AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Frequency and Time Error Monitoring – 1st Quarter 2019

December 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 January 2019 to March 2019 inclusive.

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Contents

Tables

Figures

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 January, February and March 2019 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 (NOFB) 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 stay within this standard during Quarter 1 2019. AEMO has since responded via a number of actions; most significantly through a sizeable increase in the base quantities of Regulation FCAS it procures. This will be monitored and adjusted as required on a regular basis.

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 periods where there were contingency events.

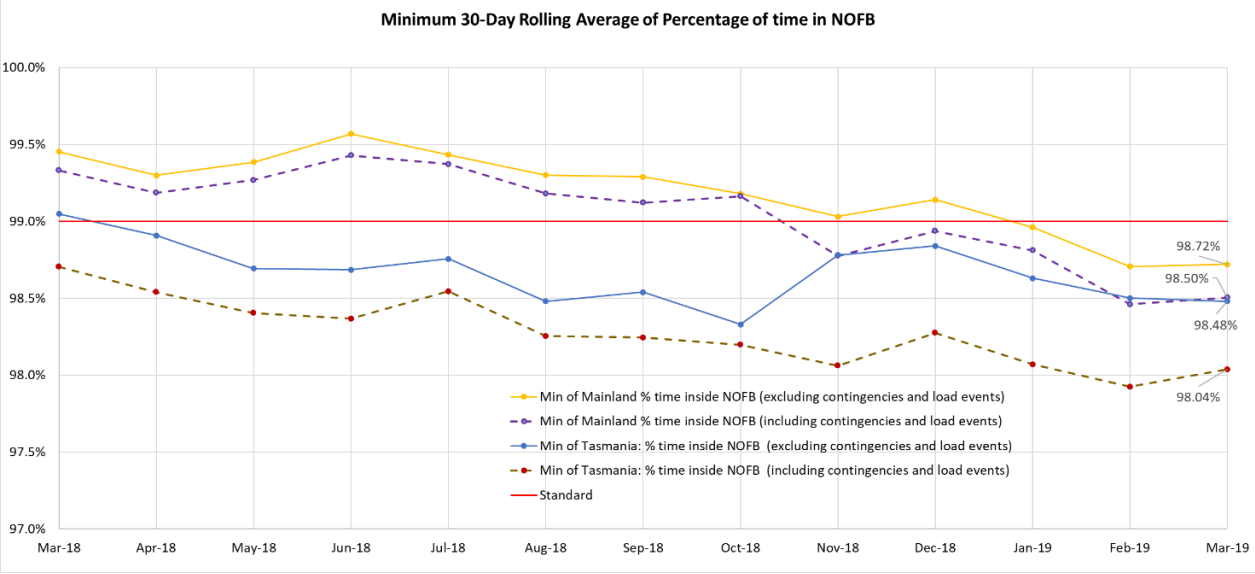

Figure 1 Minimum 30-Day rolling average of percentage of time mainland and Tasmania frequencies remained within NOFB from January 2019 to March 2019

The frequency distribution over Quarter 1 2019 is shown in Figure 2 and Figure 3. Compared with recent quarters, no major changes in the distribution were noted, other than the slight increase in time spent at or just outside the NOFB.

