

WFPS Reactive Power Capability Test Procedure

[Insert Windfarm Name]

Version 0.1

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# Document Version History

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| --- |
| **Document Version History** |
| **Version** | **Date** | **Comment** |
| 0.1 | dd/mm/yyyy | First submission for review/approval |
|  |  |  |
|  |  |  |

# Introduction

**WFPS shall highlight any changes made to this document or approval will be void.**

The WFPS shall submit the latest version of this test procedure template as published on the EirGrid website[[1]](#footnote-1).

All yellow sections shall be filled in before the test procedure shall be approved. All grey sections shall be filled in during testing. If any test requirements or steps are unclear, or if there is an issue with meeting any requirements or carrying out any steps, please contact generator\_testing@eirgrid.com.

Where a site consists of two separate controllable WFPS with a single connection point, this may impact on the test procedure outlined below.

The WFPS representative shall coordinate testing. On the day of testing, suitably qualified technical personnel may 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 is to liaise with NCC.

The availability of personnel at NCC will be necessary in order to initiate the necessary instructions for the test. NCC shall determine if network conditions allow the testing to proceed.

All wind turbines shall be available. 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, if that turbine makes up <20% of Registered Capacity, 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 section 7.4.

Following testing, the following shall be submitted to generator\_testing@eirgrid.com.

|  |  |
| --- | --- |
| **Submission** | **Timeline** |
| A scanned copy of the test procedure, as completed and signed on site on the day of testing | 1 working day |
| Test data in CSV or Excel format | 1 working day |
| Test report | 10 working days |

# Abbreviations

APC Active Power Control

AVR Automatic Voltage Regulation

HV High Voltage

MEC Maximum Export Capacity

Mvar Mega Volt Ampere – reactive

MW Mega Watt

NCC National Control Centre

PF Power Factor

TSO Transmission System Operator

WFCS Wind Farm Control System

WFPS Wind Farm Power Station

WTG Wind Turbine Generator

Leading Mvar Absorbing Mvar from System

Lagging Mvar Producing Mvar

# WFPS DATA

|  |  |
| --- | --- |
| WFPS Name | WFPS to Specify  |
| WFPS Test Co-Ordinator and contact number: | WFPS to Specify |
| WFPS Location | WFPS to Specify  |
| WFPS connection point | WFPS to Specify (*i.e.* T121 HV bushings) |
| WFPS connection voltage | WFPS to Specify  |
| Installed Turbine type, MW size and quantity | WFPS to Specify |
| Contracted MEC | WFPS to Specify  |
| Registered Capacity | WFPS to Specify |
| Limiter applied to Exported MW | WFPS to Specify |
| Limiter applied to AAP | WFPS to Specify |
| Minimum Leading Mvar requirement (Importing) at the connection point above 12% Active Power Output per Grid Code *Figure WFPS1.4* | WFPS to Specify  |
| Minimum Lagging Mvar requirement (Exporting) at the connection point above 12% Active Power Output per Grid Code *Figure WFPS1.4* | WFPS to Specify  |
| Maximum Leading Mvar at connection point | WFPS to Specify  |
| Maximum Lagging Mvar at connection point | WFPS to Specify  |
| Grid Connected Transformer Tap range | WFPS to Specify |

**Reactive Power Capability chart at connection point**

|  |  |
| --- | --- |
| The PQ chart is based on  | Modelled / Real data(If the data is based on modelled results the WFPS shall specify the model reference and confirm that this is as submitted to EirGrid through the connection process) |
| The PQ chart shows the capability at the connection point and accounts for all losses. | Yes / No  |
| The PQ chart shows the following.1. Grid Code Requirements per *Figure WFPS1.4 of Grid Code*
2. Maximum capability of the WFPS
3. Breakdown of reactive power devices e.g. turbines or STATCOM
 | 1. Yes / No
2. Yes / No
3. Yes / No
 |
| Any further information | WFPS to specify how reactive power capability is achieved i.e. fixed / switched cap banks, STATCOM, etc. |
| Note: 1. The PQ chart shall be site specific.
2. Generic PQ charts of turbines are not accepted.
 |

