

Frequency & Time Deviation Monitoring in the NEM

December 2008

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1 Introduction

NEMMCO is required to maintain the power system frequency and time deviation within the limits specified in the frequency operating standards determined for the mainland and the Tasmania Region by the Reliability Panel. This document reports on the frequency and time deviation performance observed during December 2008 in all regions of the NEM. Regions QLD, NSW, VIC and SA will be referred to as the mainland regions throughout the report.

The frequency operating standards for the mainland regions and the Tasmania region are available on the AEMC web site¹. Summaries of the frequency operating standards are provided in Appendix A.

The Frequency Control Ancillary Service (FCAS) analysis of slow and delayed service presented in this report is based on 4-second data. Data for mainland regions is sourced from the Sydney PI server and data for Tasmania region is sourced from the Brisbane PI server. The analysis of fast FCAS delivered is based on high-speed (50-millisecond) data and is only presented in this report for events where the appropriate data is available.

¹ The frequency operating standards for the mainland regions are available from <http://www.neca.com.au/ReliabilityPanel5037.html?CategoryID=35&SubCategoryID=115>. The frequency operating standards determined by the AEMC Reliability Panel that apply in the Tasmania Region from 29 May 2007 are available from <http://www.aemc.gov.au/electricity.php?r=20060525.144027>.

2 Frequency Performance

This section summarises load and contingency events that failed to meet the frequency operating standards in the mainland regions or the Tasmania region. The NEM frequency operating standards are summarised in Appendix A. Guidelines for measuring the time the frequency was outside normal operating band are shown in Appendix B.

NEMMCO is responsible for ensuring sufficient FCAS is enabled to maintain the system frequency and time error within the appropriate frequency operating standards. The FCAS performance of enabled generating units is presented for selected contingency and load events as per guidelines in Appendix C.

The FCAS responses shown in the FCAS graphs in this report are based on the methodology described in the Market Ancillary Service Specification available on the NEMMCO web site². This methodology involves averaging and scaling of values by applying a compensation factor so that the amount of FCAS evaluated as shown in the graphs can be significantly different to the simple measurement of responses. The application of the compensation factor to fast and slow raise and lower services evaluates the amount of FCAS provided by the enabled generating units by taking into account the amount of frequency deviation. Ancillary services enabled generating units are expected to deliver the full enabled amount if the frequency exceeds the raise or lower reference frequency as specified in the Market Ancillary Service Specification.

Consistent with the methodology in the Market Ancillary Service Specification, calculation of the amount of service delivered depends on the period over which assessment is made.

In the case of rapid frequency recovery to 50 Hz, the sustained delivery of slow and delayed services may not be required and this may be reflected in the assessment of these services. Refer to Appendix C for the Guidelines used for evaluating FCAS performance in this report.

For events that satisfy the FCAS evaluation criteria in Appendix C, bar charts are shown for each service. The dark bar represents the amount of service actually provided. Fast (where data is available), slow, delayed and regulation services are denoted by the letters F, S, D and R respectively.

The lighter shade bar represents the amount of fast, slow, delayed and regulation service enabled in each category. The letters RA and LA correspond to raise and lower services respectively. Note that delayed and regulation services are represented by a single bar as they are measured over the same period of time.

Delayed services are only required to be provided when enabled and if the frequency excursion is outside the enabled plant's frequency settings as outlined in the Market Ancillary Service Specification. There are five levels of frequency settings and in the mainland regions the default raise and lower frequency settings are 49.6 Hz and 50.4 Hz respectively. In Tasmania region the default raise and lower frequency settings are 48.8 Hz and 50.6 Hz respectively.

² <http://www.nemmco.com.au/powersystemops/160-0163.html>

2.1 Low Frequency Load and Contingency Events in Mainland Regions

2.1.1 Load Events

There was 1 low frequency load event in mainland regions during December 2008 that resulted in a frequency below 49.85 Hz. This event met the Mainland region frequency operating standards.

2.1.2 Generation Events

There were 3 low frequency generation events in mainland regions during December 2008 that resulted in frequencies below 49.85 Hz. All these events met the Mainland region frequency operating standards.

2.1.3 Network Events

There were no low frequency network events in mainland regions during December 2008 that resulted in a power system frequency below 49.85 Hz.

2.1.4 Islanding Events

There were no low frequency islanding events in mainland regions during December 2008 that resulted in a power system frequency below 49.85 Hz.

2.1.5 Multiple Contingency Events

There were no multiple contingency events in mainland regions during December 2008 that resulted in a power system frequency below 49.85 Hz.

2.2 High Frequency Load and Contingency Events in Mainland Regions

2.2.1 Load Events

There were no Load events in mainland regions during December 2008 that resulted in a power system frequency above 50.15 Hz.

2.2.2 Generation Events

There were no high frequency generation events in the mainland regions during December 2008 that resulted in a power system frequency above 50.15 Hz.

2.2.3 Network Events

There were no high frequency network events in mainland regions during December 2008 that resulted in a power system frequency above 50.15 Hz.

2.2.4 Islanding Events

There were no high frequency islanding events in mainland regions during December 2008 that resulted in a power system frequency above 50.15 Hz.

2.2.5 Multiple Contingency events

There were no high frequency multiple contingency events in mainland regions during December 2008 that resulted in a power system frequency above 50.15 Hz.

2.3 Low Frequency Load and Contingency Events in Tasmania

2.3.1 Load Events

There were 8 low frequency load events in the Tasmania region during December 2008 that resulted in a power system frequency below 49.85 Hz. All these events met the Tasmania region frequency operating standards.

2.3.2 Generation Events

There were no low frequency generation events in Tasmania region during December 2008 that resulted in power system frequencies below 49.85 Hz.

2.3.3 Network Events

There were no low frequency network events in the Tasmania Region during December 2008 that resulted in a power system frequency below 49.85 Hz.

2.3.4 Islanding Events

There were no low frequency islanding events in the Tasmania Region during December 2008 that resulted in a power system frequency below 49.85 Hz.

2.3.5 Multiple Contingency Events

There were no multiple contingency events in the Tasmania Region during December 2008 that resulted in a power system frequency below 49.85 Hz.

2.4 High Frequency Load and Contingency Events in Tasmania

2.4.1 Load Events

There were 53 high frequency load events in the Tasmania region during December 2008 that resulted in power system frequencies above 50.15 Hz. All these events met the Tasmania region frequency operating standards.

2.4.2 Generation Events

There were no generation events in the Tasmania Region during December 2008 that resulted in a power system frequency above 50.15 Hz.

2.4.3 Network Events

There were no high frequency network events in Tasmania region during December 2008 that resulted in a power system frequency above 50.15 Hz.

2.4.4 Islanding Events

There were no high frequency islanding events in the Tasmania region during December 2008 that resulted in a power system frequency above 50.15 Hz.

2.4.5 Multiple Contingency Events

There were no high frequency multiple contingency events in the Tasmania region during December 2008 that resulted in a power system frequency above 50.15 Hz.

2.5 Frequency Regulation

The frequency operating standards for both the mainland regions and the Tasmania region require that, during periods when there are no contingency events and no load events, the frequency be maintained within the range 49.85 to 50.15 Hz for 99% of the time, with larger deviations permitted within the range 49.75 to 50.25 Hz for no more than 1% of the time. The distribution of frequencies for normal operating frequency conditions during December 2008 is shown in Figure 1 for the mainland regions and in Figure 2 for the Tasmania region.

