AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Frequency and Time Error Monitoring – 4th Quarter 2018

April 2019

For the National Electricity Market

PURPOSE

AEMO has prepared this document to provide information about the frequency and time error performance in the National Electricity Market (Mainland and Tasmania) for the period October to December 2018 inclusive.

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1. Introduction

AEMO must use reasonable endeavours to maintain power system frequency and time error within the limits specified by the Reliability Panel in the Frequency Operating Standards (FOS)[1] for the mainland and Tasmanian regions. This document reports on the frequency and time error performance observed during October, November and December 2018 in all regions of the National Electricity Market (NEM). Queensland, New South Wales, Victoria and South Australia are referred to as the 'mainland' throughout the report.

The *Power System Frequency and Time Deviation Monitoring Report – Reference Guide*[2] outlines the calculation procedure used by AEMO to produce the quarterly Frequency and Time Error Monitoring report.

The analysis of the delivery of Slow Raise, Slow Lower, Delayed Raise and Delayed Lower Frequency Controlled Ancillary Services (FCAS) presented in this report are based on 4-second SCADA information derived from AEMO's systems. Unless otherwise noted, frequency data for the mainland is sourced from 4-second measurements in New South Wales and frequency data for Tasmania is sourced from 4-second measurements in Tasmania.

[1] https://www.aemc.gov.au/australias-energy-market/market-legislation/electricity-guidelines-and-standards/frequency-0

[2] http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Ancillary-services/Frequency-and-time-error-monitoring

2. Operation within the Normal Operating Frequency Band

Clause A.1.2(b) of the FOS provides that in the absence of a contingency event, AEMO should maintain system frequency within the applicable normal operating frequency excursion band, and should not exceed the applicable normal operating frequency band for more than five minutes on any occasion and not for more than 1% of the time over any 30 day period[3].

Frequency performance in the mainland did not meet this standard for Quarter 4 2018 in November and December.

Frequency performance in Tasmania did not meet this standard for Quarter 4 2018.

AEMO calculates the percentage of time spent inside the NOFB on a daily rolling average. The minimum of these 30-day averages observed within each month is reported in Figure 1. The figure shows statistics both including and excluding data during contingency events.

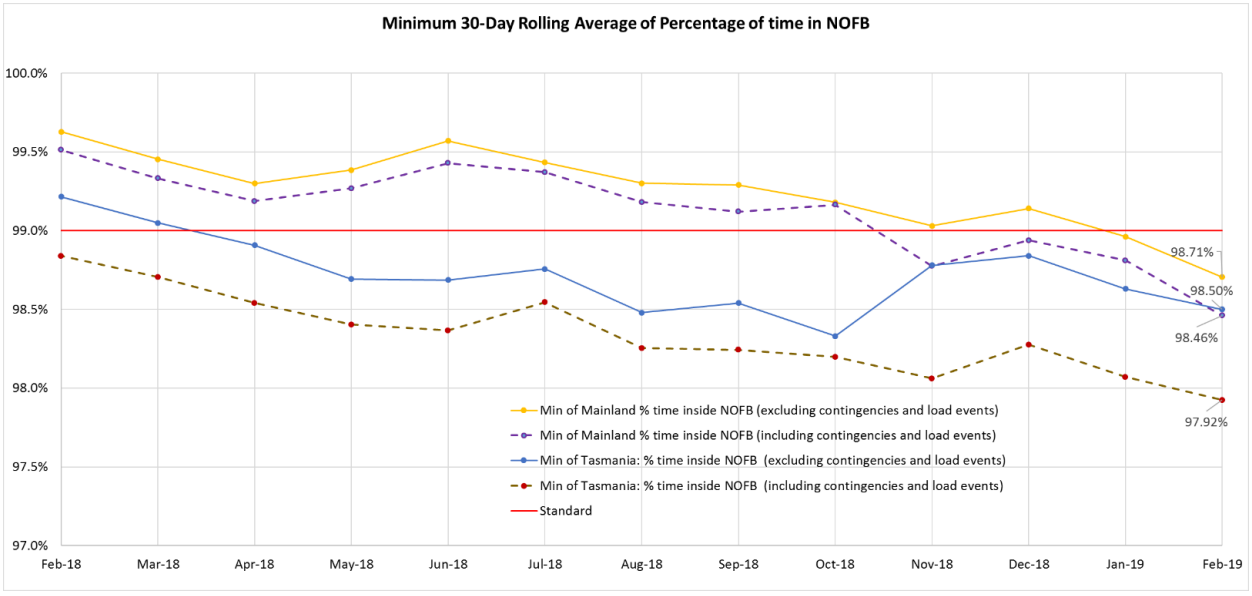

Figure 1 Minimum 30-Day rolling average of percentage of time mainland and Tasmania frequencies remained within NOFB from February 2018 to February 2019

The frequency distribution over Quarter 4 2018 is shown in Figure 2 and Figure 3.

