Fault Ride Through
Technical Assessment Report Template

Notes:

1. This template is intended to provide guidelines into the minimum content and scope of the technical studies required to demonstrate compliance with the FRT requirements defined in the Grid Code (for WFPS connections to the transmission system) and Distribution Code (for relevant WFPS connections to the distribution system).
2. Some of the text in this template is provided as a guideline or instruction on the studies that need to be performed and how they need to be documented. This type of text is provided in *italic*.
3. Additional studies may be required in cases where WTG or WFPS controller settings are modified from those assumed in the FRT assessment study.
4. This template includes references to the current version of the Grid Code at the time of writing. For WFPS connections to the distribution system the customer is requested to replace all Grid Code references and clauses with the relevant Distribution Code version and clauses. Furthermore, the customer is requested to amend any outdated references and clauses with the most up to date revisions of the Codes.
5. A modification to the Grid Code outlining the dynamic model requirements for all Users has been recently approved (MPID239). The customer should be aware and comply with the new requirements.

V 1.1 – August 2017

Disclaimer

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EIRGRID

Executive Summary

High level description of the scope and findings of the FRT studies. Include a summary table (sample template in next page), flagging any potential non-compliance issues and proposals to address them.

Table 1 – Summary of FRT compliance assessment

GC Clause	Description	Compliance for fault type (retained voltage % / fault duration ms)			
		15% / 140 ms	15% / 625 ms	50% / 1733 ms	85% / 2842 ms
WFPS 1.4.2 (a)	• Provide Active Power in proportion to the retained voltage. • Provide reactive current until the transmission system voltage recovers to normal or for, at least, 500ms – whichever is the sooner.				
WFPS 1.4.2 (b)	• Active Power recovery: provide at least 90% of the available Active Power as quickly as the technology allows and, in any event within: (a) 500ms of voltage recovery to 0.9 pu for fault durations up to 140ms or (b) 1 second of voltage recovery to 0.9 pu for longer fault durations.				
WFPS 1.4.2 (c)	• During and after faults priority shall be given to the Active Power response. • The reactive current response shall attempt to support the voltage at the Connection Point and it should be, at least, proportional to the Voltage Dip. The reactive current response shall be supplied within the rating of the Controllable WFPS, with a rise time no greater than 100ms and a settling time no greater than 300ms.				
WFPS 1.4.2 (d)	• The controllable WFPS shall be capable of providing its transient reactive response irrespective of the reactive control mode in which it was operating at the time of the Transmission System Voltage Dip. The controllable WFPS shall revert to its pre-fault reactive control mode and set point within 500ms of the Transmission System Voltage recovering to its normal operating range.				

***Note 1**: Fill in Table 1 stating compliance (or non-compliance) with the relevant clause. Include numerical values describing the maximum performance that can be achieved (i.e. MW output during voltage dip, active power recovery time, rise time of reactive current response, etc).*

***Note 2**: The clauses above apply to the Grid Code only. For connections to the distribution system, change references to the relevant Distribution Code clauses (DCC11.2).*

***Note 3:** The interpretation of WFPS 1.4.2 (d) clause should be as follows:*
Within 500ms of voltage recovering to normal limits (as per CC8.3.1):

- *the WFPS controller must return to the reactive power control mode and;*
- *the WFPS reactive power output must be importing/exporting the reactive power setpoint again.*

For example: if a 10MVAr leading setpoint was issued to the WFPS in MVAr control mode pre-fault and the WPFS reached this setpoint pre-fault then within 500ms of the voltage recovering the WFPS controller will be in MVAr control mode and the WFPS will be absorbing 10MVArs.

Table of Contents

Disclaimer 2
Executive Summary 3
Acronyms 6
1 Introduction 7
2 Fault Ride Through Requirements 7
2.1 WFPS1.4.1 7
2.2 WFPS1.4.2 8
3 Modelling and Assumptions 9
3.1 General 9
3.2 Model of Wind Farm Power Station (WFPS) 9
3.2.1 Wind Turbine Generators (WTG) 9
3.2.2 Wind Turbine Generators (WTG) Transformers 10
3.2.3 Internal WFPS collector network 10
3.2.4 Grid Connected Transformer 10
3.2.5 Other Devices 10
3.3 External Grid 10
4 Study Methodology 11
5 Study Results 13
5.1 Disturbance 1 13
5.2 Disturbance n 13
6 Summary and conclusions 14
Appendix – 1 Detailed SLD of WFPS 15
Appendix – 2 Dynamic Model 16
Appendix – 3 Supporting Information 17