For an island within the mainland regions or an island within the Tasmania power system, the frequency operating standards require that, during periods when there are no contingency events and no load events, the frequencies be maintained within the ranges 49.5 to 50.5 Hz and 49.0 and 51.0 Hz respectively.

Consistent with the standard, load events and contingency events are excluded from the frequency distributions in Figures 1 and 2.

Occasions where Basslink is starting, stopping or reversing its power flow is considered as load events as defined in the Tasmania region frequency operating standards.

The frequency distribution for the mainland regions is within the frequency operating standards. Figure 1 shows that the frequency was within the range 49.92 to 50.07 Hz for 99% of the time. The frequency was within the range 49.75 Hz – 50.25 Hz for 100% of the time. The mean value of frequency during December 2008 was 50.00 Hz with a standard deviation of 0.026 Hz.

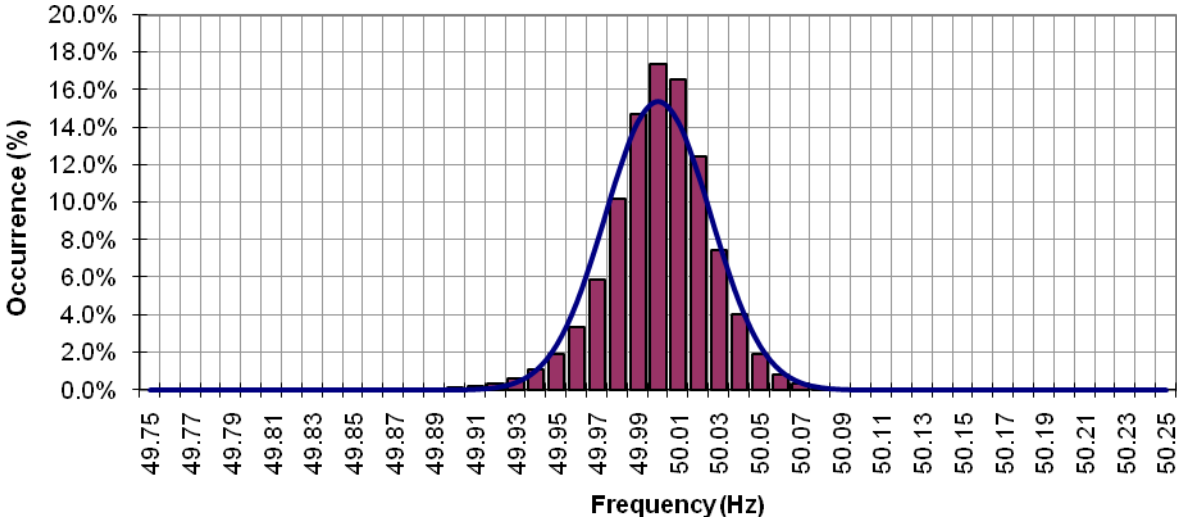


Figure 1: Mainland Regions Regulation Frequency Distribution for December 2008

Figure 2 shows that the frequency in Tasmania was within the range 49.92 – 50.08 Hz for 99% of the time. The frequency was within the range 49.75 Hz – 50.25 Hz for 100% of the time. The mean value of frequency during December 2008 was 50.00 Hz with a standard deviation of 0.030 Hz.

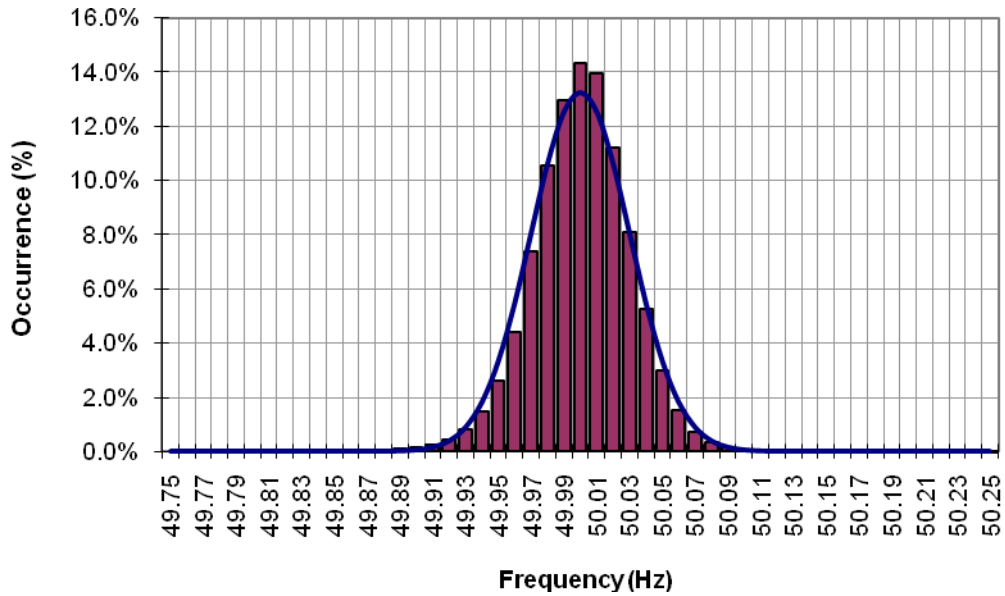


Figure 2: Tasmania Regulation Frequency Distribution for December 2008

2.5.1 Frequency Excursion for a Condition where no Contingency or Load Event is Identified

In December 2008 there were no instances in the mainland and Tasmanian Regions where the frequency deviation was outside the band 49.75 – 50.25 Hz and/or had prolonged recovery time exceeding 300 seconds where no contingency or load event was identified.

2.5.2 Daily Frequency Standard Deviation

Figures 3 and 4 below plot the daily standard deviation of the NSW and Tasmanian frequency for the past 13 months. With exception of major power system disturbances, which are excluded, the frequency standard deviation shown in Figures 3 and 4 do not exclude load and contingency events.

