Tasmanian Frequency Control Tests

Summary Report

F&M RINGROSE PTY LTD

F & M Ringrose Pty. Ltd.
36 Benjafield Tce Mount Stuart
Hobart, Tasmania, Australia, 7000
martin@fmringrose.com.au

Document Details

Title:	Tasmanian Frequency Control Tests Summary Report
Document ID:	C22-RP-001
Revision:	1
Prepared by:	Martin Ringrose F & M Ringrose Pty. Ltd.
Reviewed by:	Andrew Groom (AEMO), Matthew Holmes (AEMO), James Lindley (AEMO)
Date:	21/12/2018
Client:	Australian Energy Market Operator Ltd.
Client contact:	Andrew Groom

This page is blank

Executive Summary

In recent years, the quality of frequency control in the National Electricity Market under normal operating conditions has been steadily degrading. This has been linked to generators introducing or increasing frequency deadband and other control mechanisms to maintain compliance with their energy dispatch instructions and reduce variations in governor output. The current market mechanisms offer no direct incentive or obligation for providing primary frequency control under normal operating conditions. In Tasmania AEMO's automatic generation control (AGC) system has also been speculated as a potential factor in the degradation of performance.

The issue of frequency control during normal operation was investigated as part of the Frequency Control Frameworks Review conducted by the AEMC during 2017/18. The review did not propose any immediate regulatory changes to address the problem, but concludes that there is a need to find a more permanent solution.

During the first half of 2018, the Basslink inter-connector between Tasmania and Victoria was out of service. This presented an opportunity for testing potential improvements to frequency control during normal operation. With Basslink out of service, the influence of mainland frequency on Tasmania is removed. Tasmania is a comparatively small system when compared to the mainland NEM and currently has a single market generator, Hydro Tasmania. This enabled tests to be organised quickly and minimised coordination efforts.

The tests were conducted on selected days during May 2018. The specific aims of the tests were to assess:

1. The impact of AEMO's AGC system on Tasmanian frequency control performance
2. The system frequency performance improvement that could be achieved by reducing or removing the frequency deadband on selected generators
3. The change in governor activity caused by these modifications

Test periods were predominantly from 11:00 to 15:00 when the system could be closely monitored and changes to the underlying Tasmanian demand are minimal.

The tests were conducted with no intervention in either the energy or FCAS markets and no dispatch constraints were applied or modified. Hydro Tasmania participated in the tests on a voluntary basis and was able to withdraw at any time. Hydro Tasmania was also not compensated for and had no obligation to participate in the tests. Care was taken to ensure that Hydro Tasmania and the Tasmanian customers were not exposed to commercial or regulatory risk. This included consulting with the AER, and excluding the test periods from FCAS causer pays liability calculations.

During the testing Hydro Tasmania made changes to the governor deadband settings and operated governor data loggers. Hydro Tasmania's modern digital governors allows for the setting change to be made with the generators in operation. Changes to the AGC system settings were made by AEMO. Monitoring of the system was performed by AEMO, TasNetworks and Hydro Tasmania. All control settings were reverted to their normal values at the conclusion of testing.

Key findings from the tests were that:

1. Reducing or removing of the frequency deadband on selected generators produced a very clear improvement in system frequency performance
2. The frequency control in Tasmania was better than on the mainland during key test periods
3. The effect of changes to AEMO's AGC system were less clear; however, the primary test period was selected so as not to be challenging for AGC control

Governor activity was influenced by many factors, but could be seen to increase when the frequency deadband on a generator was reduced or removed

The impact of wind generation was also observable at times during the testing by comparing test intervals with steady wind generation to those with more varying wind generation. The periods of more variable wind generation resulted in wider variations in system frequency and increased governor activity.