WFPS shall Insert PQ chart

# Grid Code References

|  |  |
| --- | --- |
| Grid Code Version:  | WFPS to specify |

WFPS1.6.2.5 *Figure WFPS1.3* shows the relevant points appropriate to the **Voltage Regulation** **System** for a **Controllable WFPS**. *X* is the HV side of the **WTG** transformer, *Y* is the lower voltageside of the **Grid Connected Transformer** and *Z* is the **Connection Point**.



*Figure WFPS1.3 - Locations for* ***Voltage Regulation*** *set-point (Z) and the* ***Power Factor*** *range (Y). The HV side of the* ***WTG*** *transformer is (X).*

WFPS1.6.3.1 **Controllable WFPSs** operating in **Power Factor** control mode, **Voltage** **Control** mode or constant **Reactive Power** mode shall be at least capable of operating at any point within the P-Q capability ranges illustrated in *Figure WFPS1.4,* as measured at the **Connection Point** over the normal and disturbed **Transmission System Voltage** ranges specified in CC.8.3.2.

Referring to *Figure WFPS1.4:*

Point A represents the minimum Mvar absorption capability of the **Controllable WFPS** at 100% **Registered Capacity** and is equivalent to 0.95 power factor leading;

Point B represents the minimum Mvar production capability of the **Controllable WFPS** at 100% **Registered Capacity** and is equivalent to 0.95 power factor lagging;

Point C represents the minimum Mvar absorption capability of the **Controllable WFPS** at 12% **Registered Capacity** and is equivalent to the same **Mvar** as Point A;

Point D represents the minimum Mvar production capability of the **Controllable WFPS** at 12% **Registered Capacity** and is equivalent to the same **Mvar** as Point B;

Point E represents the minimum Mvar absorption capability of the **Controllable WFPS** at the cut-in speed of the individual **WTGs**;

Point F represents the minimum Mvar production capability of the **Controllable WFPS** at the cut-in speed of the individual **WTGs**;

The **TSO** accepts that the values of Points E and F may vary depending on the number of **WTGs** generating electricity in a low-wind scenario;

*Figure WFPS1.4* represents the minimum expected **Reactive Power** capabilities of the **Controllable WFPS**. The **Controllable WFPS** is obliged to tell the **TSO**/**DSO** if it can exceed these capabilities, and submit the actual P-Q capability diagram based upon the installed plant and **Collector Network** characteristics to the **TSO** during **Commissioning.**

 The **Grid Connected Transformer** tap changing range must be capable of ensuring nominal voltage at point Y for any **Voltage** at the **Connection Point** (Point Z) within the ranges specified in WFPS1.6.1.

*Figure WFPS1.4 –* Minimum**Reactive Power** Capability of **Controllable WFPS**

*Figure WFPS1.4* represents the minimum expected **Reactive Power** capabilities of the **Controllable WFPS**. The **Controllable WFPS** is obliged to tell the **TSO**/**DSO** if it can exceed these capabilities, and submit the actual P-Q capability diagram based upon the installed plant and **Collector Network** characteristics to the **TSO** during **Commissioning.**

# site Safety requirements

The following is required for the EirGrid witness to attend site:

|  |  |
| --- | --- |
| Personnel Protection Gear Requirements1. Site Safety boots
2. Hard Hat with chin strap
3. Hi Vis
4. Arc Resistive clothing
5. Safety Glasses
6. Gloves
7. Safe Pass
 | 1. Yes / No
2. Yes / No
3. Yes / No
4. Yes / No
5. Yes / No
6. Yes / No
7. Yes / No
 |
| Site Induction requirements | Yes / No (If Yes, WFPS to specify how and when the induction shall be carried out) |
| Any further information | WFPS to specify |

# Test desciption and pre conditions

## Purpose of the Test

The purpose of this test is to demonstrate the limits of the WFPS reactive power capability curve at the connection point. The test is undertaken at various load levels for both the export of reactive power from the WFPS and for the import of reactive power to the WFPS.