[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

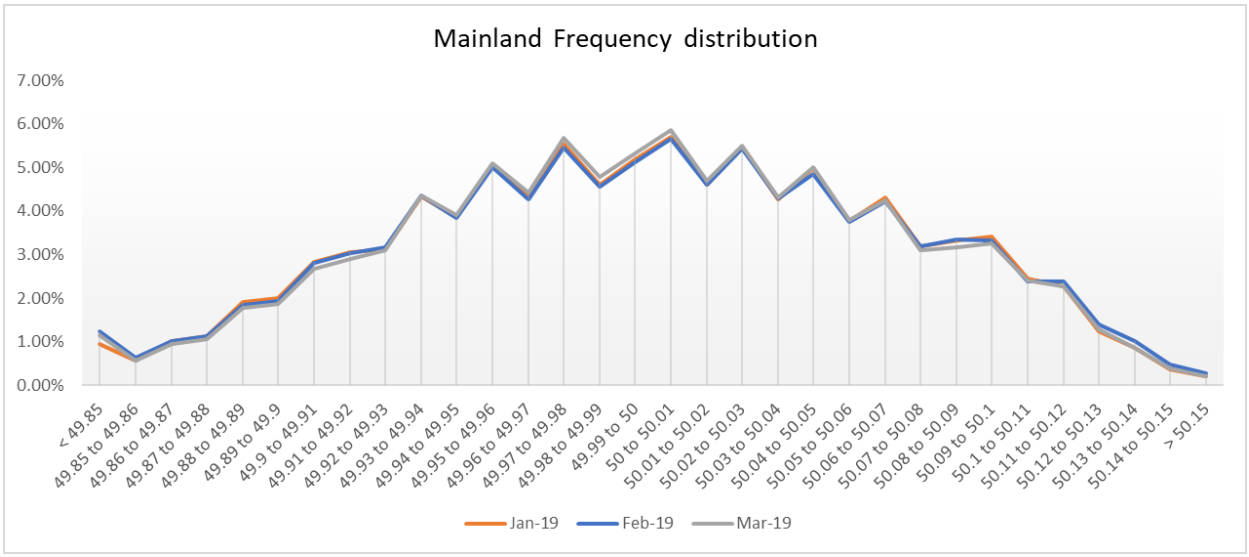

Figure 2 Mainland frequency distribution

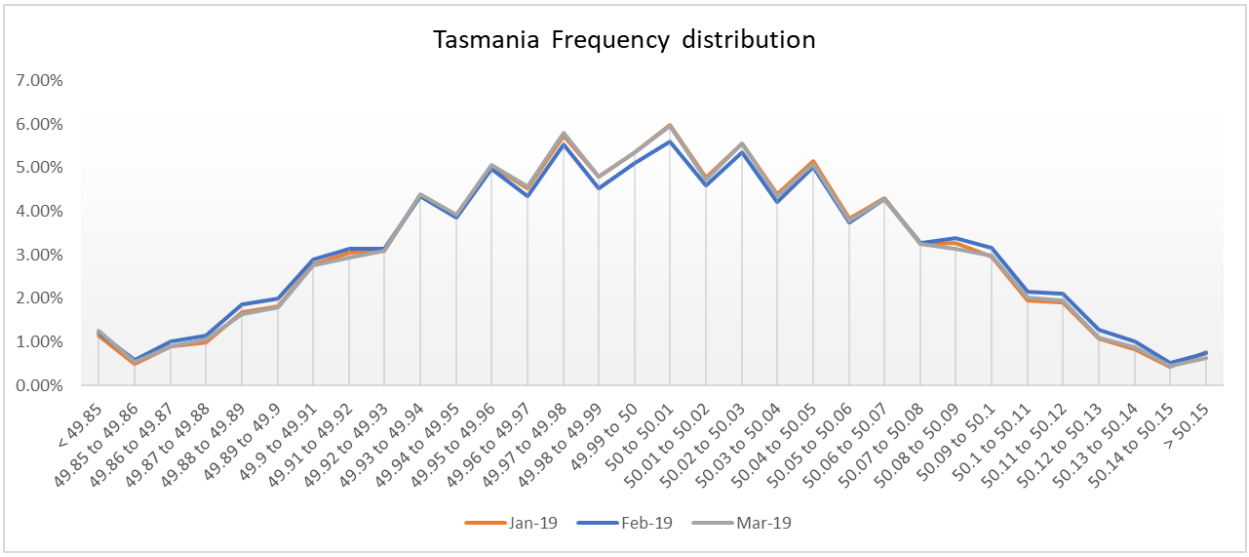

Figure 3 Tasmania frequency distribution

3. Events outside the Normal Operating Frequency Excursion Band

Table 1 and Table 2 summarise the number of events with frequency excursions outside the Normal Operating Frequency Excursion Band (NOFEB) [4] that occurred during Quarter 1 of 2019 in the mainland and Tasmania.

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, the frequency did not return to the NOFB within the specified times. 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	1	76
	HIGH	0	10
	BOTH	0	4
Load Event	LOW	0	61
	HIGH	0	124
	BOTH	0	73
Generation Event	LOW	4	11
	HIGH	0	4
	BOTH	0	1
Network Event	LOW	0	0
	HIGH	0	0
	BOTH	0	0

[4] Frequency range of 49.75 Hz – 50.25 Hz

Event	Low/High/Both Frequency Event	Number of Events	
		Mainland	Tasmania
Separation Event	LOW	0	0
	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	1	8
	HIGH	0	0
	BOTH	0	0
Load Event	LOW	0	2
	HIGH	0	0
	BOTH	0	11
Generation Event	LOW	4	0
	HIGH	0	0
	BOTH	0	1
Network Event	LOW	0	0
	HIGH	0	0
	BOTH	0	0

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

4. Frequency events outside of the FOS

This section analyses the events throughout the relevant quarter that were identified to have not met one or more of the requirements set out in the FOS.

