Frequency and Time Error Monitoring – Quarter 2 2020

August 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 April to June 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 April, May, and June 2020 in all regions of the National Electricity Market (NEM) as required by clause 4.8.16(b) of the National Electricity Rules (NER)[2]. The Queensland, New South Wales, Victoria and South Australia regions 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 is 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

The April to June 2020 quarter was unexceptional, following the challenging system conditions that occurred in the preceding quarter. The shoulder season featured milder weather, lower demand and fewer power system incidents which collectively contributed to improved frequency performance throughout the period.

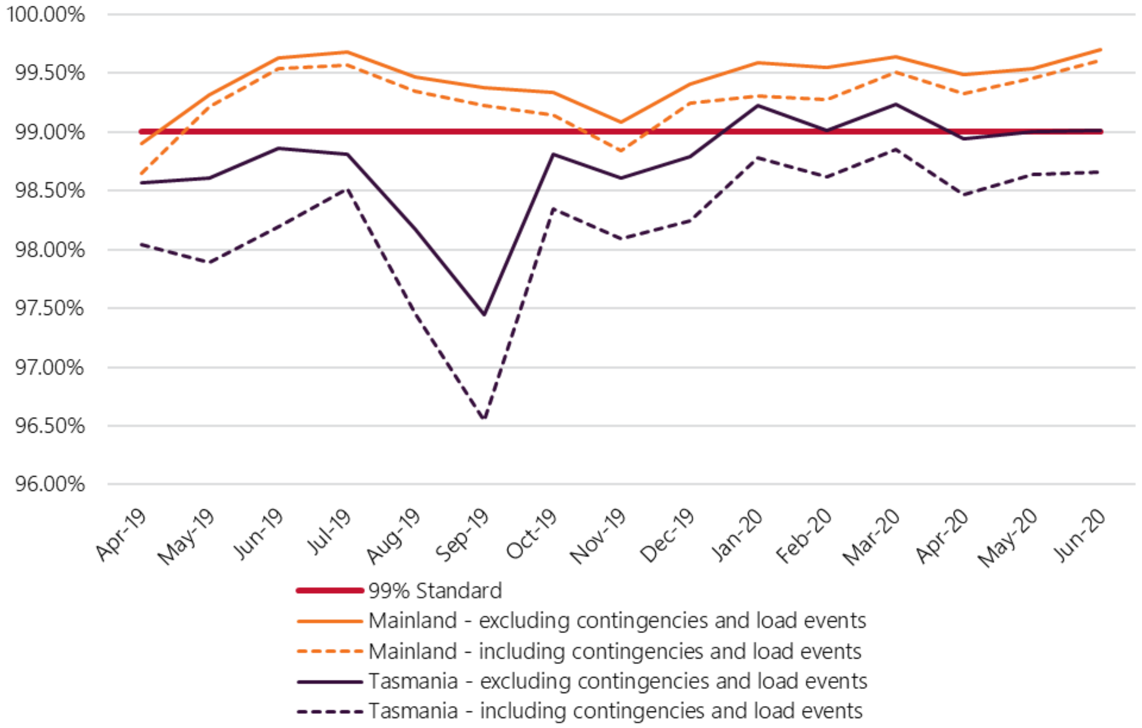
Section 3 of this report summarises how frequency control in the quarter performed against the FOS. The important requirement to keep frequency within the NOFB for more than 99% of the time was improved compared to the corresponding quarter last year. Tasmania's frequency remained at or near the 99th percentile required by the FOS while mainland performance exceeded the FOS across the quarter, as shown below.

[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.

Figure 1 Frequency within the NOFB, minimum daily percentage of time over preceding 30-day window



Two notable non-credible events occurred during the quarter:

- The simultaneous trip of Yallourn units 1, 3 and 4 and the Macarthur Wind Farm on 11 April 2020.
- Trip of Vales Point units 5 and 6 on 7 June 2020.

Overall, frequency control performance during both of these significant events was encouraging. In both cases frequency was contained within the limits for a credible event despite these being non-credible multiple contingency events.

A further notable incident during the quarter involved the failure of FCAS regulation to be dispatched for one hour on 16 April 2020 due to a systems failure.

These events are all described in further detail in this report. Identified instances where the requirements of the FOS were not met are also discussed.

While the FOS requirements were met in most instances over the quarter, there remain aspects of the prevailing frequency control arrangements in the NEM that are a concern to AEMO. These risks have been discussed extensively in various reports and forums, and include:

- Poor frequency control within the normal operating frequency band (NOFB) – where frequency control continues to be insufficient and exhibits aspects of oscillatory behaviour.
- Frequent excursions from the NOFB – poor control within the NOFB is contributing to a high number 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. A small improvement was observed this quarter.
- Unpredictable frequency behaviour – frequency behaviour during anything other than a clearly defined single credible contingency is difficult to predict and can be highly variable.

AEMO, with support from the industry, is continuing to progress initiatives intended to improve these aspects of frequency control (among others) in the NEM, including the implementation of Mandatory Primary Frequency Response (PFR). Progress on these initiatives is discussed in Section 7 of this report.

3. Achievement of the Frequency Operating Standard

AEMO's assessment of the achievement of the requirements of the FOS in Q2 2020 is summarised in Table 1.

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

Requirement	Mainland	Tasmania	Further commentary
1 – Accumulated time error	Achieved	Exceeded 3 times	5 Apr, 6 Apr & 10 Apr, see Section 4.1
2 – No contingency/load events			
• **Within NOFEB at all times**	Achieved	Exceeded 45 times*	See Section 4.2.1
• **5-minute limit outside NOFB**	Exceeded 3 times	Exceeded 2 times	See Section 4.2.2
• **Within NOFB 99% of the time**	Achieved		*Incidents discussed in Section 4.2.3
3 – Generation or load events			
• **Contained**	Achieved	Achieved	
• **Recovered**	Exceeded 4 times	Exceeded once	See Section 4.3.2
4 – Network events			
• **Contained**	Achieved	Achieved	
• **Recovered**	Achieved	Achieved	
5 – Separation events			
• **Contained**	Achieved	Achieved	
• **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

Section 4 describes frequency performance in the quarter against each of the key FOS requirements, as set out in the relevant NER.

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 Q2 2020 are provided in Table 2.

