Primary Frequency Response Test Guidelines for Semi-Scheduled Plant

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Current version release details

Version	Effective date	Summary of changes
NA	NA	Draft issues for consultation on 02 July 2025

1. Introduction

1.1. Purpose and scope

These Primary Frequency Response Test Guidelines for Semi-Scheduled Plant (**Guidelines**) are made by AEMO under clause 4.4.2A(b)(4) of the National Electricity Rules (**NER**), and have effect only for the purposes set out in the Rules. These Guidelines supplement and should be read in conjunction with the Primary Frequency Response Requirements (**PFRR**). The PFRR, the Rules and the National Electricity Law prevail over these Guidelines to the extent of any inconsistency.

AEMO has prepared this document to provide general guidance about Primary Frequency Response (**PFR**) testing of semi-scheduled generating systems, which must be conducted by the generating systems.

The objective of these tests is to validate the active power control logic for these plants. In particular, the tests focus on the plant's ability to simultaneously manage and coordinate PFR, alongside active power control via the central dispatch process.

1.2. Definitions and interpretation

1.2.1. Glossary

Terms defined in the NER have the same meanings in these procedures unless otherwise specified. These terms are intended to be identified in this document by italicising them, but failure to italicise a defined term does not affect its meaning. In addition, the words, phrases and abbreviations in the table(s) below have the meanings set out opposite them when used in this document.

Table 1 Abbreviations

Term	Definitions
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
GPS	Generator Performance Standard
HSM	High speed monitoring
Hz	Hertz
kV	Kilovolt(s)
MW	Megawatt(s)
NEM	National Electricity Market
NER	National Electricity Rules. NER followed by a number indicates the corresponding rule or clause of the NER.
NOFB	Normal Operating Frequency Band
PFR	Primary Frequency Response
PFRP	Primary Frequency Response Parameters
PFRR	Primary Frequency Response Requirements
TNSP	Transmission Network Service Provider

Term	Definitions
DI	Dispatch interval

Table 2 Defined terms

Term	Definition
Droop	As defined in NER S5.2.5.11(a).
Generating System	As defined in NER S5.2.5.11(a).
Maximum Operating Level	As defined in NER S5.2.5.11(a).
Minimum Operating Level	As defined in NER S5.2.5.11(a).
PFR Deadband	The range of Local Frequency through which a frequency response will not be provided.
Semi-Scheduled Plant	Meets dispatch level in all dispatch intervals, subject to the availability of their natural resource.

1.3. Related AEMO policies and procedures

Table 3 Related policies, procedures, instructions, and forms

Title	Location
Primary Frequency Response Requirements	https://aemo.com.au/en/initiatives/major-programs/nem-reform-program/nem-reform-program-initiatives/primary-frequency-response

2. Test conditions and summary

When a generating system implements PFR for the first time, it must assess its performance against PFR Requirements. For a newly connected generator, PFR testing should be conducted in conjunction with the Hold Point testing. For an existing operational plant, these tests must be planned and scheduled independently in consultation with AEMO at the time of the implementation of the PFR.

To effectively validate that a semi-scheduled generating system is capable of delivering PFR without undesired interactions with other active power control actions occurring simultaneously, different types of PFR tests are conducted under different operating conditions. Table 4 in Section 2.2 lists the test types and the operating condition of the generating system.

For information regarding the test requirements associated with modifications to the control system settings of the generation system, please refer to section 7 of the PFRR.

2.1. Test conditions

Variations in the input source, such as irradiance or wind speed during curtailment tests, must not impact active power output. To ensure this, sufficient active power headroom must be maintained throughout testing. Additionally, flexibility in the level of active power curtailment should be allowed, depending on available wind speed or irradiance at the time.

The exact curtailment level is not critical, as the control logic being tested is largely independent of the output level, provided active power limits are not exceeded.

Testing should occur during periods of stable, relatively high wind speed or irradiance. In periods of more variable conditions, greater curtailment may be necessary to maintain unaffected active power output, or the test postponed to a more suitable time.

Unless otherwise stated in the mentioned test, if bidding and dispatch systems are commissioned and operational, curtailment should be managed through re-bidding and semi-scheduling from AEMO's central dispatch, rather than manually adjusting of active power control setpoints at site.

