Frequency and Time Error Monitoring – Quarter 1 2020

May 2020

A report for the National Electricity Market

Important notice

PURPOSE

The purpose of this report is to provide information about the frequency and time error performance in the National Electricity Market (mainland and Tasmania) for the period January to March 2020 inclusive. AEMO has prepared this report in accordance with clause 4.8.16(b) of the National Electricity Rules, using information available as at the date of publication, unless otherwise specified.

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1. Introduction

The Reliability Panel's Frequency Operating Standard (FOS)[1] specifies limits for power system frequency and time error for the mainland and Tasmanian regions. This document reports on the frequency and time error performance observed during January, February, and March 2020 in all regions of the National Electricity Market (NEM) as required by clause 4.8.16(b) of the NER[2]. 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*[3] outlines the calculation procedure used by AEMO to produce the quarterly Frequency and Time Error Monitoring report. Where applicable, analysis of the delivery of Slow and Delayed Frequency Controlled Ancillary Services (FCAS) presented in this report are based on 4-second SCADA information derived from AEMO's systems.

Unless otherwise noted, mainland frequency data is sampled in New South Wales at 4-second intervals using the most recent GPS clock frequency measurement preceding each 4-second interval. All Tasmanian frequency data is sampled at 4-second intervals using the most recent Network Operations and Control System (NOCS) frequency measurement preceding each 4-second interval.

2. State of frequency performance

Several unique and challenging network incidents occurred in Q1 2020. The quarter included:

- The separation of Queensland and New South Wales from the southern regions on 4 January 2020 due to bushfires in the Snowy Mountains at a time of high summer demand.
- The 17 days of 'extended island' operation for South Australia after transmission towers along the 500 kilovolt (kV) corridor in western Victoria collapsed during a storm event on 31 January 2020.
- Two further separations, of Queensland on 7 January 2020 and South Australia on 2 March 2020.

Maintaining adequate frequency control in all regions during these events was challenging. The availability of local contingency services in particular was not adequate at all times during the separations of 4 January, 31 January, and 2 March 2020, and AEMO was required to intervene in several ways to reduce the risk to the power system due to insufficient FCAS capability.

Despite these unique events, frequency in the NEM remained largely within the limits set by the FOS, with frequency remaining in the normal operating frequency band (NOFB) over 99% of the time in mainland regions. This report establishes that the frequency control responses within the NEM contained and recovered these disturbances within the requirements of the FOS most of the time. The instances where the FOS was not maintained do not necessarily suggest underlying issues in the aggregate system capability to respond to frequency disturbances.

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

2 See https://www.aemc.gov.au/regulation/energy-rules/national-electricity-rules/current.

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

Despite this, AEMO remains particularly concerned about increasing risks presented by aspects of frequency control that the FOS does not directly address. These include:

- Lack of frequency control within the NOFB – within the NOFB, frequency continues to be lacking in control and exhibits aspects of oscillatory behaviour.
- More excursions from the NOFB – lack of control within the NOFB is contributing to very high numbers of events where frequency departs the NOFB (since frequency prior to a given event tends not to be close to 50 hertz [Hz]) compared with historical behaviour.
- Unpredictable frequency behaviour – frequency behaviour during anything other than a clearly defined single credible contingency is difficult to predict and highly variable.

AEMO has taken steps and is continuing to progress initiatives that are intended to improve frequency control in the NEM. These are discussed in section 8 of this report.

3. Achievement of the Frequency Operating Standard

AEMO's assessment of the achievement of the various FOS requirements[4] over the period January to March 2020 is summarised in Table 1.

Table 1 Frequency Operating Standards and assessment in the mainland and Tasmania

Requirement	Mainland	Tasmania	Further commentary
1 – Accumulated time error	Exceeded once	Achieved	31 Jan, see Section 4.1
2 – No contingency/load events			
• **Within NOFEB at all times**	Exceeded twice	Exceeded 24 times*	2 Jan and 28 Jan, see Section 4.2.10
• **5-minute limit outside NOFB**	Exceeded twice	Exceeded twice	20 Jan and 28 Jan, see Section 4.2.2
• **Within NOFB 99% of the time**	Achieved		*Incidents discussed in Section 4.2.1
3 – Generation or load events			
• **Contained**	Achieved	Achieved	23 Jan, 30 Jan and 14 Feb, see Section 4.3
• **Recovered**	Exceeded 3 times	Achieved	
4 – Network events			
• **Contained**	Achieved	Achieved	
• **Recovered**	Achieved	Achieved	
5 – Separation events			
• **Contained**	Achieved	Achieved	

[4] See https://www.aemc.gov.au/sites/default/files/2020-01/Frequency%20operating%20standard%20-%20effective%201%20January%202020%20-%20TYPO%20corrected%2019DEC2019.PDF.

Requirement	Mainland	Tasmania	Further commentary
• Managed	Achieved	Achieved	
6 – Protected events	Achieved	Achieved	
7 – Non-credible or multiple contingency events	Achieved	Achieved	
8 – Largest generation event in Tasmania	Not Applicable	Achieved	

4. Frequency performance

This section describes frequency performance in the relevant quarter against each of the significant requirements in the FOS.

4.1 Time error

Table A.2 of the FOS (requirement 1) specifies that the accumulated time error should be maintained within the range ±15 seconds in the mainland (except for an island or during supply scarcity) and in Tasmania (except for an island or following a multiple contingency event). The ranges of accumulated time error in the mainland and Tasmania in Q1 2020 are provided in Table 2.

A negative time error accumulated in the mainland frequency area not including South Australia during the South Australia separation event on 31 January 2020 from 1401 to 1753 hrs. The accumulated time error exceeded -15s and reached -17.10s at 1453 hrs. This did not meet the FOS.

A negative time error accumulated in Tasmania during the South Australia separation event on 31 January 2020 from 1401 to 1700 hrs. The accumulated time error exceeded -15s and reached -16.99s at 1453 hrs. AEMO considers this remained within the FOS requirements as the time error was initiated by the multiple contingency event in Victoria.

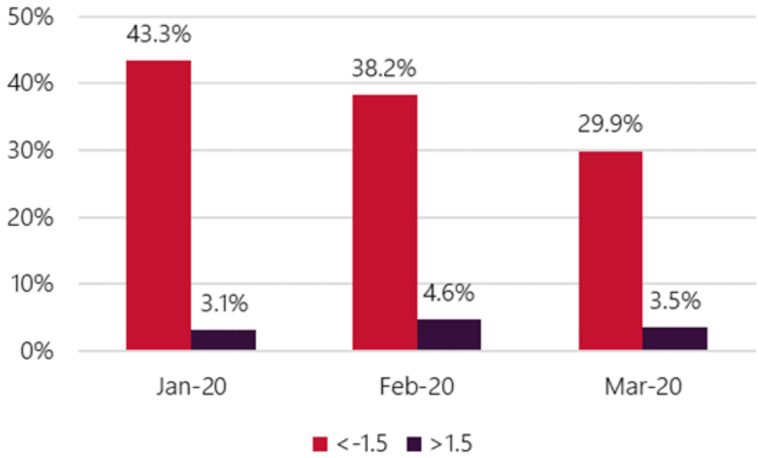
Table 2 Maximum and minimum time error measurements for mainland and Tasmania

Value	Mainland	Tasmania
Highest positive time error (seconds)	11.93	10.58
Lowest negative time error (seconds)	-17.10	-16.99

Figure 1 shows the percentage of time where mainland time error was outside the ±1.5 second threshold at which accumulated time error begins to increase Regulation FCAS volumes above their base values.

During Q1 2020, the incidence of negative time errors exceeding this threshold decreased. The exact drivers of this are unclear but would be heavily influenced by the system issues – in particular, separation events – that occurred during the first half of the quarter.

Figure 1 Proportion of time mainland time error was outside of +/-1.5 seconds



4.2 Operation during periods without contingencies or load events

When there are no associated contingency or load events in the interconnected system, table A.2 of the FOS (requirement 2) specifies that system frequency should be maintained within the applicable normal operating frequency excursion band (NOFEB) and not remain outside the applicable normal operating frequency band for more than five minutes on any occasion and for not more than 1% of the time over any 30 day period[5]. These requirements are summarised in Table 3.