Acronyms

CP	Connection Point
DC	Distribution Code
FRT	Fault Ride Through
GC	Grid Code
HV	High Voltage
MEC	Maximum Export Capacity
MV	Medium Voltage
RMS	Root Mean Square
SLD	Single Line Diagram
WFPS	Wind Farm Power Station
WTG	Wind Turbine Generator

Include any additional acronyms used in the report

1 Introduction

Describe the purpose and scope of the report. Sample text: The purpose of this document is to investigate the dynamic response of the *** Wind Farm during voltage disturbances in the transmission system and to assess compliance against the Fault Ride Through requirements defined in the Grid Code (WFPS1.4). The applicable version of the Grid Code is Version 6, issued 22nd July 2015.

Provide a high level description of the wind farm and the connection method, including MEC, number and type/model of wind turbines, internal MV collector network, WTG transformers and Grid transformer and any other device such as STATCOM, harmonic filter(s), capacitor banks, etc.

2 Fault Ride Through Requirements

The relevant clause (WFPS1.4) of Grid Code v6 is reproduced below for reference.

2.1 WFPS1.4.1

A **Controllable WFPS** shall remain connected to the **Transmission System** for **Transmission System Voltage Dips** on any or all phases, and shall remain **Stable,** where the **Transmission System Phase Voltage** measured at the HV terminals of the **Grid Connected Transformer** remains above the heavy black line in *Figure WFPS1.1*.

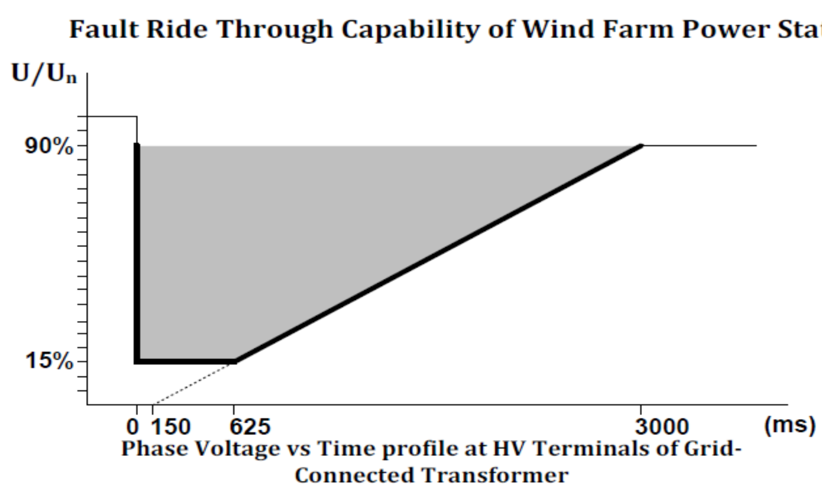

Figure WFPS1.1 - ***Fault Ride-Through*** *Capability of* ***Controllable WFPSs***

2.2 WFPS1.4.2

"In addition to remaining connected to the **Transmission System**, the **Controllable WFPS** shall have the technical capability to provide the following functions:

a) During **Transmission System Voltage Dips**, the **Controllable WFPS** shall provide **Active Power** in proportion to retained **Voltage** and provide reactive current to the **Transmission System**, as set out in WFPS1.4.2(c). The provision of reactive current shall continue until the **Transmission System Voltage** recovers to within the normal operational range of the **Transmission System** as specified in CC8.3.1, or for at least 500 ms, whichever is the sooner. The **Controllable WFPS** may use all or any available reactive sources, including installed statcoms or SVCs, when providing reactive support during **Transmission System Fault Disturbances** which result in **Voltage Dips**.

b) The **Controllable WFPS** shall provide at least 90 % of its maximum **Available Active Power** or **Active Power Set-point**, whichever is lesser, as quickly as the technology allows and in any event within 500 ms of the **Transmission System Voltage** recovering to 90% of nominal **Voltage**, for **Fault Disturbances** cleared within 140 ms. For longer duration **Fault Disturbances**, the **Controllable WFPS** shall provide at least 90% of its maximum **Available Active Power** or **Active Power Set-point**, whichever is lesser, within 1 second of the **Transmission System Voltage** recovering to 90% of the nominal **Voltage**.