2.2. Testing overview

Table 4 Test requirements summary

Test	Artificial frequency input – steps/ramps	System frequency input	Active power output curtailed via semi-scheduling	Active power output curtailed via local limit	Change semi-scheduled setpoint Up and Down
3.1Confirm basic PFR parameters (droop, deadband)	Yes		Yes		
3.2Simultaneous Frequency Response and Setpoint Adjustments	Yes		Yes		Yes
3.3Frequency Response and Setpoint Adjustments with Real System Frequency at Curtailed Output		Yes	Yes		Yes
3.4Assessment of Differences in Managing Semi-Scheduled Setpoints and Local Limit active power	Yes			Yes	

2.3. Test results

To assess PFR performance, test data needs to be analysed to demonstrate the criteria and the objectives are satisfied and met. All necessary control signals and electrical quantities need to be recorded for all tests. Table 5 lists the minimum test signal data needed for a proper PFR assessment relevant to the tests.

Table 5 Test data recording and submission requirements

Test data required for each test (where applicable)
Active Power
Artificial Freqency Input
System Frequency
Local Limit
Semi-dispatch Target

Test data required for each test (where applicable)
Semi-scheduled Cap Flag
Available Power

All tests conducted must be compiled into a report that includes charts summarising the performance of each test. Each test result will also have the corresponding raw high speed monitoring (**HSM**) data and any artificial signals used for the specific tests.

3. Detailed testing procedures

3.1. Confirm basic PFR parameters

The purpose of this is to confirm the implemented droop and deadband settings. Many aspects of this test overlap with the hold point commissioning tests. If the following test requirements and the specified test criteria were fulfilled during commissioning, and the results are available with no changes to the settings since then, there is no need to repeat this test.

3.1.1. Plant operating point

Curtail active power output to a fixed, stable level below the available wind or irradiance using Semi-Scheduling cap and target. Ensure sufficient active power headroom or footroom, accounting for expected changes in active power output and available wind speed or irradiance.

3.1.2. Upper deadband exceedance check

Introduce an artificial frequency increment, maintaining and subsequently releasing it, at a level exceeding 50 hertz (**Hz**), for a duration of 60 seconds. It is advisable to implement a frequency variation within the range of +0.15 Hz to +0.25 Hz in discrete steps. The magnitude of each step should be determined in accordance with the upper frequency deadband configurations for the PFR, ensuring that the system effectively responds to frequency disturbances for both inside and outside the designated deadband.

Assessment criteria:

- Delta active power at connection point for over-frequency is consistent with the rated maximum operating level, droop, deadband settings as established in the agreed settings for PFRP of the generating system, and the size of the frequency change.
- For frequency step less than the agreed deadband there should not be any active power change.
- The active power response to frequency is consistent, when the frequency moves from inside to outside the deadband.
- Ensure the active power returns to pre-step test level and remains there for at least 60 seconds before proceeding to next test.

3.1.3. Lower deadband exceedance check

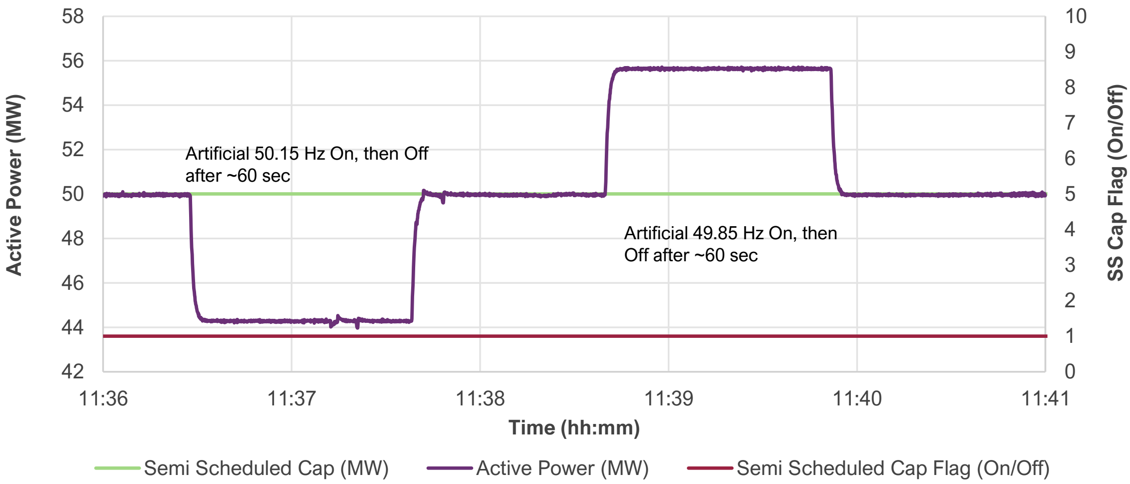
Introduce an artificial frequency decrement, maintaining and subsequently releasing it, at a level below 50 Hz, for a duration of 60 seconds. It is advisable to implement a frequency variation within the range of -0.15 Hz to -0.25 Hz in discrete steps. The magnitude of each step should be determined in accordance with the lower frequency deadband configurations for the PFR, ensuring that the system effectively responds to frequency disturbances for both inside and outside the designated deadband.