Table 3 FOS requirements for no contingency or load event in 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	

4.2.1 Frequency excursions without a contingency event outside the NOFEB

Frequency excursions outside the applicable NOFEB where an associated contingency event has not been identified are shown in Table 4 for Q1 2020.

Table 4 Number of frequency excursions without identified contingency outside the NOFEB

Event	Low/High/Both frequency event	Number of events	
		Mainland	Tasmania
No contingency or load event noted	LOW	1	13
	HIGH	1	10
	BOTH	0	1

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

Mainland

The low frequency event noted in Table 4 occurred on 2 January 2020. At 1535 hrs, mainland frequency dropped rapidly from within the NOFB to 49.72 Hz. Frequency recovery to within the NOFB occurred rapidly, by 15:35:12 (12 seconds later). A limited investigation did not identify an individual generation or load event as the cause.

The high frequency event noted in Table 4 occurred on 28 January 2020. Mainland frequency remained above the NOFB during the period from approximately 1720 to 1830 hrs. Maximum frequency observed was 50.27 Hz at 1829 hrs. The cause has been identified as an NSW demand calculation error, resulting from a failure to correctly set the initial conditions of a new commissioning generating system in the EMS. The demand error increased over the period 1700 hrs to 1830 hrs as the actual load dropped off, reaching a maximum of around 900 MW before the issue could be resolved. This impacted dispatch across the NEM.

AEMO is treating this event as a scheduling error and has taken the following actions to minimise the risk of recurrence, including:

- Having reviewed the process for loading new generation into the EMS, documentation has been improved and new checks have been put in place.
- Additional alarms have been built into the system to identify such an issue.
- AEMO's interfaces have been updated to assist with triage of data integrity errors.

Tasmania

The number of Tasmanian events where frequency exceeded the NOFEB in Q1 2020 without an associated contingency event is characteristic of the smaller Tasmania system and is in line with recent quarters. Under system normal conditions, the FOS specifies largely the same requirements for Tasmania as it does for the mainland. However, as a much smaller system, Tasmania is much more sensitive to supply/demand imbalances which manifest as larger frequency deviations. Further, frequency performance in Tasmania is largely dictated by the performance of the mainland, due to Basslink's frequency controller, meaning that most frequency issues occurring while Tasmania is interconnected need to be addressed by improving frequency control in the mainland.

4.2.2 Frequency excursions without a contingency event outside the NOFB and not recovered in FOS timeframe

Frequency excursions outside the applicable NOFB where an associated contingency event has not been identified and where the frequency did not recover inside the NOFB within five minutes are shown in Table 5 for Q1 2020.

Table 5 Number of frequency excursions without identified contingency outside the NOFB and not recovered in the FOS timeframe

Event	Low/High/Both frequency event	Number of events	
		Mainland	Tasmania
No contingency or load event noted	LOW	1	1
	HIGH	1	1
	BOTH	0	0

Mainland

On 20 January 2020, between 12:59 and 13:12, mainland frequency cycled across the lower NOFB threshold without recovering. No specific individual generation or load event has been identified as the root cause of this frequency deviation. Rather, AEMO's investigation suggest several coincident events collectively contributed to this deviation. These include the operation of several units outside their regulation limits (likely due to governor control action) and a rapid reduction in distributed solar generation in the Sydney region due to fast-moving cloud. This unscheduled generation tail-off increased the supply/demand mismatch while FCAS was trying to recover the frequency. This kind of behaviour is monitored in order to inform decisions about quantities of FCAS. The Mandatory Primary Frequency Response rule[6] is also expected to assist with similar issues by ensuring that all capable generating systems operate in a frequency-sensitive manner. The high frequency event in Table 5 occurred on 28 January 2020 and was discussed in Section 4.2.1.

Tasmania

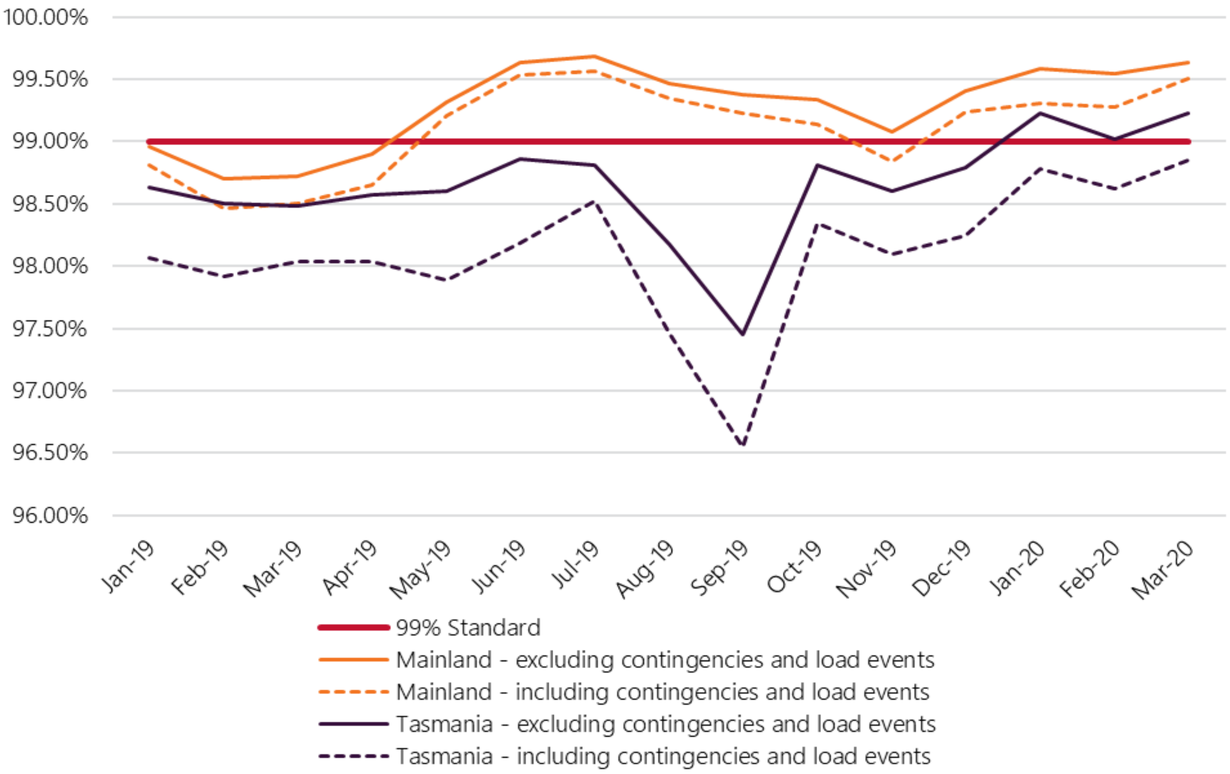
The low frequency event in Tasmania shown in Table 5 was the same event affecting the mainland on 20 January 2020, as discussed above. The high frequency event was the same event affecting the mainland on 28 January 2020, as discussed in Section 4.2.1. In both events Tasmanian frequency closely followed the mainland frequency.

4.2.3 Frequency within the NOFB over 30-day rolling average

AEMO calculates the percentage of time that frequency remained inside the NOFB daily. The minimum daily estimate in the preceding 30-day window from the last day of each month is reported in Figure 2. The figure shows statistics both including and excluding data during contingency events. The FOS requirement excludes periods of contingency or load events.

Frequency in the mainland and Tasmania remained within the NOFB for an increased percentage of time on average over summer, likely assisted by elevated demand and lower instantaneous penetrations of asynchronous units. Tasmania's frequency (excluding contingencies) returned above the 99th percentile required by the FOS.

Figure 2 Frequency within the NOFB, minimum daily percentage of time over preceding 30-day window



[6] *National Electricity Amendment (Mandatory primary frequency response) Rule 2020 No. 5*, made 26 March 2020. Substantive provisions effective 4 June 2020.