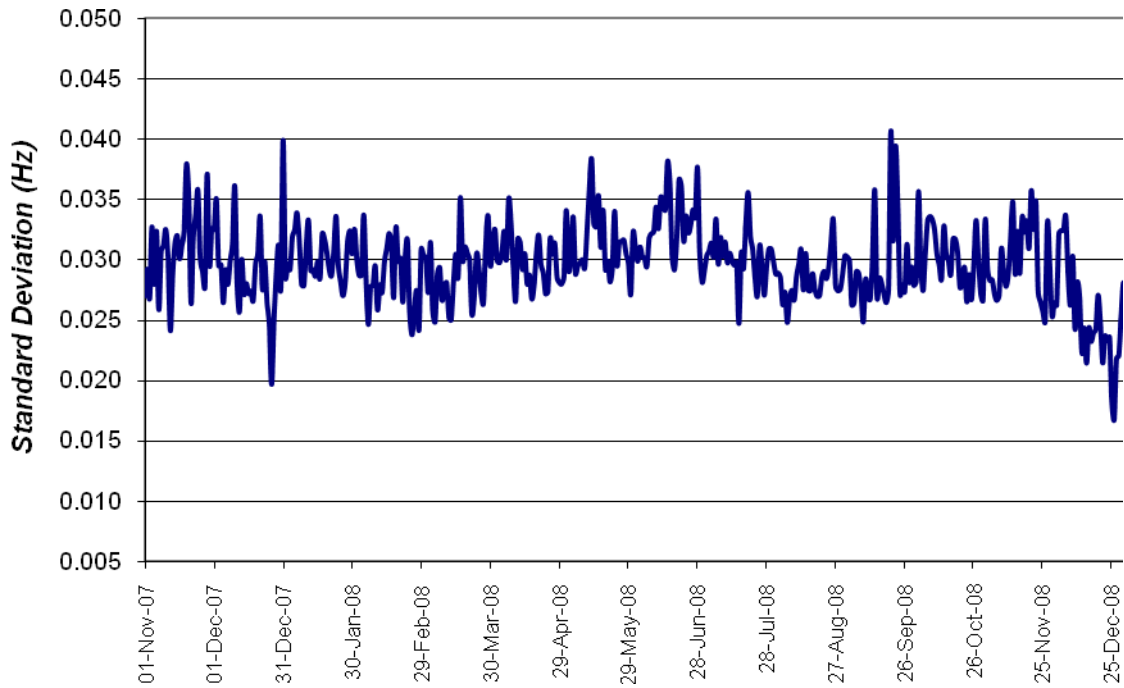


Figure 3: Daily Standard Deviation of NSW frequency

Daily standard deviation of frequency in Tasmania for the past 13 months is shown in Figure 4 below.

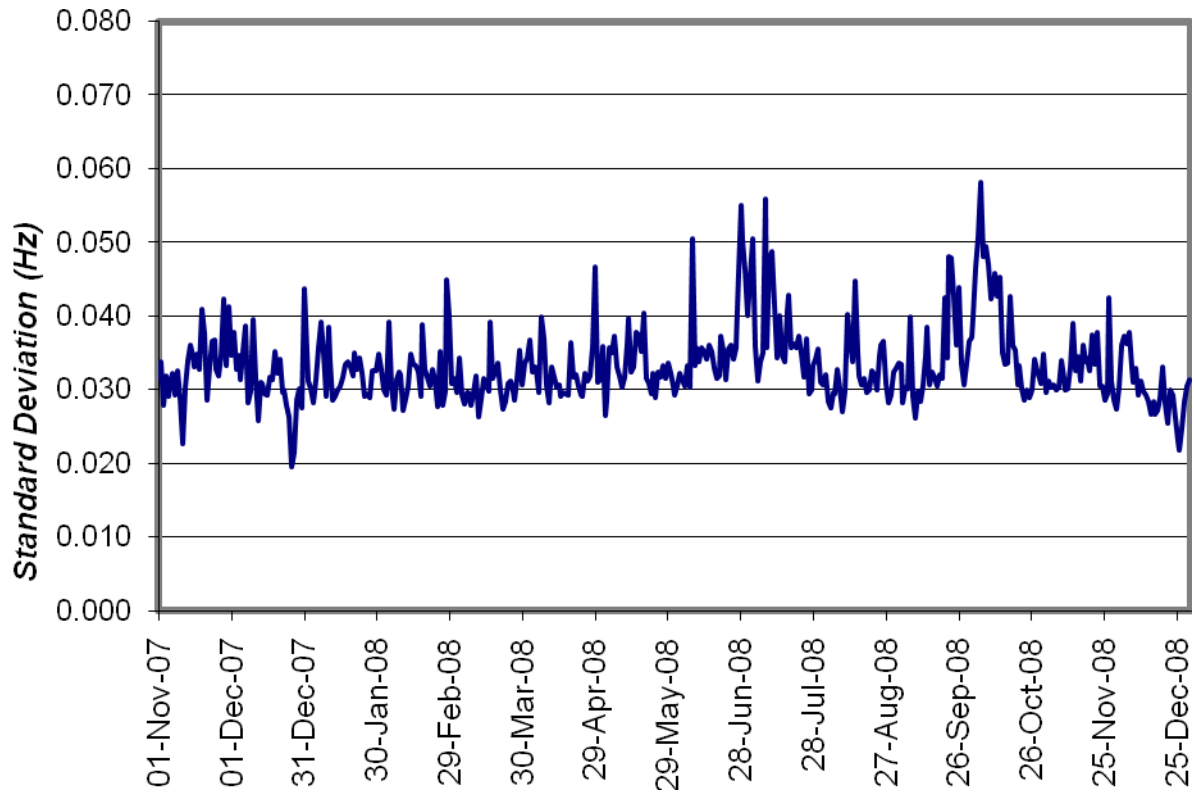


Figure 4: Daily Standard Deviation of frequency in Tasmania

2.5.3 Time of day Analysis

This section details the standard deviation of system frequency on a monthly and daily basis. Figures 5 and 6 show the average half-hourly standard deviation of the mainland regions and Tasmania frequency for October 2008, November 2008 and December 2008. The effects of contingency events have not been filtered from this time of day analysis.

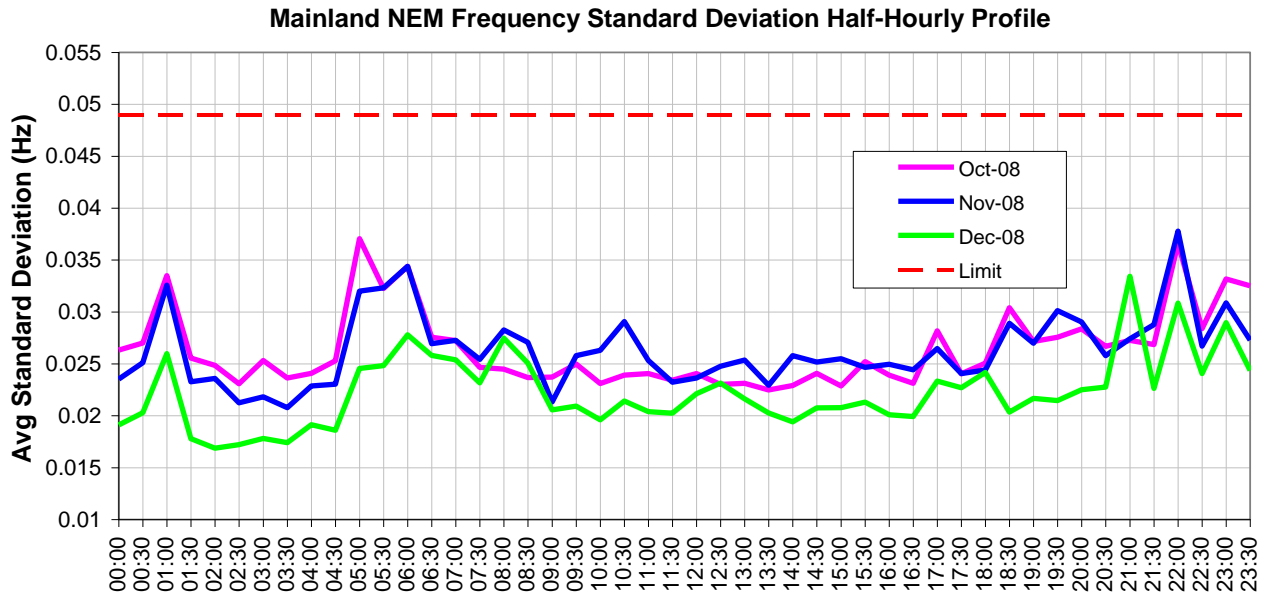


Figure 5: Daily profile of standard deviation for the frequency in the mainland regions