## Pass Criteria

The following is the pass criteria for the test. Any subsequent report for this test shall be assessed against each of these criteria.

| **Criteria** |
| --- |
| **Reactive Power Capability** |
| Demonstration that the measured P-Q capability is in line with the submitted P-Q capability diagram |
| Demonstration that the measured P-Q capability meets or exceeds the minimum expected reactive power capabilities of the controllable WFPS, as defined in Grid Code *Figure WFPS1.4,* as measured at the Connection Point |

## Instrumentation and onsite data trending

All of the following trends shall be recorded by the WFPS during the test. Failure to provide any of these trends shall result in test cancellation.

|  |  |  |  |
| --- | --- | --- | --- |
| **No.** | **Data Trending and Recording** | **Resolution** | **Check On Day Of Test** |
| 1 | Available active power from the prevailing wind in MW, derived by algorithm in the WFCS (*Figure WFPS1.3, Point Y – preferably Point Z if available*) | WFPS to Specify (≥10 Hz) | Yes / No |
| 2 | Actual active power from the wind farm in MW (*Figure WFPS1.3, Point Y – preferably point Z if available*) | WFPS to Specify (≥10 Hz) | Yes / No |
| 3 | Wind farm voltage measured at the lower voltage side of the grid connected transformer (*Figure WFPS1.3, Point Y*) | WFPS to Specify (≥10 Hz) | Yes / No |
| 4 | Grid voltage measured at the connection point (*Figure WFPS1.3, Point Z*) | WFPS to Specify (≥10 Hz) | Yes / No |
| 5 | Reactive power measured at the lower voltage side of the grid connected transformer, (*Figure WFPS1.3, Point Y*) | WFPS to Specify (≥10 Hz) | Yes / No |
| 6 | Reactive power measured at the connection point (*Figure WFPS1.3, Point Z*) | WFPS to Specify (≥10 Hz) | Yes / No |
| 7 | Grid transformer tap position | WFPS to Specify (≥10 Hz) | Yes / No |
| 8 | AVR (kV) set-point (*Figure WFPS1.3, Point Y – preferably point Z if available*) | WFPS to Specify (≥10 Hz) | Yes / No |

## Initial Conditions

If “No” is answered to any of the following, contact NCC and agree next steps in advance of making any corrective actions. If the kV set-point = system voltage at the connection point and WFPS is not producing 0 Mvar, this test may not proceed.

|  |  |
| --- | --- |
| **Conditions** | **Check on day of test** |
| All WTGs are available | # turbines installed: \_\_\_\_# turbines generating: \_\_\_\_ |
| Generated MW > 60% of Registered Capacity | Generated MW: \_\_\_\_ |
| Grid Connected Transformer Tap range | Tap range: \_\_\_\_ to \_\_\_\_ |
| Size of Mvar step changes agreed with NCC Transmission Desk (*e.g.* 5 Mvar) | \_\_\_\_ Mvar |

## Mvar changes and calculations

|  |  |
| --- | --- |
| **Calculation** | **Value** |
| 1kV change in system voltage with Voltage Regulation System slope of 4% | \_\_\_\_ Mvar(WFPS to specify calculation and formula used) |
| 3kV change in system voltage with Voltage Regulation System slope of 4% | \_\_\_\_ Mvar(WFPS to specify calculation and formula used) |

# Test Steps

## Reactive Power Capability (Importing / Leading Mvar)

The WFPS is brought from 0 Mvar at full output to maximum leading Mvar. Once at maximum leading Mvar, the active power is reduced in steps from max output to 0 MW. Reactive Power set-point is changed to require 0 Mvar response, before the WFPS is released from 0 MW to max output.