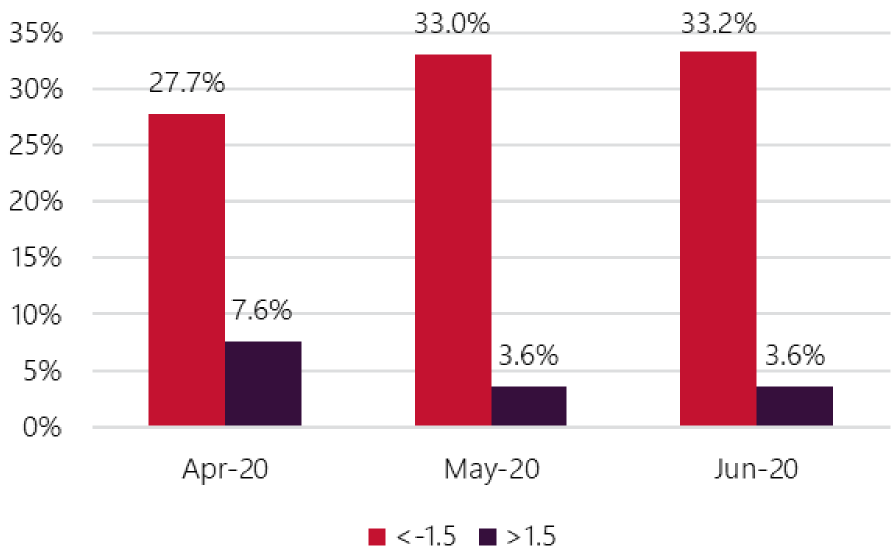
Three instances of time error exceeding the FOS requirements in Tasmania occurred during early April 2020. The accumulated time error exceeded -15 seconds on 5 April (-16.21 seconds), 6 April (-15.81 seconds), and 10 April (-16.93 seconds). AEMO is monitoring this situation and assessing options to better control time error in Tasmania. For example, revision of Automatic Generator Control (AGC) and Regulation FCAS settings for the Tasmania region are potential ways to improve this area of frequency performance. Initiatives to improve the overall tightness of frequency control (such as the Mandatory PFR rule change) are also expected to make a significant improvement to managing time error.

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

Value	Mainland	Tasmania
Highest positive time error (seconds)	3.97	2.01
Lowest negative time error (seconds)	-11.81	-16.93

Figure 2 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 Q2 2020, the incidence of negative time errors exceeding increased each month.

Figure 2 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 NOFB for more than five minutes on any occasion or more than 1% of the time over any 30-day period[4]. 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 Q2 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	0	21
	HIGH	0	19
	BOTH	0	5

Tasmania

The number of Tasmanian events where frequency exceeded the NOFEB in Q2 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 more sensitive to supply/demand imbalances which manifest as larger frequency deviations.

In addition to this, frequency performance in Tasmania is largely dictated by the performance of the mainland due to Basslink's frequency controller, which attempts to match the frequency in Tasmania to that of the (much bigger) mainland system. This means that most frequency issues are occurring while Tasmania is interconnected and are best addressed by improving frequency control in the mainland.

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

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 Q2 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	3	0
	HIGH	0	0
	BOTH	0	2

Mainland

The first instance identified began at 1705 hrs on 10 April. This was a time of rapidly increasing system demand but otherwise no single clear underlying cause was evident.

The second instance identified began at 1750 hrs on 16 April during the period from 1715 hrs to 1820 hrs when Regulation FCAS was not being dispatched in the NEM due to a previously unknown bug in AEMO's Energy Management System (EMS) application. Further detail regarding this incident is included in Section 6.3.

The third instance identified began at 1430 hrs on 12 May. No single clear underlying cause was evident.

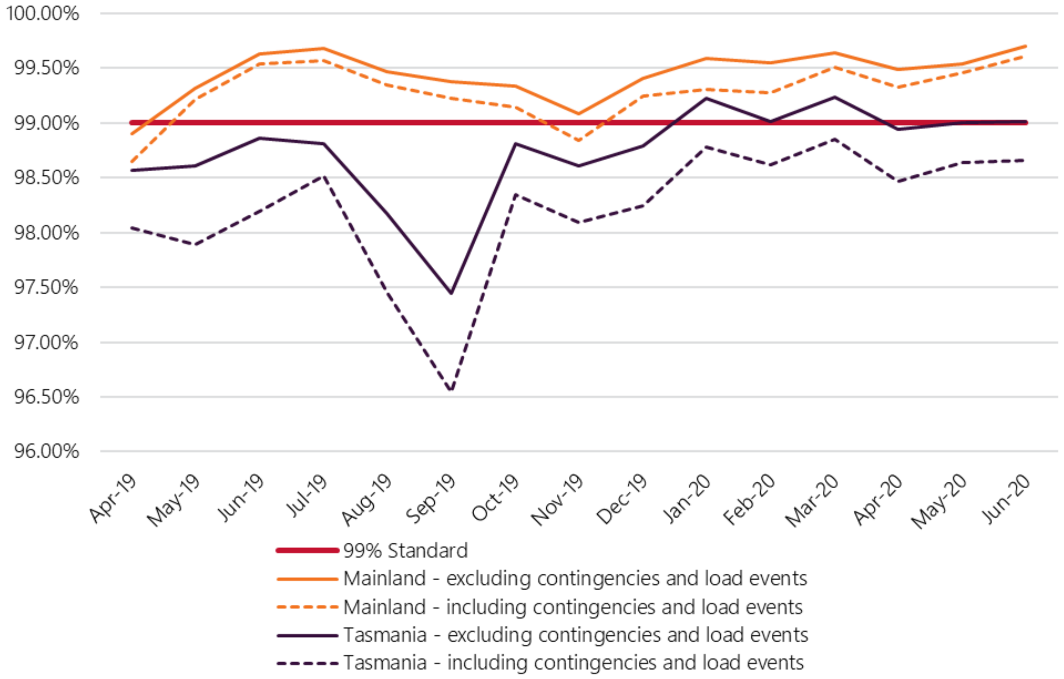
Tasmania

The two events where Tasmanian frequency was outside the NOFB for greater than five minutes in Q2 2020 were the same events on 10 April and 12 May discussed above.

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 3. The figure shows statistics both including and excluding data during contingency events. The FOS requirement excludes periods of contingency or load events.

Figure 3 Frequency within the NOFB, minimum daily percentage of time over preceding 30-day window



Frequency in the mainland remained within the NOFB for more than 99% of the time in Q2 2020, for a significantly increased percentage of time when compared to Q2 2019. Tasmania's frequency (excluding contingencies) remained at or near the 99th percentile required by the FOS. Performance in Q2 2020 was slightly below Q1 2020 in Tasmania but is still notably improved from late 2019 when Basslink returned to service from an extended outage.

4.2.4 Frequency performance within the NOFB

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 Q2 2020 is shown in Figure 4 and Figure 5 and compared with data from 2010, as an example of a period where frequency control was significantly tighter.

