Hornsdale 2 Wind Farm

FCAS Capability Test Plan

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Distribution list	
Name	**Organisation**
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Abbreviations

AEMO	Australian Energy Market Operator
AGC	Automatic Generation Control
EMS	Energy Management System
FCAS	Frequency Control Ancillary Services
HD2WF	Hornsdale 2 Wind Farm
MASS	Market Ancillary Services Specification
NEM	National Electricity Market
PPC	Power Plant Controller
PSS/E	Power System Simulation for Engineering (Software)
RoCoF	Rate of Change of Frequency
SCADA	Supervisory Control and Data Acquisition

1. Introduction

Hornsdale Wind Farm is located north of Jamestown in South Australia, in the locality of Hornsdale. The project is divided into three stages, namely Hornsdale 1, 2, & 3. When completed, the project will consist of 99 Siemens wind turbines.

Hornsdale 2 (HD2WF) will register to participate in the Frequency Control Ancillary Services (FCAS) Market.

The purpose of this document is to establish the on-site testing plan to demonstrate Hornsdale 2 Wind Farm's capability to register for all eight Frequency Control Ancillary Services (FCAS).

The data collected during the testing will also be used for PSS/E model confirmation for modelled behaviour relevant to the provision of FCAS.

The detailed test method has been drafted with reference to the Indicative Draft Test Plan [1] and the PSS/E Study Plan & Input Data Requirements [2].

1.1. Acceptance

It is intended that this document be submitted to AEMO for review well in advance of testing, with any comments incorporated into the plan. This review is to ensure that AEMO are comfortable with the nature of testing and the system impacts during testing.

AEMO are to notify the registered participant that they are in agreement with the proposed testing plan, or whether it requires changes to the plan to maintain power system security and safety of operation.

2. Communication

2.1. Main Points of Contact

The following personnel in Table 1 will be the main points of contact for their organisations during the commissioning process.

Table 1: Key commissioning personnel

Company	Role	Person	Contact Number
AEMO	Control Room		
AEMO	Operations (for test schedule updates)		
AEMO	Primary Contact		
AEMO	Secondary Contact		
Siemens Wind Power	Commissioning Lead		
Consolidated Power Projects (CPP)	Commissioning		
Hornsdale 2 WF	Control Room		
Neoen	Business Contact		

2.2. Communication Protocol

The following protocol for communication with AEMO during commissioning is proposed:

- The wind farm will provide the test schedule and daily upper MW limit information via AEMO's Market Management System Web Portal, approximately two days before commencing the FCAS tests. The wind farm will ensure that the information submitted via the Portal stays up-to-date at all times (including changes to the test plan).
- The wind farm will provide the test schedule to ops.sa@aemo.com.au, approximately five days before commencing the FCAS tests. Any changes to the test schedule also has to be notified to this email address
- Approval needs to be gained from AEMO Control Room prior to proceeding with tests noting the upper MW limit information reflects any technical limit behind the

connection point (excluding network constraints) and is used by AWEFS to cap the Pre-dispatch forecast.

- On days of FCAS testing, the wind farm shall confirm with the AEMO control room of the tests that are planned for the day.
- The wind farm shall request permission from the AEMO control rooms immediately before beginning any testing.
- At the end of each day's testing, the wind farm shall inform the AEMO control room that the FCAS tests have been completed for the day.

3. FCAS Capability

The FCAS registration parameters for Hornsdale 2 are given in Table 2 . The aim of the testing is to demonstrate the capability of Hornsdale 2 is at or above the capability represented by these parameters. Note a range of angles have been provided to take into account the uncertainty in wind conditions.

Updated FCAS registration parameters will be re-submitted to AEMO should testing show capability beyond that outlined in Table 2.

Table 2:HDWF2 FCAS Registration parameters.

Sevice	Maximum market ancillary service capacity (MW)	Minimum Enablement Level (MW)	Maximum Enablement Level (MW)	Maximum Lower Angle (Deg)	Maximum Upper Angle (Deg)
Fast Raise Service	20	10	100	90	33-45
Fast Lower Service	20	10	100	33-45	90
Slow Raise Service	20	10	100	90	33-45
Slow Lower Service	20	10	100	33-45	90
Delayed Raise Service	20	10	100	90	33-45
Delayed Lower Service	20	10	100	33-45	90
Regulating Raise Service	20	10	100	90	33-45
Regulating Lower Service	20	10	100	33-45	90

4. FCAS Test Plan

4.1. Overview

The following tests will be completed as part of the FCAS test program;

- Test 1: Step injections (test signal verification)
- Test 2: Standard frequency ramp injections
- Test 3: Extreme event ramp injections
- Test 4: Actual under and over frequency event injections
- Test 5: Regulation up/down tests

These tests are to be completed at different levels of active power as detailed in Table 3. As an example, at Power Level 1 only the 'Active Power Control Test' will be undertaken as denoted by 'X'.

The regulation up/down tests require specific wind resource levels, which will require prior forecasting and can only be completed at specific times. It is expected these tests will be conducted at the end of the test program to avoid delays.

All frequency injections are expected to be done at the Power Plant Controller (PPC) level.

Table 3: FCAS testing power levels

Power Level	Active Power Setpoint	Frequency Step injections	Standard frequency ramp injections	Extreme event ramp injections	Actual event injections	Regulation Up/ Down Tests
Contingent FCAS	40 MW	X	X	X	X	
	74 MW		X	X	X	
	88 MW		X	X	X	
Regulation FCAS	10 MW					X
	40 MW					X
	80 MW					X

4.2. PSS/E Model Confirmation

PSS/E model overlays comparing the modelled response with the recoded test response for the following tests;

- Test 2: Standard frequency ramp injections
- Test 3: Extreme event ramp injections
- Test 4: Actual under and over frequency event injections

4.3. Key Dates

Key dates can be found in Hornsdale 2 FCAS project's over-arching scheduling documentation.

4.4. Test Signal Injection

4.4.1 Frequency Profile Injection

The frequency profile injection will be facilitated via the Hornsdale 2 SCADA system. In the SCADA system the measured system frequency will be substituted by an artificial test value.

The SCADA change is a temporary change that will be put in place for the duration of the contingent FCAS tests. During this time HD2WF will be responsive to the test signal and not respond to changes of system frequency.

4.5. Measurement Equipment, Locations & Quantities

4.5.1 PoC measurement specifications

The key quantity recorded for each test is the real power at the PoC as this is the quantity that is assessed for FCAS capability.

Two Elspec meters are permanently installed at the PoC. Either can be used for testing. The meters have the following specifications-

- Manufacturer: Elspec
- Model: G4430
- Recording Type: Continuous monitoring
- Sampling Rate: 256 samples/cycle
- Measurement Data Format: CSV and COMTRADE
- Synchronisation: Data from all meters will be GPS time synchronised
- Measured Signals: The key signals to be measured at the connection point are real power and frequency. A large number of signals are measured by the Elspec. RMS voltage and reactive power will be recorded for review when any abnormal operating of the plant is observed.

The Elspec meter has a high speed internal sample rate (as provided above). For general testing and model verification data will be extracted at a rate of 20mS/sample.

Longer records used to assess FCAS provision may, in addition to the 20mS/sample data, be extracted at lower sample rates to make manipulation of the data more manageable. For Fast

Raise/Lower assessment data will be extracted at a rate of 50mS/sample, or faster. For Slow and Delayed Raise/Lower assessment data will be extracted at a rate of 4S/sample, or faster.

4.5.2 Test signal measurement

The frequency profile injection will be facilitated via the SCADA system. The injected frequency profile for each test will be time-aligned with the recoded test data at the PoC for post-test analysis.

4.5.3 Wind speed Measurements

Wind speed will be continuously recorded over the duration of each test.

4.5.4 Pitch motor movement

Pitch motor movement SCADA data be recorded over the duration of each test.

4.5.5 Other measurement equipment

Other measurement equipment, e.g. SCADA values, may be used to support the testing, but post-test analyses may rely on the data from the measurement equipment listed in above or other independent measuring devices.

Values for:

- Grid frequency;
- PCC voltage level;
- Active power; and;
- Reactive power;
- Tap position; and
- Filter status

Will be monitored via the wind farm high speed monitoring devices see section 4.5.2.

4.5.6 Possible Power and Wind Resource

The SCADA value “possible power” provides an indication of how much active power is available based on the available wind resource. This value will be used during testing to confirm the head room when generation is being deliberately curtailed in preparation for a test that requires an increase in active power, i.e a positive power setpoint change or a under frequency signal injection.

5. Contingent FCAS Power level 1 (40MW) tests

5.1. Power Level 1 - Test 1: Frequency step injections

5.1.1 Test description

The objective of this test is to verify that the active power response to a small magnitude frequency signal change is as expected (magnitude and sign) before progressing to the application of larger perturbations in the following tests. Step changes in frequency signal of progressively increasing size are used for this purpose.

5.1.2 Prerequisites

- The wind farm must be operating at the power setpoint of 40MW with available wind resource (possible power) of 65MW or greater.
- The test should be coordinated with AEMO.

5.1.3 Methodology

Perform the following steps:

1. Record current active power, frequency, and time.
2. Apply a -0.1Hz frequency step. Ensure 20 seconds of pre-step time.
3. Remove the step.
4. Confirm no active power response (+/- 0.15 Hz deadband)
5. Apply a -0.2Hz frequency step. Ensure 20 seconds of pre-step time.
6. Wait for active power to stabilise
7. Remove the step.
8. Confirm magnitude of active power response is as expected, in accordance with the droop setting.
9. Apply a -0.5Hz frequency step. Ensure 20 seconds of pre-step time.
10. Wait for active power to stabilise
11. Remove the step.
12. Confirm magnitude of active power response is as expected, in accordance with the droop setting.
13. Test complete

5.1.4 Post-test analysis

Confirm magnitude and sign of active power response is as expected for each droop setting.

$\Delta P = (Bias / Droop) \times Pmax$ [4]

Where Pmax = 100 MW and bias is with respect to 50Hz.

5.2. Power Level 1 - Test 2: Standard frequency ramp injections

5.2.1 Test description

The objective of this test is to verify the amount of Fast, Slow and Delayed (raise and lower) services for dispatch purposes [5].