| **Step No.** | **Action** | **Time** | **Comments** |
| --- | --- | --- | --- |
| 1 | WFPS begins data recording for all trends noted in Section 7.3, above |  | Operator Name \_\_\_\_\_\_\_\_\_\_\_\_Date \_\_\_\_\_\_\_\_\_\_\_\_ |
| 2 | WFPS requests permission from NCC to proceed with the Reactive Power Capability (Inductive / Leading Mvar) test and confirms the following with NCC: 1. MW output of the WFPS
2. APC is OFF
3. Frequency Response is OFF
4. Mvar (Q) control mode is ON
5. The transformer tap position
6. On Load Tap Changer Mode
7. System Voltage
8. Maximum leading Mvar capability of the WFPS
9. Mvar Export at the connection point
 |  | 1. \_\_\_\_ MW
2. Status \_\_\_\_
3. Status \_\_\_\_
4. \_\_\_\_ Mode
5. Tap # \_\_\_\_
6. \_\_\_\_ Mode
7. \_\_\_\_ kV
8. -\_\_\_\_ Mvar
9. \_\_\_\_ Mvar
 |
| 3 | WFPS requests NCC to decrease the Mvar set-point in steps as agreed in section 7.4 until the wind farm has reached its maximum leading Mvar limit at the connection point |  | -\_\_\_\_ Mvar \_\_\_\_ kV |
| 4 | WFPS requests NCC to reduce the Mvar set-point by a further step |  | WFPS shall remain at maximum lagging Mvar-\_\_\_\_ Mvar \_\_\_\_ kV |
| 5 | WFPS requests NCC to turn APC ON and issue a set-point of [insert 90% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 6 | WFPS requests NCC to issue a set-point of [insert 80% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 7 | WFPS requests NCC to issue a set-point of [insert 70% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 8 | WFPS requests NCC to issue a set-point of [insert 60% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 9 | WFPS requests NCC to issue a set-point of [insert 50% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 10 | WFPS requests NCC to issue a set-point of [insert 40% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 11 | WFPS requests NCC to issue a set-point of [insert 30% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 12 | WFPS requests NCC to issue a set-point of [insert 20% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 13 | WFPS requests NCC to issue a set-point of [insert 12% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 14 | WFPS requests NCC to issue a set-point of [insert 6% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 15 | WFPS requests NCC to issue a set-point of 0 MW and waits until 1 minutes after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 16 | WFPS requests NCC to increase the Mvar set-point in steps as agreed in section 7.4 until the WFPS is exporting 0 Mvar at the connection point |  | Mvar output shall be at 0 Mvar+/-\_\_\_\_ Mvar |
| 17 | WFPS requests NCC to issue a set-point of [insert 100% of Registered Capacity] MW and turn APC OFF and waits until 1 minute after AAP has been achieved |  |  |
| 18 | WFPS ends data recording |  |  |
| 19 | WFPS informs NCC that the Reactive Power Capability (Inductive / Leading Mvar) test is complete |  |  |

## Reactive Power Capability (Exporting / Lagging Mvar)

The WFPS is brought from 0 Mvar at full output to maximum lagging Mvar. Once at maximum lagging Mvar, the active power is reduced in steps from max output to 0 MW. Reactive Power set-point is changed to require 0 Mvar response, before the WFPS is released from 0 MW to max output.