[3] https://www.aemc.gov.au/sites/default/files/content/c2716a96-e099-441d-9e46-8ac05d36f5a7/REL0065-The-Frequency-Operating-Standard-stage-one-final-for-publi.pdf

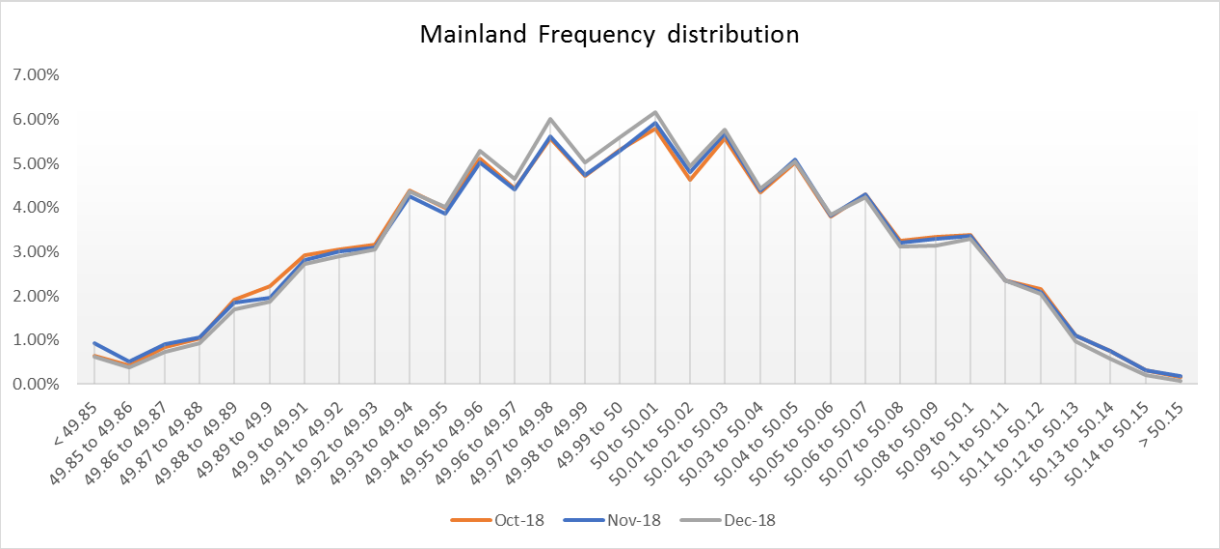

Figure 2 Mainland frequency distribution

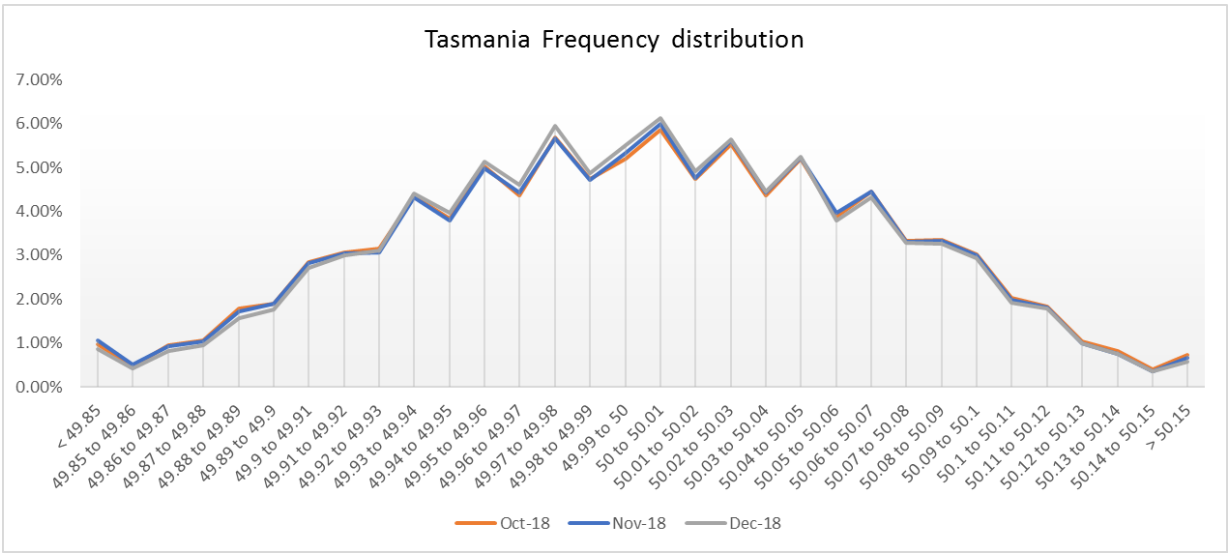

Figure 3 Tasmania frequency distribution

3. Events outside the Normal Operating Frequency Excursion Band

Table 1 and Table 2 summarise the events in the mainland and Tasmania with frequency excursions outside the Normal Operating Frequency Excursion Band (NOFEB) [4].

For all mainland and Tasmania events listed in Table 1, frequency returned to the NOFB within the times specified in the FOS. For the events in Table 2, it did not. These events are discussed further in Section 4.

Table 1 Mainland and Tasmania: Frequency excursions outside the NOFEB and returned in FOS timeframes

Event	Low/High/Both Frequency Event	Number of Events	
		Mainland	Tasmania
No contingency or load event noted	LOW	0	22
	HIGH	0	21
	BOTH	0	3
Load Event	LOW	0	94
	HIGH	0	149
	BOTH	0	58
Generation Event	LOW	2	10
	HIGH	0	2
	BOTH	0	0
Network Event	LOW	0	0
	HIGH	0	0
	BOTH	0	0
Separation Event	LOW	0	0

[4] Frequency range of 49.75 Hz – 50.25 Hz

Event	Low/High/Both Frequency Event	Number of Events	
		Mainland	Tasmania
	HIGH	0	0
	BOTH	0	0
Multiple Contingency Event	LOW	0	0
	HIGH	0	0
	BOTH	0	0

Table 2 Mainland and Tasmania: Frequency excursions outside the NOFEB not returned in FOS timeframes

Event	Low/High/Both Frequency Event	Number of Events	
		Mainland	Tasmania
No contingency or load event noted	LOW	0	2
	HIGH	0	0