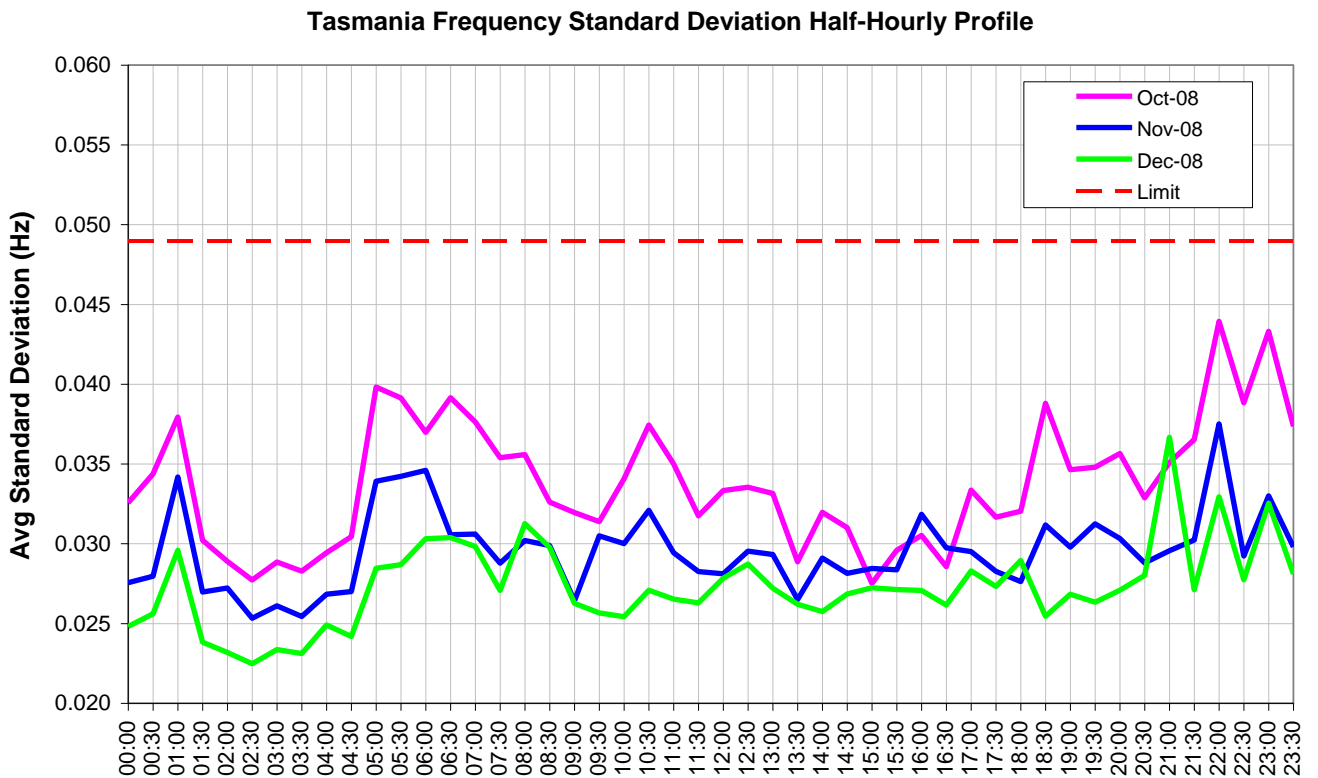


Figure 6: Daily profile of standard deviation for the frequency in Tasmania

The theoretical limit of 0.049 Hz shown in Figures 5 and 6 would ensure that 99% of observed values were in the range 49.85 - 50.15 Hz with a one in a million chance of being less than 49.75 and greater than 50.25 Hz. (This assumes that the frequency distribution follows an ideal normal distribution).

3 Accumulated Time Deviation

The frequency operating standards require that the accumulated time deviation be maintained within the range ± 5 seconds in mainland regions and ± 15 seconds in Tasmania.

For a separation event there is no requirement in the frequency operating standards that time deviation be maintained within the ranges specified above.

The range of accumulated time deviations recorded throughout the NEM during December 2008 is provided in Table 2.

Table 2: Accumulated time deviation statistics

	Queensland	NSW	Vic	SA	TAS
Maximum Positive Deviation (s)	4.74	4.64	4.05	4.13	4.64
Maximum Negative Deviation (s)	-3.92	-4.02	-4.57	-4.49	-3.86
Mean Value (s)	0.150	0.054	-0.532	-0.451	0.009
Standard Dev (s)	0.793	0.791	0.793	0.793	0.898

The distribution of time deviations based on the New South Wales region measurement is provided in Figure 7.

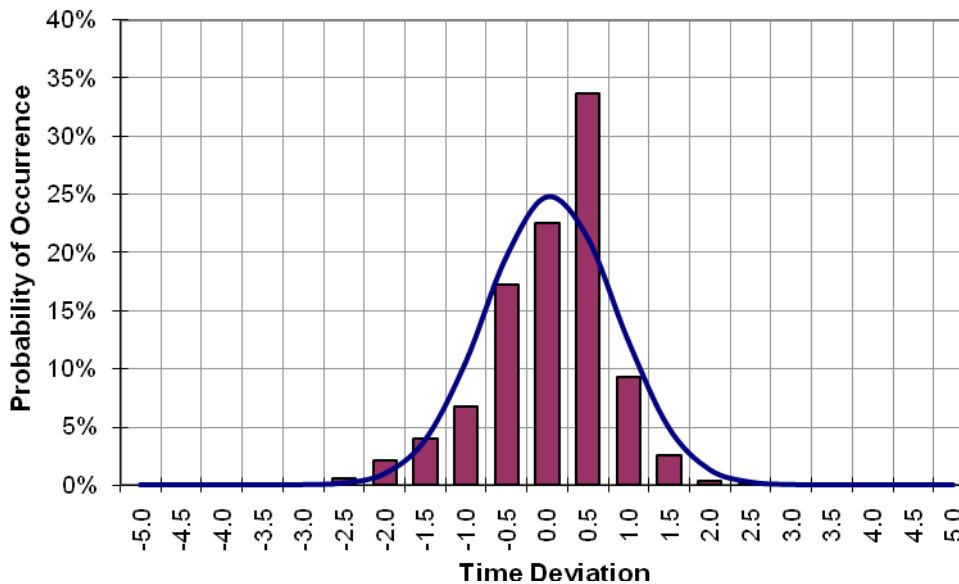


Figure 7: New South Wales Time Deviation Distribution for December 2008

The distribution of time deviations based on the Tasmania region measurement is provided in Figure 8.

