# Wind Farm and Solar Farm Guide to Contingency FCAS Registration

| | |
|---|---|
| **Prepared by:** | AEMO Operations Department – Systems Performance |
| **Version:** | 3.0 |
| **Effective date:** | 24 March 2023 |
| **Status:** | FINAL |

## Approved for distribution and use by:

| | |
|---|---|
| **Approved by:** | James Lindley |
| **Title:** | Group Manager Systems Capability - Operations |
| **Date:** | 24/3/2023 |

aemo.com.au

New South Wales | Queensland | South Australia | Victoria | Australian Capital Territory | Tasmania | Western Australia

Australian Energy Market Operator Ltd ABN 94 072 010 327

# Important notice

## Purpose

AEMO has prepared this document to provide general guidance about requirements for wind farms and solar farms to participate in the ancillary service markets for contingency raise and lower services, as at the date of publication.

## Disclaimer

This document or the information in it may be subsequently updated or amended. This document does not constitute legal or business advice, and should not be relied on as a substitute for obtaining detailed advice about the National Electricity Law, the National Electricity Rules, or any other applicable laws, procedures or policies. AEMO has made reasonable efforts to ensure the quality of the information in this document but cannot guarantee its accuracy or completeness.

Accordingly, to the maximum extent permitted by law, AEMO and its officers, employees and consultants involved in the preparation of this document:

- make no representation or warranty, express or implied, as to the currency, accuracy, reliability or completeness of the information in this document; and
- are not liable (whether by reason of negligence or otherwise) for any statements or representations in this document, or any omissions from it, or for any use or reliance on the information in it.

## Copyright

# Contents



# Tables



# Figures



# Current version release details

| Version | Effective date | Summary of changes |
|---|---|---|
| 3.0 | 24 March 2023 | Inclusion of detailed testing parameters<br>Update to determination and application of forecast error margin |

**Note: There is a full version history at the end of this document.**

# 1. Introduction and purpose

The purpose of this document is to assist market participants in registering a wind farm or a solar farm in the contingency FCAS markets.

All facilities wishing to register for Contingency Frequency Control Ancillary Services (FCAS) must undertake testing to demonstrate their FCAS capabilities. The requirements for the FCAS assessment completed during the registration process are described in this guide. The basic set of tests use frequency injection tests, or where this is not feasible, the settings of the FCAS controller are revised temporarily to observe the active power response of the FCAS facility to local frequency.

Due to their unique characteristics, a forecast error margin is incorporated to the FCAS trapeziums of a wind farm and a solar farm. The error margin is required to cover the forecast uncertainty from the intermittent generator over the next five minutes, which could result in inadequate headroom or footroom being reserved to deliver the raise or lower services. The calculation and application of the forecast error margin have been described in this document to clarify how the parameters of the FCAS trapeziums are determined.

# 2. Contingency FCAS registration requirements for wind farms and solar farms

An operator seeking to provide contingency FCAS will be required to account for the requirements below, noting that:

- For FCAS facilities with a maximum enablement level greater than 0 MW, which are typically semi-scheduled:
  - Requirements are under clauses 2(a) to 2(f), 2(h), 2(k) and 2(l).
- For FCAS facilities with a maximum enablement level of 0 MW, which are typically non-scheduled:
  - Requirements are under clauses 2(a) to 2(e), 2(g) to 2(k), and 2(m).

The requirements are as follows:

(a) Using a sufficiently accurate model (PSCAD, PSSE, Simulink, or other approved by AEMO), simulate a frequency disturbance and provide data demonstrating the active power response. The simulation test results must have been accepted by AEMO in writing before the on-site testing required under 2(c) is conducted. The desktop simulation requirements are described under clause 2((d).

(b) In addition to 2(a), if registering in the Very Fast, Fast, or both FCAS markets, demonstrate via a desktop simulation the active power response to a frequency disturbance coinciding with a voltage disturbance causing the voltage to dip down to 0.2 pu for 120ms at the connection point.

(c) Demonstrate the active power response to frequency during the on-site testing. The data captured from the site will be used to finalise the registered maximum ancillary service capacity of the FCAS facility.

(d) The metering facilities must comply with the MASS requirements specified under Table 4 of the MASS[1].

(e) The following testing parameters are to be used in all tests.