A standard under frequency ramp [5] is applied and the active power response recorded to assess the raise services. A standard over frequency ramp is applied and the active power response recorded to assess the lower services. A ramp back to 50Hz is included at the end of the test signal (after 11 minutes),

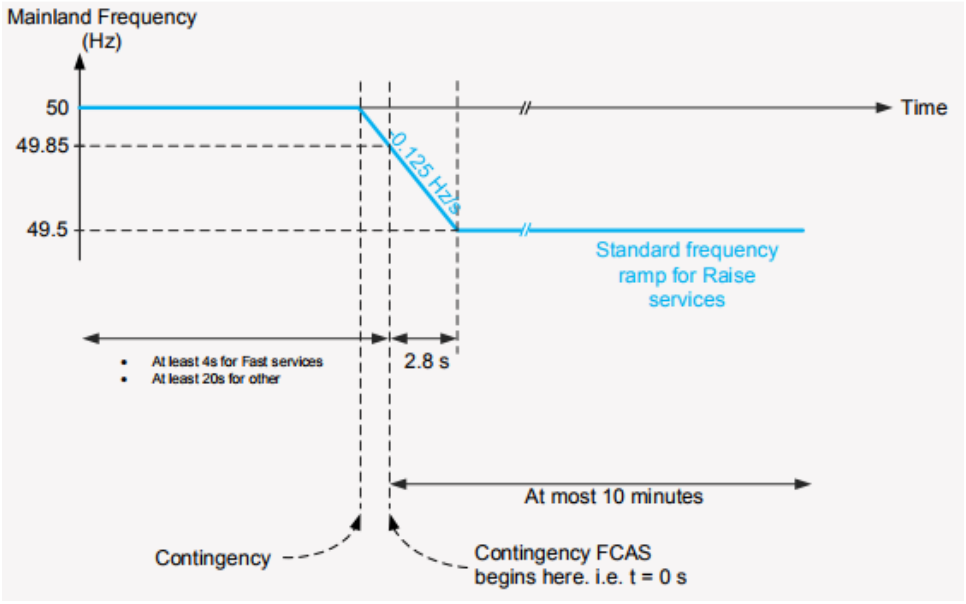

Figure 1 - Standard (Under) Frequency Ramp (Mainland) [5]

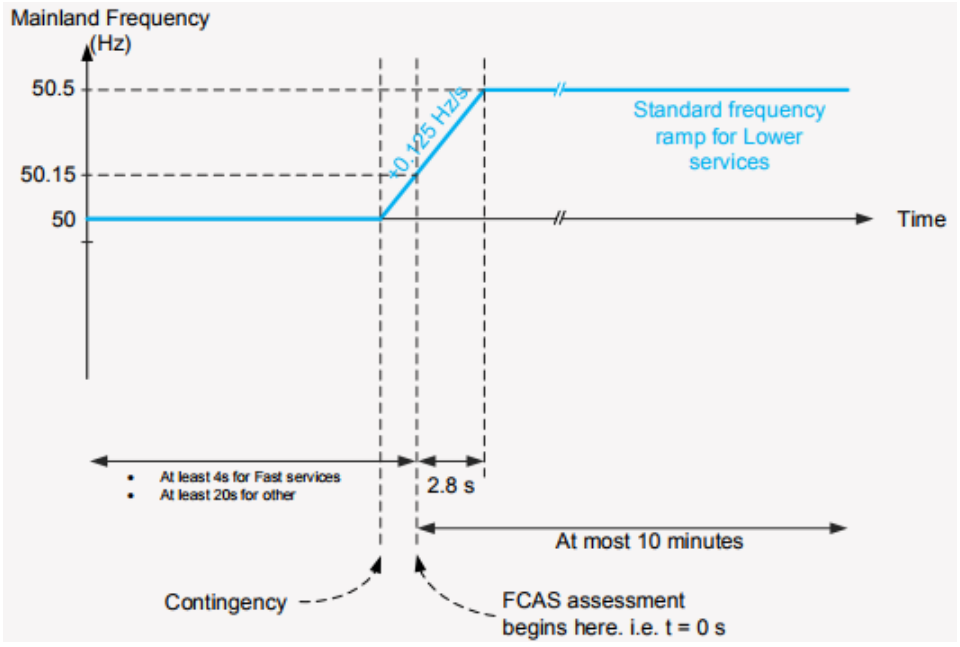

Figure 2 - Standard (Over) Frequency Ramp (Mainland) [5]

5.2.2 Prerequisites

The wind farm must be operating at the power setpoint of 40MW with available wind resource (possible power) of 65MW or greater.

The test should be coordinated with AEMO.

5.2.3 Methodology

Perform the following steps:

1. Record current active power, frequency, and time.
2. Apply standard under frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time. Record for 11 minutes.
3. Review test record to ensure system frequency was steady for the test duration.
4. Record current active power, frequency, and time.
5. Apply standard over frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time. Record for 11 minutes.
6. Slowly ramp the test signal back to zero.
7. Review test record to ensure system frequency was steady for the test duration.
8. Test complete

5.2.4 Post-test analysis

5.2.4.1 Model Overlays

Download and save the data from the meters and create a plot of the active power output of the wind farm and the injected test signal.

Simulate the test conditions in PSS/E and overlay the results against the Elspec data.

5.2.4.2 Amount Service for Dispatch Purposes

Each active power response to the standard ramp signals will be assessed, according to the MASS [5] as follows -

The amount of Fast Raise/Lower Service for Dispatch Purposes is the lesser of:

(a) twice the time average of the response (ΔP) between zero and six seconds from the Frequency Disturbance Time (1.2 seconds from beginning of ramp).

(b) twice the Time Average of the Raise Response (ΔP) between six and 60 seconds from the Frequency Disturbance Time (1.2 seconds from beginning of ramp).

The amount of Slow Raise/Lower Service for Dispatch Purposes is the lesser of:

(a) twice the time average of the response (ΔP) between six and sixty seconds from the frequency disturbance time, excluding any inertial response (1.2 seconds from beginning of ramp).

(b) twice the time average of the response (ΔP) between sixty seconds and five minutes from the frequency disturbance time (1.2 seconds from beginning of ramp).

The amount of Delayed Raise/Lower Service for Dispatch Purposes is the lesser of:

a) twice the time Average of the response between one and five minutes from the frequency disturbance time (1.2 seconds from beginning of ramp).

b) the time average of the response (ΔP) between five and ten minutes from the frequency disturbance time (1.2 seconds from beginning of ramp)

5.3. Power Level 1 - Test 3: Extreme event profile injections

5.3.1 Test description

The objective of this test is to assess HD2WF's frequency support contribution to extreme events.

Under frequency credible event and non-credible event profiles have been supplied by AEMO [6]. The credible event profile has an initial RoCoF of -1Hz/s, the non-credible event profile has an initial RoCoF of -3Hz/s. These test frequency profiles are applied and the active power response recorded to assess the raise services.

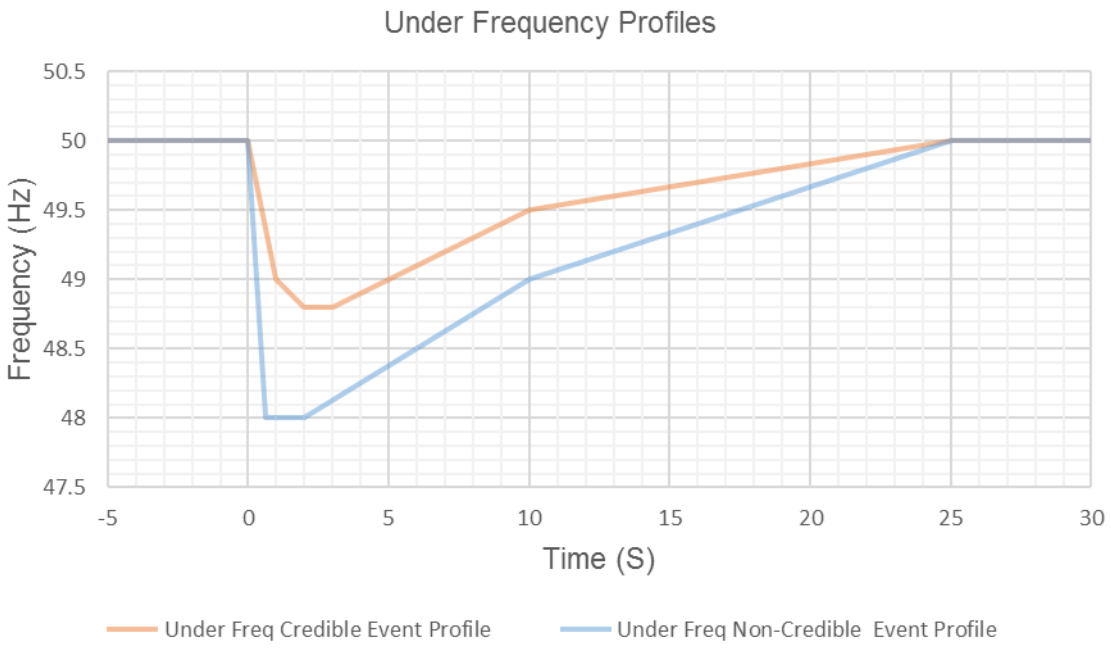

Figure 3 - Under Frequency Extreme Event Profiles

Over frequency credible event and non-credible event profiles have been supplied by AEMO [6]. The credible event profile has an initial RoCoF of 1Hz/s, the non-credible event profile has an initial RoCoF of 3Hz/s. These test frequency profiles are applied and the active power response recorded to assess the lower services.

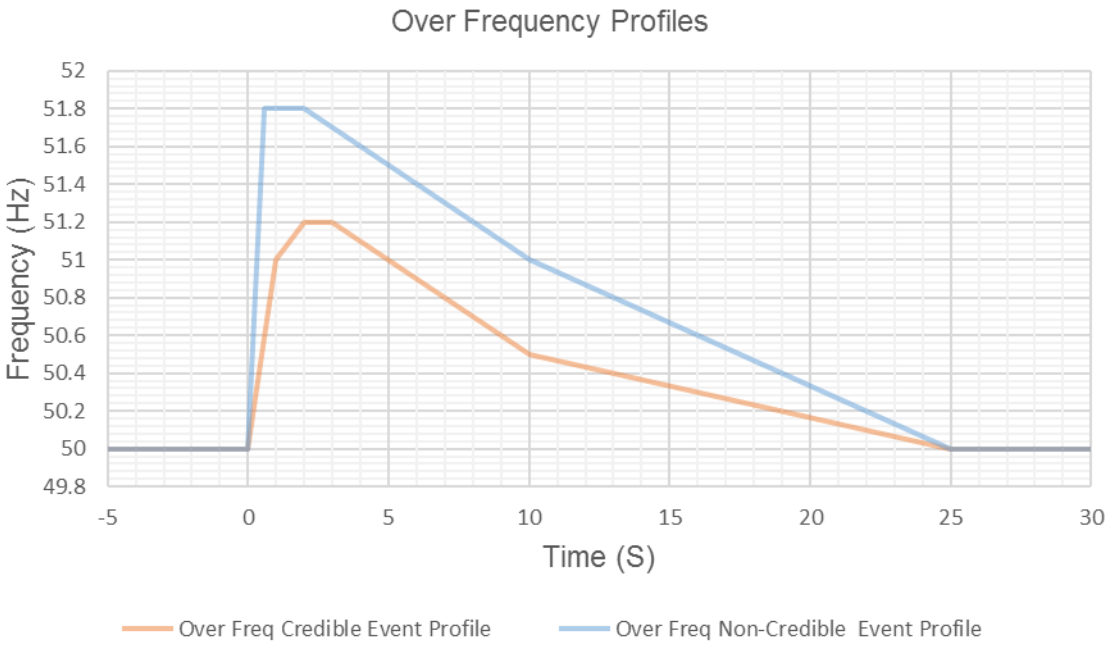

Figure 4 – Over Frequency Extreme Event Profiles

5.3.2 Prerequisites

The wind farm must be operating at the power setpoint of 40MW with available wind resource (possible power) of 65MW or greater.

The test should be coordinated with AEMO.

5.3.3 Methodology

Perform the following steps:

1. Record current active power, frequency, and time.
2. Apply credible event under frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
3. Wait for active power to settle.
4. Review test record to ensure system frequency was steady for the test duration.
5. Record current active power, frequency, and time.
6. Apply non-credible event under frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
7. Wait for active power to settle.
8. Review test record to ensure system frequency was steady for the test duration.
9. Record current active power, frequency, and time.
10. Apply credible event over frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
11. Wait for active power to settle.
12. Review test record to ensure system frequency was steady for the test duration.
13. Record current active power, frequency, and time.

14. Apply non-credible event over frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
15. Wait for active power to settle.
16. Review test record to ensure system frequency was steady for the test duration.
17. Test complete.

5.3.4 Post-test analysis

5.3.4.1 Model Overlays

Download and save the data from the meters and create a plot of the active power output of the wind farm and the injected test signal.

Simulate the test conditions in PSS/E and overlay the results against the Elspec data.