	BOTH	0	0
Load Event	LOW	0	1
	HIGH	0	1
	BOTH	0	15
Generation Event	LOW	4	4
	HIGH	0	0
	BOTH	0	3
Network Event	LOW	0	0
	HIGH	0	0
	BOTH	0	0
Separation Event	LOW	0	0

Event	Low/High/Both Frequency Event	Number of Events	
		Mainland	Tasmania
	HIGH	0	0
	BOTH	0	0
Multiple Contingency Event	LOW	0	0
	HIGH	0	0
	BOTH	0	0

4. Events Outside the Frequency Operating Standards

This section analyses the events identified as not meeting the standards in the FOS.

4.1 Mainland Events

Sixteen frequency events were recorded in the mainland that did not meet the FOS during this reporting period. This occurred due to the event duration, or where the frequency was outside the NOFEB for a reason other than a contingency event or a load event. For most situations, the FOS provides that frequency should not remain outside the NOFB for more than 300 seconds. Mainland frequency events exceeding FOS restoration timeframes are listed in Table 3.

Table 3 Mainland frequency events outside the FOS

Event	Number of Events	Min/Max Mainland Frequency (Hz)	Duration outside NOFB - 49.85 – 50.15 Hz (sec) for min/max frequency
Generation events	4	49.65 50.17	452 400
No contingency or load event	12	49.76 50.16	816 336

Following the generation events, the frequency was contained between 49.5Hz to 50.5Hz as specified in the FOS, but was not stable within the NOFB in 5 minutes or less.

On 12 occasions when there were no reported contingency or load events, the frequency exceeded the NOFB but was not stable and did not recover within 5 minutes. However, the frequency was always contained within the NOFEB.