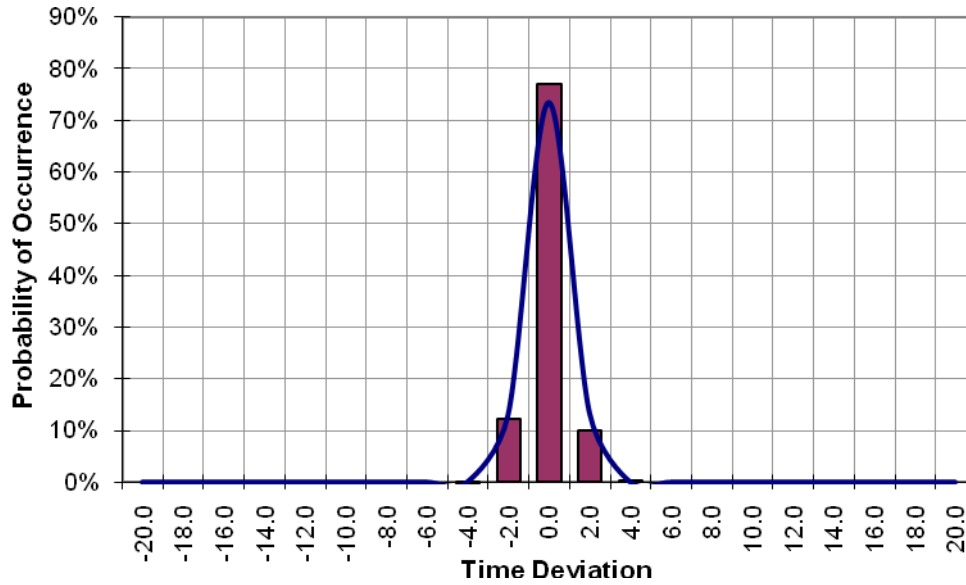


Figure 8: Tasmania Time Deviation Distribution for December 2008

3.1 Time Error Performance

Figure 9 below presents the daily maximum and minimum values of NSW time error observed for the past 13 months. Figure 10 presents the daily maximum and minimum values of Tasmania time error observed for the past 13 months.

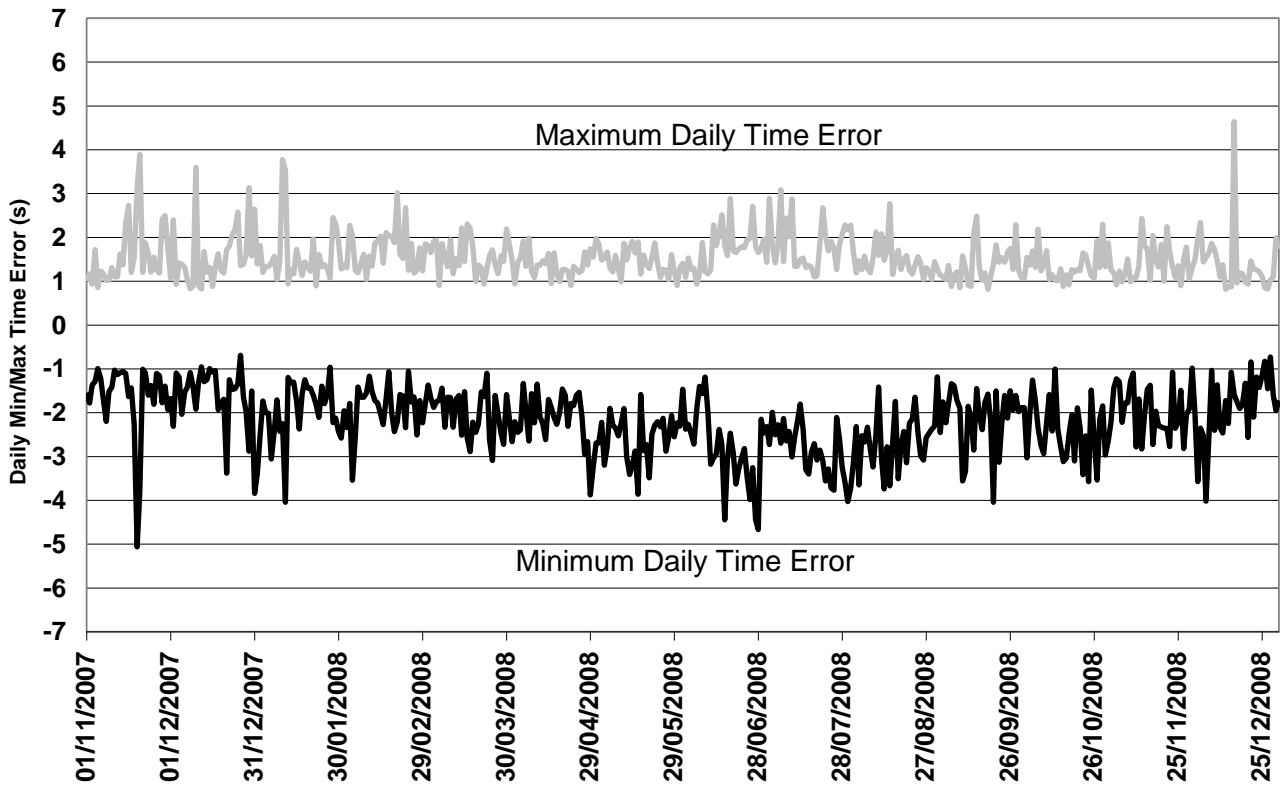


Figure 9: New South Wales Daily Maximum and Minimum Time Deviation

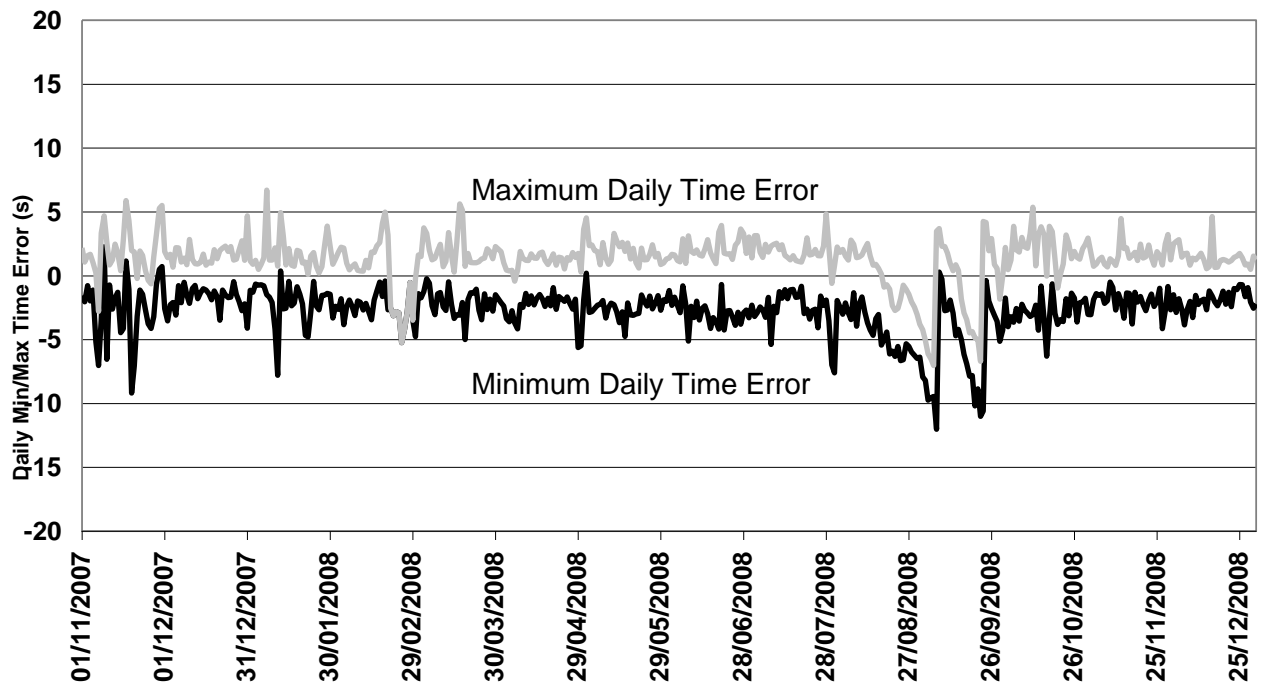


Figure 10: Tasmania Daily Maximum and Minimum Time Deviation

4 Appendix A – Frequency Operating Standards

The frequency operating standards for regions other than Tasmania are summarised in Tables A1 and A2. The Tasmania region frequency operating standards are shown in Tables A3 and A4.