Contents

1. Introduction ... 1
1.1. Frequency Control Mechanisms in the NEM ... 1
1.2. Degrading Frequency Control Performance During Normal Operation ... 2
1.3. Frequency Droop and Deadband ... 3
1.4. AEMO's AGC System ... 3
1.5. Tasmanian Frequency Control Tests ... 4
1.6. Operational Arrangements and Risk Mitigations ... 4
2. Test Summary ... 5
2.1. Tests Performed ... 5
2.1.1. AGC System Changes ... 5
2.1.2. Frequency Deadband Changes ... 5
2.2. Test Schedule ... 6
2.3. Measurement Points ... 6
3. Key Results ... 7
3.1. Baseline Test Frequency Distributions ... 7
3.2. Frequency Control with Narrow Deadbands ... 8
3.3. AGC System Changes ... 10
3.4. Governor Activity ... 11
3.4.1. Deviation from Dispatched Load Setpoint ... 11
3.4.2. Actuator Movement ... 13
4. Conclusion ... 15
Appendix A. Test Result Figures ... 17
A.1. Test Period 2 ... 17
A.2. Test Period 4 ... 18
A.3. Test Period 5 ... 19
A.4. Test Period 6 ... 20
A.5. Test Period 7 ... 21
A.6. Test Period 8 ... 22
A.7. Test Period 9 ... 23
A.8. Test Period 10 ... 24
A.9. Test Period 11 ... 25
A.10. Test Period 12 ... 26

A.11. Test Period 13 27
A.12. Test Period 14 28
A.13. Test Period 15 29

1. Introduction

1.1. Frequency Control Mechanisms in the NEM

Power system frequency varies when there is an imbalance between generation and load. Control of frequency is predominantly provided by generators varying their power output to correct the imbalance.

Traditionally there are two key frequency control mechanisms: primary control provided by the generator governor systems and secondary control provided by a central regulating system known as Automatic Generation Control (AGC). The governor systems typically operate on a 'droop characteristic' whereby a percentage change in frequency will cause a percentage change in power output away from their dispatched operating point. On their own they cannot both correct an imbalance and restore frequency to 50 Hz. Some frequency change away from 50 Hz is required to be maintained for their power output to remain away from their dispatched operating point, correcting the imbalance.

The AGC system is used to vary the operating points of one or more 'regulating' generators to restore both the frequency back to 50 Hz and the generators providing primary frequency control back to their dispatched operating point. The intention is that an imbalance is first taken up by generators providing primary frequency control then shifted to the regulating generators in the long term.

In the NEM real-time markets are used to obtain eight Frequency Control Ancillary Service (FCAS) services. Market generators provide the majority of these services and they are co-optimised with the energy market. Six of the markets are for the provision of frequency control services following a contingency event such as the loss of a generator or load. These are fast raise, fast lower, slow raise, slow lower, delayed raise and delayed lower. They are named after the direction the service provider should vary its output and the timeframe the variation must cover. The remaining two services are regulation raise and regulation lower and are controlled via AGC to more slowly correct imbalance during the normal operation of the system, in the absence of a contingency.

The frequency operating standards specify that, in the absence of a contingency event, system frequency should remain within the normal frequency operating band (50 ±0.15 Hz) at least 99 % of the time.

Contingency FCAS providers operating on droop characteristics must start to provide their service no later than when frequency goes outside of this range. At present there is no requirement to provide primary frequency control while frequency is within the normal frequency operating band. Primary frequency control that is currently delivered within this band is now often the result of control system systems arrangements and settings that either pre-date, or have been carried over from prior to the establishment of current FCAS markets.

This means that only generators dispatched for regulation FCAS and responding to AEMO's AGC system are obliged to act to correct imbalance during normal system operation. In the absence of primary frequency control, the AGC system is solely relied upon to correct frequency during normal operation. Inherent response delays and other design constraints in the AGC system limit its ability to perform this function.

1.2. Degrading Frequency Control Performance During Normal Operation

The performance of frequency control during normal operation has degraded in recent years, as explored in other recent reports[1,2]. This has been linked to increasing numbers of generators introducing or increasing frequency deadband or other control measures to limit or remove governor response while frequency is within the normal frequency operating band. Drivers for generators doing this include:

1. Maintaining close compliance with energy market dispatch instructions
2. Insufficient incentives, or obligations (direct or indirect)
3. Reducing their own unit response to declining system frequency control
4. Inability to recover costs including wear and tear caused by continual governor activity
5. Limiting exposure to cost recovery arrangements for Regulation FCAS
6. Unwillingness to provide response beyond what is explicitly compensated via the markets

The decline in the quality of frequency control in the NEM mainland and Tasmania under normal operating conditions is illustrated in the figures below. The figures show histograms of mainland frequency from Jan 2007 to Jan 2017 and Tasmanian frequency from Jan 2007 to May 2018. The tall and narrow distribution in the early years indicates that frequency is tightly controlled close to 50 Hz. The wider, flatter distribution in recent years indicates that frequency is not as well controlled and remains further away from 50 Hz for a larger percentage of the time.