Figure 4 Mainland frequency distribution

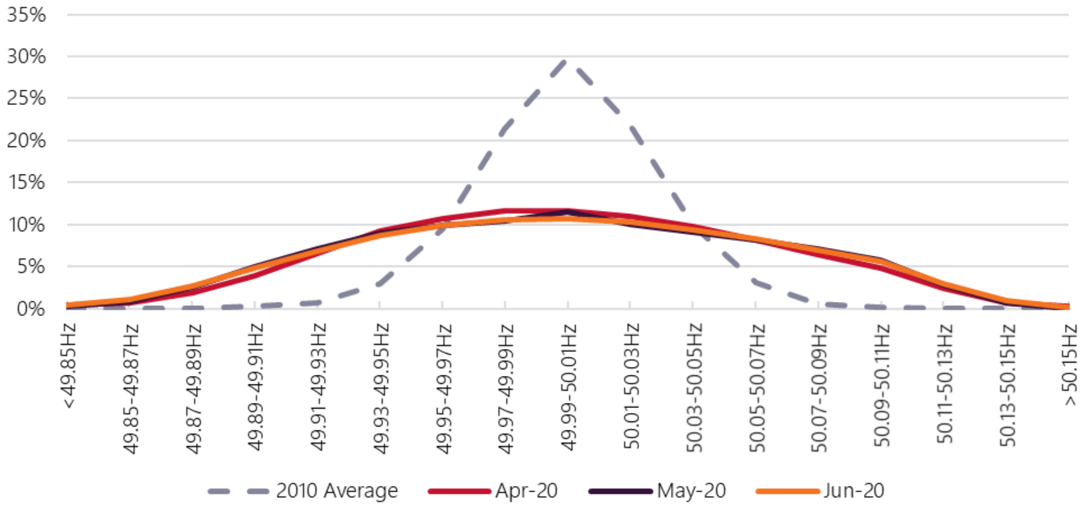


Figure 5 Tasmania frequency distribution

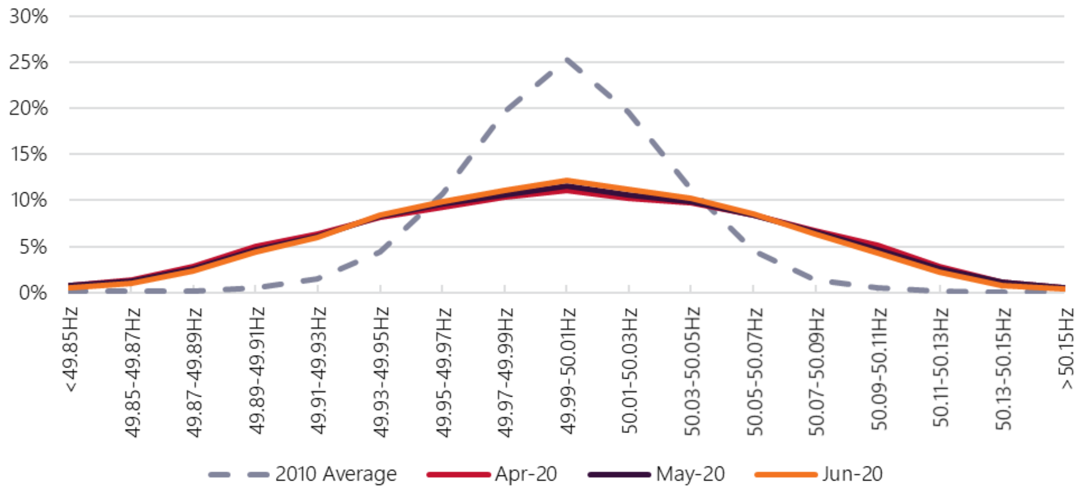
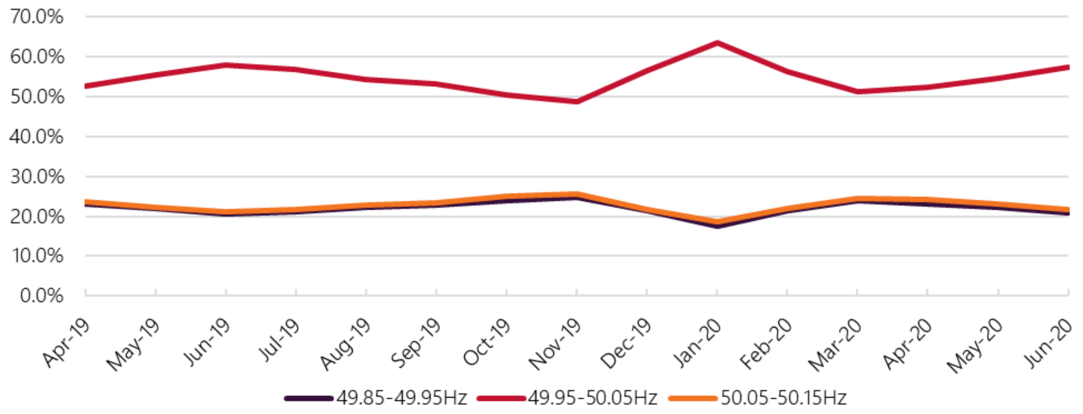


Figure 6 shows that when the frequency is *within* the NOFB in the mainland, the proportion of time that frequency is close to the boundaries of the NOFB decreased slightly in Q2 2020.

Figure 6 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) specifies 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 ten 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 GLCB

During Q2 2020, there were no events in either the mainland or Tasmania where a frequency excursion following a generation or load event resulted in system frequency deviating outside of the applicable GLCB.

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

Table 7 summarises the number of events during Q2 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 five minutes/300 seconds in the mainland, and 10 minutes in Tasmania).

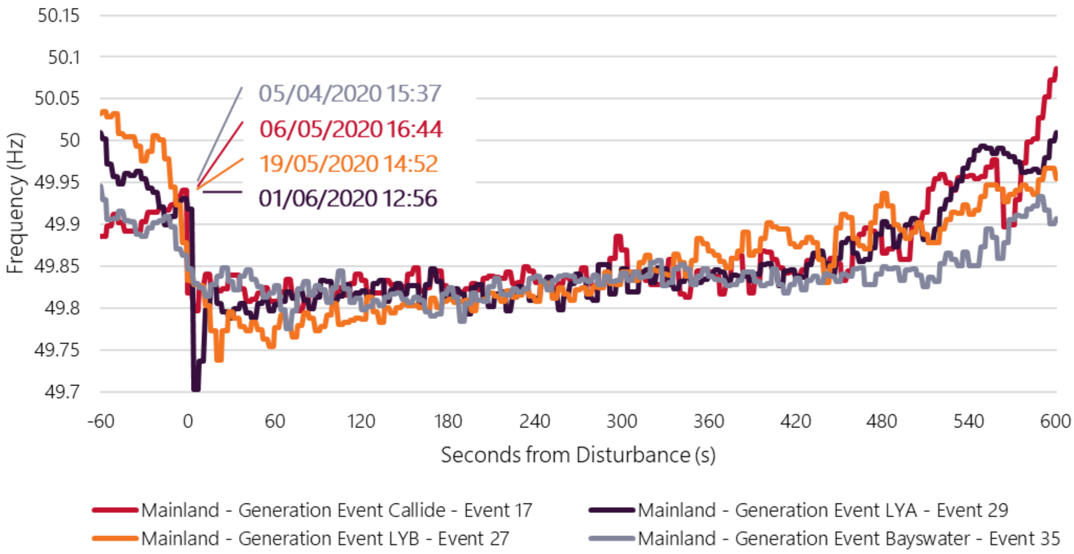
Table 7 Number of frequency excursions following a generation or load event not recovered to the NOFB within the FOS timeframe

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	4	1
	HIGH	0	0
	BOTH	0	0

Mainland

Four mainland generation events did not see recovery to the NOFB within the FOS timeframe of five minutes (300 seconds). The mainland frequency during the pre-event and post-event periods is provided in Figure 7.