4.1 Mainland Events

Twenty-five 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 FOS restoration requirement

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	49.69 50.16	368
No contingency or load event	19	49.73 50.00	664

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

On 19 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 contained within the NOFEB for 18 out of 19 occasions.

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)
Sunday 27th January 2019 0446 hrs	MAIN: 49.74 Hz TAS: 49.76 Hz	N/A	Bayswater Unit 1 trip	368
Tuesday 29th January 2019 1827 hrs	MAIN: 49.69 Hz TAS: 49.38 Hz	N/A	Eraring Unit 3 trip	320
Sunday 3rd February 2019, 1926 hrs	MAIN: 49.69 Hz TAS: 49.37 Hz	N/A	Bayswater Unit 1 trip	324
Wednesday 13th March 2019 1103 hrs	MAIN: 49.69 Hz TAS: 49.44 Hz	N/A	Loyang A Unit 4 trip	352

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
Sunday 27th January 2019 0446 hrs	560	581	575
Tuesday 29th January 2019, 1827 hrs	227	227	275
Sunday 3rd February 2019, 1926 hrs	319	330	482
Wednesday 13th March 2019, 1103 hrs	325	325	461

An assessment of the delivery of raise FCAS following the 4 events described in Table 4 was also conducted. Following the contingency events there was an under-delivery of the delayed raise service in 3 cases and an over-delivery of delayed services in one case. Under delivery of delayed FCAS services was typically due to frequency not reaching the trigger point switched controllers used by some providers of delayed FCAS. AEMO sets and reviews these settings for switched FCAS controllers and plans a major review along with a review of the MASS in 2020. AEMO is also working with providers of delayed FCAS to address any non-compliance issues.

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 further increased the time that the frequency remained outside the NOFB.

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

Event Date and Time	FCAS delivered in dispatch interval / MW
	Delayed Raise
Sunday 27th January 2019 0446 hrs	90%
Tuesday 29th January 2019, 1827 hrs	139%
Sunday 3rd February 2019, 1926 hrs	87%
Wednesday 13th March 2019, 1103 hrs	84%

4.2 Tasmanian Events

As shown in Table 7, 98 frequency events were recorded in Tasmania during this reporting period that did not meet the standards in the FOS. There were a few unplanned line outages recorded during this period due to bushfire activities which was also a contribution factor for number of frequency events being high. AEMO continues to work on actions to improve frequency performance in Tasmania.

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	98	48.97 50.47	284 244

Following the generator and load events, the frequency was contained between 48.0Hz to 52.0Hz and recovered within the FOS timeframe of 10 minutes.

On 98 occasions when there were no reported contingency or load events, the frequency exceeded the NOFEB. Out of the 98 occasions, there were 8 cases when the frequency was not stable and did not recover within 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 117 frequency excursions outside the NOFB were not associated with a contingency or load event. For these deviations, the frequency either exceeded the NOFEB 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 and further away from 50 Hz. 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.