5.3.4.2 FCAS Provision

Asses the provision of Raise and Lower services with the FCAS Verification Tool [7] (no Inertia, no change in power dispatch, Boost parameter 'G' = 1)

5.4. Power Level 1 - Test 4: Actual event injections

5.4.1 Test description

The objective of this test is to assess HD2WF's frequency support contribution to real events on the network that have previously been recorded.

An under and over frequency event record has been supplied by AEMO [6]. These frequency profiles are applied and the active power response recorded to assess.

The under frequency event data has been adjusted to start at 50Hz and ramp back to 50Hz after 10 minutes. This allows smooth application of the test signal. The test data was also filtered with a moving average filter with at 260ms window to remove higher frequency 'spikes' without affecting the overall profile of the event. The test signal, with reference to the supplied event record, is shown in Figure 5 and Figure 6 below.

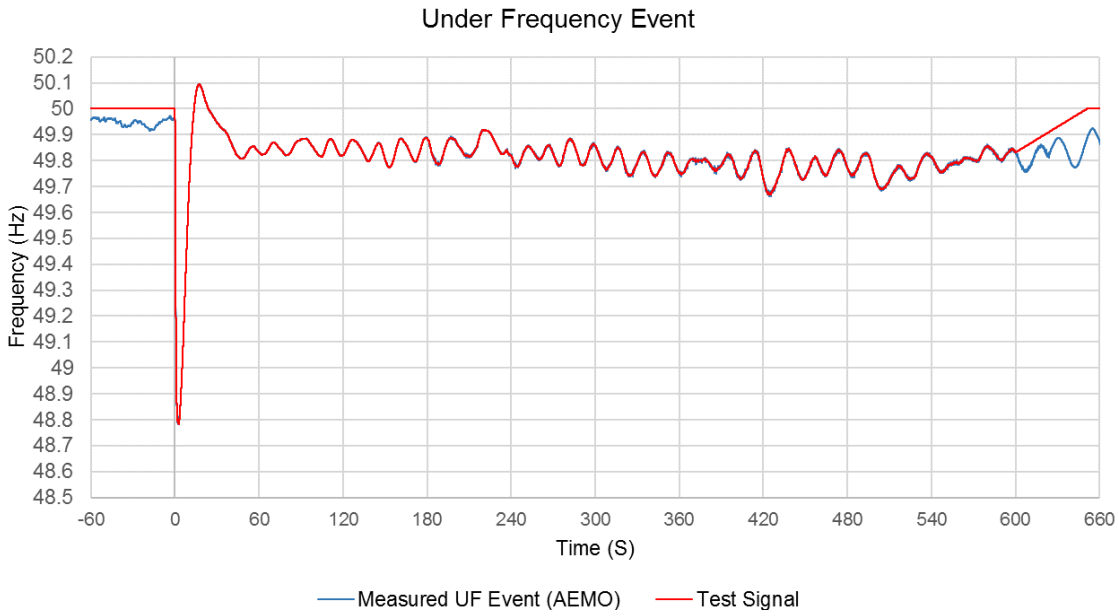

Figure 5 - Under Frequency Event Profile (10 minute)

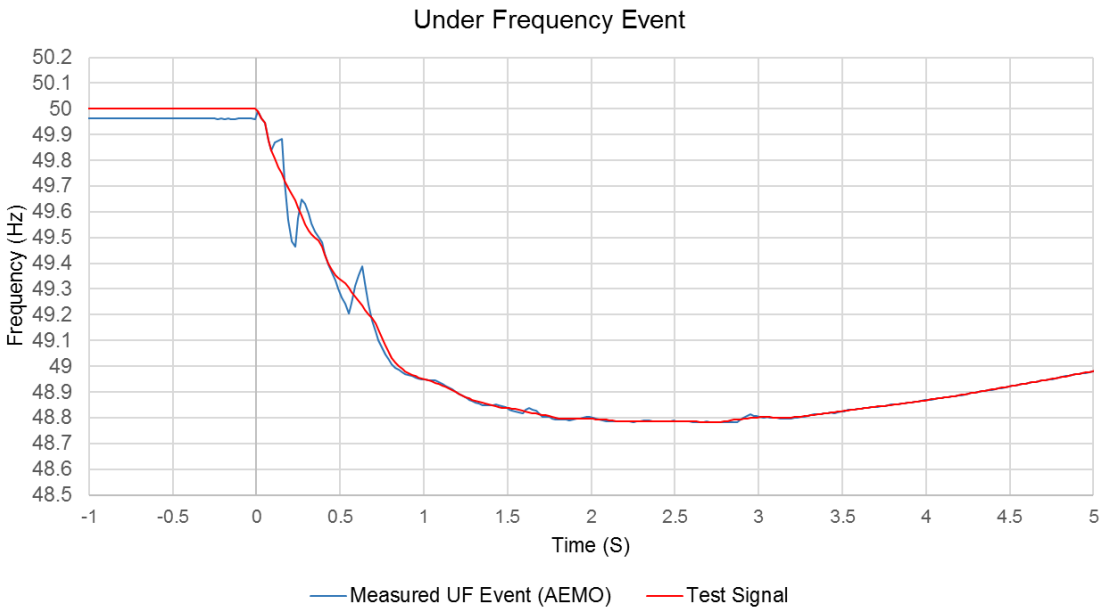

Figure 6 - Under Frequency Event Profile (first 10 seconds of Figure 5)

The over frequency event data has been adjusted to start at 50Hz and ramp back to 50Hz after 10 minutes. This allows smooth application of the test signal. The test signal, with reference to the supplied event record, is shown in Figure 7 and Figure 8 below.

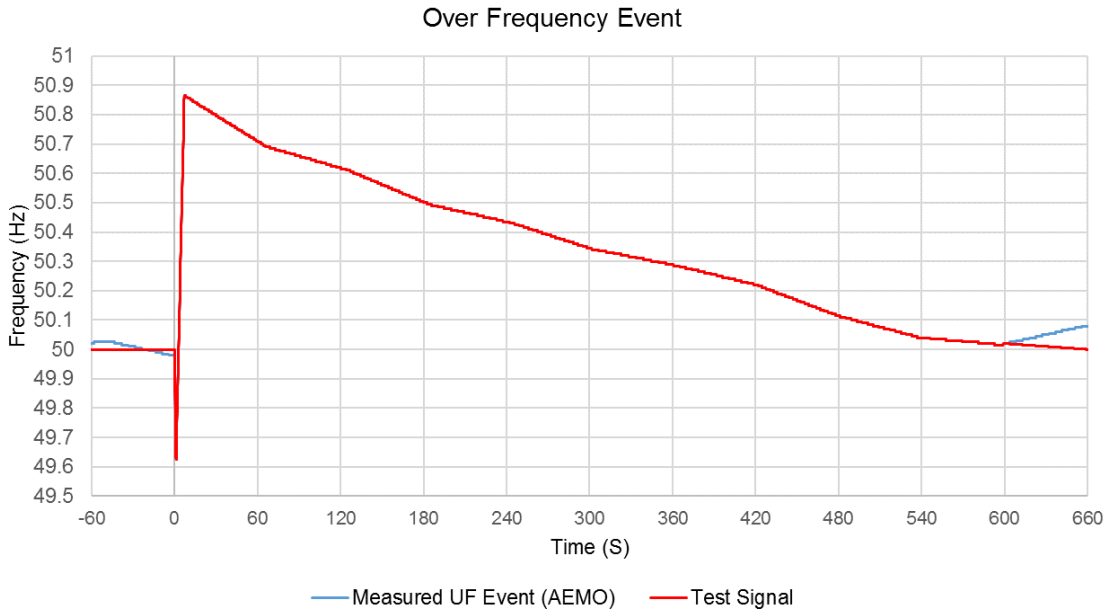

Figure 7 - Over Frequency Event Profile (10 minute)

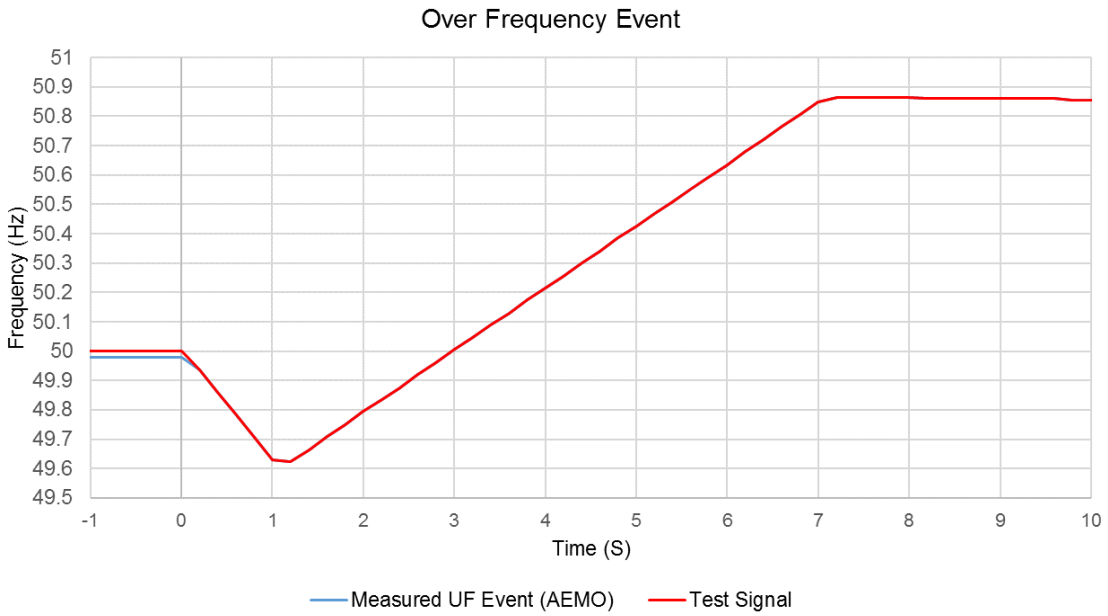

Figure 8 – Over Frequency Extreme Profile (First 10 seconds of Figure 7)

5.4.2 Prerequisites

The wind farm must be operating at the power setpoint of 40MW with available wind resource (possible power) of 65MW or greater.

The test should be coordinated with AEMO.

5.4.3 Methodology

Perform the following steps:

1. Record current active power, frequency, and time.
2. Apply the under frequency event profile to the PPC frequency test input. Ensure 20 seconds of pre ramp time and 10 minute post event time is recorded.
3. Wait for active power to settle.
4. Review test record to ensure system frequency was steady for the test duration.
5. Record current active power, frequency, and time.
6. Apply the over frequency event profile to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
7. Wait for active power to settle.
8. Review test record to ensure system frequency was steady for the test duration.
9. Test complete.

5.4.4 Post-test analysis

5.4.4.1 Model Overlays

Download and save the data from the meters and create a plot of the active power output of the wind farm and the injected test signal.

Simulate the test conditions in PSS/E and overlay the results against the Elspec data.

5.4.4.2 FCAS Provision

Asses the provision of Raise and Lower services with the FCAS Verification Tool [7] (no Inertia, no change in power dispatch, Boost parameter ‘G’ = 1)

6. Contingent FCAS Power level 2 (74MW) tests

6.1. Power Level 2 - Test 1: Standard frequency ramp injections

6.1.1 Test description

The objective of this test is to verify the amount of Fast, Slow and Delayed (raise and lower) services for dispatch purposes [5].