Figure 7 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 four events indicate that only a portion of the enabled Delayed Raise (R5) FCAS was supplied.

This is not necessarily a failure on the part of providers. These four 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 been triggered during these events, as their assigned trigger thresholds tend to be lower (between 49.5 Hz and 49.7 Hz) as required by the Market Ancillary Services Specification (MASS[5]). 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.

At these frequency levels, proportional controllers with relatively wide deadbands (e.g. +/- 150 mHz) are also generally not providing a significant response. 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 warranted further attention, and as a result AEMO is in the process of revising switched controller FCAS settings.

Table 8 Slow and Delayed service delivery during generation events not recovered to the NOFB within the FOS timeframe

Event	Time	Recovery NOFB time (s)	R60 Enabled (MW)	R60 Delivered (MW)	R5 Enabled (MW)	R5 Delivered (MW)	R5 Enabled switch controlled not triggered (MW)
Generation event – Bayswater	05/04/2020 15:37	516	527	540	420	183	203
Generation event – Callide	06/05/2020 16:44	364	491	907	292	219	93
Generation event – Loy Yang B	19/05/2020 14:52	336	513	1033	302	67	87
Generation event – Loy Yang A	01/06/2020 12:56	420	564	1017	329	122	20

Note that Fast FCAS data was not available at the time of reporting; however it is not relevant to the timeframes discussed here.

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 MASS. Further, the assessments here exclude several relatively new providers of FCAS, including virtual power plants (VPPs) and some batteries, as the relevant data was not yet available at the time of reporting.

Tasmania

One Tasmanian event on 5 April 2020 did not see recovery to the NOFB within the FOS timeframe of 10 minutes (600 seconds). A rapid decline in generation from Musselroe Wind Farm from 141 MW at 0850 hrs pushed Basslink imports to a maximum of 470 MW. Once Basslink reached its limit, a further reduction in Musselroe generation to 0 MW through to 0915 hrs caused a decoupling of Tasmanian frequency from the mainland frequency and began the ongoing underfrequency event identified. The Tasmanian and mainland

[5] 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.

frequencies during the event are provided in Figure 8. The Musselroe generation and Basslink transfer are provided in Figure 9.

Figure 8 Mainland and Tasmanian frequency during 5 April 2020 event

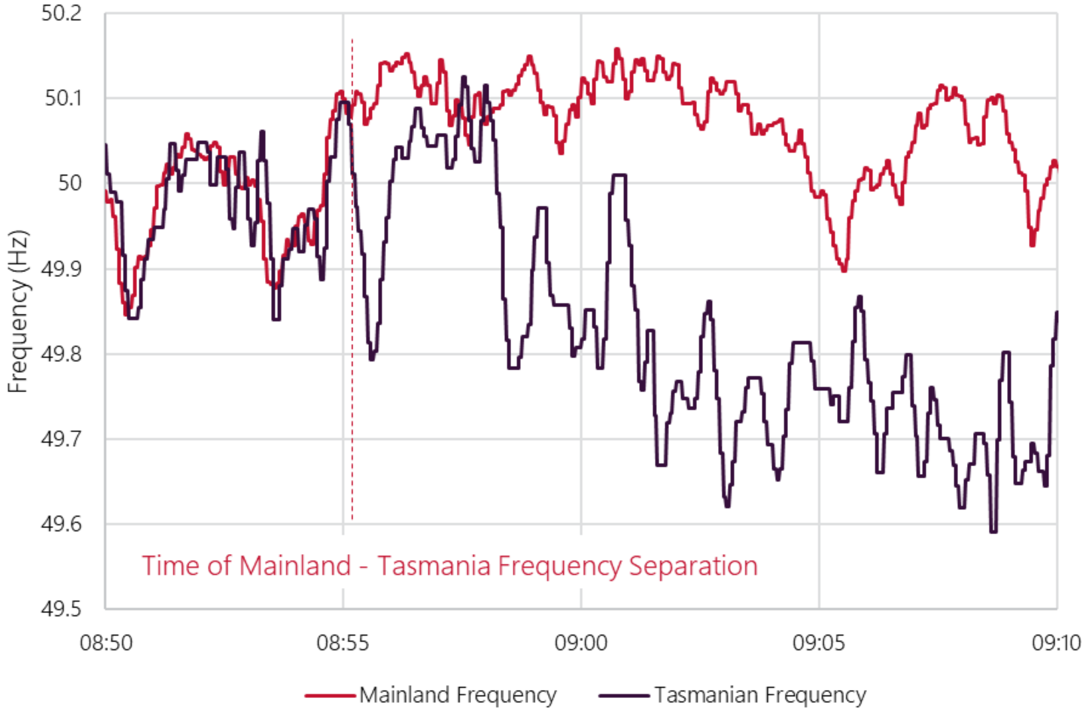
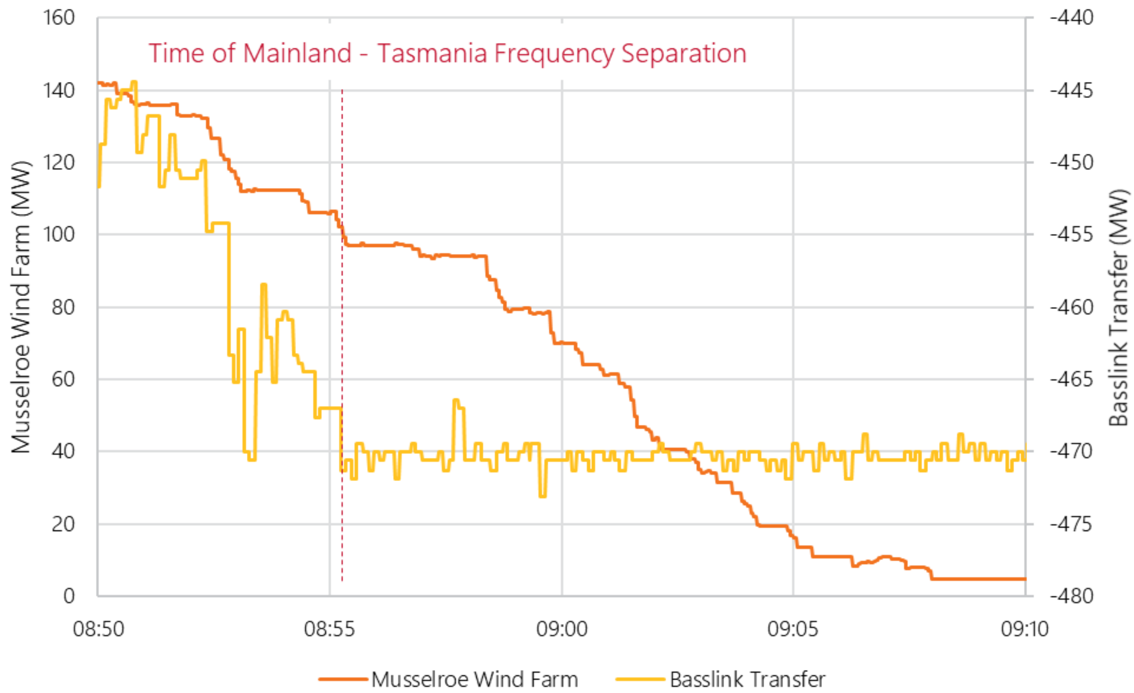