4.2.4 Frequency performance within the NOFB

Currently, the FOS does not include requirements for the control of frequency *within* the NOFB. However, frequency performance within the NOFB is important as it demonstrates the overall tightness and stability of frequency and indicates the likelihood of frequency being close to nominal when a contingency event occurs, greatly increasing the prospects of good containment and fast recovery.

The frequency distribution in the mainland and Tasmania over Q1 2020 is shown in Figure 3 and Figure 4 and compared with data from 2010, as an example of a period where frequency control was significantly tighter.

Figure 3 Mainland frequency distribution

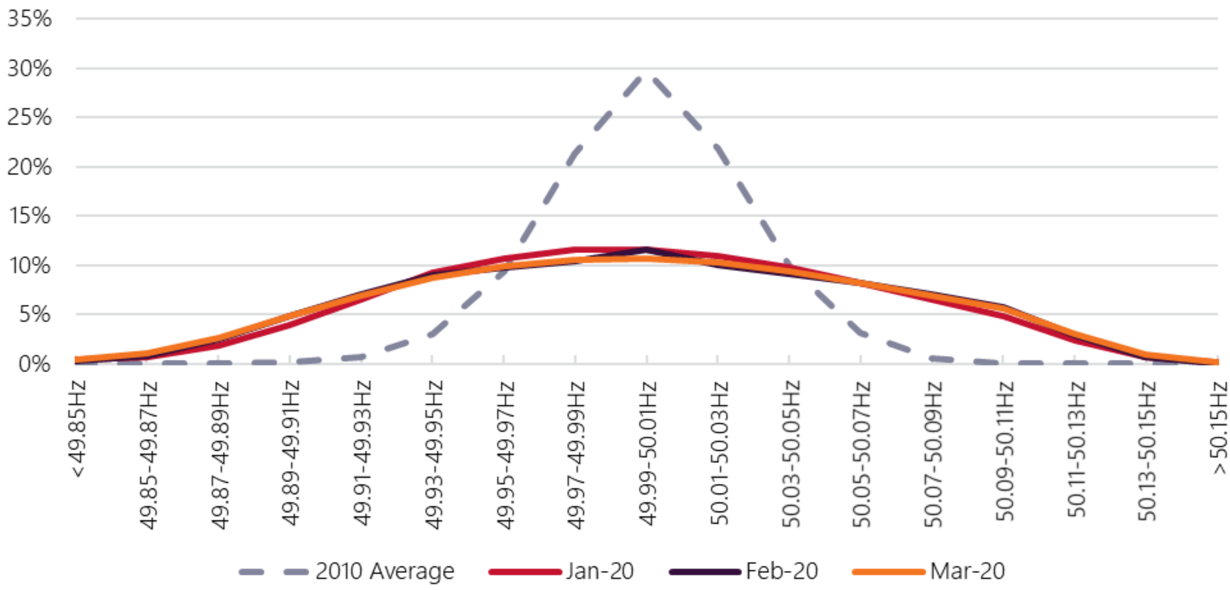


Figure 4 Tasmania frequency distribution

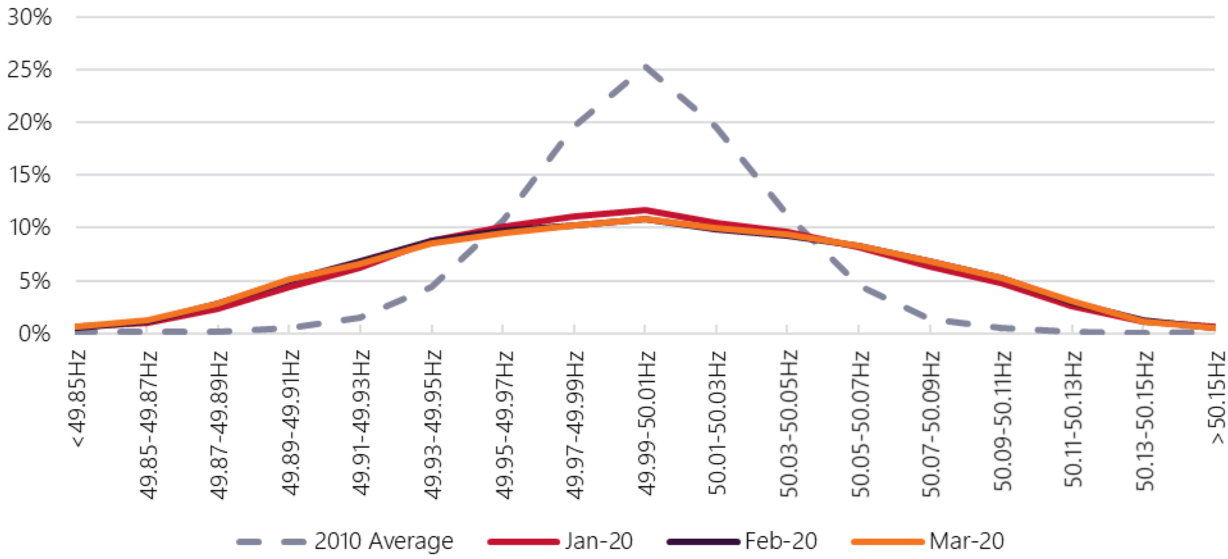
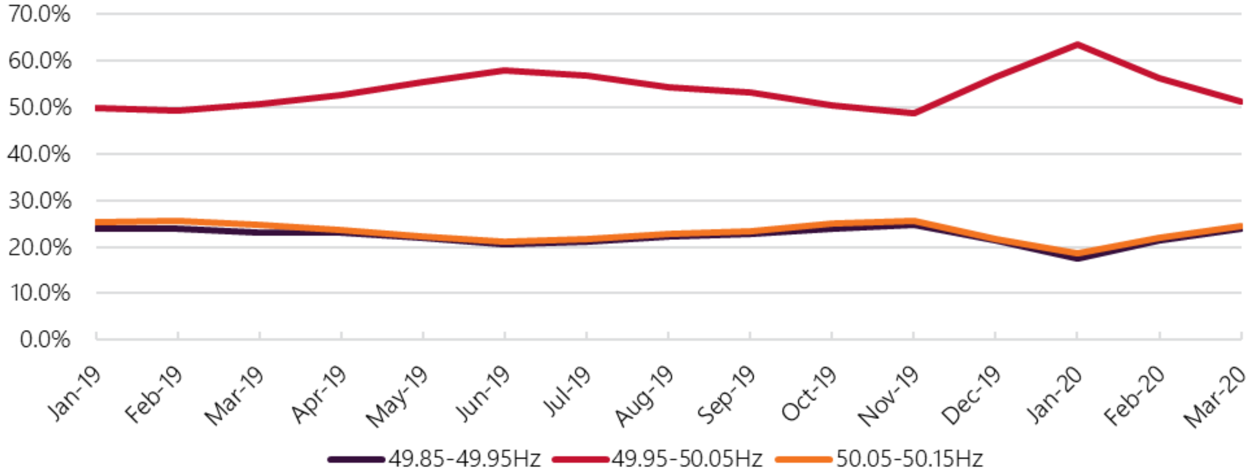


Figure 5 shows that when the frequency is *within* the NOFB in the mainland, the proportion of time that frequency is close to the boundaries of the NOFB was largely unchanged in Q1 2020, despite the slight reduction in the proportion of time spent *outside* the NOFB. In other words, while frequency performance *outside* the NOFB has changed, this is not reflected by performance *inside* the NOFB.

Figure 5 Mainland frequency time percentage spent within selected bands within the NOFB



4.3 Operation during generation or load contingency events

When there is an associated generation or load event in an interconnected system, table A.2 of the FOS (requirement 3) provides that while the entire system is interconnected, system frequency should be maintained within the applicable generation and load change band (GLCB) and not remain outside the applicable NOFB for more than five minutes in the mainland or more than 10 minutes in Tasmania, as described in Table 6.