More information on power system incidents causing large frequency deviations can be found in Table 4 and the raise contingency services dispatched to manage frequency recovery are shown in Table 5:

Table 4 Power system incidents causing frequency deviations outside the FOS

Event Date and Time	Min Frequency (Hz)	Max Frequency (Hz)	Cause for the Event	Time outside NOFB (s)
Tuesday 6th November 2018 1810 hrs	MAIN: 49.76 Hz TAS: 49.75 Hz	N/A	Stanwell U1 trip	400
Friday 14th December 2018 1148 hrs	MAIN: 49.75 Hz TAS: 49.71 Hz	N/A	Loy Yang A2 trip	600
Tuesday 18th December 2018 1520 hrs	MAIN: 49.69 Hz TAS: 49.17 Hz	N/A	Tarong North trip	404
Tuesday 25th December 2018 1530 hrs	MAIN: 49.65 Hz TAS: 48.83 Hz	N/A	Eraring U2 trip	452

Table 5 Power system incidents causing frequency deviations outside the FOS

Event Date and Time	FCAS enabled in dispatch interval / MW		
	Fast Raise	Slow Raise	Delayed Raise
Tuesday 6th November 2018 1810 hrs	307	307	392
Friday 14th December 2018 1148 hrs	379	379	455
Tuesday 18th December 2018 1520 hrs	368	368	485
Tuesday 25th December 2018 1530 hrs	415	429	389

An assessment of the delivery of the contingency FCAS services following the 4 events described in Table 4 was also conducted. The analysis for these events shows that the delivery of fast and slow raise service delivered was consistent with the amount dispatched. This conclusion is supported by the fact that power system frequency did not fall below the containment frequency.

However, there was an under-delivery of the delayed raise service in all 4 cases. The ratio of the delayed raise service delivered over the FCAS dispatched for scheduled units is shown in Table 6. The under-delivery of the delayed raise service extended the time that the frequency remained outside the NOFB. The reason for the under-delivery is that the frequency deviations were not severe enough to trigger contingency raise action from a number of FCAS providers. AEMO is now reviewing the trigger settings for switched FCAS controllers, including those registered for the delayed FCAS services.

Table 6 Percentage of Delayed FCAS delivered v/s enabled for scheduled units dispatched for the raise contingency services

Event Date and Time	Delayed Raise FCAS enabled in dispatch interval / MW	Delayed Raise FCAS delivered in dispatch interval / MW
Tuesday 6th November 2018 1810 hrs	392	255
Friday 14th December 2018 1148 hrs	455	387
Tuesday 18th December 2018 1520 hrs	485	461
Tuesday 25th December 2018 1530 hrs	389	187

4.2 Tasmanian Events

As shown in Table 7, 48 frequency events were recorded in Tasmania during this reporting period that did not meet the standards in the FOS.

Table 7 Tasmania frequency events outside the FOS

Event	Number of Events	Min/Max Tasmanian Frequency (Hz)	Duration outside NOFB - 49.85 – 50.15 Hz (sec) for min/max frequency
No contingency or load event	48	49.48 50.44	116 80

Following generation or load events, the FOS for Tasmania provides for frequency to be contained between 48.0 Hz and 52.0 Hz and recovered to within the NOFB within 10 minutes. On all 48 occasions in this period, however, the frequency exceeded the NOFEB when there were no reported contingency or load events. Of the 48 occasions, there were 5 cases when the frequency was not stable and did not recover within the applicable FOS timeframe of 5 minutes.

4.3 No contingency or load event

When there are no associated contingency or load events in an interconnected system, the FOS requires that a frequency disturbance should be contained and stabilised as shown in Table 8.

Table 8 No contingency or load event for an interconnected system

Region	Containment	Stabilisation	Recovery
Mainland	49.75 to 50.25 Hz 49.85 to 50.15 Hz, 99% of the time	49.85 to 50.15 Hz within 5 minutes	
Tasmania	49.75 to 50.25 Hz 49.85 to 50.15 Hz, 99% of the time	49.85 to 50.15 Hz within 5 minutes	

Across the mainland and Tasmania, a total of 60 frequency excursions outside the NOFB were not associated with a contingency or load event. For these deviations, the frequency either exceeded the NOFEB (only in Tasmania) or did not stabilise and recover within the NOFB in 5 minutes.

Figure 4 below shows that when the frequency is within the NOFB in the mainland, it is closer to the edge of the NOFB. The probability of the frequency leaving the NOFB has been increasing as the performance of frequency within the NOFB has deteriorated. When the frequency is within the NOFB, a supply-demand unbalance of the same magnitude is more likely to cause the frequency to exceed the NOFB.