- Frequency must be held at 50 Hz (+/- 0.01 Hz) for 20 seconds before the frequency ramp.
- After 20 seconds, frequency is to be ramped to the reference frequency shown in Table 1 at the specified ramp rate for each ancillary service. Other considerations are:
  - If the participant is registering for multiple FCAS, the fastest ramp rate out of the relevant FCAS may be used in these tests. For example, a facility wishing to register for Very Fast and Fast FCAS would use 1 Hz/s in the testing. A facility wishing to register for Fast and Slow FCAS would use 0.125 Hz/s (or 0.4 Hz/s in Tasmania).
  - If necessary, progressive step changes in frequency may be used to approximate the relevant frequency ramp.

**Table 1 Applicable Reference Frequency and Ramp Rate**

| FCAS | Mainland | | Tasmania | |
|---|---|---|---|---|
| | Reference frequency (Hz) | Ramp rate (Hz/s) | Reference frequency (Hz) | Ramp rate (Hz/s) |
| **Very Fast Raise** | 49.5 | 1 | 48 | 1 |
| **Fast Raise, Slow Raise, Delayed Raise** | 49.5 | 0.125 | 48 | 0.4 |
| **Very Fast Lower** | 50.5 | 1 | 52 | 1 |
| **Fast Lower, Slow Lower, Delayed Lower** | 50.5 | 0.125 | 52 | 0.4 |

- For Very Fast or Fast FCAS, provide at least 5 seconds of high speed data recording, as defined by the MASS, before disturbance and at least 60 seconds after disturbance.
- For all contingency FCAS, provide at least 20 seconds of appropriate data recording (at least 4s resolution as defined by the MASS) before disturbance and at least 10 minutes after disturbance.
- Measurements of power and frequency must be captured on a common time scale.
- High speed data and low speed data must be provided in clearly labelled spreadsheet tabs or files

(f) For FCAS facilities with a maximum enablement level greater than 0 MW, the following initial active power setpoints referred to as starting points must be consistent in both

[1] The measurement requirements are specified under Table 4 of MASS Version 7. A new version of the MASS will be effective from 9 October 2023 and the measurement requirements are specified under Table 5.

simulation and on-site testing to confirm the parameters of the FCAS trapezium as shown in Figure 1 of the FCAS Model in NEMDE document[2]:

- 3 starting points for both the raise and lower FCAS tests,
  - Proposed low breakpoint
  - Proposed high breakpoint
  - Middle point between proposed low and high breakpoints

(g) For FCAS facilities with a maximum enablement level of 0 MW, the following starting points must be used in on-site testing to confirm the parameters of the FCAS trapezium as shown in Figure 2 of the FCAS Model in NEMDE document:

- 1 starting point for both the raise and lower FCAS tests,
  - Minimum operating level for frequency control (Raise)
  - Maximum operating level for frequency control (Lower)

(h) If a frequency injection test cannot be completed on-site for technical reasons, as an alternative testing arrangement, the deadband or Frequency Deviation Setting may be narrowed to a value agreed with AEMO in order to demonstrate the FCAS response of the facility based on actual local frequency measurements. The FCAS facility must be curtailed to approximately 50% of its maximum possible power for one hour to demonstrate the frequency response of the controller.

The measurements of power and frequency must be captured at the same time resolution specified under Table 4 of the MASS.

(i) For an Aggregated FCAS Facility, the participant must:

- Complete the tests under clause 2(e) for each facility with a nameplate capacity greater than or equal to 1 MW. If the facilities being aggregated have a nameplate capacity of less than 1 MW each and have an identical configuration, e.g same inverter manufacturer, then the tests under clause 2(e) need only be done on one of the facilities.
- Complete a site-wide test as per clause 2(h) to demonstrate the aggregated FCAS response, and
- Capture measurements of power from the FCAS facility, and at the connection point if there are other behind-the-meter assets.

(j) If providing FCAS from within an embedded network, measurements of power are required from both:

- The child connection point with the FCAS facility, to verify the FCAS delivery, and
- The parent connection point, to demonstrate there is no direct interaction between other elements in the embedded network and the FCAS Facility.