Assessment criteria:

- Delta active power at connection point for under-frequency is consistent with the rated maximum operating level, droop and deadband settings as established in the agreed settings for PFR Parameters (**PFRP**)of the generating system, and the size of the frequency change.
- For frequency step less than the agreed deadband there should not be any active power change.
- The Semi-Scheduled active power setpoint is exceeded during under-frequency events.
- The active power response to frequency is consistent, when the frequency moves from inside to outside the deadband.
- Ensure the active power returns to pre-step test level and remains there for at least 60 seconds before proceding to next test.

Figure 1 presents an example of expected response from the generating system for both lower and upper deadband exceedance checks.

Figure 1 Example test 3.1 – Confirming basic PFR parameters



3.2. Simultaneous Frequency Response and Setpoint Adjustments

The purpose of this test is to validate the plant's ability to coordinate primary frequency response to a simulated frequency disturbance, alongside active power control via the central dispatch process. This test involves curtailing the active power output to a stable, fixed value below the available wind or irradiance using Semi-Scheduling (initial value). This is required to ensure sufficient active power headroom or footroom, considering changes in the active power setpoint, expected active power response to frequency changes, and available wind speed or irradiance.

The test steps are outlined below.

3.2.1. Verification of Over-Frequency Response with Setpoint Adjustments

(a) Inject an artificial frequency step above 50 Hz, beyond the deadbands, and hold.

(b) While the frequency remains high, adjust the Semi-Scheduling active power setpoint both above and below the initial value. Changes in the active power setpoint should be achieved through re-bidding and AEMO's central dispatch process.

(c) Maintain each setpoint for a minimum of 10 minutes, with 5 minutes allowed for ramping between setpoints and 5 minutes for stable operation.

(d) Confirm operation above and below the initial curtailment value.

(e) Return active power to the starting value.

(f) Remove the frequency step, allowing the frequency to return from outside to inside the frequency deadband.

Assessment criteria:

- Active power can be controlled in both directions while the frequency remains above the deadband.
- Delta P due to frequency deviation, is consistent with the PFRP and is relative to the Semi-Scheduled setpoint.
- Transitions between active power setpoints occur through a controlled active power ramp, rather than a step change in output.

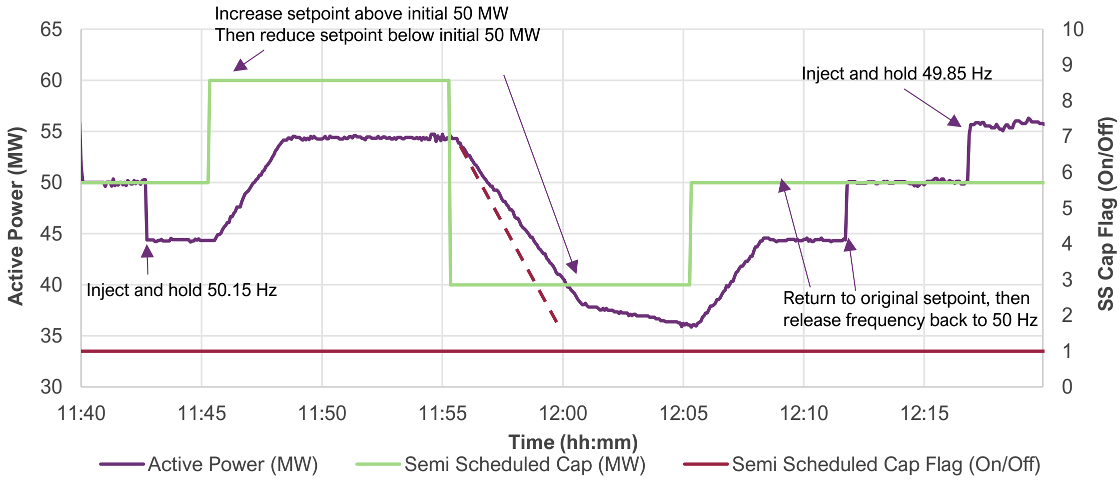
Note that actual active power ramp times may vary from the ideal 5 minute dispatch interval (**DI**) due to the impact of artificial frequency injection on initial active power values, and the calculation of ramp rates based on initial-to-target active power trajectories.