A standard under frequency ramp [5] is applied and the active power response recorded to assess the raise services. A standard over frequency ramp is applied and the active power response recorded to assess the lower services. A ramp back to 50Hz is included at the end of the test signal (after 11 minutes),

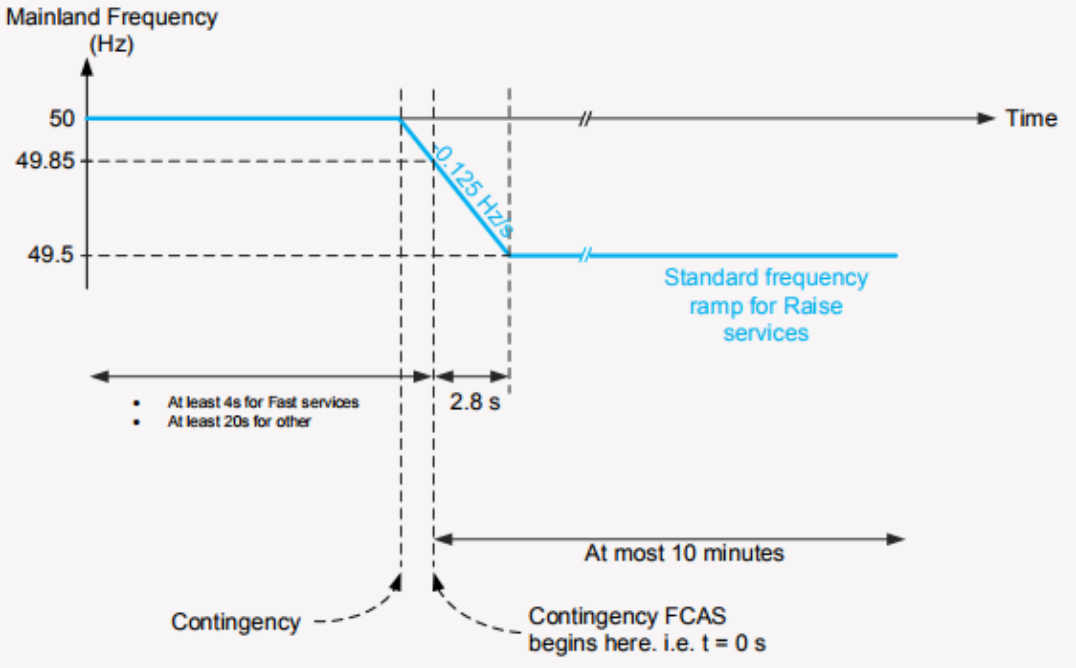

Figure 9 - Standard (Under) Frequency Ramp (Mainland) [5]

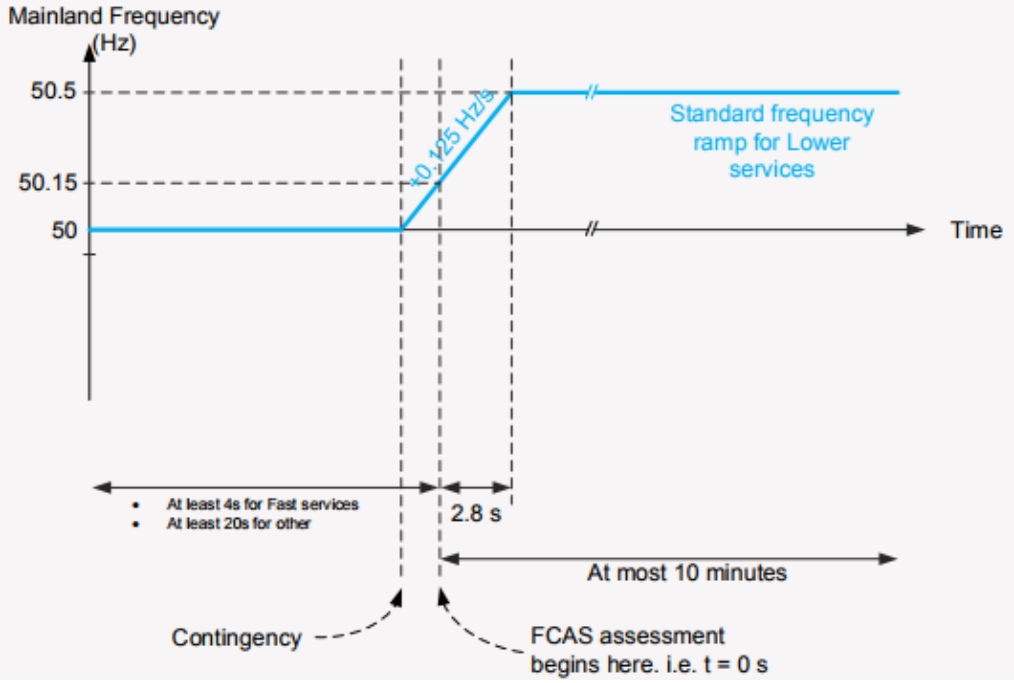

Figure 10 - Standard (Over) Frequency Ramp (Mainland) [5]

6.1.2 Prerequisites

The wind farm must be operating at the power setpoint of 74MW with available wind resource (possible power) of 99MW or greater.

The test should be coordinated with AEMO.

6.1.3 Methodology

Perform the following steps:

1. Record current active power, frequency, and time.
2. Apply standard under frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time. Record for 11 minutes.
3. Review test record to ensure system frequency was steady for the test duration.
4. Record current active power, frequency, and time.
5. Apply standard over frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time. Record for 11 minutes.
6. Slowly ramp the test signal back to zero.
7. Review test record to ensure system frequency was steady for the test duration.
8. Test complete.

6.1.4 Post-test analysis

6.1.4.1 Model Overlays

Download and save the data from the meters and create a plot of the active power output of the wind farm and the injected test signal.

Simulate the test conditions in PSS/E and overlay the results against the Elspec data.

6.1.4.2 Amount Service for Dispatch Purposes

Each active power response to the standard ramp signals will be assessed, according to the MASS [5] as follows -

The amount of Fast Raise/Lower Service for Dispatch Purposes is the lesser of:

(a) twice the time average of the response (∆P) between zero and six seconds from the Frequency Disturbance Time (1.2 seconds from beginning of ramp).

(b) twice the Time Average of the Raise Response (∆P) between six and 60 seconds from the Frequency Disturbance Time (1.2 seconds from beginning of ramp).

The amount of Slow Raise/Lower Service for Dispatch Purposes is the lesser of:

(a) twice the time average of the response (ΔP) between six and sixty seconds from the frequency disturbance time, excluding any inertial response (1.2 seconds from beginning of ramp).

(b) twice the time average of the response (ΔP) between sixty seconds and five minutes from the frequency disturbance time (1.2 seconds from beginning of ramp).

The amount of Delayed Raise/Lower Service for Dispatch Purposes is the lesser of:

a) twice the time Average of the response between one and five minutes from the frequency disturbance time (1.2 seconds from beginning of ramp).

b) the time average of the response (ΔP) between five and ten minutes from the frequency disturbance time (1.2 seconds from beginning of ramp).

6.2. Power Level 2 - Test 2: Extreme event profile injections

6.2.1 Test description

The objective of this test is to assess HD2WF's frequency support contribution to extreme events.

Under frequency credible event and non-credible event profiles have been supplied by AEMO [6]. The credible event profile has an initial RoCoF of -1Hz/s, the non-credible event profile has an initial RoCoF of -3Hz/s. These test frequency profiles are applied and the active power response recorded to assess the raise services.

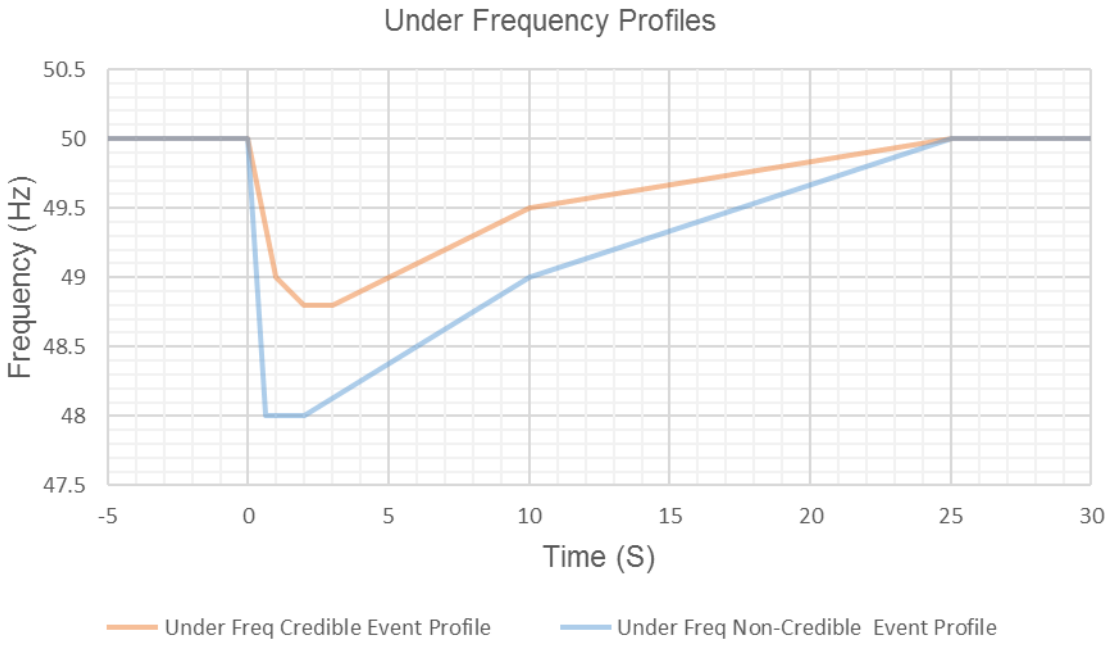

Figure 11 - Under Frequency Extreme Event Profiles

Over frequency credible event and non-credible event profiles have been supplied by AEMO [6]. The credible event profile has an initial RoCoF of 1Hz/s, the non-credible event profile has an initial RoCoF of 3Hz/s. These test frequency profiles are applied and the active power response recorded to assess the lower services.

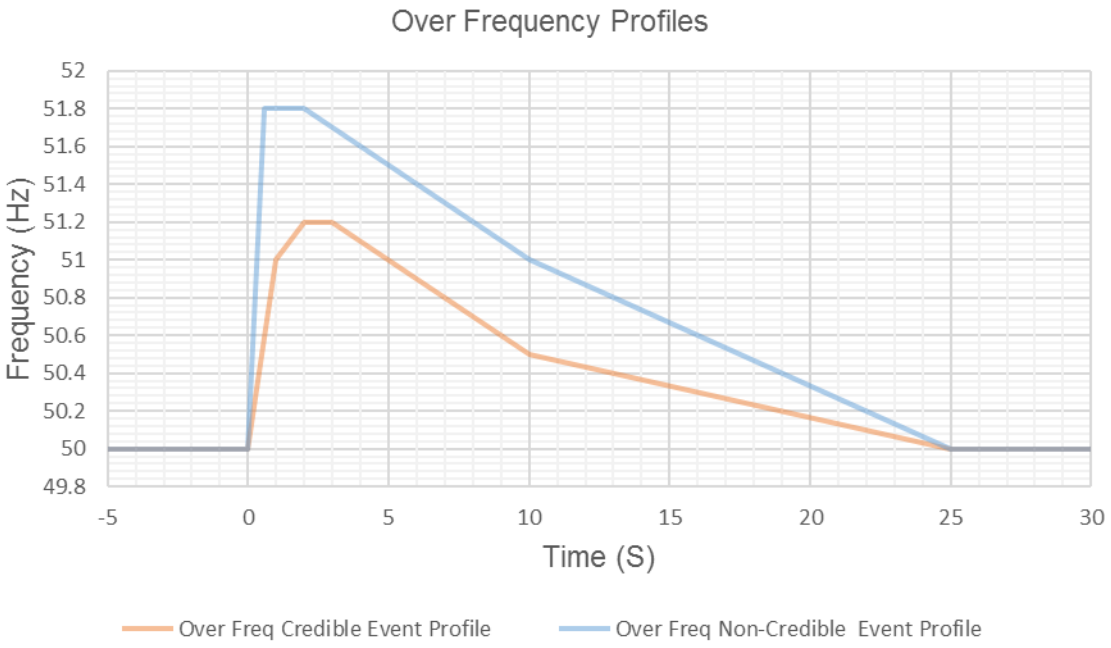

Figure 12 – Over Frequency Extreme Event Profiles

6.2.2 Prerequisites

The wind farm must be operating at the power setpoint of 74MW with available wind resource (possible power) of 99MW or greater.