Figure 9 Musselroe wind farm generation and Basslink import during 5 April 2020 event



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 Q2 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 most 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) sets out expectations for the initial frequency containment, recovery, and revised requirements for further contingency events in the islanded region. AEMO is required to maintain system frequency within the applicable containment band and should recover frequency to the NOFB within the FOS timeframe.

No separation events occurred during Q2 2020 in the mainland or Tasmania.

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) specifies 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

In both the mainland and Tasmania, there were no instances during Q2 2020 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.

4.5.2 Frequency performance following generation or load events

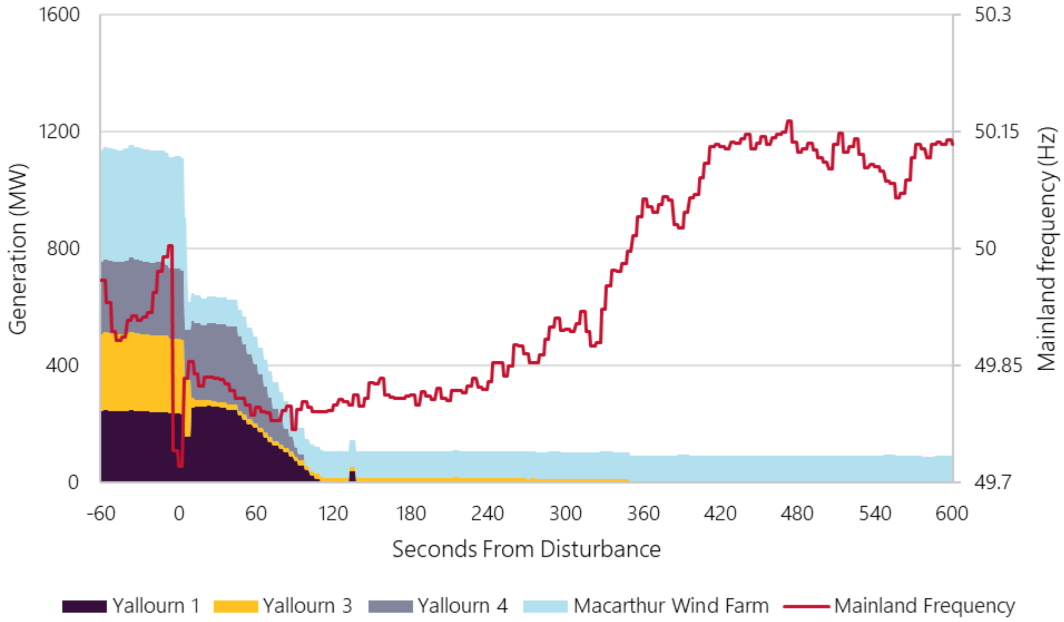
11 April 2020

The non-credible trip of the Yallourn unit 3 and the Macarthur Wind Farm at 1326 hrs on 11 April 2020 reduced frequency to 49.70 Hz. Yallourn units 1 and 4 rapidly reduced generation to near-zero within two minutes of the event. Frequency containment and recovery to within the NOFB in less than 10 minutes was supported by significant quantities of Delayed Raise service in due course as part of AEMO's FCAS compliance processes.

Table 9 Slow and Delayed service delivery during 11 April 2020 non-credible generation event

Time	R60 Enabled (MW)	R60 Delivered (MW)	R5 Enabled (MW)	R5 Delivered (MW)
11/04/2020 13:26	540	1263	432	976

Figure 10 Yallourn and Macarthur WF generation during 11 April 2020 non-credible generation event



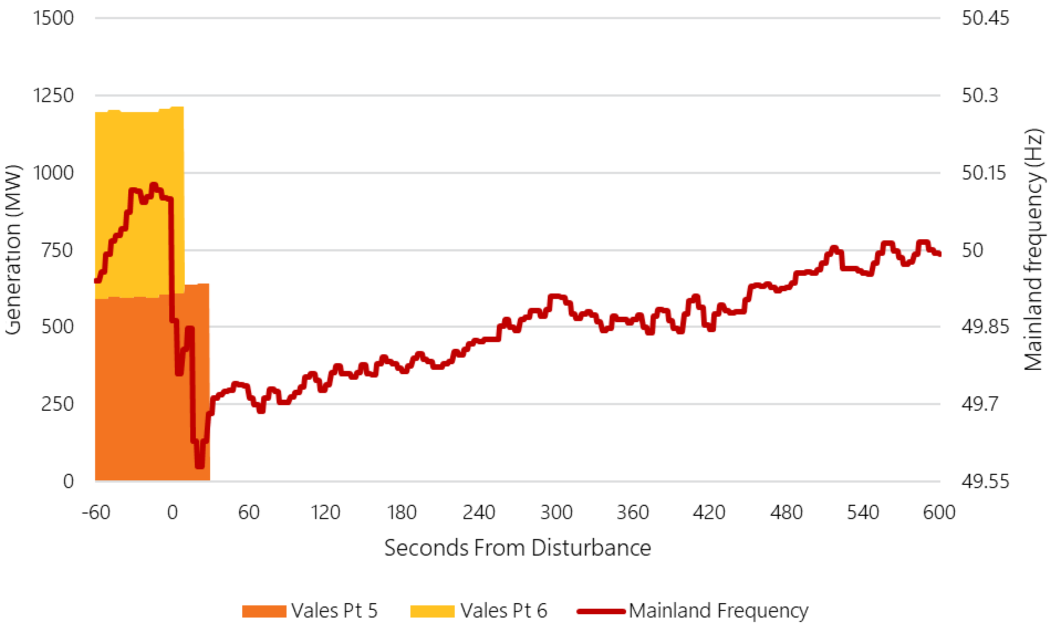
7 June 2020

The non-credible trip of Vales Point units 5 and 6 at 1333 hrs on 7 June 2020 reduced frequency to 49.58 Hz. Frequency containment and recovery to within the NOFB in less than 10 minutes was supported by significant quantities of Delayed Raise service from switched load providers, as shown in in Table 10. As with the 11 April event described above, analysis of Fast Raise services will be conducted in due course.

