

5.12 Tests #10.6 – #10.8: Control Signals from NCC to Controllable WFPS

This test is to confirm the functionality and accuracy of signals as outlined in **Grid Code** clause **WFPS1.7.2** which refers to Control Signals required from the TSO to Controllable WFPS.

Purpose of Test and Description:		Pass Criteria:
WFPS1.7.2.2	Active Power Control	
	Signal from NCC at 0%, 5%, 15%, 25%, 50%, 75%, 90%, 100% of rated capacity	<ul style="list-style-type: none"> - Signal received by wind farm - Error of 0.5% or less - Change of status relayed within 5 s - Commence implementation within 10 s
WFPS1.7.2.2	Active Power Control enable / disable	
	Signal from NCC. See also WFPS1.7.2.5	<ul style="list-style-type: none"> - No error for status - Response time <1sec
WFPS1.7.2.3	Frequency Response Curve 1 / Curve 2	
	Signal from NCC. See also WFPS1.7.2.5	<ul style="list-style-type: none"> - No error for status - Response time <1sec
WFPS1.7.2.3	Frequency Response enable / disable	
	Signal from NCC. See also WFPS1.7.2.5	<ul style="list-style-type: none"> - No error for status - Response time <1sec
WFPS1.7.2.4	Voltage Regulation	
	Simulated signal from NCC for the following voltages: 80%, 90%, 100%, 110%, 120% of nominal system voltage.	<ul style="list-style-type: none"> - Signal received by wind farm - Error of 0.5% or less - Change of status relayed within 5 s - Commence implementation within 20 s
WFPS1.7.2.4	Voltage Regulation	
	Signal from NCC. See also WFPS1.7.2.5	No error for status, response time <1sec

5.13 Test #10.9: Control Signals from NCC to Controllable WFPS

This test is to confirm the functionality and accuracy of signals as outlined in **Grid Code** clause **WFPS1.7.2** which refers to the Black Start Shutdown signal required from the TSO to Controllable WFPS

Purpose of Test and Description:	Pass Criteria:
Normal Operating Conditions:	
-Black Start Shutdown 'On' Transmitted - 'Off'	
Signal from NCC 'Off' (0 Volt)	<ul style="list-style-type: none"> - No error for status - Response time <1sec
-Black Start Shutdown 'Off' Transmitted - 'Off'	
Signal from NCC 'Off' (0 Volt)	<ul style="list-style-type: none"> - No error for status - Response time <1sec
-Black Start Shutdown 'On' Signal - 'Off' feedback to NCC	
Signal from NCC 'Off' (0 Volt)	<ul style="list-style-type: none"> - No error for status - Response time <1sec
-Black Start Shutdown 'Off' Signal - 'On' feedback to NCC	
Signal from NCC 'On' (+V (PI))	<ul style="list-style-type: none"> - No error for status - Response time <1sec
-Black Start Shutdown Indication - 'Off'	
Signal from NCC 'Off' (Blue Lamp)	<ul style="list-style-type: none"> - No error for status - Response time <1sec
-Wind farm system command to trip designated circuit breaker(s)	
No signal to trip circuit designated breaker(s)	<ul style="list-style-type: none"> - No error for status - Response time <1sec
-Wind farm system inhibit closing designated circuit breaker(s)	
Circuit breaker re-close inhibit 'Off'	<ul style="list-style-type: none"> - No error for status - Response time <1sec
NCC Black Start Shutdown 'On'	
-Black Start Shutdown 'On' Transmitted - 'Pulse'	
Signal from NCC 'Pulse' (24 Volt (0.5 sec))	<ul style="list-style-type: none"> - No error for status - Response time <1sec
-Black Start Shutdown 'Off' Transmitted - 'Off'	
Signal from NCC 'Off' (0 Volt)	<ul style="list-style-type: none"> - No error for status - Response time <1sec
-Black Start Shutdown 'On' Signal - 'On' feedback to NCC	
Signal from NCC 'On' (+V (PI))	<ul style="list-style-type: none"> - No error for status - Response time <1sec
-Black Start Shutdown 'Off' Signal - 'Off' feedback to NCC	
Signal from NCC 'Off' (0 Volt)	<ul style="list-style-type: none"> - No error for status - Response time <1sec
-Black Start Shutdown Indication - 'On'	
Signal from NCC 'Off' (Blue Lamp)	<ul style="list-style-type: none"> - No error for status - Response time <1sec
-Wind farm system command to trip designated circuit breaker(s)	
Trip designated circuit breaker (Pulse)	<ul style="list-style-type: none"> - No error for status - Response time <1sec
-Wind farm system inhibit closing designated circuit breaker(s)	
Circuit breaker re-close inhibit 'On'	<ul style="list-style-type: none"> - No error for status