The test should be coordinated with AEMO.

6.2.3 Methodology

Perform the following steps:

1. Record current active power, frequency, and time.
2. Apply credible event under frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
3. Wait for active power to settle.
4. Review test record to ensure system frequency was steady for the test duration.
5. Record current active power, frequency, and time.
6. Apply non-credible event under frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
7. Wait for active power to settle.
8. Review test record to ensure system frequency was steady for the test duration.
9. Record current active power, frequency, and time.
10. Apply credible event over frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
11. Wait for active power to settle.
12. Review test record to ensure system frequency was steady for the test duration.
13. Record current active power, frequency, and time.

14. Apply non-credible event over frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
15. Wait for active power to settle.
16. Review test record to ensure system frequency was steady for the test duration.
17. Test complete.

6.2.4 Post-test analysis

6.2.4.1 Model Overlays

Download and save the data from the meters and create a plot of the active power output of the wind farm and the injected test signal.

Simulate the test conditions in PSS/E and overlay the results against the Elspec data.

6.2.4.2 FCAS Provision

Asses the provision of Raise and Lower services with the FCAS Verification Tool [7] (no Inertia, no change in power dispatch, Boost parameter 'G' = 1)

6.3. Power Level 2 - Test 3: Actual event injections

6.3.1 Test description

The objective of this test is to assess HD2WF's frequency support contribution to real events on the network that have previously been recorded.

An under and over frequency event record has been supplied by AEMO [6]. These frequency profiles are applied and the active power response recorded to assess.

The under frequency event data has been adjusted to start at 50Hz and ramp back to 50Hz after 10 minutes. This allows smooth application of the test signal. The test data was also filtered with a moving average filter with at 260ms window to remove higher frequency 'spikes' without affecting the overall profile of the event. The test signal, with reference to the supplied event record, is shown in Figure 5 and Figure 6 below.

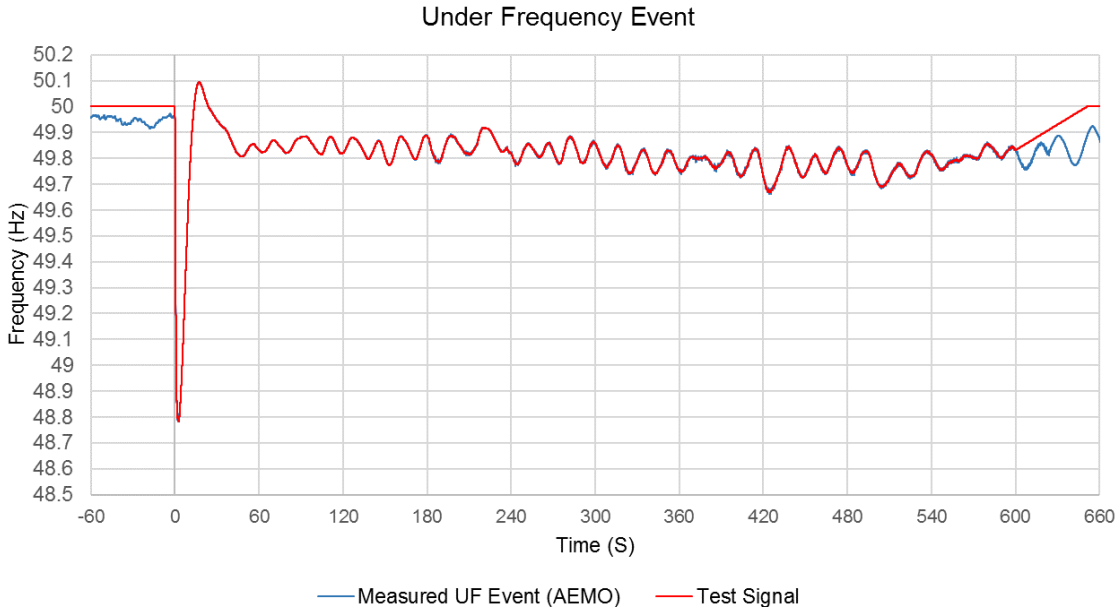

Figure 13 - Under Frequency Event Profile (10 minute)

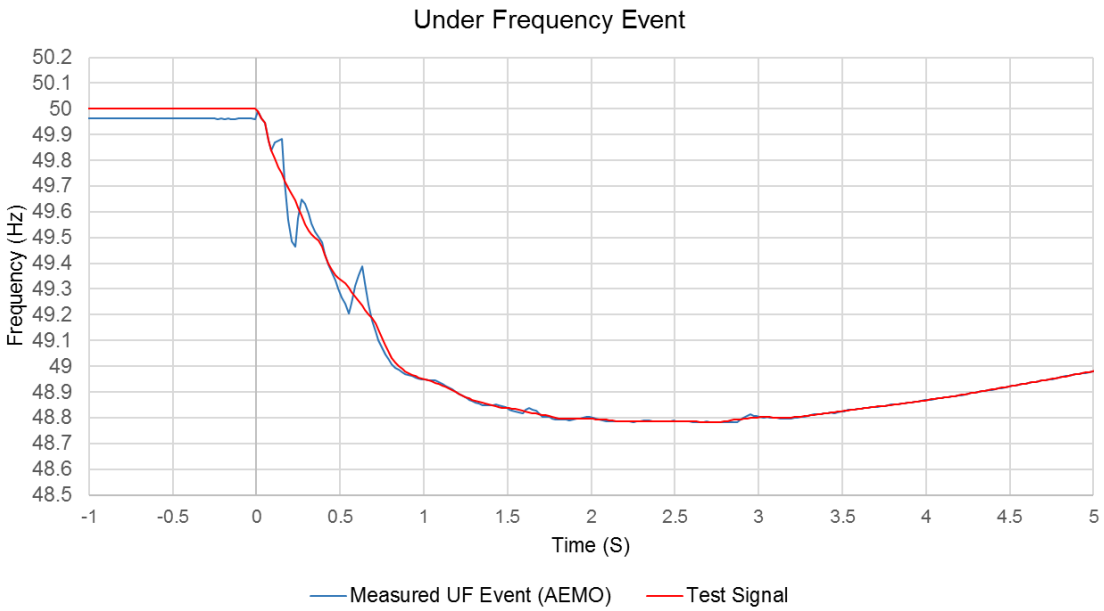

Figure 14 - Under Frequency Event Profile (first 10 seconds of Figure 13)

The over frequency event data has been adjusted to start at 50Hz and ramp back to 50Hz after 10 minutes. This allows smooth application of the test signal. The test signal, with reference to the supplied event record, is shown in Figure 7 and Figure 8 below.

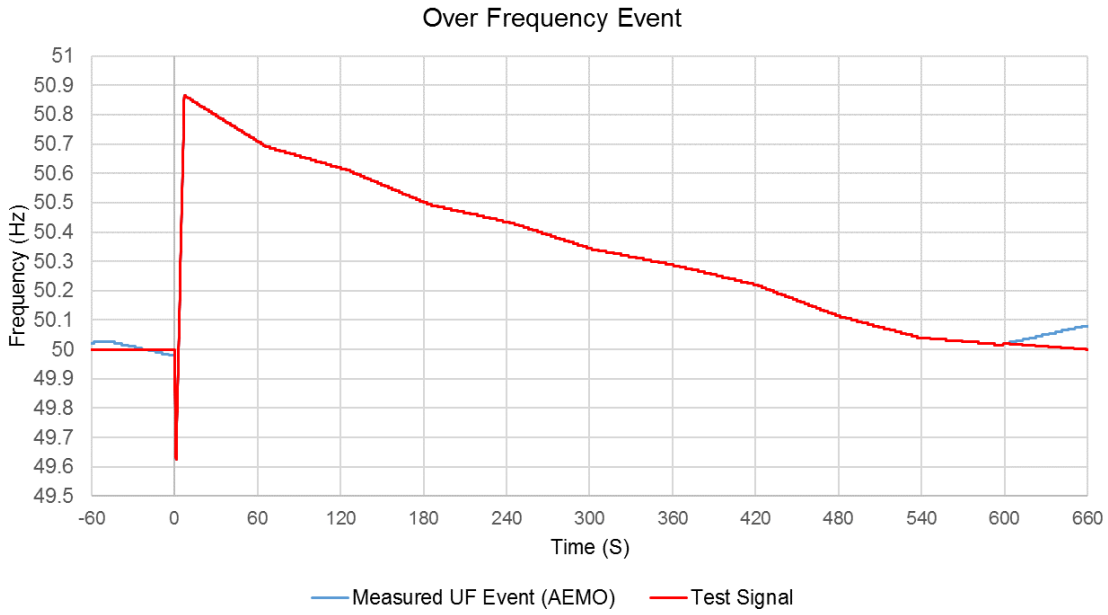

Figure 15 - Over Frequency Event Profile (10 minute)

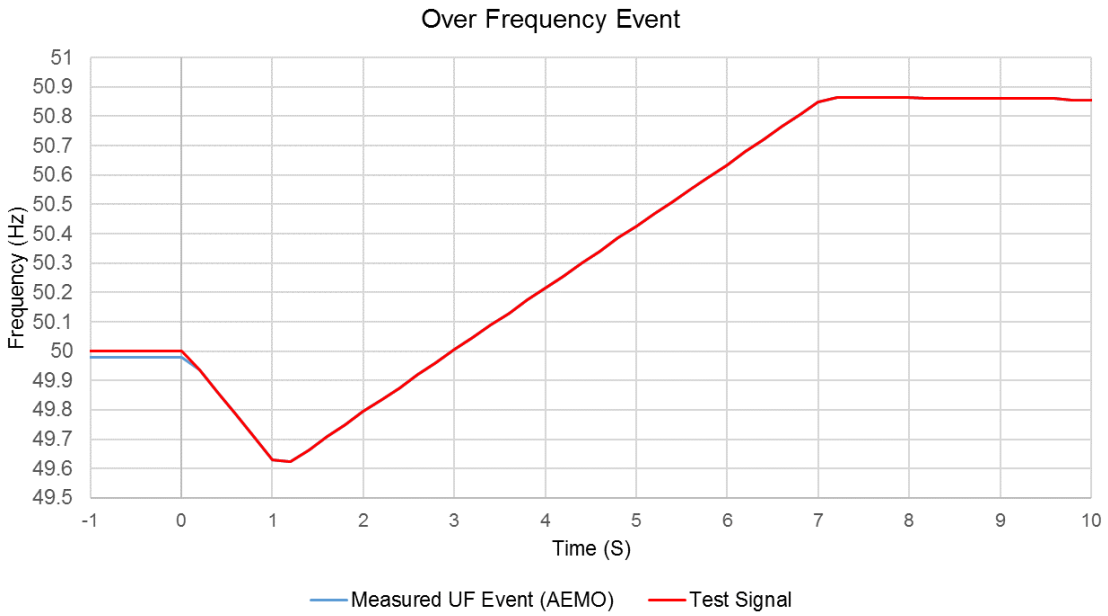

Figure 16 – Over Frequency Event Profile (Fist 10 seconds of Figure 15)

6.3.2 Prerequisites

The wind farm must be operating at the power setpoint of 74MW with available wind resource (possible power) of 99MW greater.