Table 10 Slow and Delayed service delivery during 6 June 2020 non-credible generation event

Time	R60 Enabled (MW)	R60 Delivered (MW)	R5 Enabled (MW)	R5 Delivered (MW)
07/06/2020 13:33	623	1923	467	546

Figure 11 Vales Point generation during 6 June 2020 non-credible generation event



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 therefore 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. ROCOF assessment has only been attempted for periods with data longer than two seconds. For the purposes of this report, the maximum ROCOF recorded between five seconds prior and 30 seconds after 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 0.125 Hz/s, is provided in Table 11. 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 11 ROCOF during frequency events in Q2 2020 in the mainland

Month	ROCOF (Hz/s)	Associated event	Event time
April	0.114	Trip of Yallourn 1, 3 & 4 units	11/04/2020 13:36
May	0.051	Trip of APD potline	16/05/2020 08:57
June	0.091	Trip of Vales Point 5 & 6 units	07/06/2020 13:33

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[6], 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 0.1 Hz of frequency deviation;

(ii) **F** is the current measured system frequency;

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

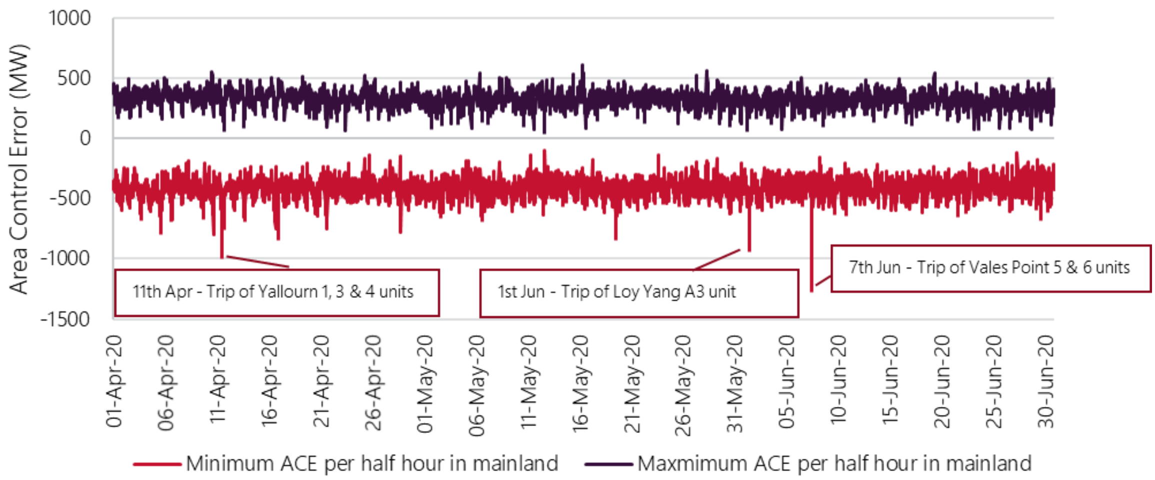
(iv) **FO** is a frequency offset representing accumulated frequency deviation, that is, time error.

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 Q2 2020.

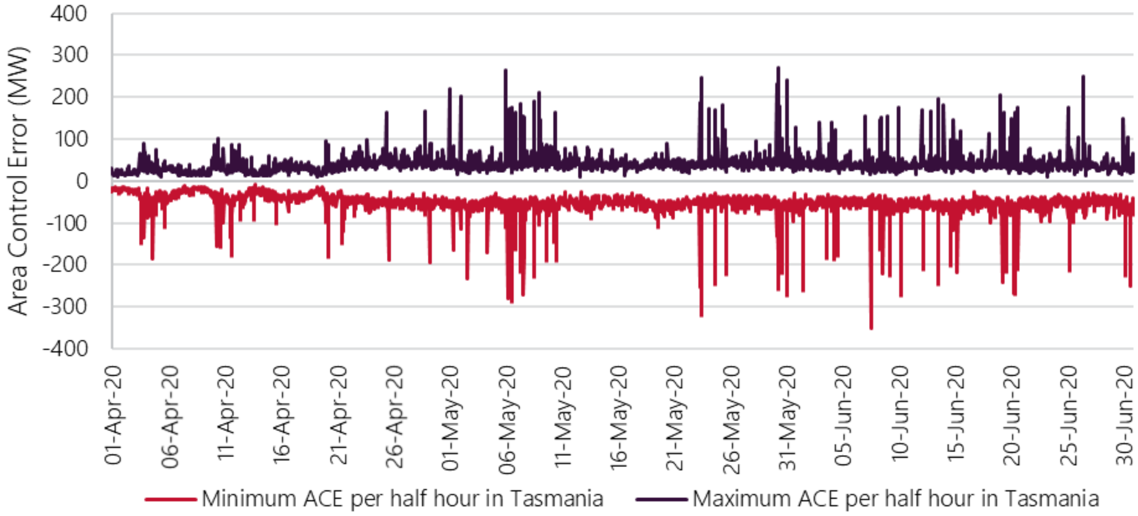
Over time, ACE may be considered to represent a rough proxy for the required Regulation FCAS volume.

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



[6] 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



6.3 AGC operations

On 16 April 2020, a failure in one of AEMO's systems caused Regulation FCAS to not operate for a period of approximately one hour (1715 hrs to 1820 hrs). Energy and FCAS Contingency services were dispatched as required during this period. An incident investigation was conducted to identify the root cause and necessary follow-up actions.

At approximately 1715 hrs on 16 April, towards the end of a routine EMS database load, an issue was identified that required a restart of SCADA. The restart unknowingly caused generator regulation statuses to become suspect in the Market systems, resulting in no Regulation FCAS being dispatched from 1720 hrs.