| **Step No.** | **Action** | **Time** | **Comments** |
| --- | --- | --- | --- |
| 1 | WFPS begins data recording for all trends noted in Section 7.3, above |  | Operator Name \_\_\_\_\_\_\_\_\_\_\_\_Date \_\_\_\_\_\_\_\_\_\_\_\_ |
| 2 | WFPS requests permission from NCC to proceed with the Reactive Power Capability (Capacitive / Lagging Mvar) test and confirms the following with NCC: 1. MW output of the WFPS
2. APC is OFF
3. Frequency Response is OFF
4. Mvar (Q) control mode is ON
5. The transformer tap position
6. On Load Tap Changer Mode
7. System Voltage
8. Maximum lagging Mvar capability of the WFPS
9. Mvar Export at the connection point
 |  | 1. \_\_\_\_ MW
2. Status \_\_\_\_
3. Status \_\_\_\_
4. \_\_\_\_ Mode
5. Tap # \_\_\_\_
6. \_\_\_\_ Mode
7. \_\_\_\_ kV
8. +\_\_\_\_ Mvar
9. \_\_\_\_ Mvar
 |
| 3 | WFPS requests NCC to increase the Mvar set-point in steps as agreed in section 7.4 until the wind farm has reached its maximum lagging Mvar limit at the connection point |  | -\_\_\_\_ Mvar |
| 4 | WFPS requests NCC to increase the Mvar set-point by a further step |  | WFPS shall remain at maximum leading Mvar-\_\_\_\_ Mvar |
| 5 | WFPS requests NCC to turn APC ON and issue a set-point of [insert 90% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 6 | WFPS requests NCC to issue a set-point of [insert 80% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 7 | WFPS requests NCC to issue a set-point of [insert 70% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 8 | WFPS requests NCC to issue a set-point of [insert 60% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW\_\_\_\_ Mvar |
| 9 | WFPS requests NCC to issue a set-point of [insert 50% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 10 | WFPS requests NCC to issue a set-point of [insert 40% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 11 | WFPS requests NCC to issue a set-point of [insert 30% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 12 | WFPS requests NCC to issue a set-point of [insert 20% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 13 | WFPS requests NCC to issue a set-point of [insert 12% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 14 | WFPS requests NCC to issue a set-point of [insert 6% of Registered Capacity] MW and waits until 1 minute after the set-point has been achieved |  | \_\_\_\_ MW-\_\_\_\_ Mvar |
| 15 | WFPS requests NCC to issue a set-point of 0 MW and waits until 1 minutes after the set-point has been achieved |  |  |
| 16 | WFPS requests NCC to decrease the Mvar set-point in steps as agreed in section 7.4 until the WFPS is exporting 0 Mvar at the connection point |  | Mvar output shall be at 0 Mvar+/-\_\_\_\_ Mvar |
| 17 | WFPS requests NCC to issue a set-point of [insert 100% of Registered Capacity] MW and turn APC OFF and waits until 1 minute after AAP has been achieved |  | \_\_\_\_ MW |
| 18 | WFPS ends data recording |  |  |
| 19 | WFPS informs NCC that the Reactive Power Capability (Capacitive / Lagging Mvar) test is complete |  |  |

## Return to Standard Settings

The steps below return the WFPS to standard settings at the completion of testing.

|  |  |  |  |
| --- | --- | --- | --- |
| **Step No.** | **Action** | **Time** | **Comments** |
| 2 | WFPS confirms the following with NCC: 1. AAP of the WFPS
2. MW output of the WFPS
3. APC is OFF
4. Frequency Response is ON
5. Frequency Response is in Curve 1
6. AVR (kV) control mode is ON
7. The transformer tap position
8. On Load Tap Changer is in Automatic mode
9. System Voltage
10. kV Set-point = system voltage at connection point
11. Voltage slope setting = 4%
12. Mvar Export at the connection point
 |  | 1. \_\_\_\_ MW
2. \_\_\_\_ MW
3. Status \_\_\_\_
4. Status \_\_\_\_
5. Curve \_\_\_\_
6. \_\_\_\_ Mode
7. Tap # \_\_\_\_
8. \_\_\_\_ Mode
9. \_\_\_\_ kV
10. \_\_\_\_ kV
11. \_\_\_\_%
12. \_\_\_\_ Mvar
 |
| 3 | WFPS informs NCC that Reactive Power Control testing is complete |  |  |

## Comments & Signatures

|  |
| --- |
| **Comments:**  |
| WFPS Witness signoff that this test has been carried out according to the test procedure, above.Signature: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |
| EirGrid Witness signoff that this test has been carried out according to the test procedure, above.Signature: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |

1. <http://www.eirgridgroup.com/library> [↑](#footnote-ref-1)