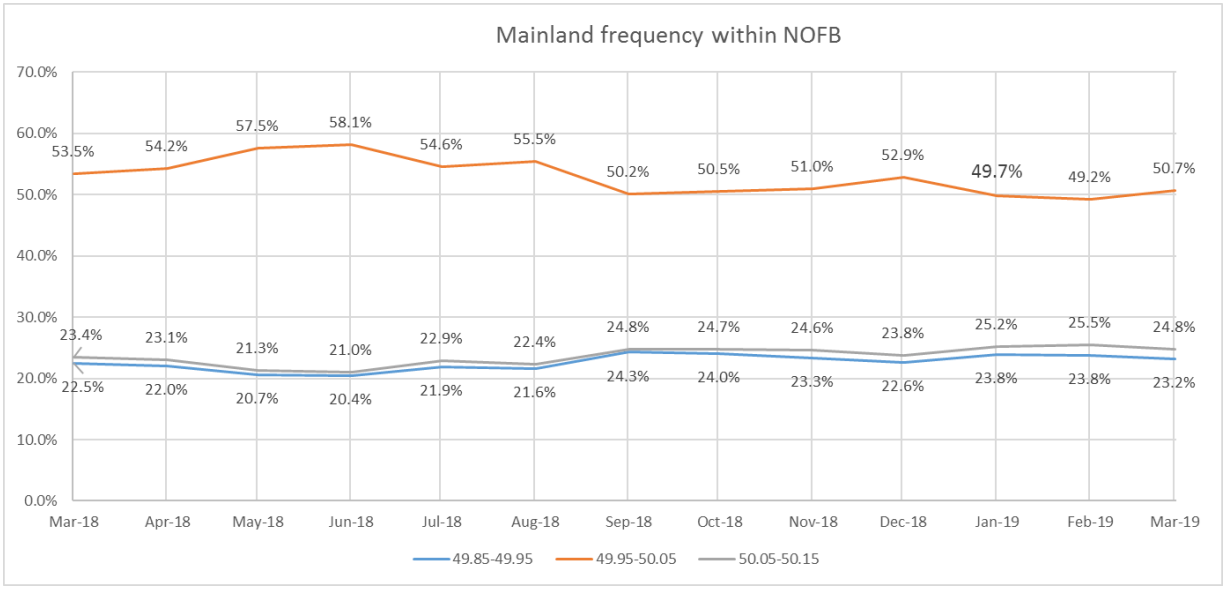

Figure 4 Mainland frequency performance within the NOFB

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. Time error correction is performed via AEMO's AGC system using Regulation FCAS. Dynamic constraint equations can increase the amount of Regulation FCAS enabled if time error exceeds certain thresholds. The ranges of accumulated time error recorded for measurements in mainland and Tasmania during Quarter 1 2019 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)	4.97	7.54
Lowest negative time error (seconds)	-12.00	-23.17

The accumulated time error in Tasmania reached -23.17 seconds on the 10th January 2019. AEMO has addressed issues associated with AGC and regulation FCAS performance in Tasmania to improve time error performance.

Figure 5 shows the percentage of time that the time error was less than or greater than 1.5 seconds, which is the threshold at which accumulated time error begins to increase Regulation FCAS volumes above base values.

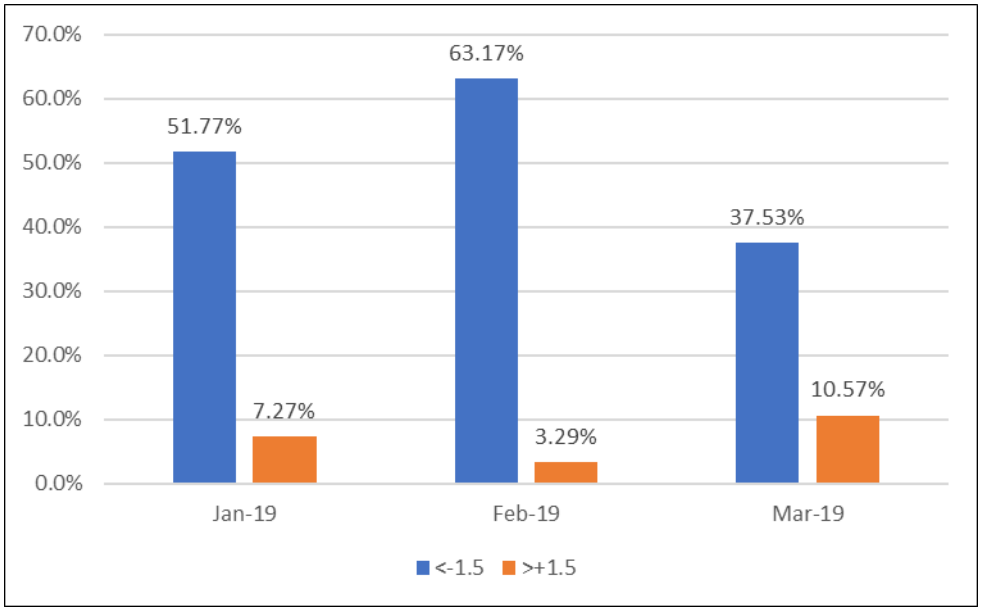

Figure 5 Percentage of time additional Regulation FCAS was procured in the Mainland based on time error

6. Area Control Error

Trends in Area Control Area (ACE) give an indication of how frequency is performing from the perspective of AGC. For the absence of doubt, there are no specific requirements pertaining to ACE in the FOS, but it is reported on here due to its relationship with usage of Regulation FCAS and its inclusion in the AEMC's rule change on frequency control performance reporting[5].

AEMO calculates area control error (ACE), representing the MW equivalent size of the current frequency deviation and accumulated frequency deviation (time error) of the system in accordance with the following equation:

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 6 and 7 show the minimum and maximum ACE values recorded in each dispatch intervals in the mainland and Tasmania over Quarter 1 2019.