The Basslink inter-connector has a frequency control function which aims to limit the difference between the Tasmanian and NEM mainland system frequencies. When Basslink is in operation the frequencies of the two systems are therefore strongly related. When Basslink is out of service the two systems are entirely unrelated as they are disconnected from one another.

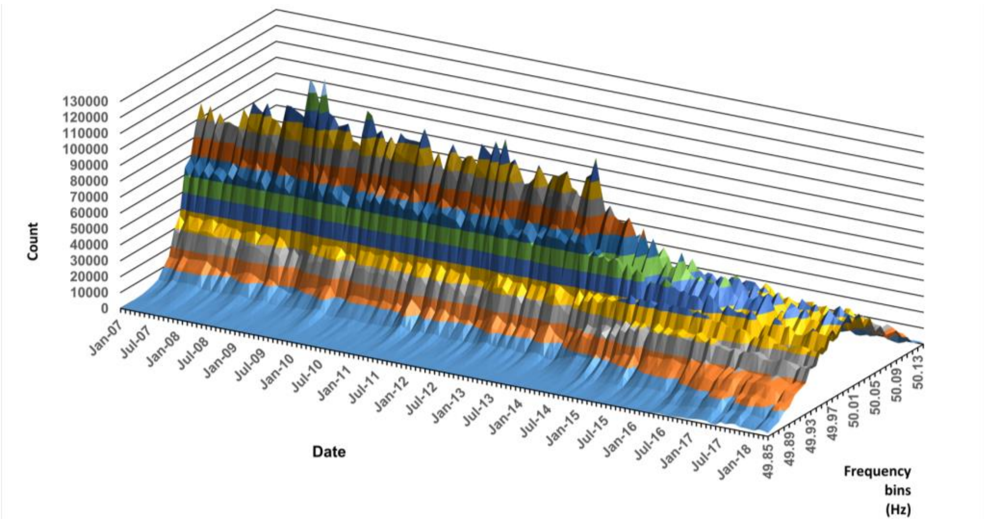

Figure 1.1 NEM mainland frequency histogram Jan 2007 to June 2018

---

[1] DIgSILENT Pacific, *Review of Frequency Control Performance in the NEM under Normal Operating Conditions*, Final Report, Rev. 3, J. Crisp, 19 September 2017

[2] AEMC, *Frequency control frameworks review*, Final report, 26 July 2018

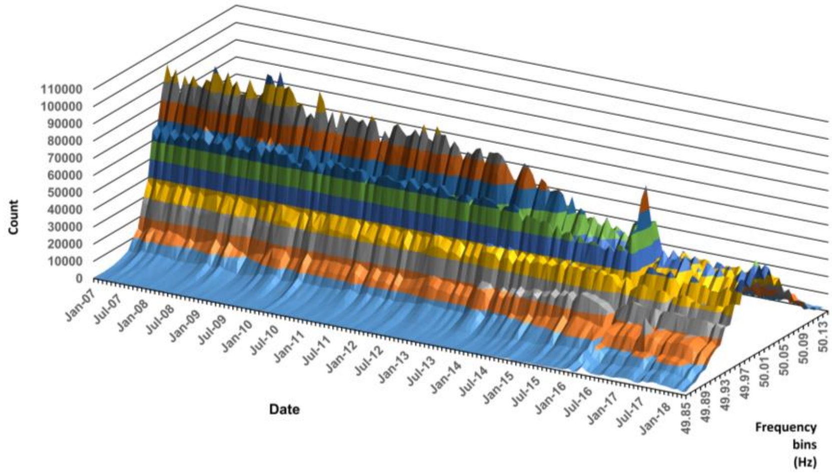

Figure 1.2 Tasmanian frequency histogram Jan 2007 to May 2018

1.3. Frequency Droop and Deadband

Traditionally, the majority of governor systems operated with a droop characteristic whereby a percentage change in frequency will cause a percentage change in power output away from their load setpoint. Although, many modern governor systems have multiple operating modes, some of which do not provide droop response, or which will defeat or limit any short term response delivered via droop characteristics.

Frequency deadband is a governor function that operates by removing the governor's droop response while frequency is within the deadband region, as illustrated below.