Table 6 FOS requirements for a generation or load event in an interconnected system

Region	Containment	Stabilisation	Recovery
Mainland	49.5 to 50.5 Hz	49.85 to 50.15 Hz within 5 minutes	
Tasmania	48.0 to 52.0 Hz	49.85 to 50.15 Hz within 10 minutes	

4.3.1 Frequency excursions following a generation or load event outside the GLCB

As shown in Table 7, no events occurred during Q1 2020 in the mainland or Tasmania where there was a frequency excursion following a generation or load event outside of the applicable GLCB.

Table 7 Number of frequency excursions following a generation or load event outside the GLCB

Event	Low/High/Both frequency event	Number of events	
		Mainland	Tasmania
Load event	LOW	0	0
	HIGH	0	0
	BOTH	0	0
Generation event	LOW	0	0
	HIGH	0	0
	BOTH	0	0

4.3.2 Frequency excursions following a generation or load event not recovering to the NOFB within the FOS timeframe

Table 8 summarises the number of events during Q1 2020 following a generation or load event in the mainland or Tasmania where there was a frequency excursion that was not recovered to the NOFB within the applicable FOS timeframe (typically 5 minutes, or 300 seconds).

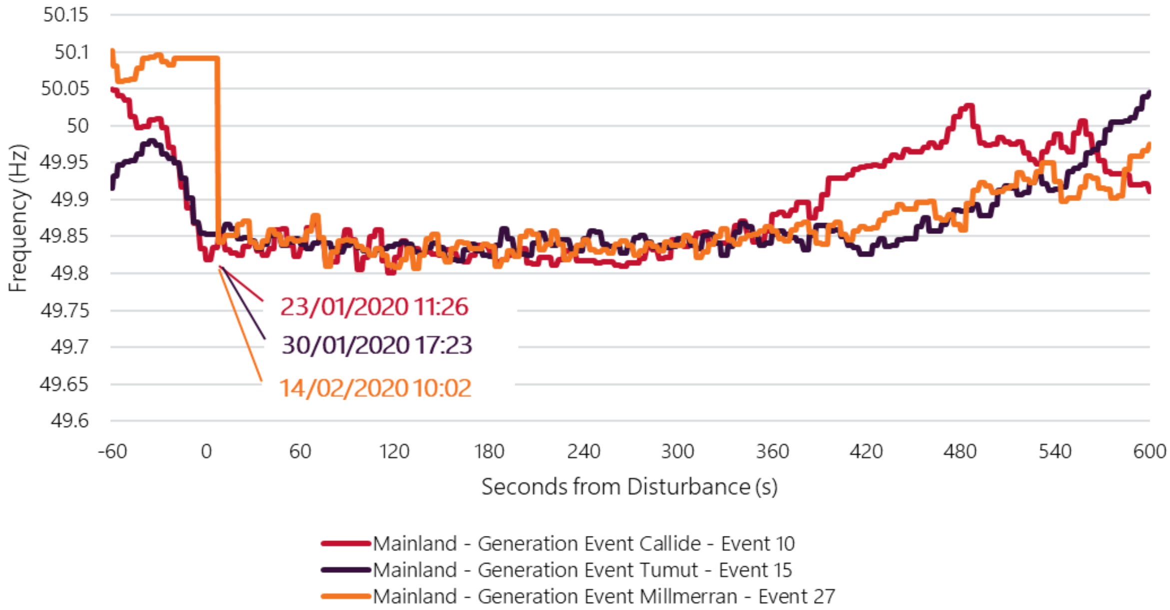
Table 8 Number of frequency excursions following a generation or load event not recovered to the NOFB within the FOS timeframe

Event	Low/High/Both frequency event	Number of events	
		Mainland	Tasmania
Load event	LOW	0	0
	HIGH	0	0
	BOTH	0	0
Generation event	LOW	3	0
	HIGH	0	0
	BOTH	0	0

Mainland

Three mainland generation events did not see recovery to the NOFB within the FOS timeframe of 5 minutes (300 seconds). The mainland frequency during the pre-event and post-event periods is provided in Figure 6.

Figure 6 **Frequency excursions following generation or load events not recovered to the NOFB within the FOS timeframe**



Recovery of frequency following such events is assisted by the operation of the Slow and Delayed FCAS services. Assessments of the delivered Slow Raise and Delayed Raise FCAS during these three events indicate that only a portion of enabled Delayed Raise (R5) FCAS was supplied. This is not necessarily a failure on the part of suppliers. These three events were all characterised by a relatively shallow frequency nadir, not lower than 49.80 Hz. Most providers of Delayed Raise FCAS using switched controllers would not have triggered during these events, as their assigned trigger thresholds tend to be lower (between 49.5 Hz and 49.7 Hz). Without their contribution, the FCAS response to assist recovery to the NOFB would rely heavily on AGC (via Regulation FCAS), which may at times not be sufficient. Importantly, these events may also have been influenced by other factors; for example, lower than expected output from variable renewable plant, and/or underestimation of system load by the forecasting system. Nonetheless, it is apparent that for some events, the 'gap' between the edge of the NOFB and the frequency band where switched FCAS providers are active needs to be considered further by AEMO.

Table 9 **Slow and Delayed service delivery during generation events not recovered to the NOFB within the FOS timeframe**

Event	Time	R60 Enabled (MW)	R60 Delivered (MW)	R5 Enabled (MW)	R5 Delivered (MW)	R5 Enabled Switch Controlled Not Triggered (MW)
Generation event – Callide	23/01/2020 11:26	441	610	332	111	244
Generation event – Tumut	30/01/2020 17:23	455	382	245	144	97
Generation event – Millmerran	14/02/2020 10:02	541	502	451	54	324

The delivered quantities represent assessed FCAS response, which is different to actual megawatt (MW) output change from enabled generators. Full details on calculation of the FCAS response are provided in the

Market Ancillary Services Specification (MASS)[7]. Further, the assessments here exclude several relatively new providers of FCAS, including VPPs and batteries, due to their unique data arrangements.

Tasmania

No frequency excursions in Tasmania exceeded the FOS timeframe for recovery to the NOFB following a generation or load event.

4.3.3 Frequency performance following generation or load events

AEMO assesses frequency performance over time with metrics complementary to the requirements of the FOS. Several generation and load events occurred in Q1 2020 which demonstrate the frequency response characteristic of the system despite these events remaining within the boundaries of the FOS.

There continues to be adequate containment of generation and load events well within the GLCB and frequency recovers to the NOFB within the FOS timeframe during the majority of events, except those discussed in Section 4.3.2.

4.4 Operation during separation contingency events

When there is a separation event, table A.2 of the FOS (requirement 5) provides the initial frequency containment, recovery, and revised requirements for further contingency events in the islanded region. AEMO should maintain system frequency within the applicable containment band and should recover frequency to the NOFB within the FOS timeframe.

4.4.1 Frequency excursions following separation events not contained or managed within FOS requirements until resynchronisation

As shown in Table 10, no separation events occurred during Q1 2020 in the mainland or Tasmania where a frequency excursion was not contained and managed until synchronisation within the FOS timeframe.

Table 10 Number of occurrences of separation events in which frequency was not contained or managed until resynchronisation within FOS

Event	Low/High/Both frequency event	Number of events				
		Queensland	New South Wales	Victoria	South Australia	Tasmania
Separation event	LOW	0	0	0	0	0
	HIGH	0	0	0	0	0
	BOTH	0	0	0	0	0