c) During and after faults, priority shall always be given to the **Active Power** response as defined in WFPS1.4.2(a) and WFPS1.4.2(b). The reactive current response of the **Controllable WFPS** shall attempt to control the **Voltage** back towards the nominal **Voltage**, and should be at least proportional to the **Voltage Dip**. The reactive current response shall be supplied within the rating of the **Controllable WFPS**, with a **Rise Time** no greater than 100ms and a **Settling Time** no greater than 300ms. For the avoidance of doubt, the **Controllable WFPS** may provide this reactive response directly from individual **WTGs**, or other additional dynamic reactive devices on the site, or a combination of both.

d) The **Controllable WFPS** shall be capable of providing its transient reactive response irrespective of the reactive control mode in which it was operating at the time of the **Transmission System Voltage Dip**. The **Controllable WFPS** shall revert to its pre-fault reactive control mode and set point within 500ms of the **Transmission System Voltage** recovering to its normal operating range as specified in CC.8.3.1.

3 Modelling and Assumptions

3.1 General

Include any general assumptions (if applicable) – for example assumed transformer tap position, WFPS active power output and reactive power control mode prior to disturbance, etc.

Indicate the software tool and version used for the dynamic studies. Note: ***A complete dynamic model of the WFPS and associated parameter settings must be provided to EirGrid in PSS/E format[1-2] along with this technical report*** *(printout of raw and dyre files to be included in an Appendix). If the FRT studies are performed in a different software platform, the Customer is requested to provide documentation demonstrating model conversion and validation for PSS/E use. Specify the time step required to run the simulations.*

The WFPS dynamic model must contain an accurate representation of all WTGs, WTG transformers, internal MV collector network, grid connected transformer and any associated controls and reactive compensation equipment to be installed in the facility. For computational reasons, an aggregate model capturing the combined response of all WFPS components is preferable.

3.2 Model of Wind Farm Power Station (WFPS)

Describe the WFPS configuration and how is represented for the purpose of FRT studies (i.e. detailed representation, aggregation, etc.). If an aggregated model is used, provide details of the aggregation method. Include an SLD showing the WFPS, as represented in the dynamic model.

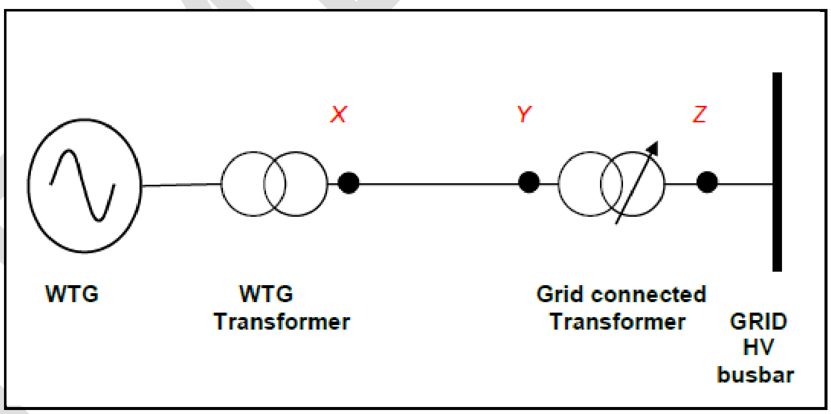

Figure 1 – Wind Farm representation for FRT study (example)

3.2.1 Wind Turbine Generators (WTG)

Indicate the library/object model (name and version) used to represent the WTGs. Indicate any assumption or known limitation of this model (if applicable). ***Include a table with site specific parameter***

[1] *Requirement described in GC clause PC.A8.8 (MPID 239).*

[2] *The software version and any other model requirements will be specified in the document issued by EirGrid with the Minimum System Strength data applicable at the Connection Point.*

settings *highlighting any parameters that have been changed from the generic default settings and reasons why.*

3.2.2 Wind Turbine Generators (WTG) Transformers

Describe the representation of the WTG transformers.

Number of WTG transformers		
Rating of WTG transformer		MVA
WTG transformer voltage ratio		
WTG transformer resistance (pos sequence)		% (based on transformer MVA)
WTG transformer reactance (pos sequence)		% (based on transformer MVA)

3.2.3 Internal WFPS collector network

Describe the internal MV collector network and how the individual WTGs are interconnected. Include a detailed SLD in an Appendix. Provide technical details of each MV cable type (R, X, B) and section lengths.

3.2.4 Grid Connected Transformer

Describe the representation of the Grid connected transformer.