3.2.2. Verification of Under-Frequency Response with Setpoint Adjustments

This test is a repeat of the test in Section 3.2.1 above, with an artificial under-frequency step injection, beyond the deadband, applied at the start of the test. The assessment criteria are the equivalent of the above test, for under frequency conditions.

Figure 2 presents an example of a test response from the generating system for both under- and over-frequency response. For the DI between 11:55 and 12:00 the plant ramp is affected by the active power response to primary frequency response (PFR) at the beginning of the DI. The red dashed line illustrates the ideal response.

Figure 2 Example test Section 3.2.1 and Section 3.2.2 – Simultaneous frequency response and setpoint adjustment



3.2.3. Verification of Active Power Ramping with Artificial Frequency Injection

This test involves the injection and subsequent removal of artificial frequency changes during active power ramping between two setpoints. The goal is to confirm that the plant can ramp between active power targets while the frequency moves from inside to outside, and then back inside the frequency deadband.

The test steps are as follows:

(a) Inject an artificial frequency of 50.0 Hz.

(b) Curtail the active power output to a stable level below the available wind or irradiance using Semi-Scheduling.

(c) The plant's active power output should then be adjusted via Semi-Scheduling and AEMO's central dispatch process to shift at least twice between two different active power levels, creating a total of four active power ramp periods – two with increasing active power ramp and two with decreasing active power ramp.

(d) Each ramp period shall last a period of at least 5 minutes (one DI), followed by at least 5 minutes of stable operation at each active power level.

(e) During each of the four ramp periods, an artificial frequency change, greater than frequency deadband, shall be injected, held for 60 seconds, and then removed.

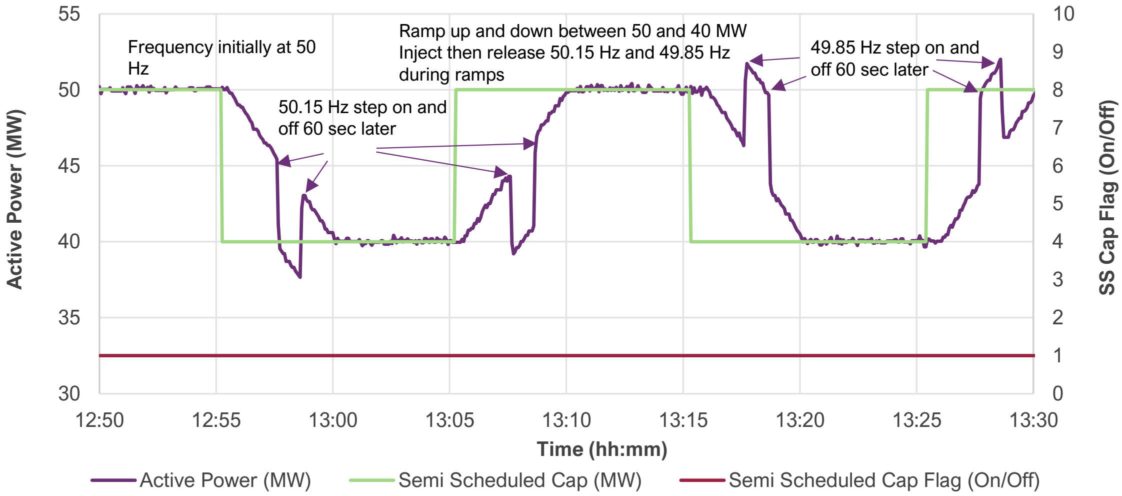
(f) All four combinations of upward/downward active power ramp and over/under frequency injection and removal must be tested.

Assessment criteria:

- The active power ramp continues while an artificial frequency change is injected.
- The instantaneous change in active power output during the artificial frequency change behaves as per agreed droop and deadband settings.
- Upon removal of the artificial frequency change, the active power ramp resumes its original trajectory.