4.4.2 Frequency performance following separation events

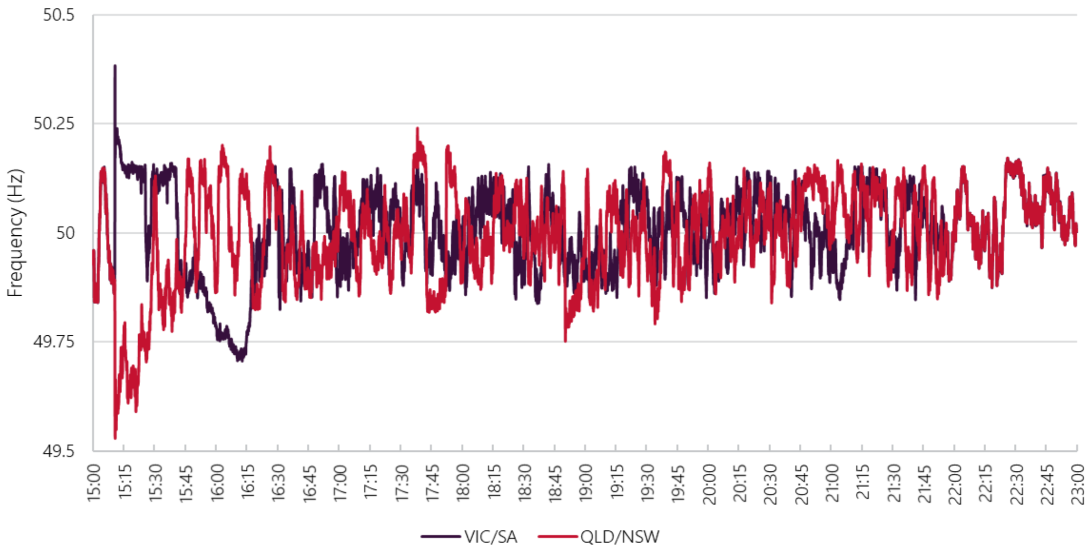
AEMO assesses frequency performance over time with metrics complementary to the requirements of the FOS. Several separation events occurred in Q1 2020 which demonstrate the frequency response characteristic of the system despite remaining within the boundaries of the FOS.

[7] See https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/ancillary-services/market-ancillary-services-specification-and-fcas-verification-tool.

4 January 2020

A preliminary investigation into the separation of Victoria and South Australia from Queensland and New South Wales on 4 January 2020, due to bushfires in the Snowy Mountains region, has been published[8]. The frequency of both areas was contained within the island separation band (49-51 Hz) and remained within the FOS requirements for a separation caused by a credible contingency until resynchronisation.

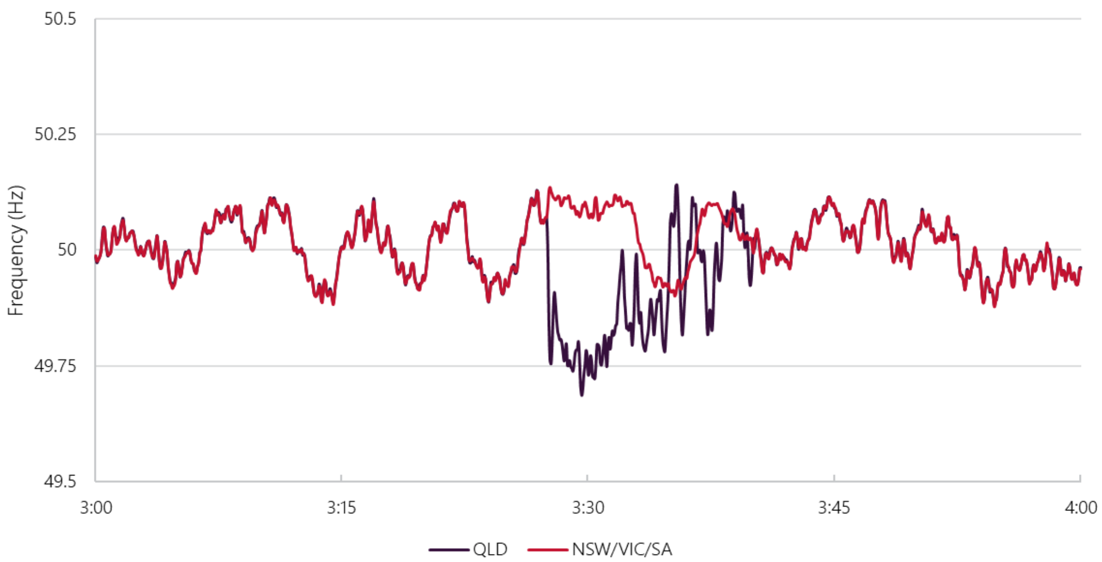
Figure 7 Frequency in mainland areas following Victoria – New South Wales separation on 4 January 2020



7 January 2020

Queensland separated from the mainland NEM on 7 January 2020. The frequency of both the Queensland island and the mainland was contained within the island separation band (49-51 Hz) and remained within the FOS requirements for a separation caused by a credible contingency until resynchronisation.

Figure 8 Frequency in mainland areas following Queensland separation 7 January 2020



[8] See https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2020/preliminary-report-nsw-and-victoria-separation-event-4-jan-2020.pdf?la=en.

31 January 2020 – 17 February 2020

AEMO has published a preliminary report on the non-credible separation of South Australia from the mainland on 31 January 2020 due to loss of the Moorabool – Mortlake 500 kV line and the Moorabool – Haunted Gully 500 kV line[9]. The frequency of the mainland and South Australia islands (including the extended island incorporating part of the Western Victoria system) was contained within the FOS requirements for a non-credible contingency and otherwise remained within the FOS until resynchronisation.

Figure 9 Frequency in mainland areas following South Australia separation 31 January 2020

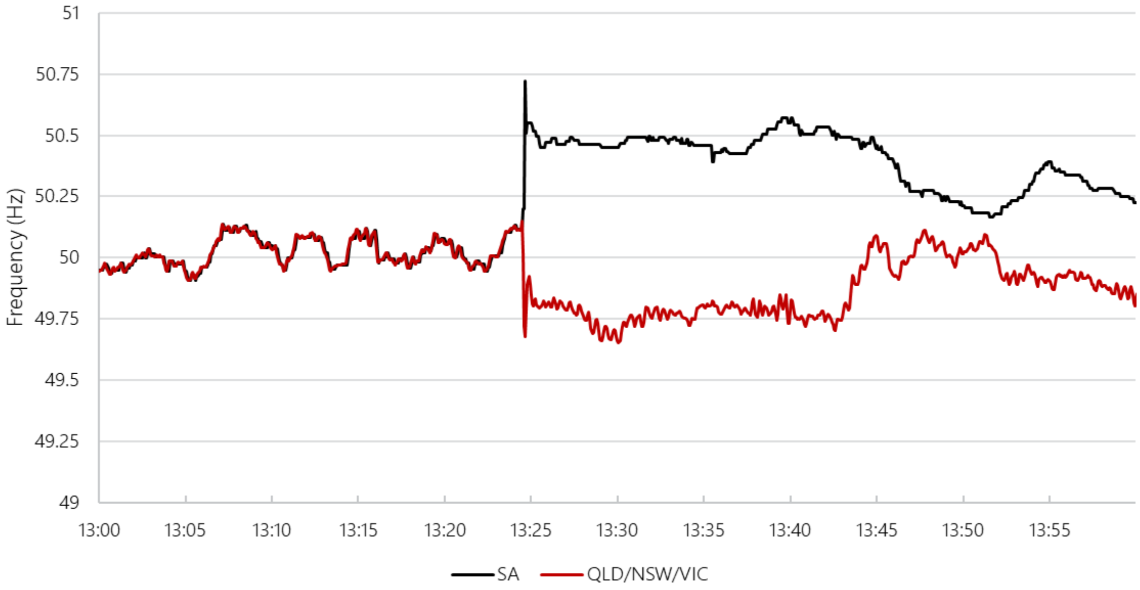
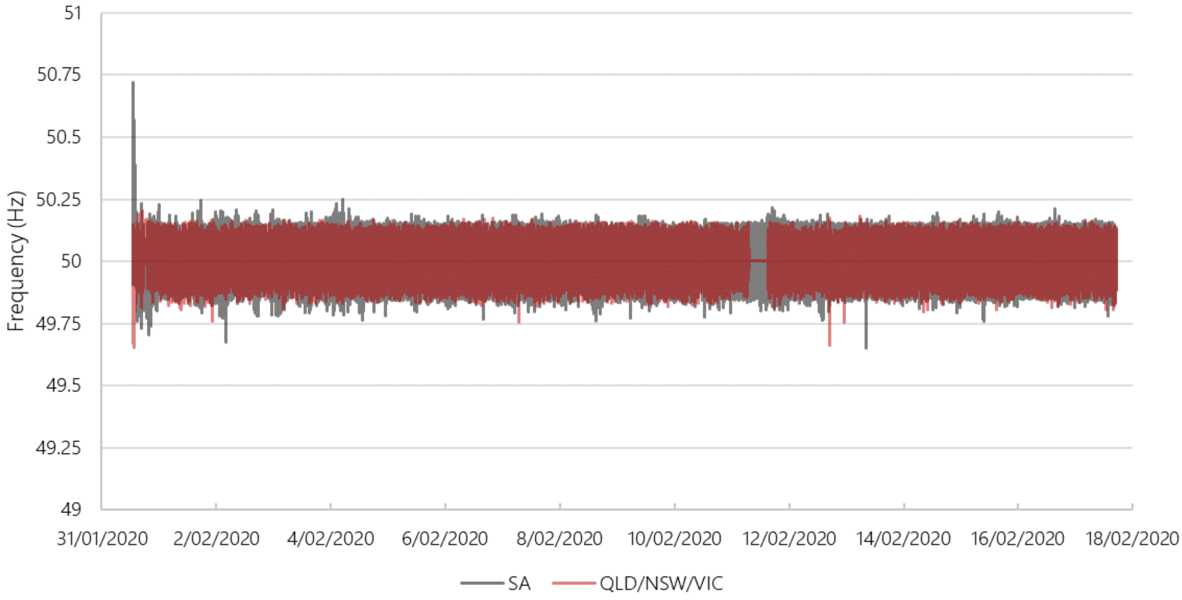