Table A1: Summary of the mainland regions frequency operating standards (non-islanded system)

Condition	Containment	Stabilisation	Recovery
No contingency or load event	49.75 – 50.25 Hz 49.85 to 50.15 Hz 99 % of time	49.85 to 50.15 Hz within 5 minutes	
Generation or load event	49.5 to 50.5 Hz	49.85 to 50.15 Hz within 5 minutes	
Network Event	49 to 51 Hz	49.5 – 50.5 Hz within 1 minute	49.85 – 50.15 Hz within 5 minutes
Separation Event	49 to 51 Hz	49.5 – 50.5 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes
Multiple Contingency Event	47 to 52 Hz	49.5 to 50.5 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes

Table A2: Summary of the mainland regions frequency operating standards (islanded system)

Condition	Containment	Stabilisation	Recovery
No contingency or load event	49.5 to 50.5 Hz		
Generation, load or network event	49 to 51 Hz	49.85 to 50.15 Hz within 5 minutes	
Separation event that formed the island	49 to 51 Hz ³	49.0 – 51.0 Hz within 2 minutes	49.5 – 50.5 Hz within 10 minutes
Multiple Contingency Event	47 to 52 Hz	49.0 to 51.0 Hz within 2 minutes	49.5 to 50.5 Hz within 10 minutes

³ Or a wider band notified to NEMMCO by a relevant Jurisdictional Coordinator.

Table A3: The following table applies to any part of the Tasmanian *power system*, other than an *island*:

Condition	Containment	Stabilisation	Recovery
Accumulated time error	15 seconds		
No contingency or load event	49.75 – 50.25 Hz 49.85 to 50.15 Hz 99 % of time	49.85 to 50.15 Hz within 5 minutes	
Load Event	49.0 to 51.0 Hz	49.85 to 50.15 Hz within 10 minutes	
Generation Event	47.5 to 51.0 Hz	49.85 to 50.15 Hz within 5 minutes	
Network Event	47.5 to 53.0 Hz	49.0 – 51.0 Hz within 1 minute	49.85 – 50.15 Hz within 5 minutes
Separation Event	46 to 55 Hz	47.5 – 51.0 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes
Multiple Contingency Event	46 to 55 Hz	47.5 to 51.0 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes

Table A4: The following table applies to an *island* within the Tasmanian *power system*, with effect from the date of OFGSS commissioning:

Condition	Containment	Stabilisation	Recovery
No contingency or load event	49.0 to 51.0 Hz		
Generation or network event	47.5 to 53.0 Hz ^(Note)	49.0 to 51.0 Hz within 5 minutes	
Load event	47.5 to 53.0 Hz ^(Note)	49.0 to 51.0 Hz within 10 minutes	
The separation event that formed the island	46 to 60 Hz	47.5 – 53.0 Hz within 2 minutes	49.0 – 51.0 Hz within 10 minutes
Multiple Contingency Event including a further separation event	46 to 60 Hz	47.5 to 53.0 Hz within 2 minutes	49.0 to 51.0 Hz within 10 minutes

Note: Where it is not feasible to schedule sufficient frequency control ancillary service to limit frequency excursions to within this range, operation of the UFLSS or OFGSS is acceptable on the occurrence of a further contingency event.

5 Appendix B – Guidelines for measuring the time the frequency was outside normal operating band following a load or contingency event

The amount of time frequency was outside normal operating band as a result of low or high frequency event is measured as described in the steps below:

- 1) Start measurement the first instance the frequency exceeds normal operating band following a load or contingency event,
- 2) Add up all the times the frequency was outside normal operating band (areas shaded in grey in Figures B1 and B2 below)
- 3) If the frequency is still outside the normal operating band when the contingency event has ceased, then stop measurement the first instance the frequency returns to within the normal operating band following the end of the load or contingency event. Otherwise, stop measurement the last instance the frequency returns to within the normal operating band prior to the end of the contingency event.⁴

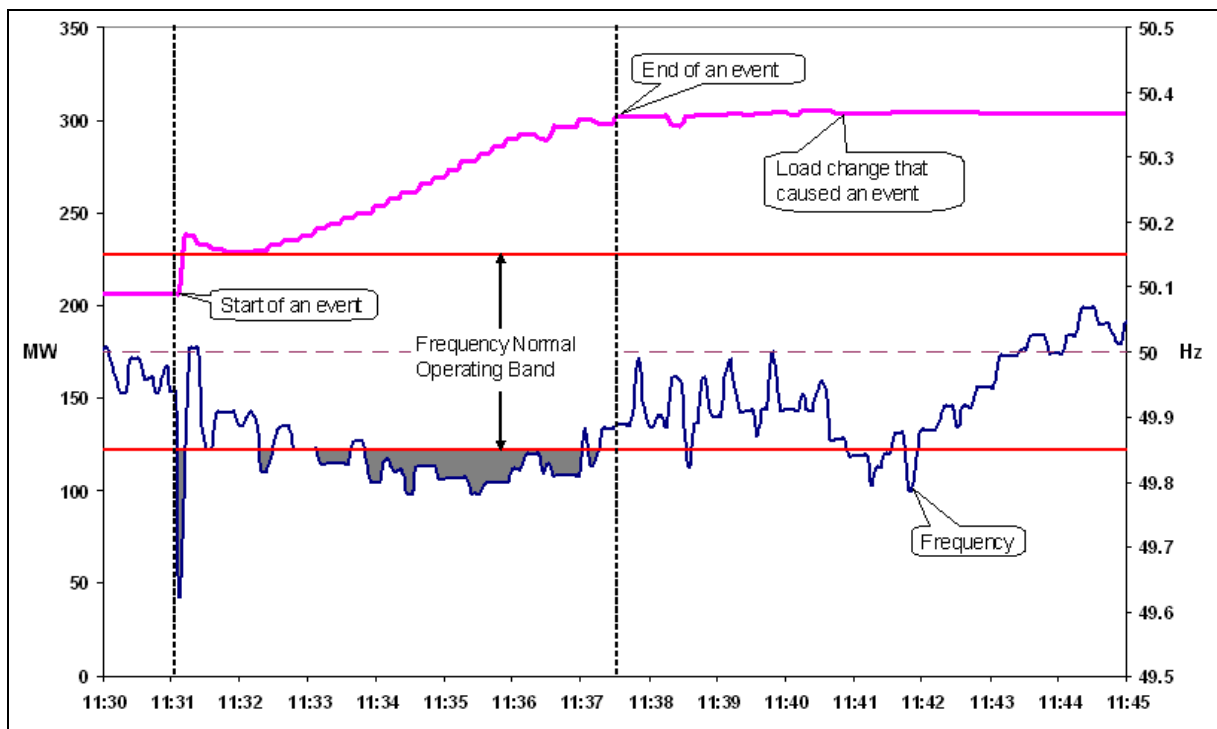


Figure B1: Example showing the time frequency was outside the normal operating band

⁴ A “contingency event” means an event affecting the *power system* which *NEMMCO* expects would be likely to involve the failure or removal from operational service of a *generating unit* or *transmission element*.

Example 2 in Figure B2 illustrates the nature of load events in Tasmania and how the measurement of time outside the normal operating band is not always straight forward. It also shows that for the event in this example, the standard requiring recovery to 49.85 to 50.15 Hz within a time of 300 seconds was not met.