Figure 3 presents an example of expected response from the generating system.

Figure 3 Example test 3.2.3 – Verifying active ramping and the PFR



3.3. Frequency Response and Setpoint Adjustments with Real System Frequency at Curtailed Output

3.3.1. Frequency Response and Setpoint Stability with Real System Frequency under Curtailed Output

The purpose of this test is to validate the plant's ability to simultaneously manage and coordinate primary frequency response to actual frequency disturbance, alongside active power control via the central dispatch process. During this test, real system frequency is applied into the plant controls. Frequency deadbands must be smaller than the normal range of system frequency variation. The aim is to demonstrate that active power adjusts correctly in response to frequency changes, aligning with the specified droop settings.

The test procedure and conditions are:

(a) Curtailing the active power output below the available wind or irradiance using Semi-Scheduling via the AEMO central dispatch process to ensure sufficient headroom.

(b) If necessary, initial curtailment can be achieved with an artificial 50.0 Hz frequency injection, followed by switching to the real system frequency once a stable active power output is reached.

(c) The plant must operate at a fixed, stable active power setpoint with real system frequency input for a minimum period of 1 hour.

Assessment criteria:

- Active power output moves continuously above and below curtailed active power value at connection point and is consistent with the rated maximum operating level, droop and deadband settings, and the size of the frequency change as per the agreed settings of the generating system defined in the PFRR .

- The plant returns to the fixed active power setpoint when real system frequency is within the PFR deadband.
- The active power output of the plant does not 'drift', or continuously move away from the fixed active power setpoint.
- There are no unexpected or undesirable active power discontinuities as frequency moves in and out of the frequency deadband.
- When the active power and the system frequency data from this test period are plotted, the results align with the expected behaviour based on the plant's droop and deadband settings.

Figure 4 presents an example of expected response from the generating system except around 14:15 hrs when irradiance sag occurred. Figure 5 shows the response against ideal response for the given PFRP.

Figure 4 Example test 3.3.1 – Fixed active power curtailment, real frequency

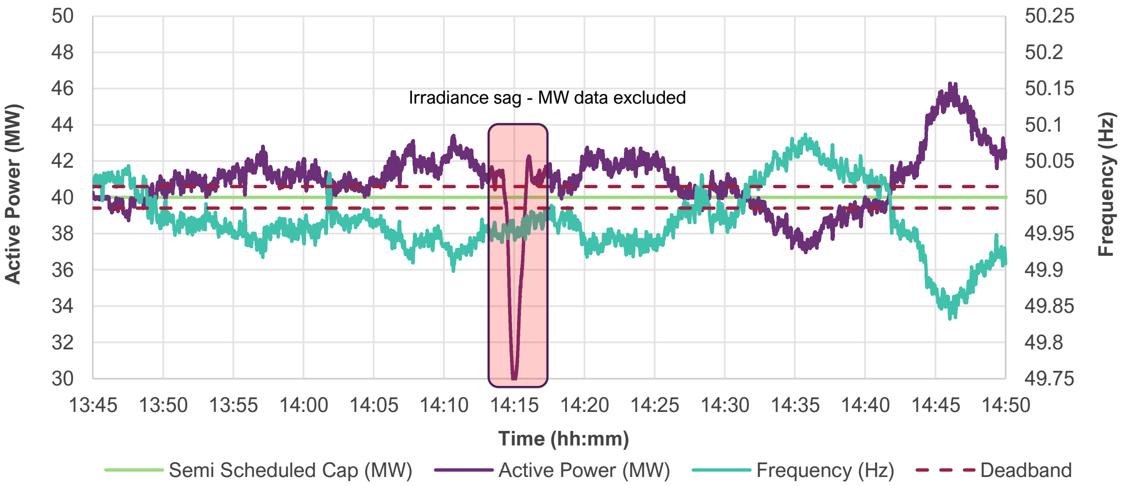
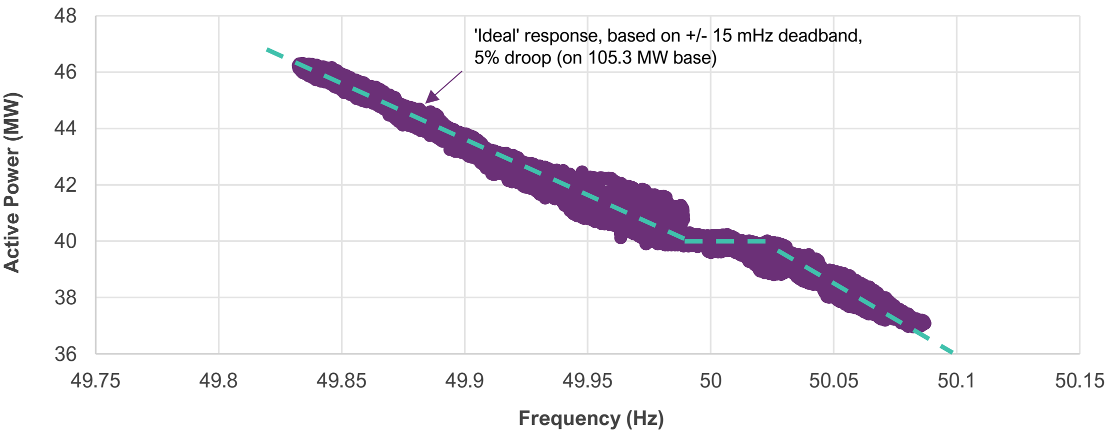