Figure 10 Frequency in mainland areas following South Australia separation 31 January 2020

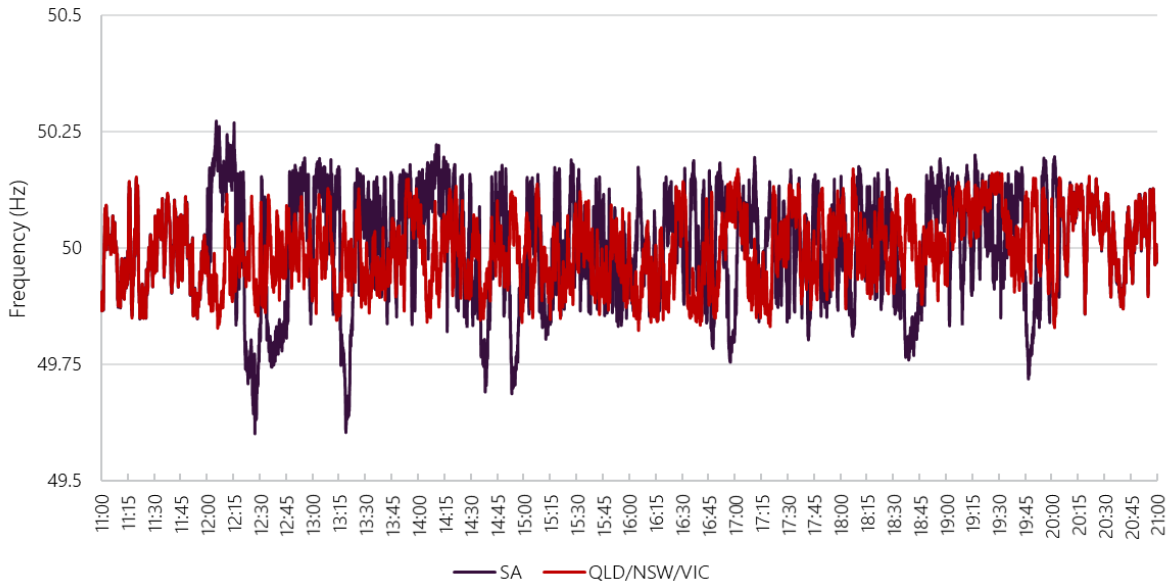


[9] See https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2020/preliminary-report-31-jan-2020.pdf?la=en.

2 March 2020

On separation of South Australia from the mainland on 2 March 2020, the frequency of both the South Australia island and the rest of the mainland was contained within the island separation band and remained within the FOS requirements for a separation caused by a credible contingency until resynchronisation.

Figure 11 Frequency in mainland areas following South Australia separation 2 March 2020



4.5 Operation during network, protected, non-credible, or multiple contingency events

When there is a network contingency, protected event, non-credible contingency, or multiple contingency event in an interconnected system, table A.2 of the FOS (requirements 4 to 7) provides that while the entire system is interconnected, system frequency should be maintained within the applicable containment band and recover to the NOFB within the FOS timeframe.

4.5.1 Frequency excursions following network, protected, non-credible or multiple contingency events not within the FOS

As indicated in Table 11, no events occurred during Q1 2020 in the mainland and Tasmania where a frequency excursion following a network event, protected event, non-credible event, or multiple contingency event was not contained within the applicable containment band and/or not recovered to the NOFB within the FOS timeframe.

Table 11 Number of frequency excursions following a network, protected, non-credible, or multiple contingency event not within the FOS

Event	Low/High/Both frequency event	Number of events	
		Mainland	Tasmania
Network event	LOW	0	0
	HIGH	0	0
	BOTH	0	0
Protected event	LOW	0	0
	HIGH	0	0
	BOTH	0	0
Non-credible event	LOW	0	0
	HIGH	0	0
	BOTH	0	0
Multiple contingency event	LOW	0	0
	HIGH	0	0
	BOTH	0	0

5. Rate of change of frequency

5.1 ROCOF methodology

The rate of change of frequency (ROCOF) following a frequency event is an indicator of the evolving system response to frequency disturbances. Measuring a system variable such as ROCOF is influenced by several assumptions concerning the available data and measurement methodology. This ROCOF methodology used snapshots of measured frequency from the AEMO/TNSP PMU system at 1-second intervals, which is a higher resolution than is available from the GPS clock system and more appropriate for assessing ROCOF.

For the purposes of this report, ROCOF has been assessed as the recorded change in frequency per second over an interval of one second, or over an interval of two seconds when the measurement interval in between is not available. No ROCOF assessment has been attempted for periods without data longer than 2 seconds. For the purposes of this report, the maximum ROCOF recorded between 5 seconds prior to 30 seconds following each frequency event is considered to be the ROCOF associated with that event.

$$If\ 1s\ data\ available\ then\ ROCOF_t = MAX\left(ABS\left(\frac{f_{t+1} - f_t}{t_{t+1} - t_t}\right)\right) \forall\, t$$

$$else\ \ if\ 2s\ data\ available\ then\ ROCOF_t = MAX\left(ABS\left(\frac{f_{t+2} - f_t}{t_{t+2} - t_t}\right)\right) \forall\, t$$

$$else\ no\ measurement\ attempted,$$

Where:

(i) **f** is system frequency

(ii) **t** is time in seconds

5.2 ROCOF during frequency events

The maximum ROCOF recorded each month, and any other ROCOF exceeding the standard Frequency Ramp Rate for the mainland as specified in the MASS of 0.125Hz/s, is provided in Table 12. The MASS's standard frequency ramp rate is used as a standardised value for assessing FCAS capability. In real events, and especially in islanded systems, the ROCOF can be quite different.

Table 12 ROCOF during frequency events in Q1 2020 in the mainland

Month	ROCOF (Hz/s)	Associated event	Event time
January	0.22	Victoria/South Australia separation from New South Wales/Queensland (Victoria/South Australia island)	04/01/2020 15:11
	0.60	South Australia separation from mainland (South Australia island)	31/02/2020 13:24
	0.15	South Australia separation from mainland (mainland excluding South Australia)	31/02/2020 13:24
February	0.09	Trip of Eraring unit	21/02/2020 14:18
March	0.10	Trip of Bayswater unit	22/03/2020 18:40

Note: Estimates of ROCOF may vary significantly depending on data source, sampling window and calculation method.

6. Automatic Generation Control

6.1 ACE methodology

As per the Regulation FCAS Contribution Factors Procedure[10], AEMO first calculated an area control error (ACE), representing the MW equivalent size of the current frequency deviation and accumulated frequency deviation (time error) of the system.