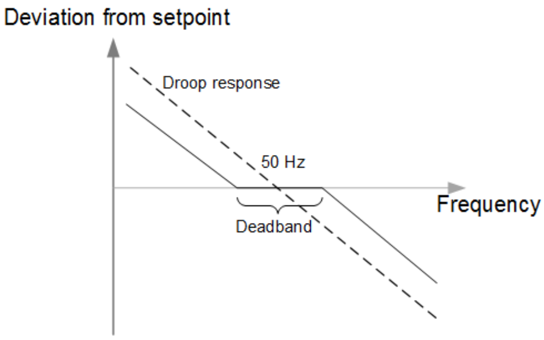

Figure 1.3 Frequency deadband illustration

While frequency is within the deadband region, the governor will remain at its setpoint and not assist with correcting a frequency deviation. Historical deadband settings were commonly ±0.05 Hz or less, resulting in tight frequency control. Frequency deadband settings are now commonly set as high as ±0.15 Hz, at the limit of the normal frequency operating band.

Another way of reducing a governor's response to frequency deviations is to monitor the generator's power output and adjust its setpoint to counter movements away from its dispatch instruction. This is commonly used on older governors which don't have a frequency deadband function. Such arrangements to ensure dispatch compliance prevent the delivery of sustained frequency response.

1.4. AEMO's AGC System

AEMO's AGC system monitors the system frequency on the NEM mainland and Tasmania and issues setpoint change commands to generators dispatched for regulation FCAS services. It has two main control objectives: to correct frequency to 50 Hz and to correct time error to 0. Time error is accumulated when frequency is not at 50 Hz for a period of time.

Although there are a number of settings that influence the responsiveness of the AGC system, the primary setting is the 'frequency bias'. It determines the magnitude of the setpoint change that is sent to the regulating generators for a given frequency error. The standard frequency bias setting applied currently for the NEM mainland is 280 MW/0.1 Hz and the standard setting for Tasmania is 20 MW/0.1 Hz, reflecting the much smaller size of the Tasmanian system.

It had been speculated that inappropriate configuration of the AGC system could be one of the factors contributing to the deterioration of frequency control performance in Tasmania during normal operation.

1.5. Tasmanian Frequency Control Tests

The Basslink inter-connector between Tasmania and Victoria was out of service during the first half of 2018. This was used as an opportunity for performing tests related to frequency control performance improvement. With Basslink out of service, the NEM mainland has no influence over Tasmanian frequency.

Tasmania is a significantly smaller system than the NEM mainland and currently has a single market generator; Hydro Tasmania. This enabled the tests to be organised quickly and minimised coordination efforts.

The specific aims of the tests were to assess:

1. The impact of AEMO's AGC system on Tasmanian frequency control performance
2. The performance improvement that could be achieved by removing the frequency deadband on selected generators
3. The change in governor activity caused by these modifications

The tests were conducted on selected days during May 2018. The four hour period between 11:00 and 15:00 was targeted for testing as it is characterised by flat Tasmanian demand and enabled close monitoring of some tests. A number of test periods were monitored with no changes from normal operation to gather baseline information. Several key tests were repeated.

During the testing Hydro Tasmania made changes to the governor deadband settings and operated governor data loggers. Changes to the AGC system settings were made by AEMO. All settings were reverted to their pre-test values at the conclusion of testing.

1.6. Operational Arrangements and Risk Mitigations

To minimise their impact, the tests were conducted with no intervention in either the energy or FCAS markets, no dispatch constraints were applied or modified and no attempt was made to alter generator dispatch. Hydro Tasmania was also not compensated for and had no obligation to participate in the tests. Care was taken to ensure that Hydro Tasmania and the Tasmanian customers were not exposed to commercial or regulatory risk. This included consulting with the AER prior to testing, and excluding the test periods from FCAS causer pays liability calculations.

Monitoring of the system during testing was performed at various stages by AEMO, TasNetworks and Hydro Tasmania. Arrangements were in place for any of the parties to call a halt to testing. Briefings were held each morning before testing commenced.

2. Test Summary

2.1. Tests Performed

The following tests were performed:

1. Baseline (no change from normal operation)
2. AGC system suspended with normal frequency deadbands
3. Frequency deadbands narrowed on selected generators with normal AGC system operation
4. Frequency deadbands narrowed on selected generators with AGC system suspended
5. AGC system settings changes
    a. Dynamic frequency bias
    b. Permissive blocking

Apart from the AGC system settings changes, each of the tests was repeated on different days.