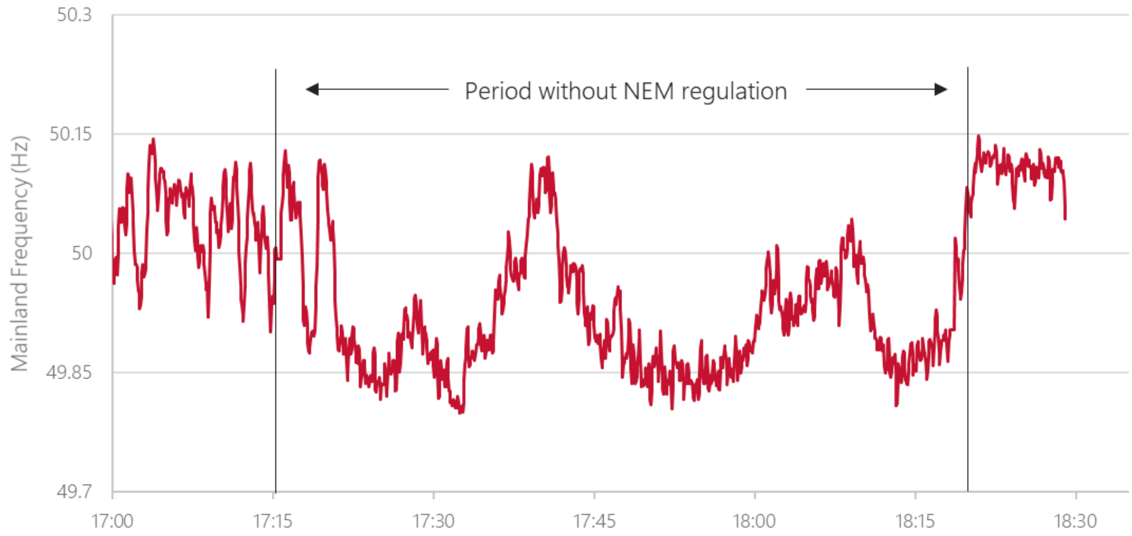
The incident was escalated and at 1815 hrs was resolved through restarting AGC. Dispatch of Regulation FCAS began again from 1820 hrs.

The root cause was found to be a previously unknown bug in the EMS SCADA application which was triggered by this particular restart of SCADA. All Regulation FCAS is dispatched via SCADA. The SCADA-reported availability of all Regulation FCAS-providing units was deemed 'suspect' due to the bug and registered in AEMO's market system as 'not available'. Without any reported availability of Regulation FCAS services, no Regulation FCAS was dispatched.

An expedited IT change was implemented on 23 April 2020 to rectify the bug.

During part of the period of approximately one hour when Regulation FCAS was not dispatched, frequency dwelled around the lower limit of the NOFB (refer to Figure 14). Contingency FCAS was actively containing frequency when it drifted outside the NOFB, but the lack of Regulation FCAS dispatch meant there was no AGC action to 'drive' the system back towards 50 Hz once it was at the edge of the NOFB. Frequency control performance failed to meet the FOS during this period, as the frequency exited the NOFB and was not restored successfully within a five-minute period.

Figure 14 Mainland frequency during period without NEM regulation



The failure of Regulation FCAS dispatch during this period meant that fewer resources than usual would have been available to respond had a power system event occurred during this time. In addition to rectifying the root cause of this incident, AEMO has initiated a range of actions to mitigate both the risk and the consequences of a similar issue occurring in future. These actions include:

- The bug in the EMS SCADA application which caused this issue has been rectified.
- New AGC status indicators have been created on the AEMO's internal grid dashboards.
- AEMO is conducting a review of incident communication and escalation protocols to allow better co-ordination and faster resolution for events like this.

AEMO is treating this as a potential failure to follow the central dispatch process, which is defined in the rules as a scheduling error.

6.4 Reviewable operating incidents

AEMO is required to review operating incidents that meet the criteria in the NER and Reliability Panel guidelines for identifying reviewable operating incidents[7]. No such incidents were reported during Q2 2020.

7. Actions to improve frequency control performance

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. In this quarterly report, AEMO has

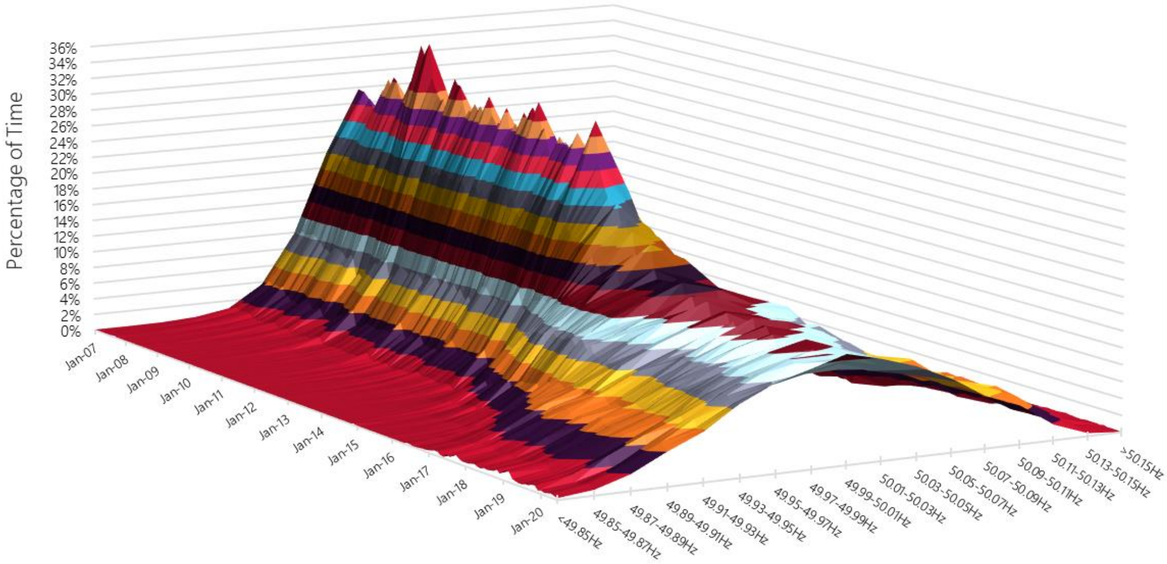
[7] See https://www.aemc.gov.au/sites/default/files/2018-02/Final-revised-guidelines.pdf.

published 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 are important indicators of frequency stability. These also form a basis for assessing the impacts of further actions, such as the implementation of the Mandatory PFR rule, which commenced on 4 June 2020.[8]

7.1 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 substantial flattening of the frequency distribution within the NOFB. This means frequency is spending more time out towards the edges of the NOFB than it used to. Among other things, this means when a contingency event occurs, the resulting frequency change is more likely to deviate significantly away from 50 Hz. A small improvement was observed in Q2 2020.