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

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

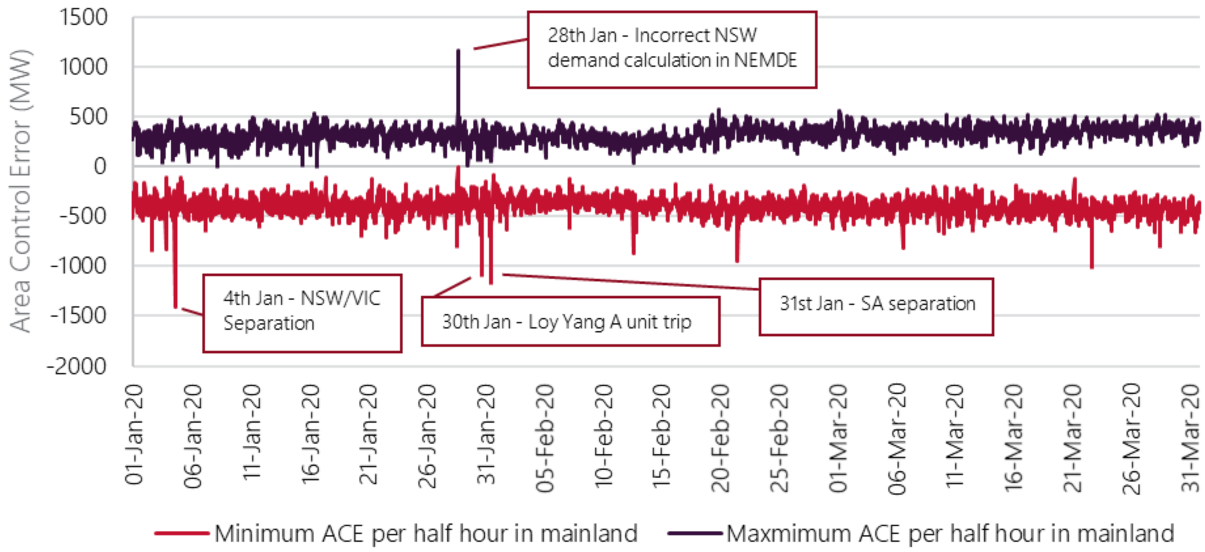
(iv) **FO** is a frequency offset representing accumulated frequency deviation, i.e. time error.

6.2 ACE reporting

Figure 12 and Figure 13 show a comparison of the minimum and maximum ACE per dispatch intervals in the mainland and Tasmania in Q1 2020.

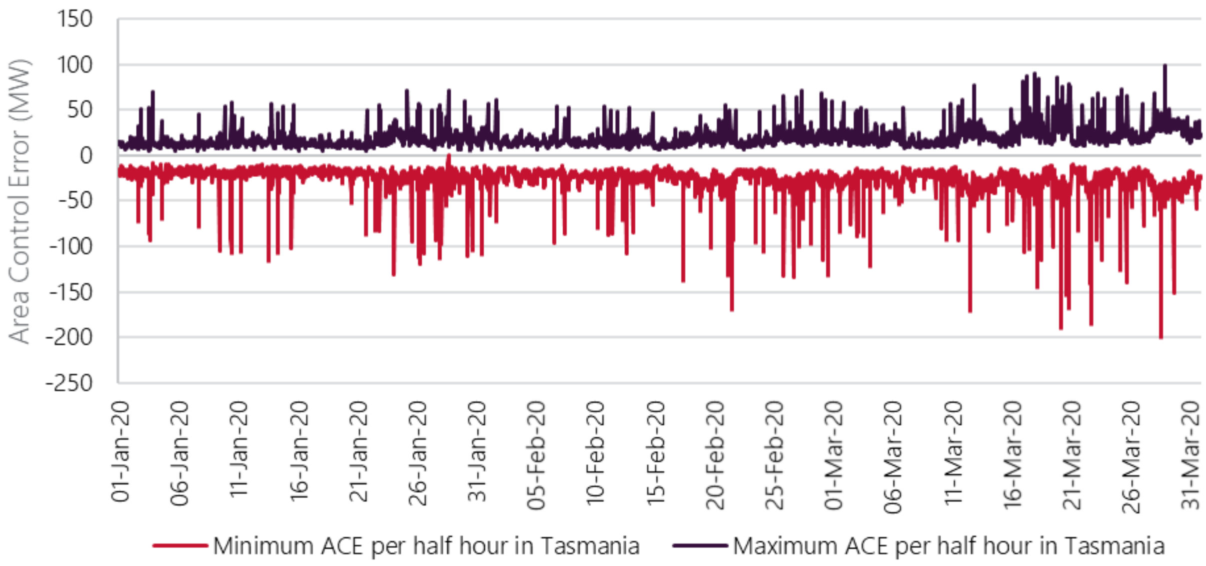
ACE represents a rough proxy for the required regulation FCAS volume.

Figure 12 Minimum and maximum ACE per half-hour in mainland



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

Figure 13 Minimum and maximum ACE per half-hour in Tasmania



7. Reviewable operating incidents

A list of reviewable operating incidents for Q1 2020 is provided in Table 13. This list reflects the incidents AEMO is required to review under the guidelines for identifying reviewable operating incidents[11].

Table 13 Reviewable operating incidents in Q1 2020

Event	Date	Maximum/minimum frequency (Hz)	Description
South Australia separation	31 January 2020	51.11 Hz in South Australia island	The separation of South Australia from the mainland due to the loss of the loss of the Moorabool – Mortlake 500 kV line and the Moorabool – Haunted Gully 500 kV line.

[11] See https://www.aemc.gov.au/sites/default/files/2018-02/Final-revised-guidelines.pdf.

8. Actions to improve frequency control performance

8.1 Recent updates

The general decline in frequency control performance under normal conditions in the NEM has been well documented and is the subject of many inter-related areas of work. The following measures are underway to improve frequency control performance in line with the requirements of the FOS.

- AEMO progressively increased base Regulation FCAS volumes between March and May 2019, with base volumes remaining now at 220/210 MW Raise/Lower.
- The final step change in mainland load relief to 0.5% was completed on 16 January 2020. This series of changes resulted in an increase in contingency FCAS volumes, particularly for Fast Raise and Lower services. No further changes are currently planned. AEMO will monitor load relief periodically.
- AEMO has started to revise switched controller settings to trigger frequency response earlier during a frequency excursion. The updated settings are expected to be implemented in Q2 2020.
- Weekly frequency reporting commenced from 1 Jan 2020 as required by NER 4.8.16(a). All available weekly reports are available on AEMO's website[12].
- Quarterly frequency reporting has been aligned with the requirements in NER 4.8.16(b).

8.2 Primary frequency response initiative

AEMO intends to use part of this quarterly report to document progress on the implementation of the Mandatory Primary Frequency Response (PFR) rule and particularly the changes in frequency performance associated with the implementation of that rule. A summary of this Rule, from the Australian Energy Market Commission's (AEMC's) web page[13] is provided below:

On 26 March 2020, the Commission made a final rule to require all scheduled and semi-scheduled generators in the NEM to support the secure operation of the power system by responding automatically to changes in power system frequency.

The final rule is designed to address the immediate need to improve frequency control as identified by AEMO and the other rule change proponent Dr Peter Sokolowski. The substantive elements of the final rule commence on 4 June 2020 and sunset after 3 years on 4 June 2023.

Key aspects of the final rule include:

- *All scheduled and semi-scheduled generators, who have received a dispatch instruction to generate to a volume greater than 0 MW, must operate their plant in accordance with the performance parameters set out in the Primary frequency response requirements (PFRR) as applicable to that plant*
- *AEMO must consult on and publish the PFRR, which will specify the required performance criteria for generator frequency response, which may vary by plant type.*

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[12] See https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/ancillary-services/frequency-and-time-deviation-monitoring.

[13] See https://www.aemc.gov.au/rule-changes/mandatory-primary-frequency-response.

Generators may request and AEMO may approve variations or exemptions to the PFRR for individual generating plant.