2.1.1. AGC System Changes

When the AGC system was suspended, its frequency and time error correction functions were disabled. The system was put into monitoring mode so that changes in load would be incorporated into dispatch changes at the end of each five minute dispatch interval. However, no corrections were sent to the regulating generators during each interval.

During a Basslink outage in 2016 AEMO temporarily introduced a dynamic variation of the Tasmanian frequency bias setting based on the strength of the Tasmanian system. The fixed setting was subsequently restored. The dynamic frequency bias calculation was tested during May 2018 for comparison against the fixed bias setting.

Permissive blocking is an AGC system setting that prevents generator setpoint changes being issued that are in the same direction as the frequency error (that is, counter to correcting frequency). AEMO typically operates with this function disabled but its impact was trialed during the tests.

2.1.2. Frequency Deadband Changes

The frequency deadband settings on the following generators were reduced to 0 during the scheduled tests:

1. Bastyan
2. Cethana
3. Gordon Unit 1
4. Gordon Unit 2
5. Mackintosh
6. Reece Unit 2
7. Tribute

These generators represent a high proportion of the total generation in operation at the time. Each of the generators normally has a deadband setting of ±0.08 Hz.

2.2. Test Schedule

Testing was conducted over the period 14th to 28th May 2018. The schedule of tests is shown below:

Table 2.1 Schedule of tests

	14-May Test	14-15 May	15-May Test	15-16 May	16-May test	16-17 May	17-May Test	17-18 May	18-May Test
AGC Normal	X	X		X	X	X		X	X
AGC Suspended	X		X				X		
AGC Calculated Bias									
AGC Permissive blocking									
Deadbands Normal	X	X	X	X*	X	X			
Deadbands Narrow	X						X	X	X
Test Measurement Period*	1		2*		4*	5a,5b,5c,5d	6*	7a,7b,7c,7d	8*

	21-May Test	21-22 May	22-May Test	22-23 May	23-May Test	23-24 May	24-May Test	24-25 May	25-May Test
AGC Normal	X	X	X	X		X	X		
AGC Suspended					X				
AGC Calculated Bias								X	X
AGC Permissive blocking									
Deadbands Normal	X	X	X	X				X	X
Deadbands Narrow					X	X	X		
Test Measurement Period			9*	10a,10b,10c,10d	11*	12a,12b,12c,12d	13*		14*

	28-May Test
AGC Normal	
AGC Suspended	
AGC Calculated Bias	
AGC Permissive blocking	X
Deadbands Normal	X
Deadbands Narrow	
Test Measurement Period	15*

(light blue)	Baseline measurement period
(grey-blue)	AGC system suspended, normal deadbands
(light orange)	AGC system suspended, narrow deadbands
(light green)	AGC system normal, narrow deadbands
(light yellow)	AGC system settings changes, normal deadbands

* Governor logger data available

Test period 1 was used to briefly trial AGC system suspension and governor deadband removal. Baseline measurements (no settings modified) were taken on the periods labelled 4, 5, 9 and 10. Periods 5 and 10 were from over-night monitoring rather than the four-hour test period from 11:00 to 15:00 and have each been split into four separate sub-periods for analysis. Governor logger data was only available for the nominated four-hour test periods.

Measurements with the AGC system suspended and normal deadband settings were taken on the 15th of May (labelled period 2). Measurements with the AGC system suspended and narrow deadbands on the selected generators were taken on the 17th and 23rd of May (labelled period 6 and period 11).

Measurements with the AGC system normal and narrow deadbands were taken overnight on the 17th 23rd of May (split into sub-periods 7a–7d and 12a-12d) and during the four-hour test period from 11:00 to 15:00 on the 18th and 24th of May (periods 8 and 13).

The performance of dynamically calculated AGC bias setting was tested for a 24h period starting at approximately 15:00 on the 24th of May. AGC permissive blocking was tested on the 28th of May. The permissive blocking function described in Section 2.1.1 only influences generators dispatched for regulation services at the time. These were Cethana, Tribute, Mackintosh, Reece 1 and Reece 2.