Rating of Grid transformer		MVA
Grid transformer voltage ratio		
Grid transformer resistance (pos sequence)		% (based on transformer MVA)
Grid transformer reactance (pos sequence)		% (based on transformer MVA)

3.2.5 Other Devices

Describe the representation and ***site specific parameter settings*** *of any other devices such as Power Plant Controller, STATCOM, harmonic filter, capacitor banks, etc (when applicable).*

3.3 External Grid

The external power system must be represented as an infinite bus behind the Equivalent Thevenin Impedances provided by EirGrid or ESBN. The model must include two external grids with a changeover between the pre-disturbance and post-disturbance characteristics. A proposed switchover scheme is presented in Figure 2, with switches controlled as described in Table 2.

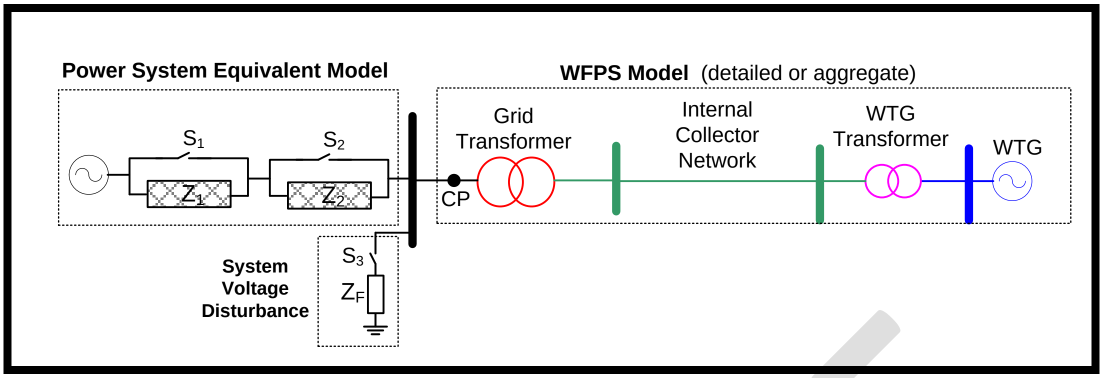

Figure 2 – Representation of external Grid - example

Table 2 – Proposed switching of external network equivalents - example

	S_1	S_2	S_3	*Comment*
$t < t_1$	*Open*	*Closed*	*Open*	*Steady state, prior to disturbance.*
$t_1 \le t < t_2$	*Open*	*Closed*	*Closed*	*Apply voltage disturbance.*
$t_2 \le t$	*Closed*	*Open*	*Open*	*Remove voltage disturbance and change over system source impedance. Voltage recovery to a new steady state.*

For completeness, include a table with the source impedance values assumed in the study (as provided by EirGrid or ESBN):

	Equivalent Thevenin Impedances provided by EirGrid or ESBN (pu on 100MVA base)	
	R [pu]	**X [pu]**
External Grid (pre disturbance) – $\mathbf{Z_1}$	*0.0509*	*0.1462*
External Grid After Fault (voltage recovery) – $\mathbf{Z_2}$	*0.0819*	*0.2202*

The pre-disturbance voltage at the Connection Point (CP) must be set to 1 pu.

The fault impedance values (Z_F) must be calculated for each scenario to achieve the retained voltages defined in Table 3 at the CP.

4 Study Methodology

Dynamic simulation studies must be carried out to demonstrate that the Wind Farm is designed to comply with the Fault Ride Through requirements defined in the most up-to-date Grid Code version (see section 2). The studies must simulate a 3-phase fault at the CP with a suitable fault impedance (Z_F) to depress the voltage at the CP to the levels described in Table 3. The simulations must be run until a new steady state is reached at the CP in terms of system voltage, active power and reactive power output from the WFPS.

The dynamic study must assess the capability of the WFPS to ride through the voltage disturbances described in Table 3. Note that the voltage disturbances are described in terms of retained voltage at the Connection Point (i.e. the HV bushings of the grid transformer). For the purposes of this assessment, all voltage disturbances shall be assumed to be 3-phase (i.e. same voltage depression on each of the three phases).

The pre-disturbance operating conditions shall be 1 per unit for the Power System Voltage at the Connection Point and the output of the Wind Farm shall be equal to its Maximum Export Capability (MEC) operating at unity power factor.

If static reactive support devices (capacitor banks or harmonic filters) are to be installed in the WFPS, two scenarios must be assessed: (1) all reactive devices switched IN and (2) all reactive devices switched OUT. All the disturbances listed in Table 3 must be tested for each scenario.

The Thevenin equivalent representing the Transmission System at the Connection Point shall be changed during the simulation from the "pre-disturbance" (Z_1) to the "post-disturbance" (Z_2) values advised by EirGrid/ESBN to reflect the reduction in system strength as a result of a trip of a transmission (or distribution) circuit – see section 3.3.