(k) Demonstrate evidence of a forecasting system to ensure that the facility will meet its FCAS requirements while managing its intermittency and provide data required by AEMO

[2] https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/dispatch/policy_and_process/fcas-model-in-nemde.pdf?la=en

to calculate the forecast error margin. A forecast error margin is required to cover forecast uncertainty over the next 5 minutes. The calculation of forecast error margin is described in Section 3.

- This forecasting system may be one of AEMO's forecasting systems if available, but can also be independent of AEMO.
- The forecast error margin will default to 10% of the registered capacity of a wind farm and 30% of the registered capacity of a solar farm if forecast data is not yet available.
- If the FCAS Facility comprises of an aggregation of smaller generating units, the forecast error margin may be reduced subject to AEMO's review and at AEMO's discretion.
- The baseline factor of 10% for a wind farm and 30% for a solar farm can be reviewed after six months based on actual forecast performance. The effect of the forecast error margin is explained in Appendix A.

(l) For an FCAS facility with a maximum enablement level greater than 0 MW:

- The forecast error margin will be reflected in the FCAS trapeziums as follows:
  - For the raise services by narrowing the registered maximum lower angle, and narrowing the registered maximum upper angle which is referred to as Option A as shown in Figure 3.
  - For the lower services by narrowing the registered maximum lower angle as shown in Figure 4.
- The maximum upper angle for raise services may be set to 45° when a provider demonstrates to AEMO's satisfaction that headroom can be maintained through trading intervals by continuously adjusting the quantity of curtailed energy below the facility's maximum possible power. This can be demonstrated during the FCAS registration process where evidence of continuous energy curtailment equal to the proposed maximum market ancillary service capacity can be provided. This is referred to as Option B as shown in Figure 3.

(m) For an FCAS facility with a maximum enablement level equal to 0 MW, the forecast error margin will be reflected in the raise and lower FCAS trapeziums by decreasing the registered maximum market ancillary service capacity as shown in Figure 5 and Figure 6.

# 3. Calculation of forecast error margin

As noted under Section 2, where the forecast data is not yet available, AEMO will apply a forecast error margin of 10% for wind farms and 30% for solar farms. Once forecast data is available for a continuous period of six months, a participant can request AEMO to calculate the forecast error margins relative to the maximum possible power as shown below.

The calculation of positive forecast error margin for a DUID is provided below.

$$Positive\ forecast\ error\ margin\ = \frac{3 \times stdev\left(Initial\ MW_{d,t+1} - Forecast\ Availability_{d,t}\ \forall\ t_{UIGF}\right)}{Registered\ Capacity_{d}}$$

where:

- **d** is DUID
- **t** are the trading intervals in the 6 month period where unit *UIGF* is in range $U_1 – U_2$, excluding intervals with a semi-dispatch cap or forecast availability equal to zero.
- $Initial\ MW_{d,t+1} - Forecast\ Availability_{d,t} > 0$, implying there was an under-forecast of actual energy relative to the forecast energy target.

The calculation of negative forecast error margin for a DUID is provided below.

$$Negative forecast\ error\ margin = \frac{3 \times stdev\left(Initial\ MW_{d,t+1} - Forecast\ Availability_{d,t}\ \forall\ t_{UIGF}\right)}{Registered\ Capacity_d}$$

where:

- **d** is DUID
- **t** are the trading intervals in the 6 month period where unit *UIGF* is in range $U_1 – U_2$, excluding intervals with a semi-dispatch cap or forecast availability equal to zero.
- $Initial\ MW_{d,t+1} - Forecast\ Availability_{d,t} < 0$, implying there was an over-forecast of actual energy relative to the forecast energy target.

# 4. Application of forecast error margin to FCAS trapeziums

***The following is relevant for FCAS facilities with a maximum enablement level greater than 0 MW.***

The forecast error margin is used to define the firm FCAS capacity of the facility, using the following equations:

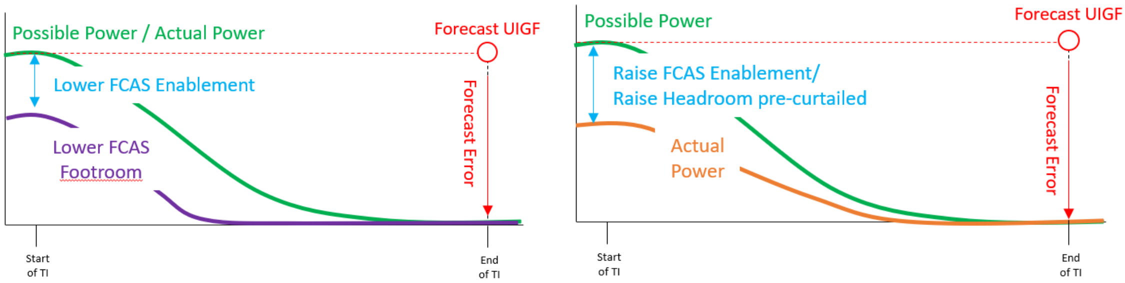
$$Firm\ FCAS\ Capacity_{over-forecast} = UIGF - Negative\ Forecast\ Error\ Margin$$

$$Firm\ FCAS\ Capacity_{under-forecast} = Nameplate\ Capacity - UIGF - Positive\ Forecast\ Error\ Margin$$

In this document, *over-forecast* is defined as actual output being below forecast energy target and *under-forecast* is defined as actual output being above forecast energy target at any given time in a trading interval.

*Over-forecast* can reduce the ability to supply Lower and Raise FCAS as demonstrated in Figure 1. The forecast error error margin decreases the FCAS capacity that can be provided when possible power decreases during a trading interval.

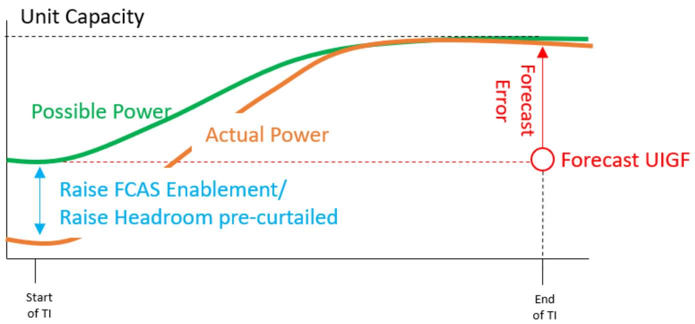
**Figure 1 Impact of over-forecast on Lower FCAS and Raise FCAS availability**



*Under-forecast* can reduce the ability to supply Raise FCAS as demonstrated in Figure 2. The forecast error error margin decreases the FCAS capacity that can be provided when possible power increases during a trading interval, and the actual power is not sufficiently curtailed to maintain the Raise headroom required.

As noted under clause 2((l), if a participant can demonstrate that the Raise FCAS headroom is maintained by curtailing the actual power throughout a trading interval where the possible power increases, a maximum upper angle of 45° may be applied for the Raise FCAS trapeziums.

**Figure 2 Impact of under-forecast on Raise FCAS availability**




The firm FCAS capacity determines the implied lower angle and upper angle of the relevant FCAS trapezium. Subsequently, the narrowest implied lower angle due to the over-forecast, is considered as the maximum lower angle, and narrowest implied upper angle due to the under-forecast, is considered as the maximum upper angle of the FCAS trapezium. Where applicable, angles are rounded down to the nearest integer.

The calculation of implied lower angle is given by the following formula:

$$\tan x = \frac{Firm\ FCAS\ Capacity}{UIGF} = \frac{60\text{MW}}{150\text{MW}}$$

$$x = 21.8° \sim 21°$$

The calculation of implied upper angle is given by the following formula:

$$\tan x = \frac{Firm\ FCAS\ Capacity}{Nameplate\ Capacity - \ UIGF} = \frac{5\text{MW}}{150\text{MW} - 140\text{MW}}$$

$$x = 26.56° \sim 26°$$

These calculations produce the results as shown in Table 2 and Table 3 for a 150 MW facility.