The test should be coordinated with AEMO.

6.3.3 Methodology

Perform the following steps:

1. Record current active power, frequency, and time.
2. Apply the under frequency event profile to the PPC frequency test input. Ensure 20 seconds of pre ramp time and 10 minute post event time is recorded.
3. Wait for active power to settle.
4. Review test record to ensure system frequency was steady for the test duration.
5. Record current active power, frequency, and time.
6. Apply the over frequency event profile to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
7. Wait for active power to settle.
8. Review test record to ensure system frequency was steady for the test duration.
9. Test complete.

6.3.4 Post-test analysis

6.3.4.1 Model Overlays

Download and save the data from the meters and create a plot of the active power output of the wind farm and the injected test signal.

Simulate the test conditions in PSS/E and overlay the results against the Elspec data.

6.3.4.2 FCAS Provision

Asses the provision of Raise and Lower services with the FCAS Verification Tool [7] (no Inertia, no change in power dispatch, Boost parameter ‘G’ = 1)

7. Contingent FCAS Power level 3 (88MW) tests

7.1. Power Level 3 - Test 1: Standard frequency ramp injections

7.1.1 Test description

The objective of this test is to verify the amount of Fast, Slow and Delayed (raise and lower) services for dispatch purposes [5].

A standard under frequency ramp [5] is applied and the active power response recorded to assess the raise services. A standard over frequency ramp is applied and the active power response recorded to assess the lower services. A ramp back to 50Hz is included at the end of the test signal (after 11 minutes),

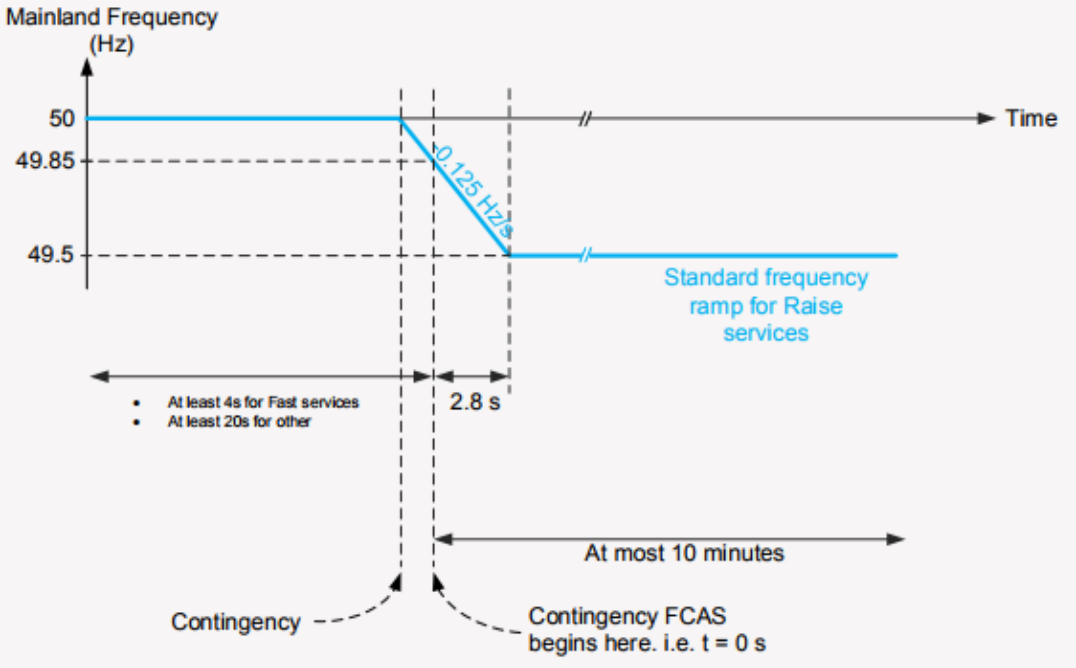

Figure 17 - Standard (Under) Frequency Ramp (Mainland) [5]

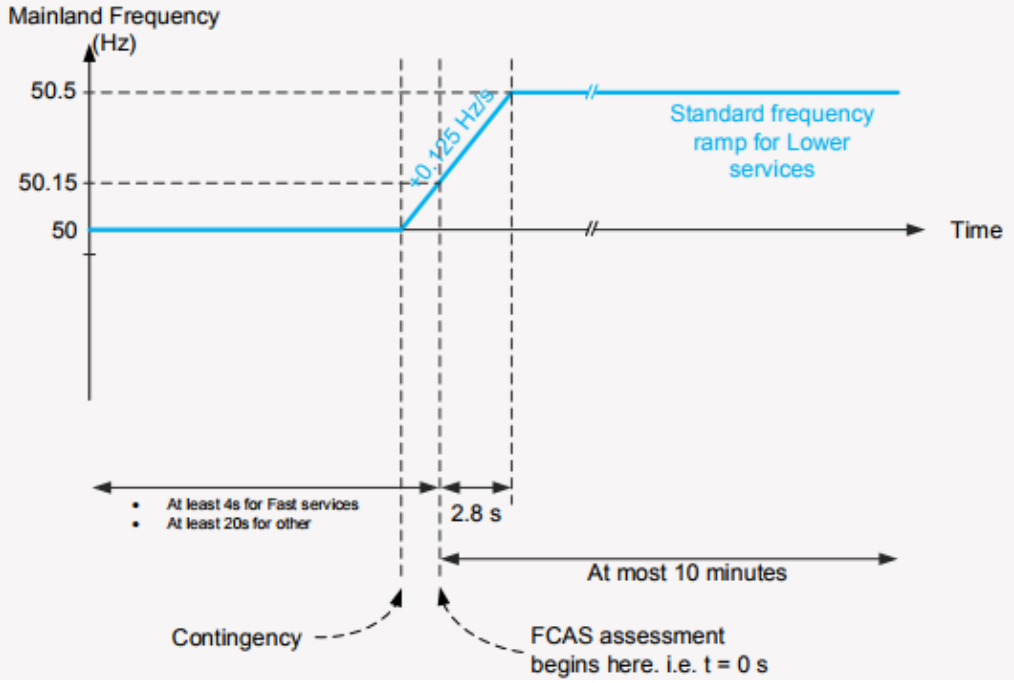

Figure 18 - Standard (Over) Frequency Ramp (Mainland) [5]

7.1.2 Prerequisites

The wind farm must be operating at the power setpoint of 88MW with available wind resource (possible power) of 102MW. It is expected that the response to the under-frequency signal will be capped at the maximum active power.

The test should be coordinated with AEMO.

7.1.3 Methodology

Perform the following steps:

1. Record current active power, frequency, and time.
2. Apply standard under frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time. Record for 11 minutes.
3. Review test record to ensure system frequency was steady for the test duration.
4. Record current active power, frequency, and time.
5. Apply standard over frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time. Record for 11 minutes.
6. Slowly ramp the test signal back to zero.
7. Review test record to ensure system frequency was steady for the test duration.
8. Test complete.

7.1.4 Post-test analysis

7.1.4.1 Model Overlays

Download and save the data from the meters and create a plot of the active power output of the wind farm and the injected test signal.

Simulate the test conditions in PSS/E and overlay the results against the Elspec data.

7.1.4.2 Amount Service for Dispatch Purposes

Each active power response to the standard ramp signals will be assessed, according to the MASS [5] as follows -

The amount of Fast Raise/Lower Service for Dispatch Purposes is the lesser of:

a) twice the time average of the response (∆P) between zero and six seconds from the Frequency Disturbance Time (1.2 seconds from beginning of ramp).

b) twice the Time Average of the Raise Response (ΔP) between six and 60 seconds from the Frequency Disturbance Time (1.2 seconds from beginning of ramp).

The amount of Slow Raise/Lower Service for Dispatch Purposes is the lesser of:

a) twice the time average of the response (ΔP) between six and sixty seconds from the frequency disturbance time, excluding any inertial response (1.2 seconds from beginning of ramp).

b) twice the time average of the response (ΔP) between sixty seconds and five minutes from the frequency disturbance time (1.2 seconds from beginning of ramp).

The amount of Delayed Raise/Lower Service for Dispatch Purposes is the lesser of:

a) twice the time Average of the response between one and five minutes from the frequency disturbance time (1.2 seconds from beginning of ramp).

b) the time average of the response (ΔP) between five and ten minutes from the frequency disturbance time (1.2 seconds from beginning of ramp).

7.2. Power Level 3 - Test 2: Extreme event profile injections

7.2.1 Test description

The objective of this test is to assess HD2WF's frequency support contribution to extreme events.

Under frequency credible event and non-credible event profiles have been supplied by AEMO [6]. The credible event profile has an initial RoCoF of -1Hz/s, the non-credible event profile has an initial RoCoF of -3Hz/s. These test frequency profiles are applied and the active power response recorded to assess the raise services.

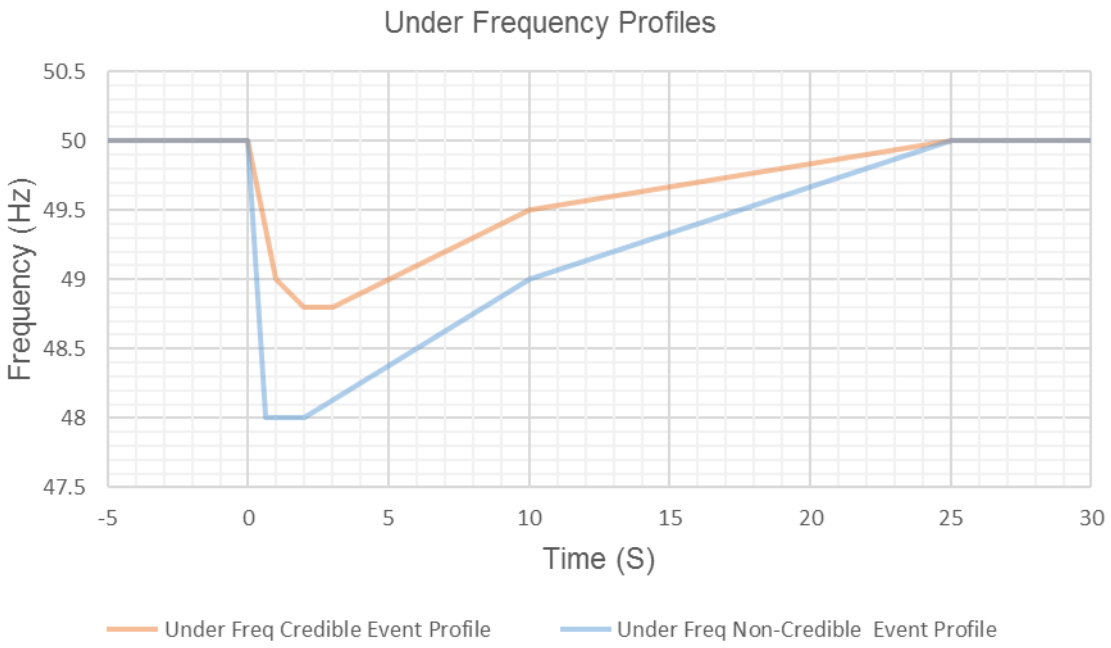

Figure 19 - Under Frequency Extreme Event Profiles

Over frequency credible event and non-credible event profiles have been supplied by AEMO [6]. The credible event profile has an initial RoCoF of 1Hz/s, the non-credible event profile has an initial RoCoF of 3Hz/s. These test frequency profiles are applied and the active power response recorded to assess the lower services.