2.3. Measurement Points

A TasNetworks Phasor Measurement Unit at Sheffield sub-station was used as the primary Tasmanian frequency measurement point. It records frequency at 20 ms intervals.

AEMO SCADA was used to monitor system load and total wind generation at 4 s intervals.

Inbuilt governor loggers were available on Tribute, Bastyan, Cathana, Mackintosh and Reece 2 generators. Generator frequency, guide vane position, active power setpoint and active power output were available on the loggers and sampled at 100 ms intervals.

3. Key Results

3.1. Baseline Test Frequency Distributions

The baseline test periods have no settings modified and represent the normal operation of the Tasmanian system while Basslink is out of service. For comparison purposes, the baseline test periods identified as having noisy (variable) wind generation are shown below.

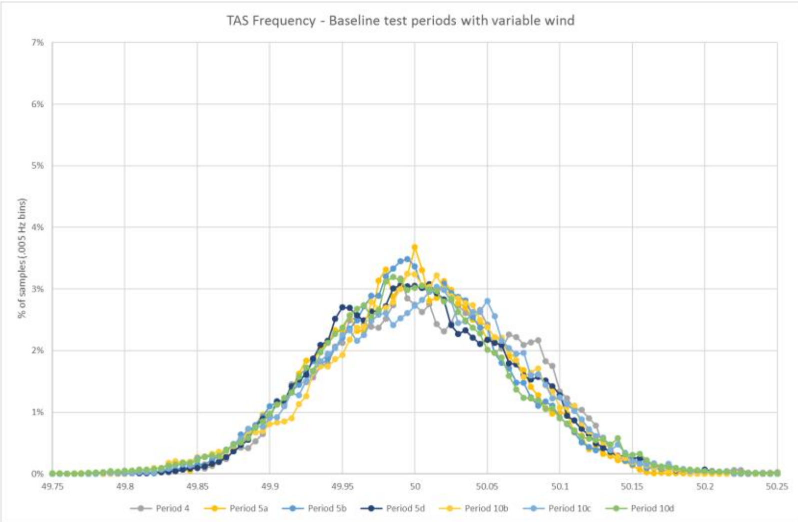

Figure 3.1 Baseline test frequency distributions with variable wind generation

Periods 1, 9 and 10a were identified as having flat wind generation profiles (little variation in wind generation power output). The frequency distributions for these periods are included along with the rest of the baseline test periods below. The variable wind generation can be seen to have a noticeable impact on frequency control performance. The periods with flat wind generation profiles have narrower, taller histograms indicating better control of frequency during those periods.

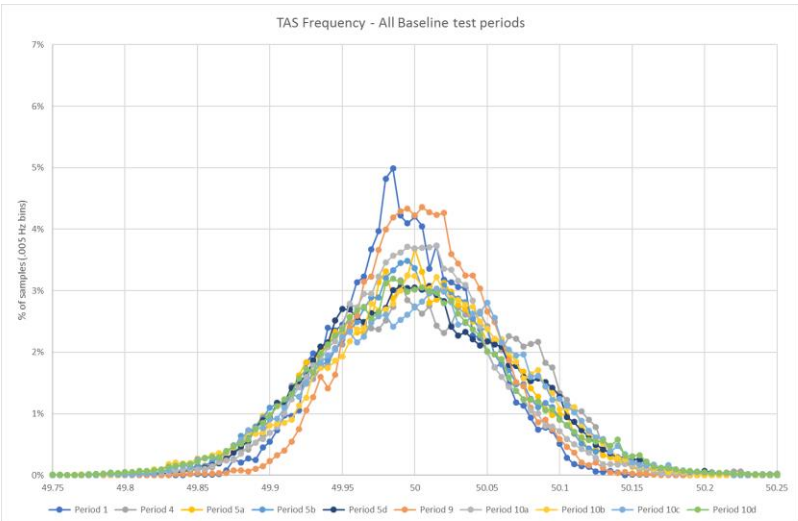

Figure 3.2 All Baseline frequency distributions

Period 4 is used as an indicative baseline distribution in subsequent comparisons.

3.2. Frequency Control with Narrow Deadbands

There was a clear improvement in frequency control performance during test periods with narrow deadbands. The figure below compares the frequency histogram for test period 13 which had narrow deadbands and flat wind generation against baseline period 4. The distribution is considerably narrower demonstrating better frequency control performance.