Figure 15 Monthly frequency distribution

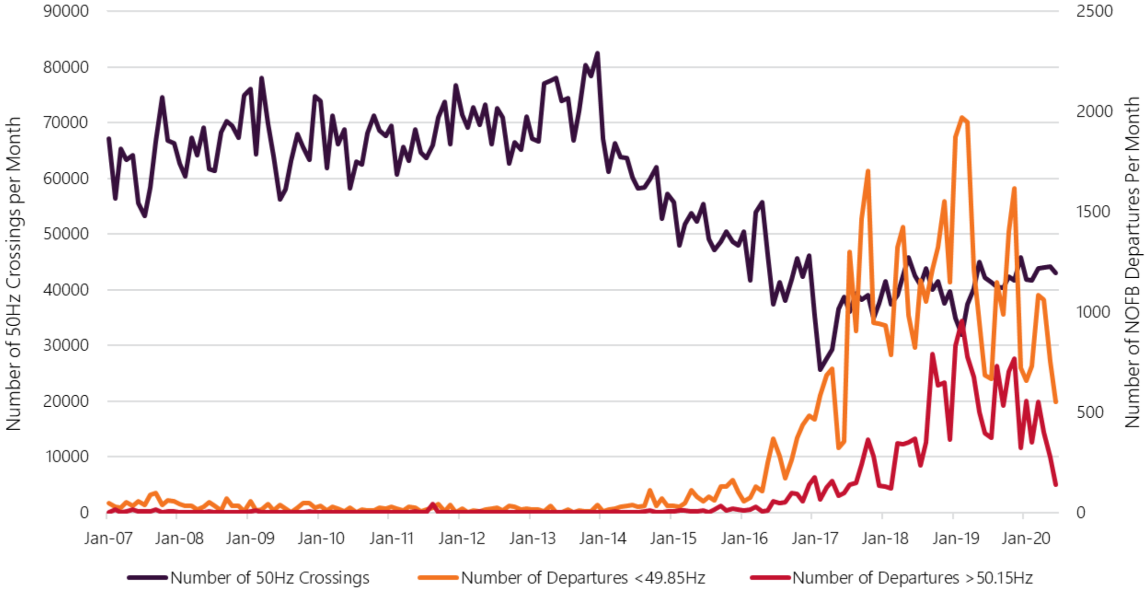


7.2 Measures 2 and 3 – number of frequency crossings and NOFB excursions

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 away from 50 Hz, and therefore does not have as much opportunity to cross. Therefore, the average number of zero crossings is likely to increase if frequency is held much more tightly around 50 Hz. The month of June 2020 saw a significant drop in departures from the NOFB, which will be monitored with interest as the rollout of the Mandatory PFR rule continues.

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

Figure 16 Monthly frequency crossings – under 49.85 Hz, across 50 Hz, beyond 50.15 Hz



7.3 Measure 4 – frequency 'mileage'

This measure examines the total amount of change in frequency over time. This measure 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. The measurements below are derived from 4-second intervals.

Table 12 Example frequency mileage calculation for a series of four-second intervals

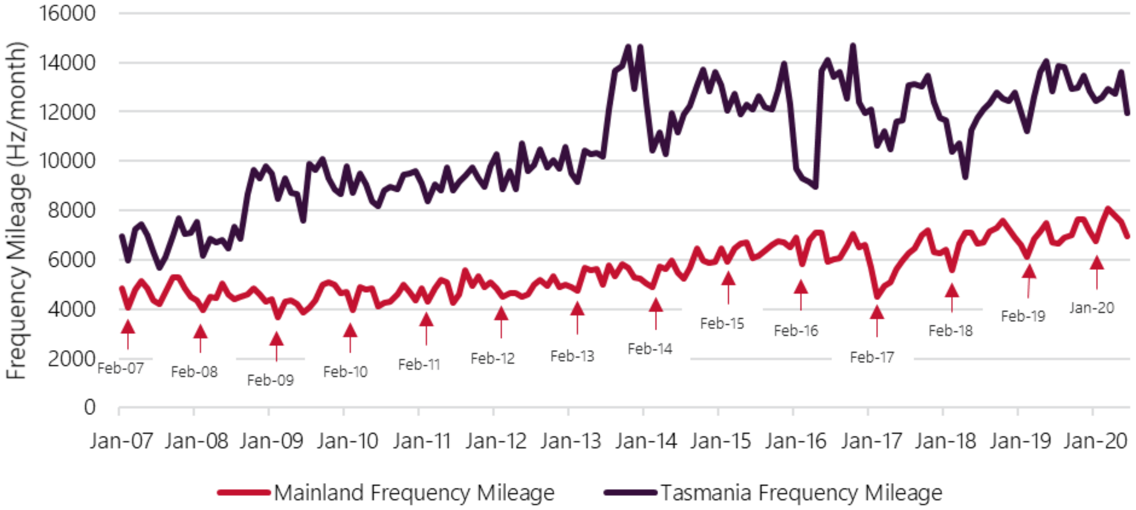
Sample	0s	4s	8s	12s	Mileage sum
NSW frequency (Hz)	50	50.5	49.5	50	
Mileage (Hz)		ABS(50.5-50)=0.5	ABS(49.5-50.5)=1.0	ABS(50-49.5)=0.5	0.5+1.0+0.5 = 2.0Hz

Frequency mileage per month has been increasing steadily since 2007, as demonstrated in Figure 17. Recent increases in Regulation FCAS and Contingency FCAS volumes do not appear to have had any discernible impact on frequency mileage.

The Q1 2020 Frequency and Time Error Monitoring report was published with only Tasmanian frequency mileage. Mainland frequency mileage has been added below.

Within the long-term trend of increasing mainland frequency mileage since 2007, a seasonal cycle is observed, which is lowest in February, typically low over winter, and highest in the shoulder seasons of autumn and spring. This is likely due to there being more units in service over summer and winter serving the higher demands, with higher unit numbers contributing to greater overall frequency control.

Figure 17 Monthly frequency mileage



7.4 Progress on primary frequency response initiative

Implementation of the Mandatory PFR rule is a major work program currently underway. The Australian Energy Market Commission (AEMC) summarised the rule as follows[9]:

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.*

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

While the Mandatory PFR rule commenced from 4 June 2020, actual physical changes to generating plant controls (and therefore frequency performance) are subject to a careful assessment and implementation strategy. This is being undertaken in stages based on generator size. Current plans are for at least the first stage of this rollout, which affects generators 200 MW or greater, to be completed prior to summer 2020. AEMO has created a new area on its website for information and documentation relating to Mandatory PFR implementation[10].

AEMO intends to publish periodic updates on the rollout of the Mandatory PFR rule in this area. The first of these reports is available at https://aemo.com.au/-/media/files/initiatives/primary-frequency-response/2020/pfr-implementation-report-17-jul-20.pdf.

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

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

7.5 Other recent actions

Other measures taken to improve frequency control in the last 12 months include:

- Base Regulation FCAS volumes were increased progressively between March and May 2019 up to their current levels of 220/210 MW Raise/Lower.
- Following a detailed review, mainland load relief was adjusted progressively down from 1.5% to 0.5% over the period up to 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 and AEMO will monitor load relief periodically.
- AEMO has commenced revising switched controller settings to better distribute response across the relevant frequency bands.
- Weekly frequency reporting commenced from 1 January 2020 as required by NER 4.8.16(a). All available weekly reports are available on AEMO's website[11].
- Quarterly frequency reporting has been aligned with the requirements in NER 4.8.16(b).
- A revision of the MASS was completed 1 June 2020 (effective 1 July 2020) which made some changes to the measurement of FCAS to help ensure frequency response within the NOFB was recognised towards Contingency FCAS providers' obligations.

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