**Table 2 Implied Lower Angle for Negative Forecast Error Margin**

| UIGF | Negative FEM | Firm FCAS Capacity (over-forecast) | Implied Lower Angle |
|---|---|---|---|
| **0** | 0 | 0 | NA |
| **10** | 5 | 5 | 26 |
| **20** | 10 | 10 | 26 |
| **…** | … | … | |
| **140** | 80 | 60 | 23 |

| UIGF | Negative FEM | Firm FCAS Capacity (over-forecast) | Implied Lower Angle |
|---|---|---|---|
| **150** | 90 | 60 | 21 |
| | | Narrowest Lower Angle | 21 |

### Table 3 Implied Upper Angle for Positive Forecast Error Margin

| UIGF | Positive FEM | Firm FCAS Capacity (under-forecast) | Implied Upper Angle |
|---|---|---|---|
| **0** | 70 | 80 | 28 |
| **10** | 65 | 75 | 28 |
| **20** | 55 | 75 | 29 |
| **…** | … | … | |
| **140** | 5 | 5 | 26 |
| **150** | 0 | 0 | NA |
| | | Narrowest Upper Angle | 26 |

These calculations are represented in Figure 3 and Figure 4 below, where Firm FCAS Capacity for each UIGF is represented by dark blue dots. As shown below, the Firm FCAS Capacity values over the maximum registered FCAS capacity are ignored, which may result in a wider lower and upper angle. Accordingly, in the example considered below, only the Firm FCAS Capacity values at or below 10 MW and corresponding UIGFs were considered for the calculation of the negative and positive forecast error margins.

### Figure 3 Raise FCAS trapezium

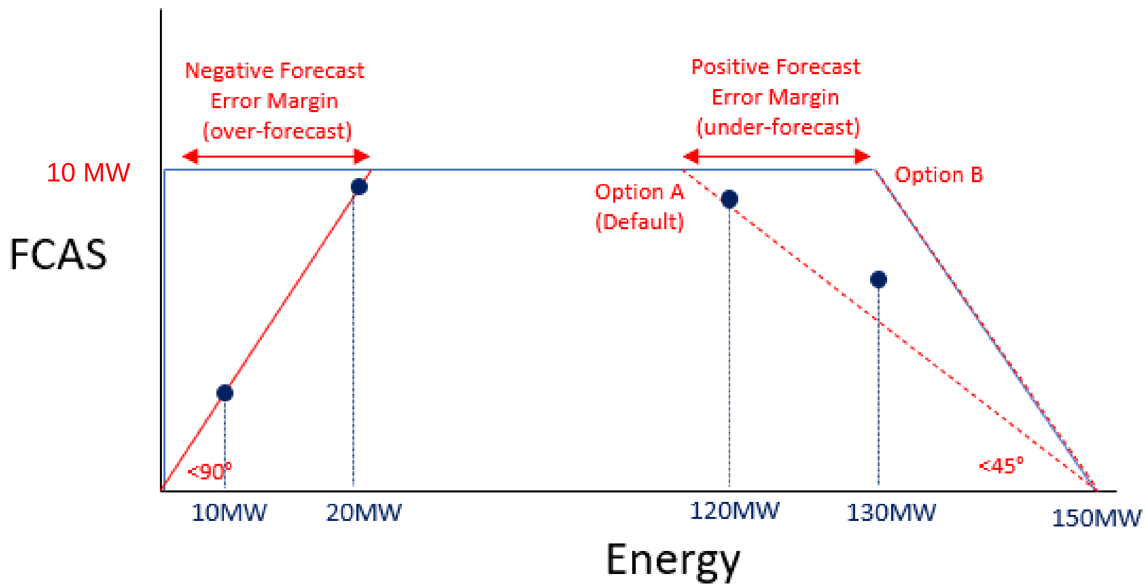
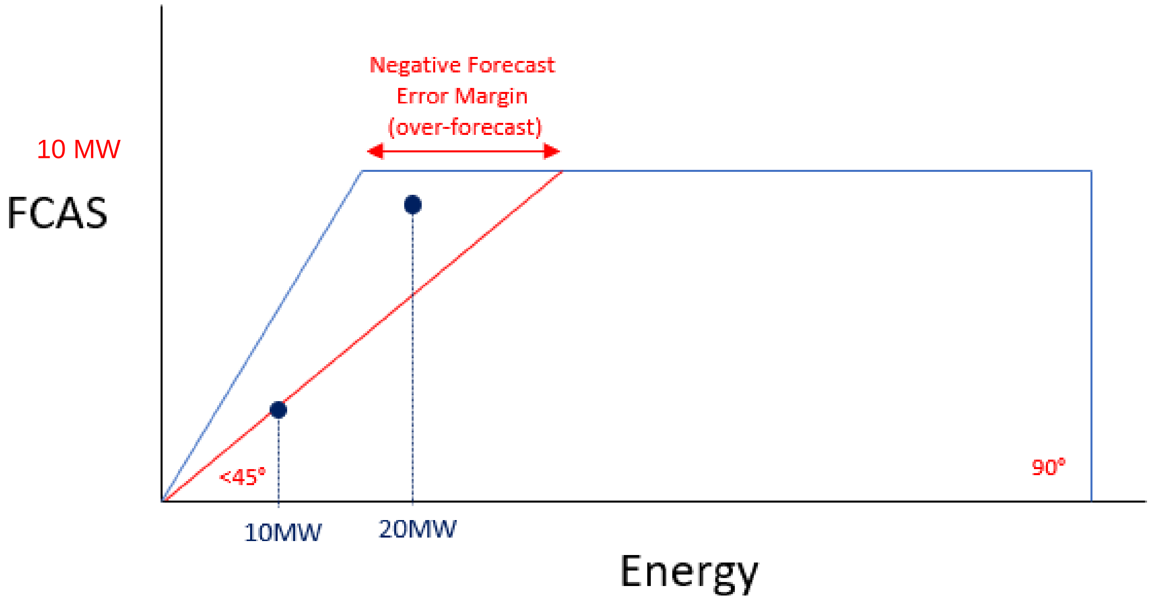