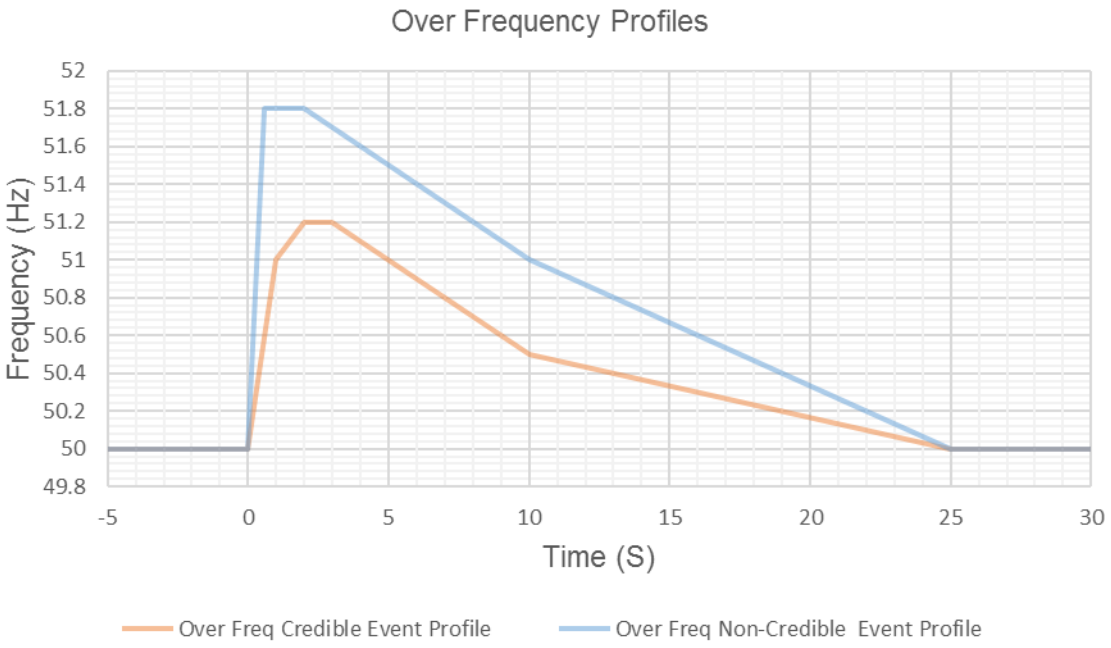

Figure 20 – Over Frequency Extreme Event Profiles

7.2.2 Prerequisites

The wind farm must be operating at the power setpoint of 88MW with available wind resource (possible power) of 102MW. It is expected that the response to the under-frequency signal will be capped at the maximum active power.

The test should be coordinated with AEMO.

7.2.3 Methodology

Perform the following steps:

1. Record current active power, frequency, and time.
2. Apply credible event under frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
3. Wait for active power to settle.
4. Review test record to ensure system frequency was steady for the test duration.
5. Record current active power, frequency, and time.
6. Apply non-credible event under frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
7. Wait for active power to settle.
8. Review test record to ensure system frequency was steady for the test duration.
9. Record current active power, frequency, and time.
10. Apply credible event over frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
11. Wait for active power to settle.
12. Review test record to ensure system frequency was steady for the test duration.
13. Record current active power, frequency, and time.

14. Apply non-credible event over frequency ramp to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
15. Wait for active power to settle.
16. Review test record to ensure system frequency was steady for the test duration.
17. Test complete.

7.2.4 Post-test analysis

7.2.4.1 Model Overlays

Download and save the data from the meters and create a plot of the active power output of the wind farm and the injected test signal.

Simulate the test conditions in PSS/E and overlay the results against the Elspec data.

7.2.4.2 FCAS Provision

Asses the provision of Raise and Lower services with the FCAS Verification Tool [7] (no Inertia, no change in power dispatch, Boost parameter 'G' = 1)

7.3. Power Level 3 - Test 3: Actual event injections

7.3.1 Test description

The objective of this test is to assess HD2WF's frequency support contribution to real events on the network that have previously been recorded.

An under and over frequency event record has been supplied by AEMO [6]. These frequency profiles are applied and the active power response recorded to assess.

The under frequency event data has been adjusted to start at 50Hz and ramp back to 50Hz after 10 minutes. This allows smooth application of the test signal. The test data was also filtered with a moving average filter with at 260ms window to remove higher frequency 'spikes' without affecting the overall profile of the event. The test signal, with reference to the supplied event record, is shown in Figure 5 and Figure 6 below.

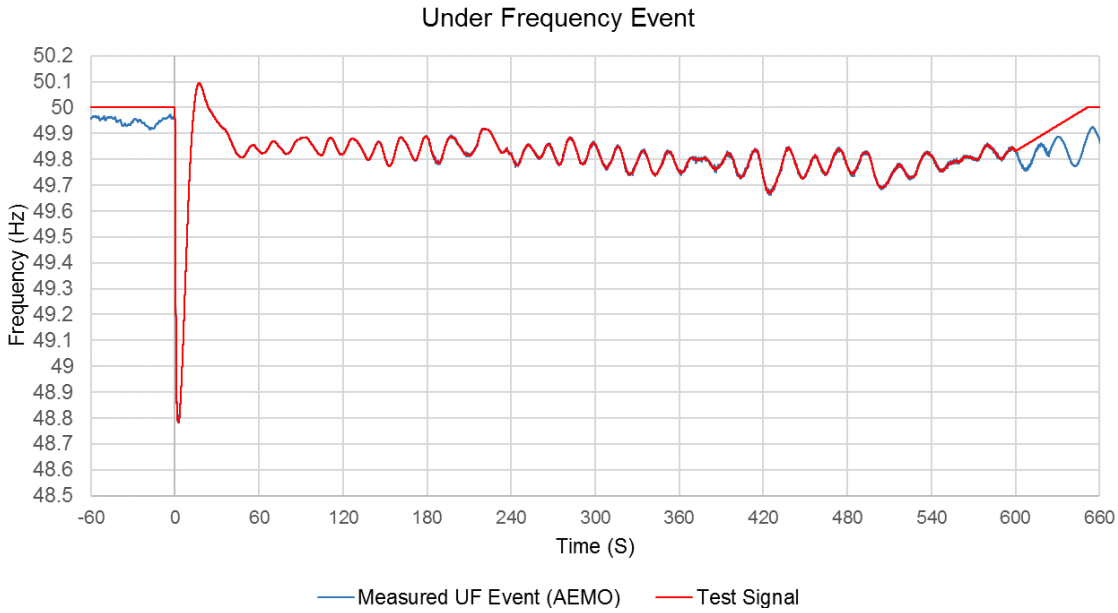

Figure 21 - Under Frequency Event Profile (10 minute)

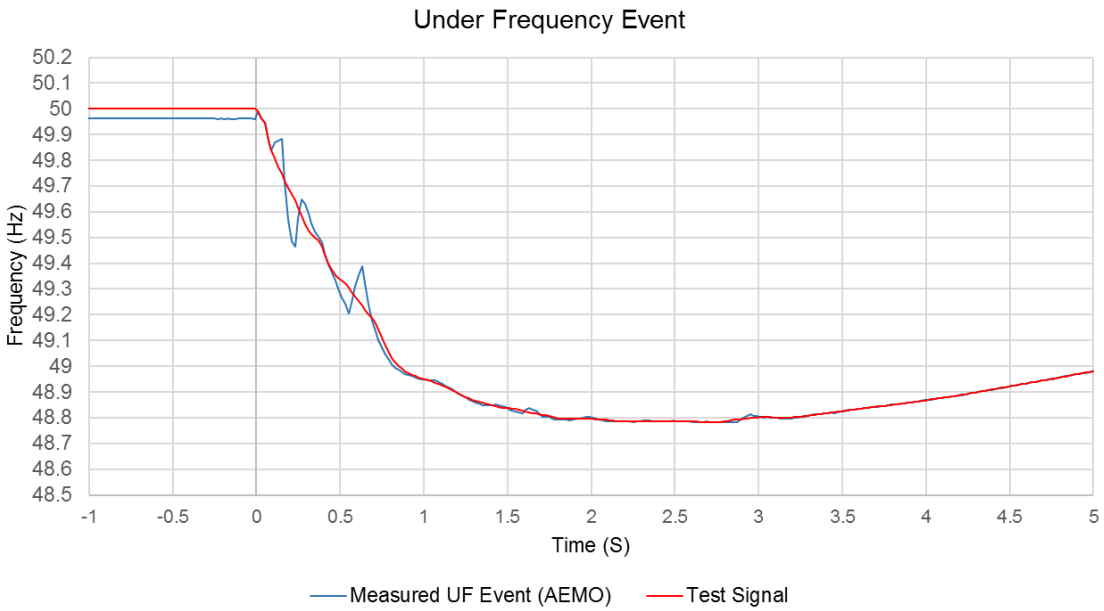

Figure 22 - Under Frequency Event Profile (first 10 seconds of Figure 21)

The over frequency event data has been adjusted to start at 50Hz and ramp back to 50Hz after 10 minutes. This allows smooth application of the test signal. The test signal, with reference to the supplied event record, is shown in Figure 7 and Figure 8 below.

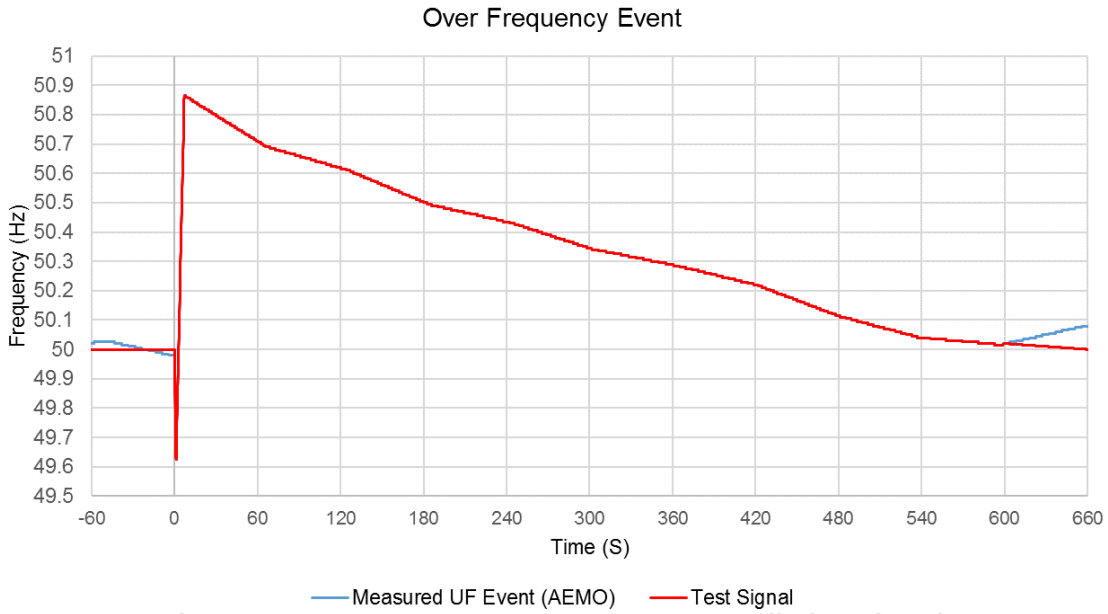

Figure 23 - Over Frequency Extreme Event Profile (10 minute)