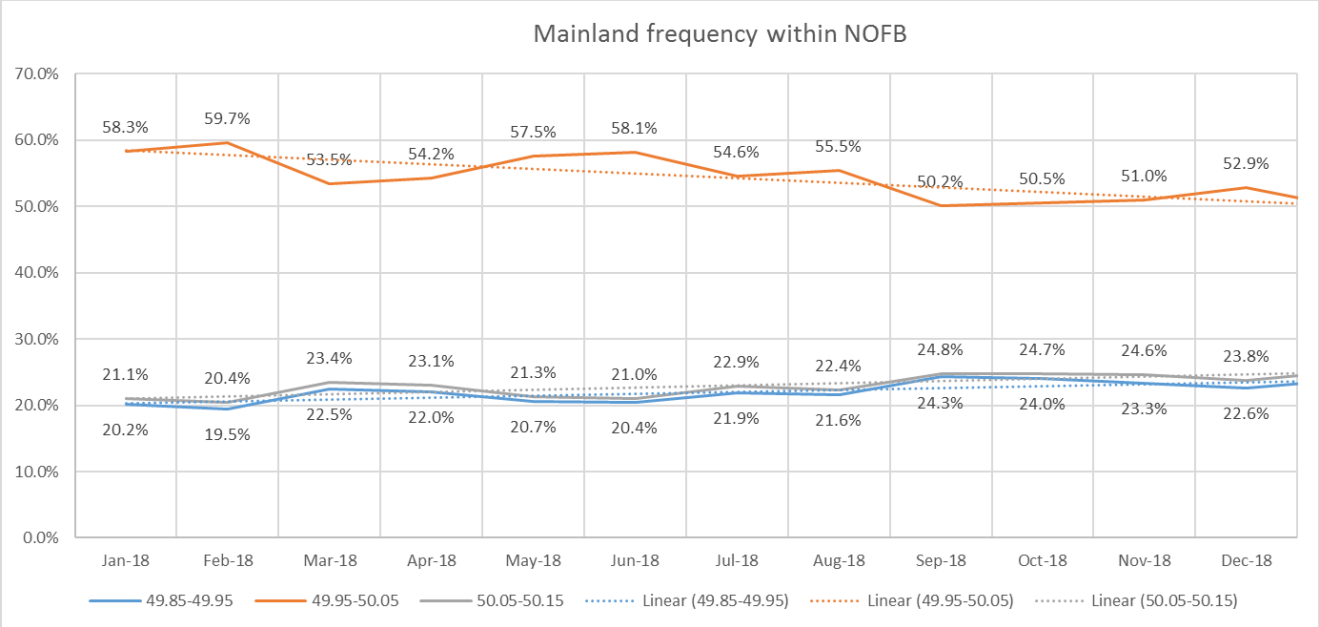

Figure 4 Mainland frequency performance within the NOFB

4.4 Planned actions to improve frequency control performance

Following the decline in frequency control performance under normal conditions in the NEM, AEMO is in the process of implementing and investigating a number of measures with a view to keeping frequency within the NOFB 99% of the time.

- AEMO to increase base regulation FCAS volumes by 50MW (up from 130/120MW Raise/Lower) – Implemented 22nd March 2019.
- AEMO to review frequency performance every 4 weeks and determine whether to hold or further increase regulation FCAS requirements (up to potentially ~250MW).
- AEMO to progress a range of other frequency control initiatives such as:

- Ensure contingency FCAS providers are applying appropriate frequency response deadband settings
- Reviewing the percentage of contingency FCAS volume enabled for switching controllers and variable/proportional controllers.
- Reviewing the frequency deviation setting of switching controllers
- Reviewing contingency FCAS volumes, in line with revised estimations of load relief

5. Accumulated Time Error

The FOS specifies that the accumulated time error should be maintained within the range ±15 seconds in the mainland and Tasmania. Constraint equations used to control mainland accumulated time error by varying the amount of regulation FCAS enabled, are based on measurements taken in Queensland and New South Wales. The ranges of accumulated time error recorded for measurements in mainland and Tasmania are provided in Table 9.