Figure 4 Lower FCAS trapezium




***The following is relevant for FCAS facilities with a maximum enablement level of 0 MW.***

The forecast error margin is used to define the firm FCAS capacity of the facility, using the following equations:

$$Firm\ FCAS\ Capacity_{over-forecast} = Unit\ Capacity - \ Negative\ Forecast\ Error\ Margin$$

$$Firm\ FCAS\ Capacity_{under-forecast} = Unit\ Capacity - \ Positive\ Forecast\ Error\ Margin$$

The firm FCAS capacity determines the maximum market ancillary service capacity of the relevant FCAS trapezium. Where applicable, capacity is rounded down to the nearest integer

Figure 5 Raise FCAS trapezium

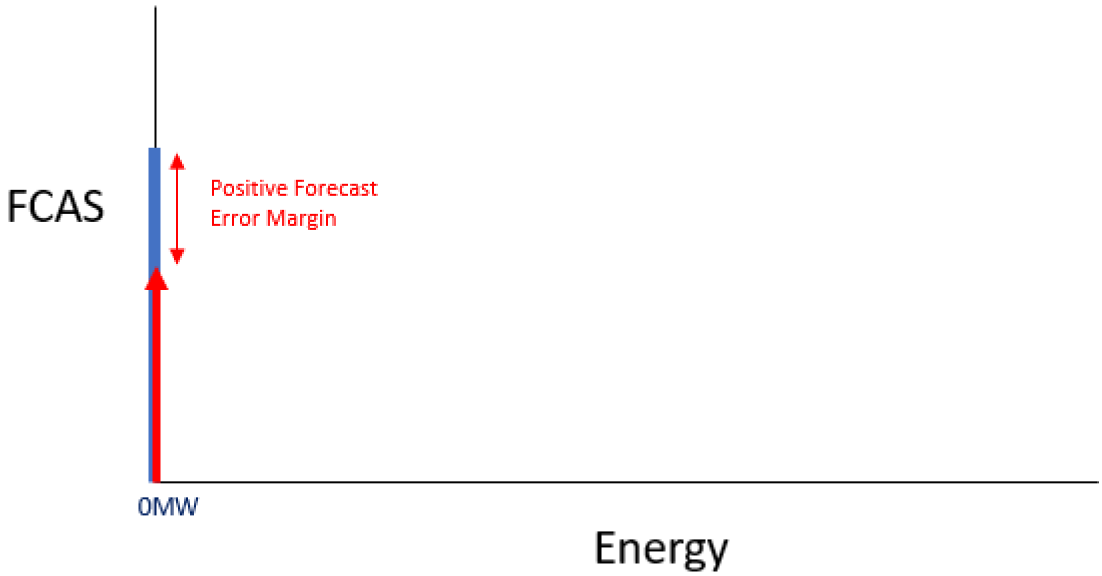
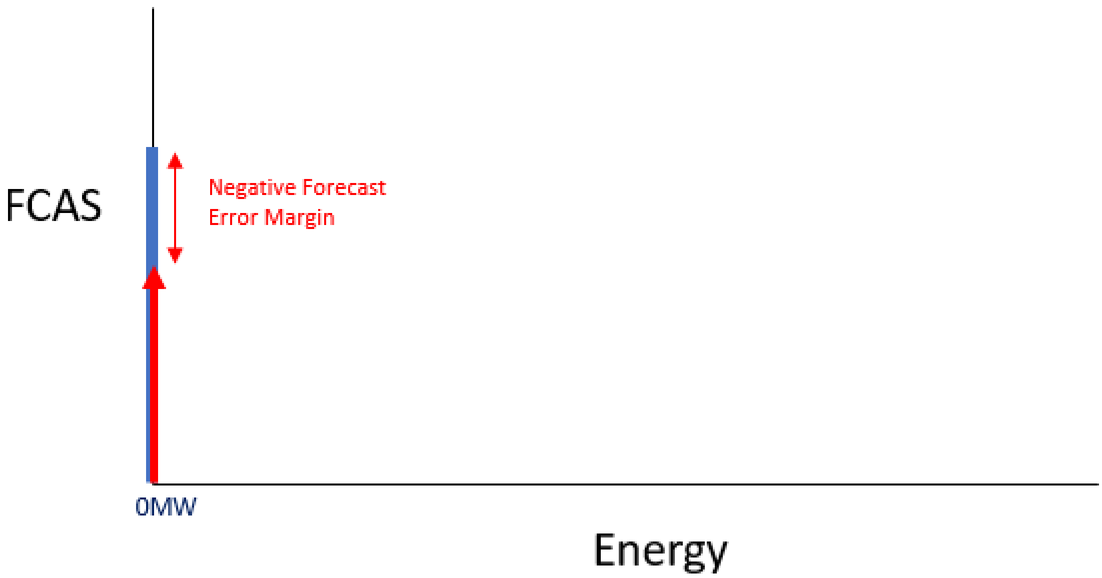