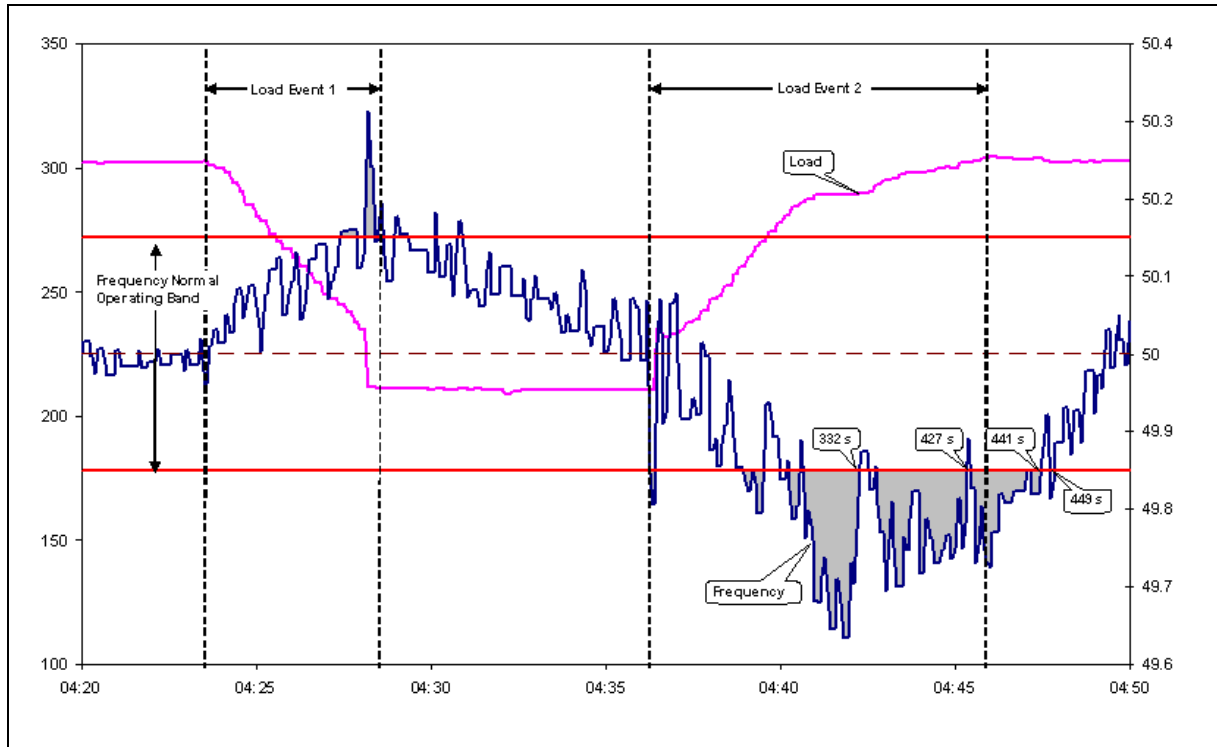


Figure B2: Example showing two consecutive load events, load reduction and load restoration and the times frequency was outside normal frequency operating band

Figure B2 illustrates the issues relating to controlling the frequency during such events. The load restoration commenced with a step increase and then gradually increased further over time. After the initial portion of load was restored the frequency immediately recovered to the pre-event level; however the gradual restoration of load continued over the longer period of time during which the frequency moved outside the normal operating frequency band. Figure B2 also illustrates that measuring the time the frequency was outside the normal operating frequency band is subjective and is left to interpretation to identify when the load event is complete. In Figure B2 there are number of times that could be selected as the event end time.

The guidelines applied by NEMMCO to the example in figure B2 indicate a recovery time of 441 seconds.

Figure B2 also illustrates the issues relating to evaluating FCAS performance during such load events. During the second load event (load restoration) the frequency has almost instantaneously recovered to 50 Hz which suggests that fast service was effective in arresting the frequency fall. However as the load continues to be restored the frequency begins to fall again. Evaluation of slow and delayed services for this particular example can not be evaluated because FCAS evaluation does not continue beyond the first instance that the frequency returns to 50 Hz. This is further explained in Appendix C.

6 Appendix C – Guidelines used for evaluating FCAS performance

NEMMCO is responsible for ensuring sufficient FCAS is enabled to maintain the system frequency within the frequency operating standards.

Generally, generating unit trips causes the generation output to decrease suddenly and the process for measuring the amounts of FCAS provided is straight forward.

However in some cases, load or generation events can occur as a ramp rather than a step change, as has been observed in Tasmania. In these cases measurement of FCAS response as per methodology described in Market Ancillary Services Specification can yield inconsistent results. Therefore the FCAS assessment will be made according to the criteria described below:

- For an event that causes instantaneous frequency deviation outside its normal operating band (typically generating unit trips as shown in Figure C1), the measurement of response begins when frequency exceeds normal operating band.
- For an event that causes gradual frequency deviations outside its normal operating band (typically caused by the ramping of load, Figure C2) the measurement begins when the change in identifiable load is greater than 20 MW in the Tasmania region and 50 MW in other NEM regions.
- For an FCAS assessment to be made the frequency must be outside the normal operating band and at least 60 seconds of data is required (in Figure C3 frequency has recovered to 50Hz within 60 seconds, as there is insufficient data no assessment is made). There should be no other contingency events occurring during the period over which the assessment is made.