	- Response time <1sec
NCC Black Start Shutdown 'Off'	
-Black Start Shutdown 'On' Transmitted - 'Off'	
Signal from NCC 'Off' (0 Volt)	- No error for status - Response time <1sec
-Black Start Shutdown 'Off' Transmitted - 'Pulse'	
Signal from NCC 'Pulse' (24 Volt (0.5 sec))	- No error for status - Response time <1sec
-Black Start Shutdown 'On' Signal - 'Off' feedback to NCC	
Signal from NCC 'Off' (0 Volt)	- No error for status - Response time <1sec
-Black Start Shutdown 'Off' Signal - 'On' feedback to NCC	
Signal from NCC 'On' (+V (PI))	- No error for status - Response time <1sec
-Black Start Shutdown Indication - 'Off'	
Signal from NCC 'Off' (Blue Lamp)	- No error for status - Response time <1sec
-Wind farm system command to trip designated circuit breaker(s)	
No signal to trip circuit designated breaker(s)	- No error for status - Response time <1sec
-Wind farm system inhibit closing designated circuit breaker(s)	
Circuit breaker re-close inhibit 'Off'	- No error for status - Response time <1sec

5.14 Test #11: Capacity Test

5.14.1 Purpose of the Test

The purpose of this test is to confirm that the wind farm can operate at its maximum export capacity, at rated lagging (export) reactive power for a period sufficient to ensure its ability to continue to do so indefinitely.

5.14.2 Instrumentation

Recorded data that will be required at the wind farm for the test will consist of the following:

- Available active power from the prevailing wind in MW, derived by algorithm in the wind farm control system
- Actual active power from the wind farm in MW measured at grid voltage using permanently installed metering equipment. Refer to **Grid Code** Figure **WFPS1.3**, Point Z, (where this metering is provided by the wind farm contractor)
- Energy from the wind farm in MWhr measured at grid voltage using permanently installed metering equipment. Refer to **Grid Code** Figure **WFPS1.3**, Point Z, (where this integrating metering is provided by the wind farm contractor)
- Actual active power measured at the low voltage side of the grid connected transformer, using permanently installed metering equipment. Refer to **Grid Code** Figure **WFPS1.3**, Point Y, (where this metering is provided by the wind farm contractor). (This should be the same Active Power information that is transmitted to Eirgrid (Signal List # 1(a)).
- Reactive power measured at the low voltage side of the grid connected transformer. Refer to **Grid Code** Figure **WFPS1.3**, Point Y.

Where power and energy measurements are made at the low voltage side of the grid connected transformer only, the wind farm contractor shall take account of the losses in the grid transformer in calculating the power at grid voltage. .

5.14.3 Pre-conditions:

Wind conditions should be sufficient to produce in excess of 90% of the rated active power capacity of the wind farm at a relatively constant level. If 90% cannot be reached on the day of testing, the % of MEC with which it does operate at for an extended period should be recorded. If this occurs, data of the wind farm operating in excess of 90% for an extended period at a time following **Grid Code** compliance testing may be accepted as proof of capacity on agreement with the TSO, on confirmation that the metered data correlates with the data provided by the wind farm operator.

5.14.4 Procedure

- The wind farm operator should set the reactive power of the wind farm so as to export reactive power (lagging) to the grid at rated capacity (as measured at wind farm voltage).
- The test should run for a period of at least one hour.

There will be a requirement to coordinate the periods of energy measurement with Eirgrid in order to correlate the results from the wind farm and those from the commercial metering at NCC.

5.14.5 Test Results

On completion of the tests, the results should demonstrate:

- Where wind conditions are in excess of 90% of the capacity of the wind farm, confirm as far as is practicable, that the wind farm can produce output towards its registered maximum export capacity (MEC), and at rated lagging reactive power (export) for a period of at least one hour without distress to the equipment, such distress being identified by the occurrence of an alarm or a shutdown condition on any wind turbine.