**Figure 6 Lower FCAS trapezium**



# Appendix A. Extract from Hornsdale 2 WF FCAS trial report

The section below is an edited extract from the HWF2 FCAS trial report[5]. Section A3 of the HWF2 FCAS trial report contains more information on the calculation of forecast error margin.

### The need for forecast error margin

During the pre-classification technical assessment process, AEMO must consider whether an intending FCAS provider can operate in energy and FCAS markets according to their proposed FCAS trapezium. If the power system is relying on enabled ancillary services being available to the grid following occurrence of a fault, the system operator will need to be confident that these services can be provided accurately and precisely as expected. In the case of wind and solar plant, the ability of the plant operator to provide an acceptable forecast of generation in the coming dispatch interval as part of their FCAS offers (bids) becomes particularly important.

To provide AEMO with confidence in the forecasting capability, an FCAS parameter was developed to reflect a minimum headroom (or pre-curtailment) requirement. This forecast error margin approximates a 3-standard deviation error in its 5-minute ahead generation forecast (that is, an error not exceeded for 99.7% of the time). This ensures that generator output can be steadily controlled over the 5-minute interval over which it may be enabled to provide the service. Failing to provide the service could have an adverse impact on frequency.

For HWF2, this calculation resulted in a minimum of around 10 MW (or 10% of registered capacity) of forecast error margin to manage the risk of forecasting error across all operating conditions, measured over the period from 21 February to 18 July 2017. It is noted that this period was during the commissioning phase of the HWF2 wind farm, for which forecasting performance data was available – this minimum level of 10 MW of headroom resulted from benchmarking against actual forecast data from this period.

[5] http://aemo.com.au/-/media/Files/Electricity/NEM/Strategic-Partnerships/2018/HWF2-FCAS-trial-paper.pdf

# Version release history

| Version | Effective Date | Summary of Changes |
|---|---|---|
| 2.0 | 16 February 2022 | Update references to the Market Ancillary Services Specification to be consistent with version 7.0 effective from 1 February 2022. |
| 1.0 | 5 October 2018 | First issue of the wind and solar farms testing requirements for Contingency FCAS registration. |