While the Mandatory PFR rule commences from 4 June 2020, actual physical changes to generating plant controls (and therefore frequency performance) will not occur till some months after, as these changes must be carefully assessed and then rolled out across the fleet in a prudent and manageable way. Current plans are for at least the first stage of this rollout, which affects generators which are 200 MW or greater, to be completed prior to summer 2020.

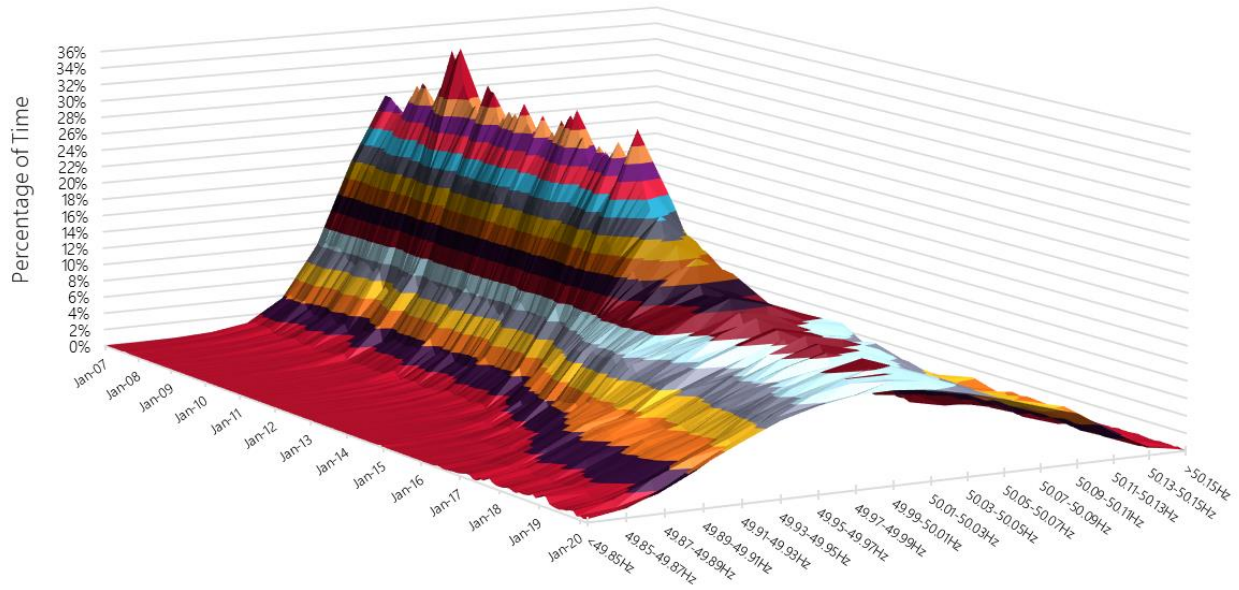
AEMO has created a new area on its website that will contain all information and documentation relating to Mandatory PFR[14]. In particular, at this time AEMO wishes to draw participants' attention to the draft Primary Frequency Response Requirements (PFRR), scheduled to be finalised by end May 2020.

In this quarterly report, AEMO will set out a range of metrics which are intended to document aspects of frequency control that are not necessarily directly related to requirements in the FOS, but that may be important indicators of the level of performance improvement related to the implementation of the Mandatory PFR rule.

8.2.1 Measure 1 – Distribution of frequency within NOFB

This measure examines the distribution of frequency within the NOFB. It is apparent that over time, and particularly since approximately 2014-15, there has been a dramatic flattening of frequency within the NOFB. This means frequency is spending far more time out towards the edges of the NOFB than it used to. Among other things, this means that when a contingency event occurs, the resulting frequency change is far more likely to deviate significantly away from 50 Hz.

Figure 14 Monthly frequency distribution



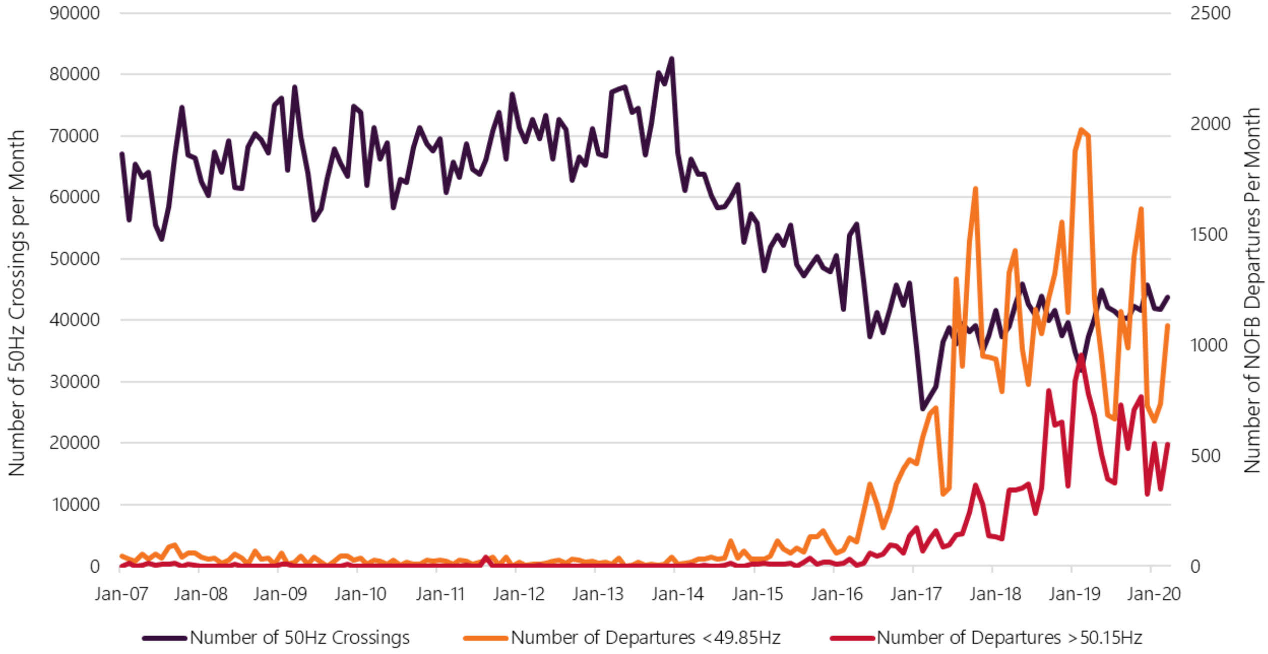
8.2.2 Measures 2 and 3 – Number of frequency crossings and NOFB excursions

These measures examine the number of times frequency crosses the nominal 50 Hz target, and also how often frequency departs the NOFB. There has been a dramatic increase in the number of instances where frequency departs the NOFB over the last few years. Interestingly, there has also been a significant decline in the number of zero crossings, which probably relates to the fact frequency tends to spend much more time

[14] See https://aemo.com.au/initiatives/major-programs/primary-frequency-response

away from 50 Hz, and therefore does not have as many ‘opportunities’ to cross. Therefore, the average number of zero crossings is likely to increase if frequency is held much more tightly around 50 Hz.

Figure 15 Monthly frequency crossings – under 49.85Hz, across 50Hz, beyond 50.15Hz



8.2.3 Measure 4 – Frequency ‘mileage’

This measure examines the total amount of change in frequency over time. This measure is important in that it is another way of measuring how stable frequency is; that is more stable frequency will see a lower mileage. A simple demonstration of the calculation method is provided below. The final estimate of mileage is highly dependent on the selection of the length of time interval and the measurements below are derived from 4-second intervals.

Table 14 Example frequency mileage calculation for a series of 4s intervals

Sample	0s	4s	8s	12s	Mileage Sum
NSW frequency (Hz)	50	50.5	49.5	50	
Mileage (Hz)		ABS(50.5-50)=0.5	ABS(49.5-50.5)=1.0	ABS(50-49.5)=0.5	0.5+1.0+0.5 = 2.0Hz

Frequency mileage per month has been increasing steadily since 2007, as demonstrated in Figure 16. Recent increases in Regulation FCAS and Contingency FCAS volumes do not appear to have had any discernible impact on frequency mileage.

Figure 16 Monthly frequency mileage