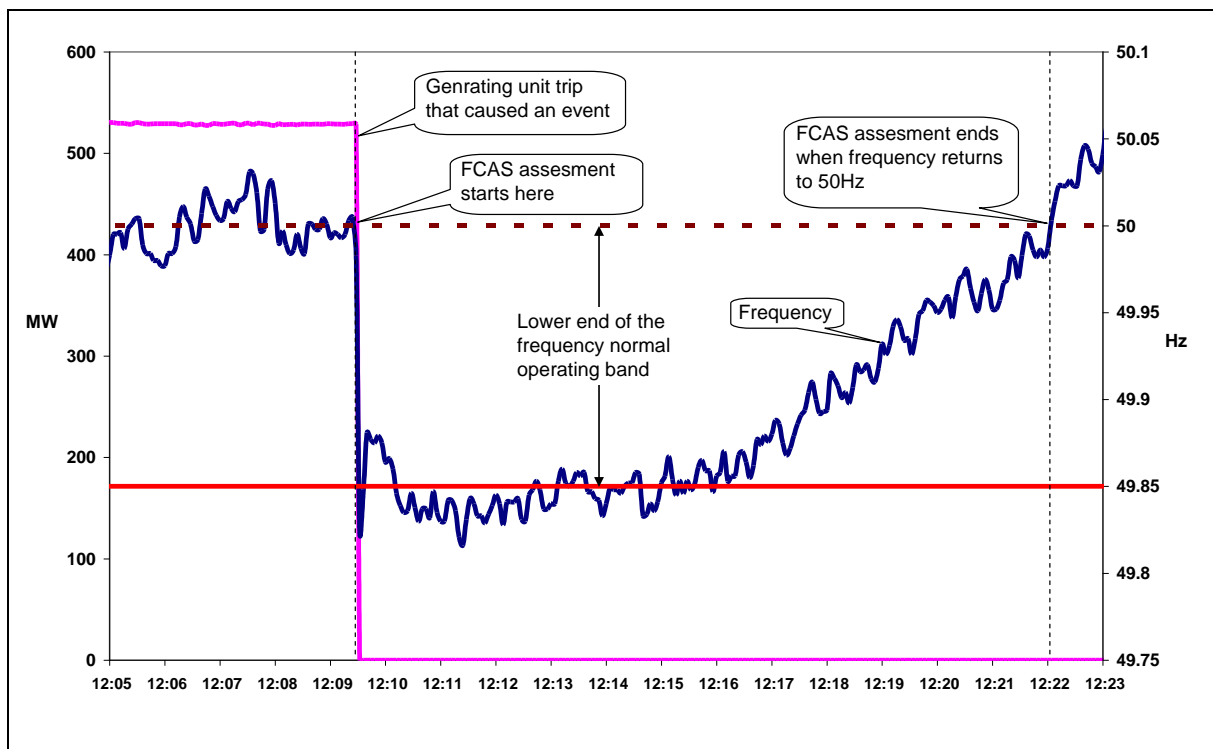


Figure C1: Example of an event where frequency change is rapid

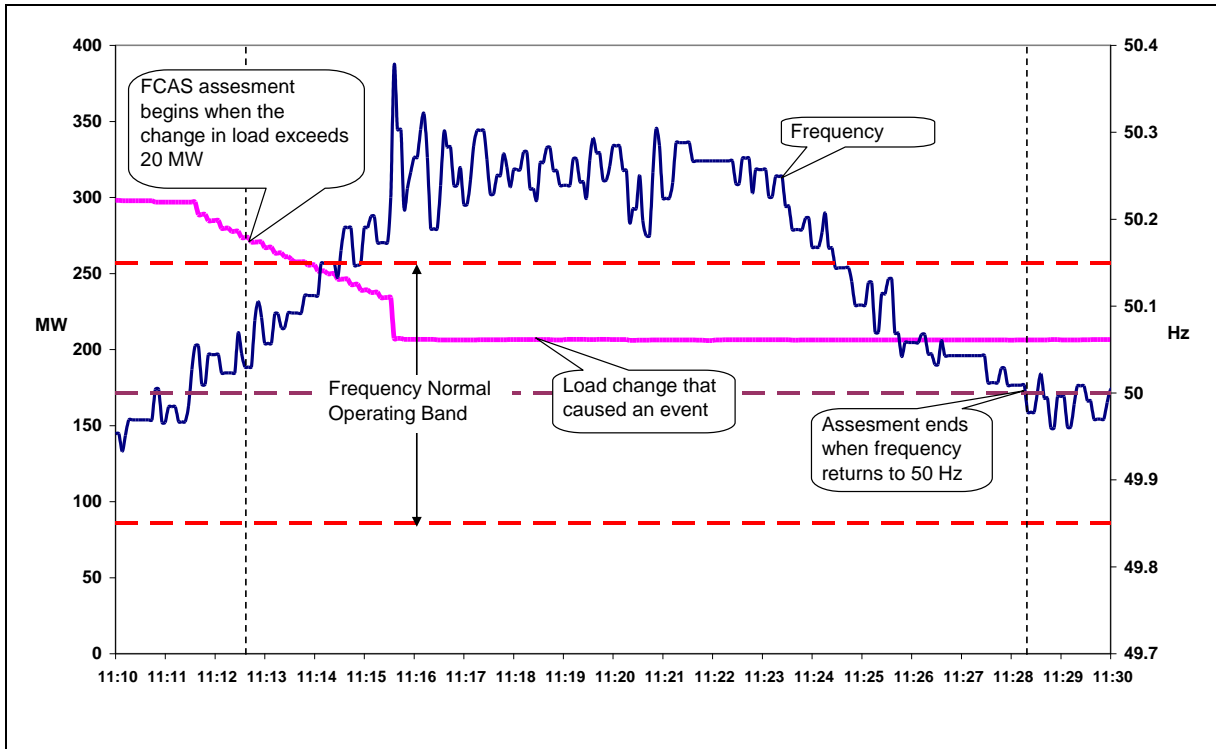


Figure C2: Example of an event in Tasmania where frequency change is gradual

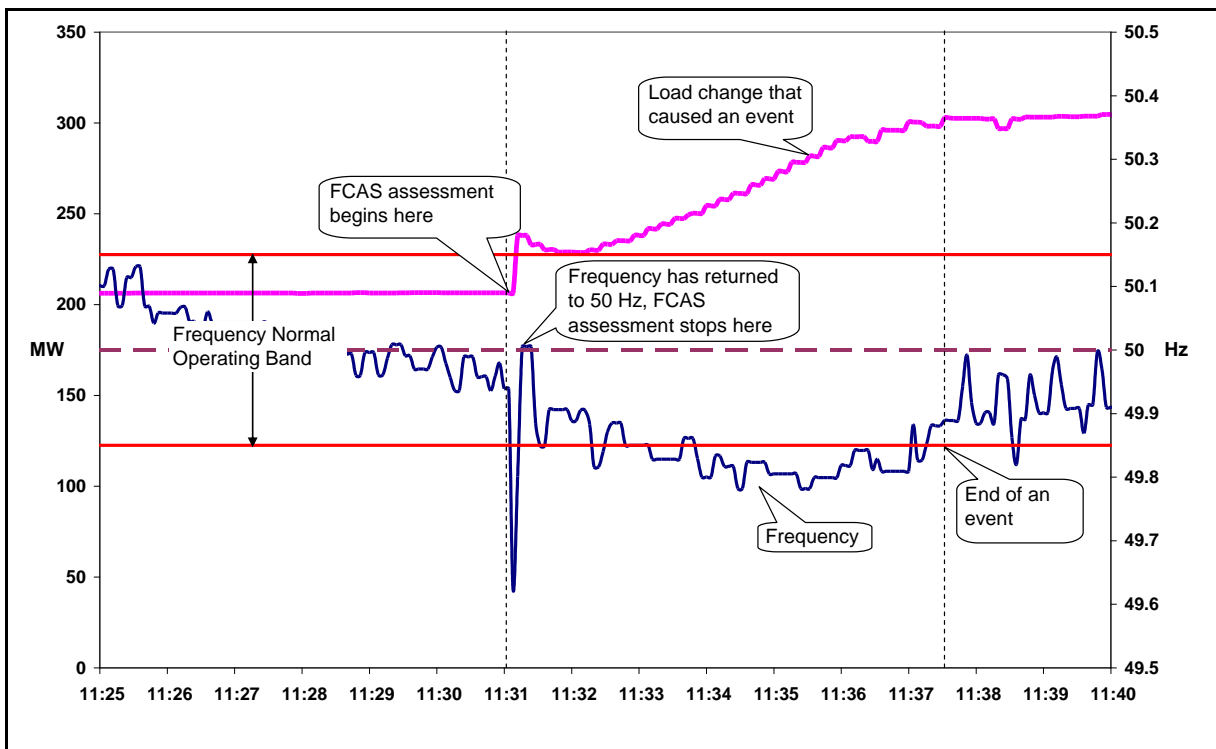


Figure C3: Example of an event where frequency recovery has been too quick for FCAS assesment to be made

7 Appendix D – Changes to FCAS Regulation Services Requirements for the NEM

7.1 Changes in regulating FCAS requirements effective 17 December 2007.

NEMMCO has developed FCAS constraint equations in dispatch to determine amounts of regulation FCAS (raise and lower) based on the time error. These constraint equations are now implemented following a trial that commenced on 17 December 2007.