Table 9 Maximum and Minimum time error measurements for mainland and Tasmania

Value	Mainland	Tasmania
Highest positive time error (seconds)	5.75	13.75
Lowest negative time error (seconds)	-11.90	-16.67

The accumulated time error in Tasmania reached -16.67 seconds on the 1st December 2018. AEMO is actively working on mitigation strategies as the time error in Tasmania has been accumulating to unsatisfactory levels.

Figure 5 and 6 below show the percentage of time that the time error has been less than or greater than 1.5 seconds and the Area Control Error Regulation was increased accordingly due to the time error constraint being active.

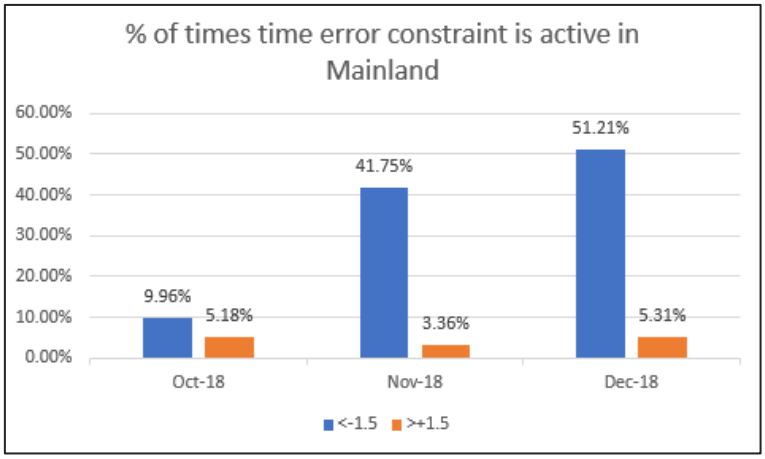

Figure 5 Time error constraint active in Mainland

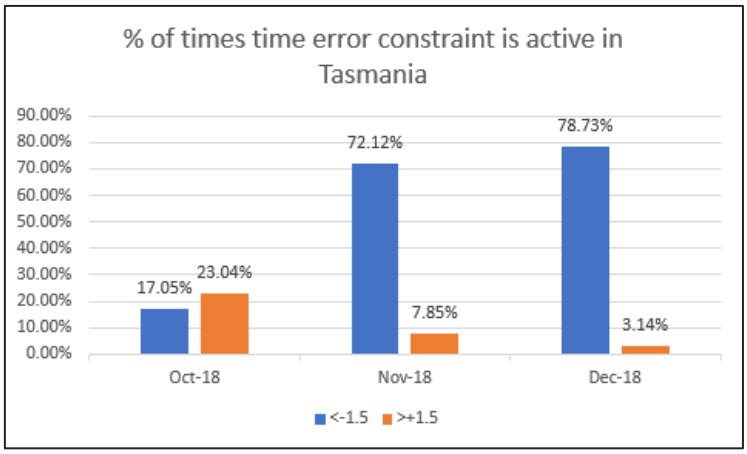

Figure 6 Time error constraint active in Tasmania

6. Area Control Error

As per the Regulation FCAS Contribution Factors Procedure[5], AEMO first calculates an area control error (ACE), representing the MW equivalent size of the current frequency deviation and accumulated frequency deviation (time error) of the system.

EQ. 1 $$ACE = 10 \cdot Bias \cdot (F - FS - FO)$$

Where:

(i) Bias is the area frequency bias and is a tuned value that represents the conversion ratio between MW and 0.1Hz of frequency deviation;

(ii) F is the current measured system frequency;

(iii) FS is the scheduled frequency (50.0Hz); and

(iv) FO is a frequency offset representing accumulated frequency deviation, i.e. time error.

Figure 7 and 8 show a comparison of the minimum and maximum ACE per dispatch intervals in the mainland and Tasmania in the last quarter.