Figure 5 Example test 3.3.1 – Fixed active power curtailment, real frequency



3.3.2. Active power Control and Ramping with Real Frequency under Curtailed Output

The Semi-Scheduled active power setpoint is adjusted up and down from the initial curtailed active power value using the AEMO central dispatch process. Sufficient changes in active power setpoint shall be applied to create at least four ramping periods, both increasing and decreasing.

Test is conducted as follows:

(a) Apply the real system frequency into the controls.

(b) Adjust the semi-scheduled active power setpoint up and down from the initial curtailed active power value using the AEMO central dispatch process.

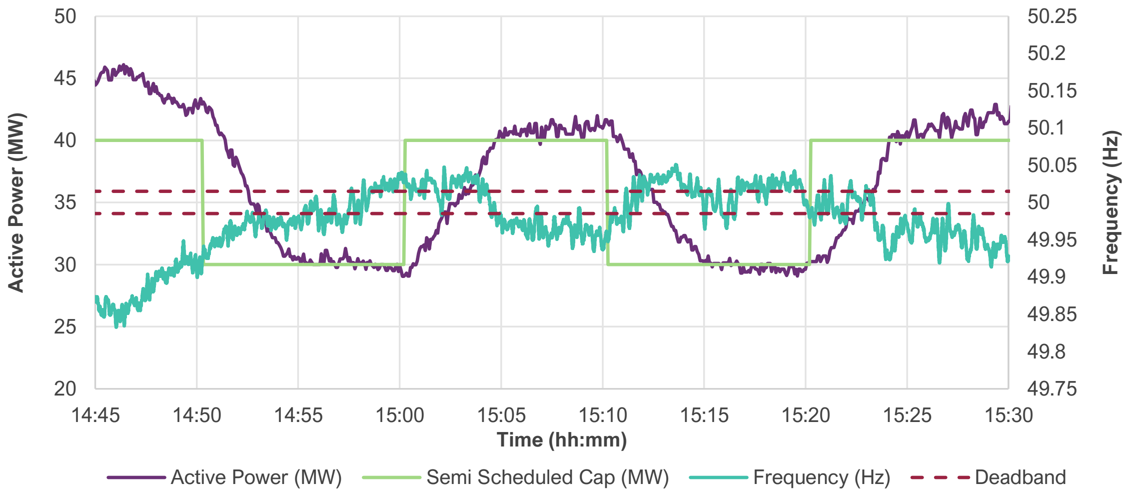
(c) Maintain each new active power setpoint for at least 10 minutes of stable operation.

Assessment criteria:

- Active power control is maintained in both directions, while also responding to real frequency changes in active power output between setpoint levels through smooth ramping, without steps or sudden changes in output. The active power deviation from a straight-line active power ramp is as expected, based on the actual grid frequency variation.
- No unexpected or undesirable active power discontinuities as frequency moves in and out of deadband.

Figure 6 presents an example of the test and expected response from the generating system.

Figure 6 Example test 3.3.2 – Varying curtailment, real frequency



3.3.3. Frequency Response and Setpoint Adjustments with Real Frequency and Multiple Transitions Between Curtailed and Uncurtailed Operation

No initial curtailment of output is applied, and the plant operates at its available wind or irradiance. Real system frequency is applied into the controls during the test. Frequency deadband must be smaller than the normal range of system frequency variation.