Purpose of Test and Description	Instrumentation & Information Output	Instrumentation Accuracy and Information Output Accuracy	Pass Criteria
Confirm that the wind farm can provide its registered maximum export capacity (MEC) at rated reactive power (lagging) for a period of no less than one hour.	Data recording of the following: <ul style="list-style-type: none"> • Available active power • Active power at grid voltage • Energy at grid voltage • Reactive power at wind farm voltage 	<ul style="list-style-type: none"> • Use of installed permanent metering for active power. • Limits of overall accuracy in measurement and resolution $\pm 1.0\%$, time resolution 1 second. 	No alarms or trip conditions

5.15 Test #14: Disturbance Test:

5.15.1 Purpose of the Test

The purpose of the disturbance test is to confirm the ability of the wind farm to go into a safe shut down mode for a range of tripping incidents. Furthermore, this test is to verify the ability of the wind farm to satisfactorily re-start following re-instatement of the high voltage supply to the grid transformer. The wind farm should be operating normally prior to the disturbance test. This test should only be undertaken where there is no auto-reclosing on the line feeding the wind farm, or where re-closing is fitted, with the auto-reclosing feature switched off.

The test shall demonstrate that the wind farm can safely shut down and re-start following:

1. HV line trip with standby diesel generator
2. HV line trip without standby diesel generator

5.15.2 Separate Standby Supply from Distribution Network

Note whether or not the wind farm has a separate standby supply from the local distribution network and whether this supply is configured to automatically provide supply to essential low voltage services.

5.15.3 General

In addition to the personnel required to be present for other **Grid Code** compliance tests, an ESB Networks Operator will be required at the wind farm high voltage substation to carry out and monitor the HV switching operations locally for the Disturbance Test.

5.15.4 Instrumentation

Recorded data that will be required for the test will consist of the following:

- Available active power from the prevailing wind in MW, derived by algorithm in the wind farm control system
- Actual active power from the wind farm in MW
- Grid voltage measured at the high voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Z)
- Wind farm voltage measured at the low voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Y)
- Reactive power measured at the low voltage side of the grid connected transformer, (Figure **WFPS1.3**, Point Y)
- Essential systems (UPS and d.c.) voltage for substation and control room
- Record grid transformer tap position.
- Record times when the diesel generator powers the essential services

Measuring instrumentation to accuracy Class 1 or better and time resolution to 1 second are required.

As this test incurs the loss of a.c. supplies and consequent interruption of supply to essential a.c. services, it is a requirement of this test to ensure that there is a continuous supply to all of the test instrumentation without interruption.

5.15.5 Procedure

The wind farm should be in normal operation at no less than 60% of its rated capacity.

1. HV line trip with standby diesel generator (DG):

Party	Instruction	Note
NCC	Arrange to trip grid supply to the wind farm at a remote substation.	<i>When grid supply is tripped, there will be no external source of supply to any individual turbine.</i>
NCC	Trip high voltage CB feeding the WF grid connected transformer.	<i>HV supply should remain 'off' for a period of approx 10 minutes.</i>
WF	Open main WF medium voltage CB	<i>Monitor response of WF</i>
	<i>WF should come to a halt and the standby DG should automatically start up and provide power to essential circuits at the WF substation and associated systems</i>	<i>Record:</i> <ul style="list-style-type: none"> - <i>time for the DG to establish supply to the essential services following loss of mains</i> - <i>the overall time that the DG is supplying the essential services</i>
NCC	After the passing of 10 minutes, re-instate grid supply to WF substation by closing HV CB feeding the grid connected transformer.	
WF	Wind farm operator to close main medium voltage CB again	<i>Record response of the WF</i>
	<i>After a short period the essential circuits should transfer from DG supply to mains supply and the DG should undergo a controlled shutdown while the WF should progressively start up and begin exporting to full available capacity</i>	

2. HV line trip without standby diesel generator:

Party	Instruction	Note
NCC	Arrange to trip grid supply to the wind farm at a remote substation.	<i>When grid supply is tripped, there will be no external source of supply to any individual turbine.</i>
NCC	Trip high voltage CB feeding the WF grid connected transformer.	<i>HV supply should remain 'off' for a period of approx 10 minutes.</i>
WF	Open main WF medium voltage CB	<i>Monitor response of WF</i>
	<i>WF should come to a halt.</i>	
NCC	After the passing of 10 minutes, re-instate grid supply to WF substation by closing HV CB feeding the grid connected transformer.	
WF	Wind farm operator to close main medium voltage CB again	
	<i>Record response of WF. The WF should progressively start up and connect to the system to export power to the grid to full capacity available from the wind.</i>	