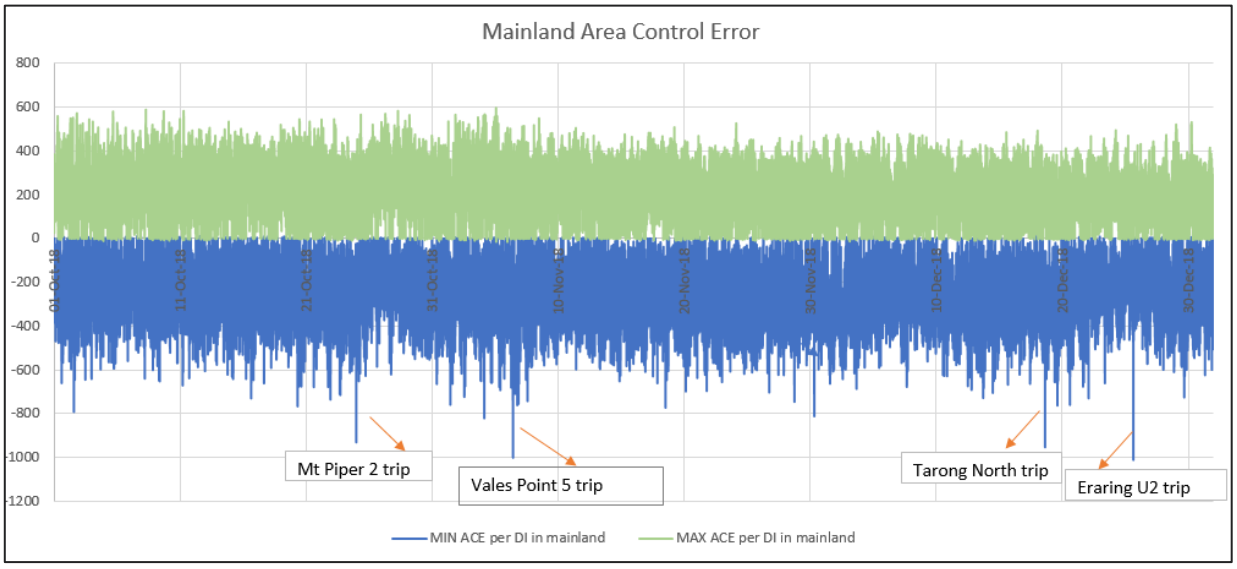

Figure 7 Minimum and maximum ACE per DI in mainland

[5] http://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Ancillary_Services/Regulation-FCAS-Contribution-Factors-Procedure.pdf

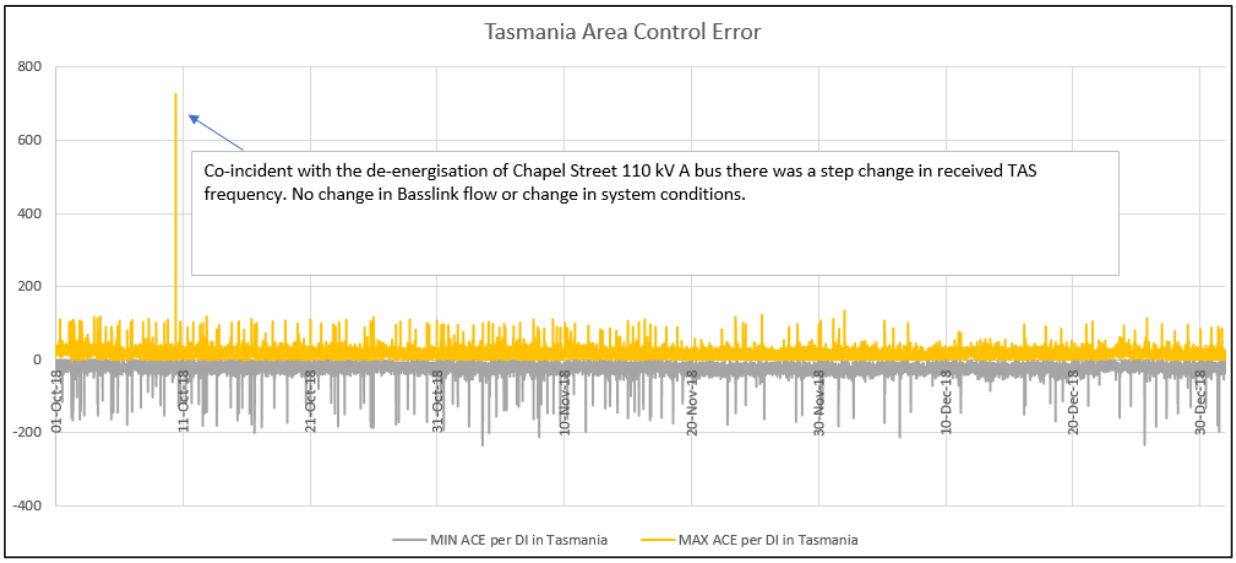

Figure 8 Minimum and maximum ACE per DI in Tasmania