The WFPS response during and after the disturbances listed in Table 3 shall be compared against the FRT requirements defined in the Grid Code (reproduced in section 2 for reference). In case of no compliance, the studies shall assess mitigation options and discuss the proposed solution.

Table 3 – List of Voltage Disturbances that need to be assessed

Disturbance	Retained Voltage at Connection Point [% of Nominal]	Duration [ms]
D-1	15	140
D-2	15	625
D-3	50	1733
D-4	85	2842

For each scenario, clear plots showing the following parameters must be provided (as a minimum):

Plot 1. Voltage and Active Power output from the WFPS at the Connection Point.
Plot 2. Voltage and Reactive Power output from the WFPS at the Connection Point.
Plot 3. Voltage and Reactive Current output from the WFPS at the Connection Point.

Additional plots can be included to illustrate specific behaviour of individual WTGs, if necessary (for example, to illustrate the trip of a group of units and the retained voltage at their terminals).

The scale and resolution of the plots must be sufficient to clearly identify the active and reactive power response of the WFPS during and after the voltage disturbance and to allow easy comparison against the *responses specified in the Grid Code, which must be captured in the graphs as well. The scale may need to be readjusted for the different disturbances to clearly show compliance with the required timescales. In some cases, it may be necessary to provide a second plot with a zoomed-in area. The relevant WFPS outputs and response times must be clearly highlighted in the plots. A sample plot is provided in Figure 3 showing the level of detail and clarity required in the simulation results.*

5 Study Results

Provide plots of the RMS response of the WFPS, as seen at the Connection Point, for each of the disturbance scenarios defined in Table 3. For each scenario, indicate the fastest Active Power recovery time that can be achieved with the selected WTGs and control settings (WFPS 1.4.2 (b)).

5.1 Disturbance 1

Include plotted results and commentary. Include summary table with simulated response.

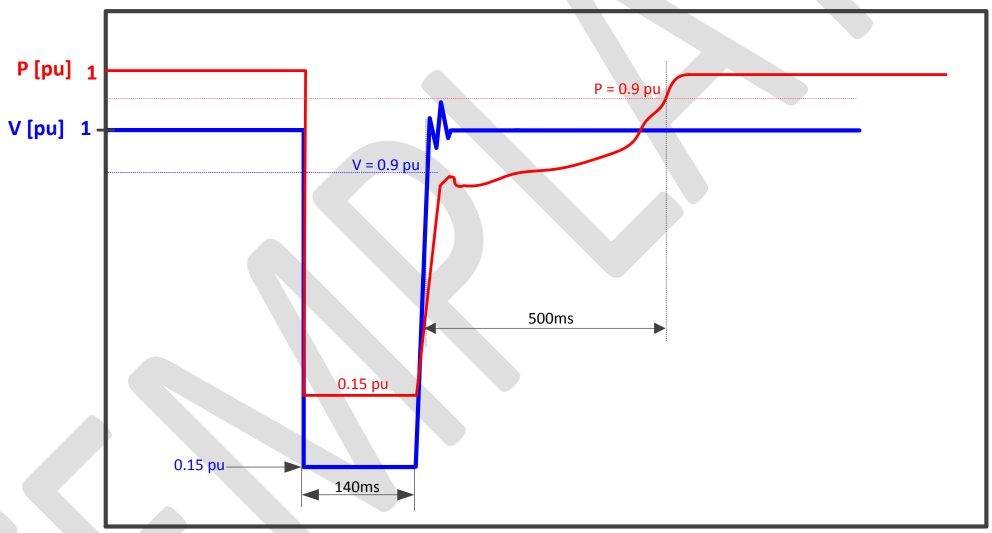

Figure 3 – Sample (fictitious) Plot illustrating Active Power response during and after voltage disturbance

Table 4 - Disturbance #1 – 15% retained voltage for 140ms

Active Power during voltage dip [MW]	Active Power Recovery time (to 90%) [ms]	Reactive Power during voltage dip [MVAr]	Reactive current during voltage dip [pu]	Reactive Current rise time / settling time [ms]	Compliant?

5.2 Disturbance n

Include plotted results and commentary. Include summary table with simulated response.

6 Summary and conclusions

Appendix – 1 Detailed SLD of WFPS

Appendix – 2 Dynamic Model

Include PSS/E raw (pos sequence) and Dyre files representing the facility, with the appropriate model and parameter settings, as identified in the FRT study.

Raw file

Dyre file

Appendix – 3 Supporting Information

Include any additional simulation plots and supporting information