5.15.6 Test Results:

Grid Code Compliance Test	Instrumentation & Information Output	Pass Criteria
Disturbance Test 1: Trip HV Line to WF with DG	Data recording of the following: -Available active power. -Active power -Grid voltage -Wind farm system voltage -Reactive power at wind farm voltage -Transformer tap position	Refer to 'Pass Criteria' itemised below: 1 - 7
Disturbance Test 2: Trip HV Line to WF without DG	Data recording of the following: -Available active power. -Active power -Grid voltage -Wind farm system voltage -Reactive power at wind farm voltage -Essential systems voltage -Transformer tap position	Refer to 'Pass Criteria' itemised below: 1 - 6

5.15.7 Pass Criteria

1. Capability of the wind farm to shut down safely on loss of grid supply.
2. Standby diesel generator to start up automatically and supply essential ac services
3. On re-instatement of grid supply, automatic transfer of essential ac services onto mains supply, diesel generator to automatically shut down.
4. Wind farm to progressively start up where each wind turbine progressively connects to the system and generates power.
5. Wind farm to provide full output to the capability of the prevailing wind conditions within a period of 1.5 hours following re-instatement of the grid supply.
6. No more than 1 wind turbine should fail to start within the 1.5 hour period where the wind farm has a rated capacity up to 75 MW.
7. No more than 2 wind turbines should fail to start within the 1.5 hour period where the wind farm has a rated capacity of greater than 75 MW.

5.16 Test #18: Black Start Shutdown Test

5.16.1 Purpose of the Test

The purpose of the Black Start Test is to confirm the ability of the wind farm to disconnect, and remain disconnected from the grid on receiving a Black Start Shutdown signal from the NCC according to clause **WFPS1.7.2.5** in the **Grid Code**.

5.16.2 General

In addition to the personnel required to be present for other **Grid Code** compliance tests, an ESB Networks Operator will be required at the wind farm high voltage substation to carry out and monitor the HV switching operations locally for the Black Start Shutdown Test.

5.16.3 Instrumentation

Recorded data that will be required for the test will consist of the following:

- Available active power from the prevailing wind in MW, derived by algorithm in the wind farm control system
- Actual active power from the wind farm in MW
- Grid voltage measured at the high voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Z)
- Wind farm voltage measured at the low voltage side of the grid connected transformer (Figure **WFPS1.3**, Point Y)
- Reactive power measured at the low voltage side of the grid connected transformer, (Figure **WFPS1.3**, Point Y)

Measuring instrumentation to accuracy Class 1 or better and time resolution to 1 second are required.

5.16.4 Procedure:

The wind farm should be in normal operation at no less than 60% of its rated capacity.

Party	Instruction	Note
NCC	Enable Black Start Shutdown signal	<i>This should trip the main WF CB feeding the WF</i>
	<i>Monitor response of WF WF should come to a halt.</i>	
NCC	Instruct the ESB Networks Operator to attempt to manually reclose the HV CB feeding the grid connected transformer	<i>The HV CB should not manually reclose while the Black Start Shutdown signal is enabled</i>
	<i>Observe any changes at grid connected transformer</i>	
NCC	Disable Black Start Shutdown signal	<i>This should re-instate grid supply to WF substation by closing HV CB feeding the grid connected transformer.</i>
WF	Wind farm operator to close main CB again	
	<i>WF should progressively start up and connect to the system to export power to the grid to full available capacity</i>	

5.16.5 Test Results:

On completion of the Black Start Test, the results should confirm or otherwise compliance with the relevant section WFPS1.7.2.5 of the **Grid Code** as follows:

Grid Code clause (V3.4)	Instrumentation & Information Output	Pass Criteria
WFPS 1.7.2.5	Data recording of the following: -Available active power. -Active power -Grid voltage -Wind farm system voltage -Reactive power at wind farm voltage -Transformer tap position	Refer to 'Pass Criteria' itemised below: 1 - 6

1. Capability of the wind farm to disconnect from the network on receiving a Black Start Shutdown signal
2. Capability to shutdown the turbines in a controlled manner
3. Prevent re-connection to the network while the Black Start Shutdown signal is enabled
4. Progressively connect each turbine to the system on reconnection of grid supply