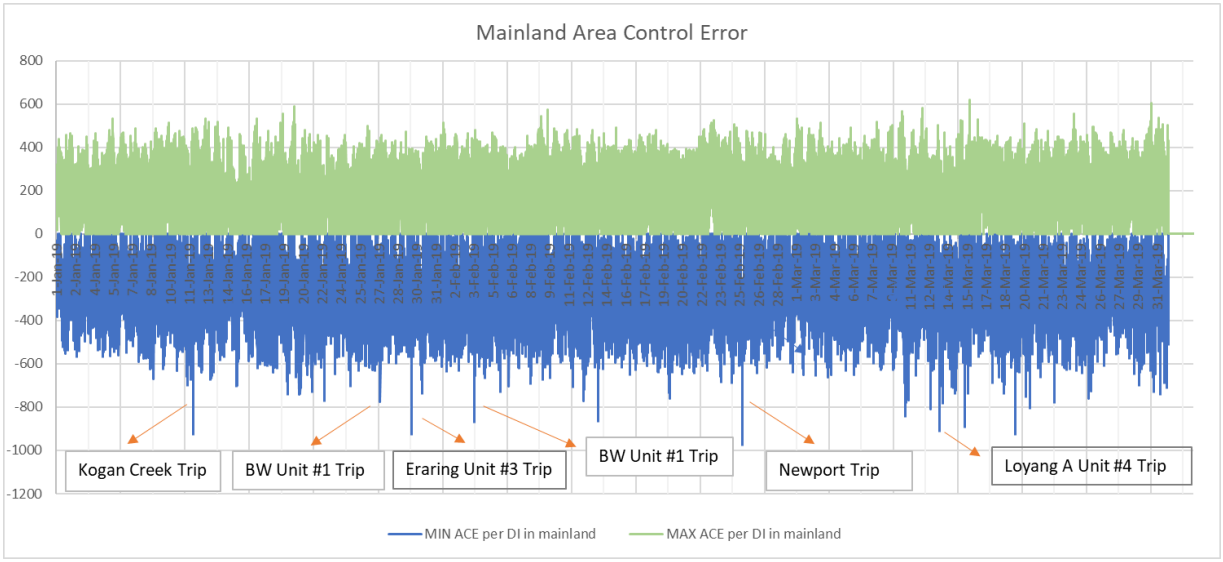

Figure 6 Minimum and maximum ACE per DI in mainland

[5] https://www.aemc.gov.au/rule-changes/monitoring-and-reporting-frequency-control-framework

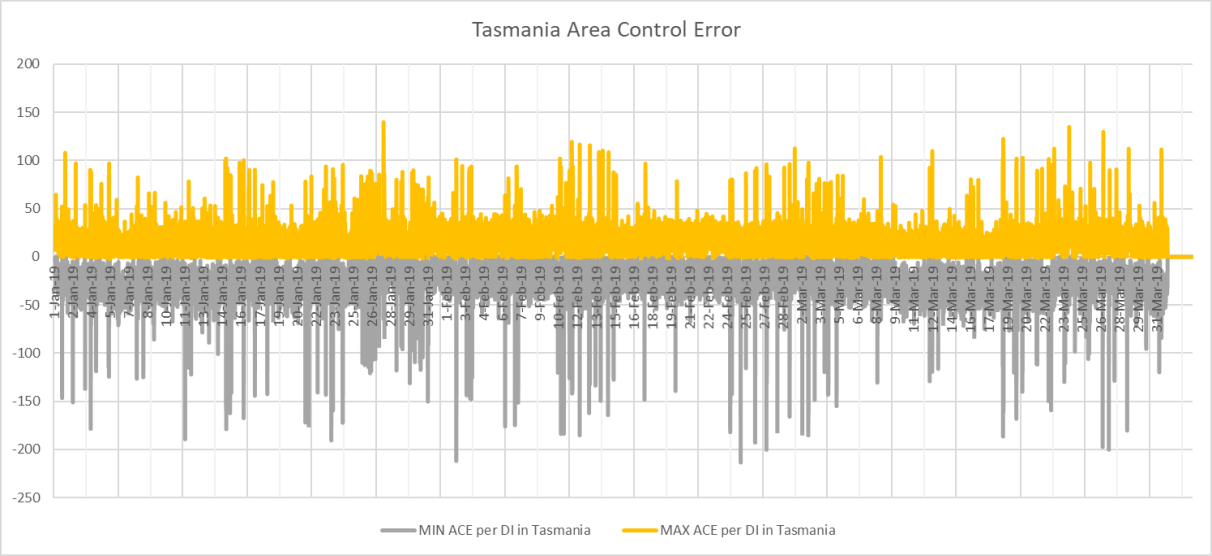

Figure 7 Minimum and maximum ACE per DI in Tasmania