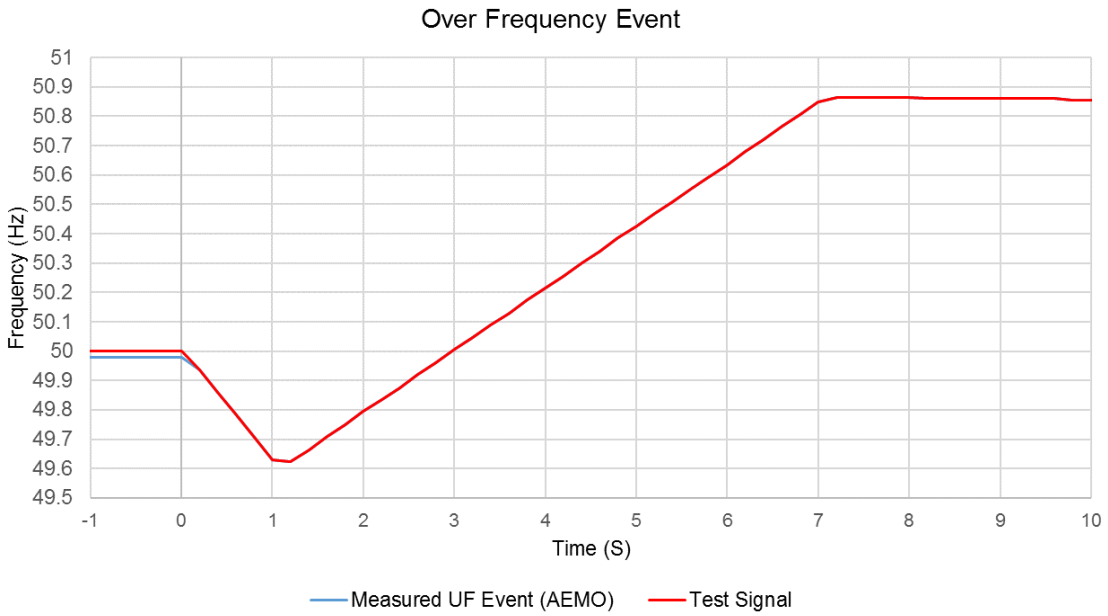

Figure 24 – Over Frequency Extreme Event Profile (Fist 10 seconds of Figure 23)

7.3.2 Prerequisites

The wind farm must be operating at the power setpoint of 88MW with available wind resource (possible power) of 102MW. It is expected that the response to the under-frequency signal will be capped at the maximum active power.

The test should be coordinated with AEMO.

7.3.3 Methodology

Perform the following steps:

1. Record current active power, frequency, and time.
2. Apply the under frequency event profile to the PPC frequency test input. Ensure 20 seconds of pre ramp time and 10 minute post event time is recorded.
3. Wait for active power to settle.
4. Review test record to ensure system frequency was steady for the test duration.
5. Record current active power, frequency, and time.
6. Apply the over frequency event profile to the PPC frequency test input. Ensure 20 seconds of pre ramp time.
7. Wait for active power to settle.
8. Review test record to ensure system frequency was steady for the test duration.
9. Test complete.

7.3.4 Post-test analysis

7.3.4.1 Model Overlays

Download and save the data from the meters and create a plot of the active power output of the wind farm and the injected test signal.

Simulate the test conditions in PSS/E and overlay the results against the Elspec data.

7.3.4.2 FCAS Provision

Asses the provision of Raise and Lower services with the FCAS Verification Tool [7] (no Inertia, no change in power dispatch, Boost parameter ‘G’ = 1)

8. Regulation Up/ Down Tests

8.1. Regulation Up/Down - Test 1: (10 MW)

8.1.1 Test description

The objective of this test is to demonstrate the wind farm's ability to follow AEMO's AGC dispatch signals by showing response to local power setpoint changes and AGC signals.

Local active power setpoint changes will be made using a local command in the wind farm SCADA system and the active power response on the windfarm monitored. Following this live AGC signals will be received.

8.1.2 Prerequisites

- The wind farm must be operating at the power setpoint of 10MW.
- Wind resource must be sufficient for the wind farm to generate at the requested power set points or greater over the duration of the test.
- During testing, the wind farm's active power will be varied.
- The test should be coordinated with AEMO.

8.1.3 Methodology

Perform the following steps:

1. Confirm Possible power of additional 20MW via the possible power SCADA value.
2. Set the wind farm's active power control to local control.
3. Record current active power, frequency, and time.
4. Set the wind farm's active power setpoint to the current operating point to 30MW.
5. Wait for active power levels to stabilise (5 minutes).
6. Return the wind farm's active power setpoint to 10 MW.
7. Wait for active power levels to stabilise (5 minutes).
8. Restore the wind farm's active power control to remote control, AGC enabled.
9. Request AEMO send 20 minutes of AGC regulation signals **(AEMO).** The regulation signals are to regulate the wind farm's output in the range of 10-20MW.
10. Monitor the wind farm's response.

8.1.4 Post-test analysis

Download and save the data from the Elspec meter data and SCADA record. Create a plot of the active power output of the wind farm.

Download the received AGC data from the SCADA system.

8.2. Regulation Up/Down - Test 2: (40 MW)

8.2.1 Test description

The objective of this test is to demonstrate the wind farm's ability to follow AEMO's AGC dispatch signals by showing response to local power setpoint changes. AEMO have indicated that end-to-end testing with test AGC data is not possible.

Local active power setpoint changes will be made using a local command in the wind farm SCADA system and the active power response on the windfarm monitored.

8.2.2 Prerequisites

- The wind farm must be operating at the power setpoint of 40MW.
- Wind resource must be sufficient for the wind farm to generate at the requested power set points or greater over the duration of the test.
- During testing, the wind farm's active power will be varied.
- The test should be coordinated with AEMO.

8.2.3 Methodology

Perform the following steps:

1. Confirm Possible power of additional 20MW via the possible power SCADA value.
2. Set the wind farm's active power control to local control.
3. Record current active power, frequency, and time.
4. Set the wind farm's active power setpoint to the current operating point to 60MW.
5. Wait for active power levels to stabilise (5 minutes).
6. Return the wind farm's active power setpoint to 40 MW.
7. Wait for active power levels to stabilise (5 minutes).
8. Set the wind farm's active power setpoint to the current operating point 20MW.
9. Wait for active power levels to stabilise (5 minutes).
11. Restore the wind farm's active power control to remote control, AGC enabled.
12. Request AEMO send 20 minutes of AGC regulation signals **(AEMO).** The regulation signals are to regulate the wind farm's output in the range of 20-60MW.
13. Monitor the wind farm's response.

8.2.4 Post-test analysis

Download and save the data from the Elspec meter data and SCADA record. Create a plot of the active power output of the wind farm.

Download the received AGC data from the SCADA system.

8.3. Regulation Up/Down - Test 3: (80 MW)

8.3.1 Test description

The objective of this test is to demonstrate the wind farm's ability to follow AEMO's AGC dispatch signals by showing response to local power setpoint changes and AGC signals.

Local active power setpoint changes will be made using a local command in the wind farm SCADA system and the active power response on the windfarm monitored. Following this live AGC signals will be received.

8.3.2 Prerequisites

- The wind farm must be operating at the power setpoint of 80MW.

- Wind resource must be sufficient for the wind farm to generate at the requested power set points or greater over the duration of the test.
- During testing, the wind farm's active power will be varied.
- The test should be coordinated with AEMO.

8.3.3 Methodology

Perform the following steps:

1. Confirm Possible power of additional 20MW via the possible power SCADA value.
2. Set the wind farm's active power control to local control.
3. Record current active power, frequency, and time.
4. Set the wind farm's active power setpoint to the current operating point to 100MW.
5. Wait for active power levels to stabilise (5 minutes).
6. Return the wind farm's active power setpoint to 80 MW.
7. Wait for active power levels to stabilise (5 minutes).
8. Set the wind farm's active power setpoint to the current operating point 60MW.
9. Wait for active power levels to stabilise (5 minutes).
14. Restore the wind farm's active power control to remote control, AGC enabled.
15. Request AEMO send 20 minutes of AGC regulation signals **(AEMO).** The regulation signals are to regulate the wind farm's output in the range of 60-100MW.
16. Monitor the wind farm's response.

8.3.4 Post-test analysis

Download and save the data from the Elspec meter data and SCADA record. Create a plot of the active power output of the wind farm.

Download the received AGC data from the SCADA system.

9. FCAS Market Trial

9.1. Overview

Following completion of this test program, Hornsdale 2 Wind Farm will participate in a 48 hour market trial within the Production environment of the registered FCAS. Notional dates for the trial can be found in Hornsdale 2 FCAS project's over-arching scheduling documentation.

During the Market Trial period Hornsdale 2 may be enabled for regulation and contingency service provision. The trial seeks to demonstrate end-to-end delivery of market services from Hornsdale 2 Wind Farm, including the receipt and processing of FCAS enablement targets, subsequent remote enablement of frequency controllers and delivery of an actual active power response consistent with enabled FCAS.

9.2. Market Trial Plan

Prior to commencement of the Market Trial, the parties (i.e. AEMO and Hornsdale 2 Wind Farm) will agree upon a Market Trial Plan. The Market Trial Plan will specify:

- A Communications protocol and nominated contact points for the Market Trial period, including basic emergency protocols;
- Which services will be offered as a part of the Market Trial (i.e. subject to the outcome of Hornsdale 2 Wind Farm's FCAS registration);
- The minimum duration of enablement of offered services required to demonstrate capability; and
- Any additional protocols or procedures that may be required to ensure bidding and enablement can take place.

10. File Naming Convention

This section explains the convention for naming meter data files after they have been exported using the meter interface software.

10.1. File naming convention

The file naming is based on 'keywords' connected by underscores ("_"). The following convention should be used in naming meter data files:

HD2WF_%TEST%_%MW%__%START%_%AVG%_%DESC%.csv

The first keyword BSF refers to Hornsdale 2 Wind Farm. The keywords with % signs are variable and should be changed to suit the file as described in the following lines. Spacing and case should be followed exactly as illustrated. The file extension should be .csv indicating a comma delimited text file.

%TEST% refers to the test being undertaken as per Table 4.

Table 4: File name %TEST% values

Meter	%TEST% value
Step Injection	STEP
Standard Frequency Ramp	STDRAMP
Extreme Event Ramp	EXRAMP
Actual Event Injection	EVENT
Regulation Up/ Down Tests	REGTEST
Other	OTHER

%START% refers to the start date and time of the measurements, in the format **yyyymmdd.hhmmss**, but this may be shortened as follows.

For exports longer than one minute and less than one day, %START% can be shortened to **yyyymmdd.hhmm**.

For exports shorter than one minute, the full format should be used.

In cases where shorter formats could result in files with the same name, the next higher precision format should be used.

%MW% indicates the active power setpoint at the start of the test

%AVG% refers to the averaging time of the data. It should consist of a number followed by a unit, e.g. 2hr, 10min, 3sec, etc. Valid units are: day, hr, min, sec, cycle.

%DESC% is a keyword describing the data, e.g. the channels that it contains. Individual testing instructions may contain guidance on what value to use for %DESC%. If no %DESC% value is given, the person collecting the data should use a suitable keyword while striving for consistency between data sets.

11. References

[1] Schedule 1– Indicative Draft Test Plan, supplied by Siemens Wind Power 12 July 2017.

[2] Lloyd's Register, PSS/E Study Plan & Input Data Requirements Revision 1, 20 July 2017.

[3] Siemens, Hornsdale II Contract Power Curve Rev. 0, supplied from Daniel Gallagher (Siemens) by email on 27 July 2017.

[4] AEMO, Turbine Governor Testing and Model Validation Guideline, May 2015.

[5] AEMO, Market Ancillary Services Specification (MASS) v5.0, 30 July 2017.

[6] AEMO, "contingency FCAS frequency trajectories.xls", supplied from Ian Devaney (AEMO) to Daniel Gallagher (Siemens) by email on 25 July 2017.

[7] AEMO, External_MASS_4_0_FCAS_Verification_Tool_v2_08.xlsx v2.08, 26 May 2014.