The test includes:

(a) The plant transitioning between uncurtailed and curtailed operation, with a Semi-Scheduled cap applied, with at least two transitions in each direction.

(b) A curtailment level of 50-60% of the available output, based on prevailing wind speed or irradiance, is recommended.

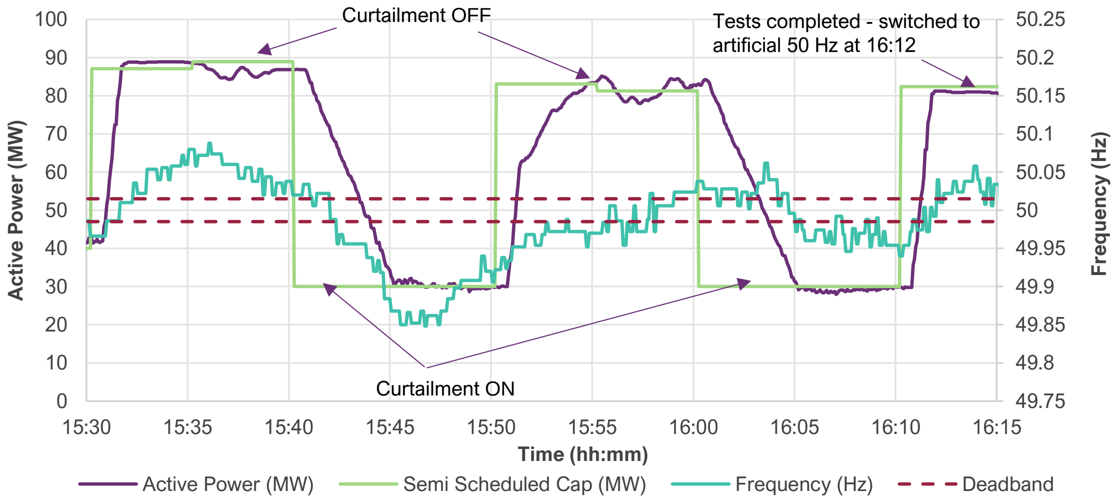
(c) This curtailment should be managed through plant re-bidding and the AEMO central dispatch process.

Assessment criteria:

- The plant is able to maintain and return to active power output near the maximum available level, based on wind speed or irradiance, when operating uncurtailed.
- No unexpected active power discontinuities occur as the frequency moves in and out of the deadband.
- Active power transitions between curtailed and uncurtailed operation occur smoothly, without sudden changes in plant output. During the curtailed operation, the plant's active power output varies as expected, in response to real system frequency conditions.

Figure 7 presents an example of the test and expected response from the generating system.

Figure 7 Example test 3.3.3 – Curtailment ON and OFF, with real frequency



3.4. Assessment of Differences in Managing Semi-Scheduled Setpoints and Local Limit active power

The purpose of this test is to validate the plant's ability to simultaneously manage and coordinate PFR, alongside active power local limit. For the test, curtail the active power output below the available wind or irradiance using a Local Limit, rather than through the AEMO central dispatch. Note that for some control implementations, the Local Limit active power may serve as rated operating level in this scenario.

3.4.1. Evaluation of MW Control under Local Limit versus Semi-Scheduled Setpoints

(a) Apply a Local Limit on active power (as opposed to a Semi-Scheduled limit from the central dispatch) by adjusting local control signals at the plant.

(b) Inject artificial frequency steps (or ramps) above and below 50 Hz, beyond the deadbands. The frequency step should be sufficiently large to generate a frequency response that exceeds the local limit under normal conditions, thereby demonstrating the hard limit.

Assessment criteria:

- The reduction in active power at the connection point during over-frequency is consistent with the minimum operating level, droop and deadband settings, as established in the agreed settings for PFRP of the generating system, and the size of the frequency rise.
- Response time and damping are adequate.
- Confirm whether local Limit active power setpoint is exceeded or maintained during under-frequency. Generally, it is expected that the Local Limit active power will not be exceeded (that is, it acts as a 'hard' limit on site output), but the importance of this test depends on how Local Limits are used at each site.

The consequences of exceeding the Local Limit active power when set may vary based on site-specific and local network conditions.