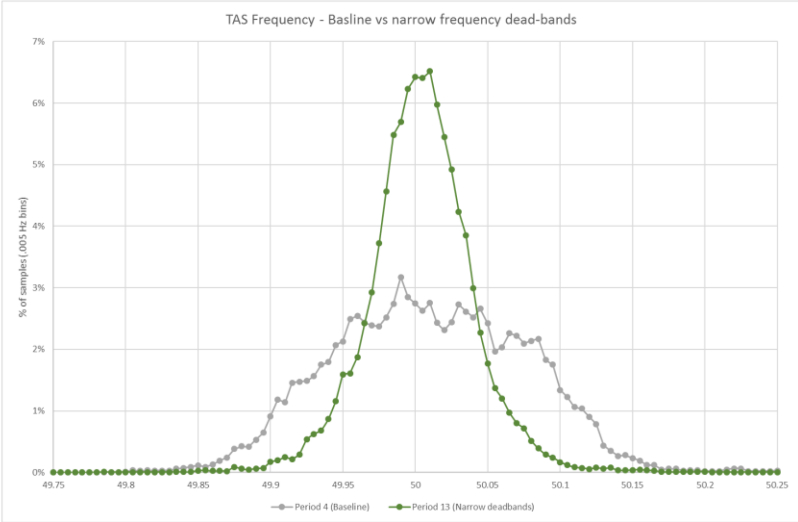

Figure 3.3 Baseline vs narrow deadband frequency distributions

The effect of variable wind generation could also be seen in the frequency control performance with narrow deadbands. The figure below compares the frequency distributions for test period 8, which had material variations in wind generation and narrow deadbands, against period 13 which had flat wind generation and narrow deadbands. Frequency control performance is clearly impacted by the variable wind generation.

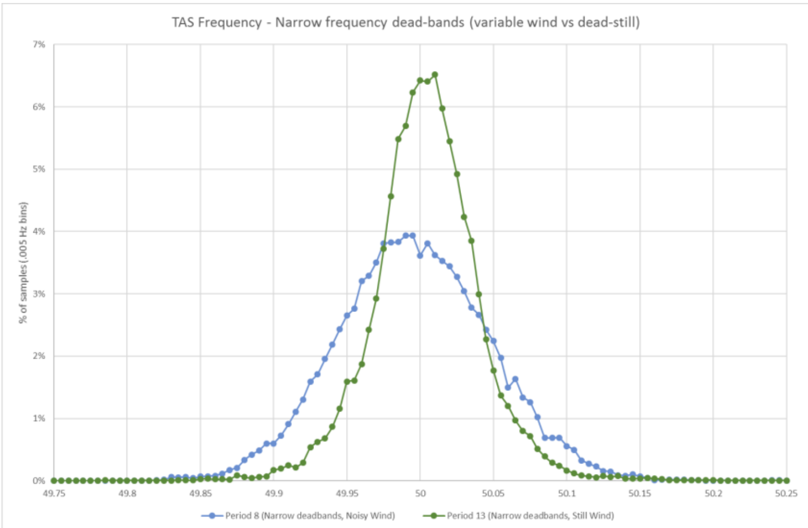

Figure 3.4 Frequency histograms for narrow deadbands with variable and still wind generation

The Tasmanian demand (calculated as the sum of all visible generation) and total wind generation for the two periods are show below:

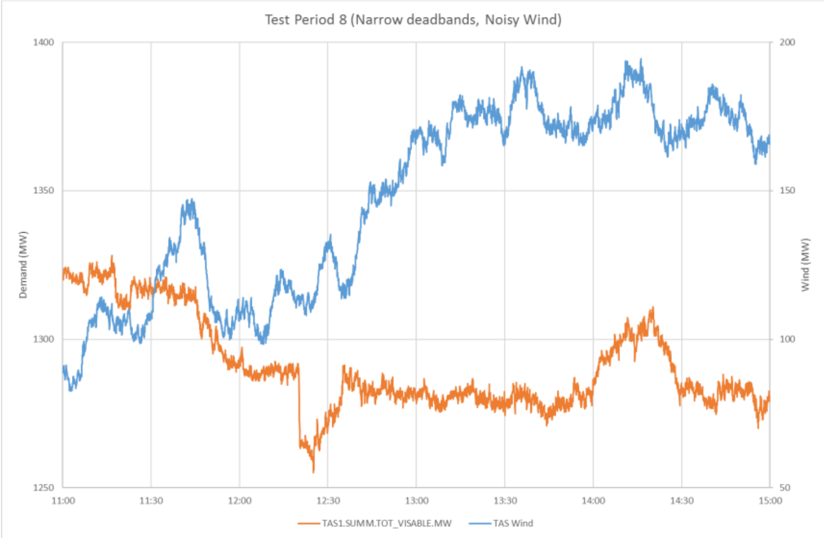

Figure 3.5 Tasmanian demand and total wind generation during test period 8

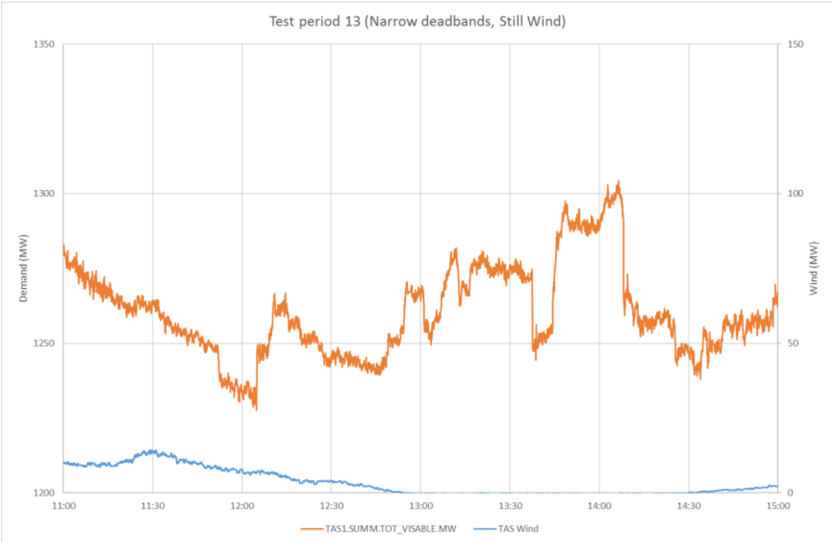

Figure 3.6 Tasmanian demand and total wind generation during test period 13

With narrow deadbands, frequency control performance in Tasmania was generally better than on the mainland as illustrated below. Typically, frequency control performance is worse in Tasmania due to the significantly smaller size of the system, proportionally larger disturbances and the predominance of hydro generation.

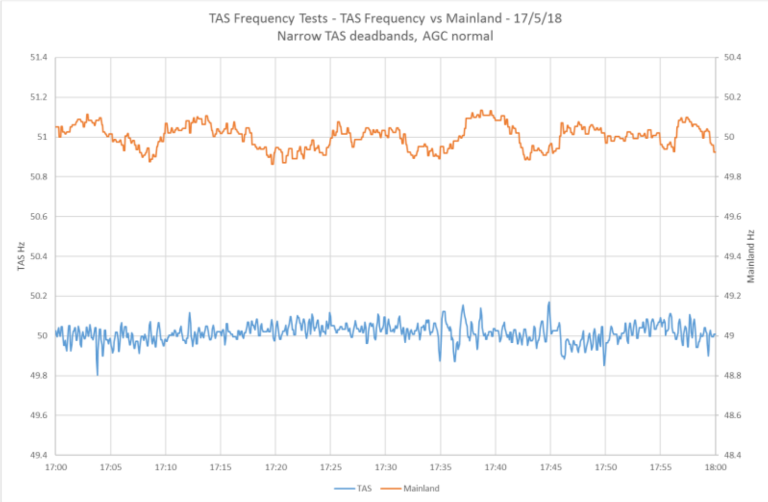

Figure 3.7 Comparison between NEM mainland and Tasmanian frequency with narrow Tasmanian deadbands

3.3. AGC System Changes

The impact of AGC system changes was not as clear cut as for the governor deadband reduction tests. The trial periods were chosen to coincide with flat Tasmanian demand particularly for tests with the AGC system suspended and were generally not challenging for AGC control.

A comparison between the frequency distribution for a baseline test period and a period with the AGC system suspended and with normal deadbands is shown below. The test period with the AGC system suspended has only a slightly wider distribution but notably has a significant proportion of the time outside of the normal frequency operating band.

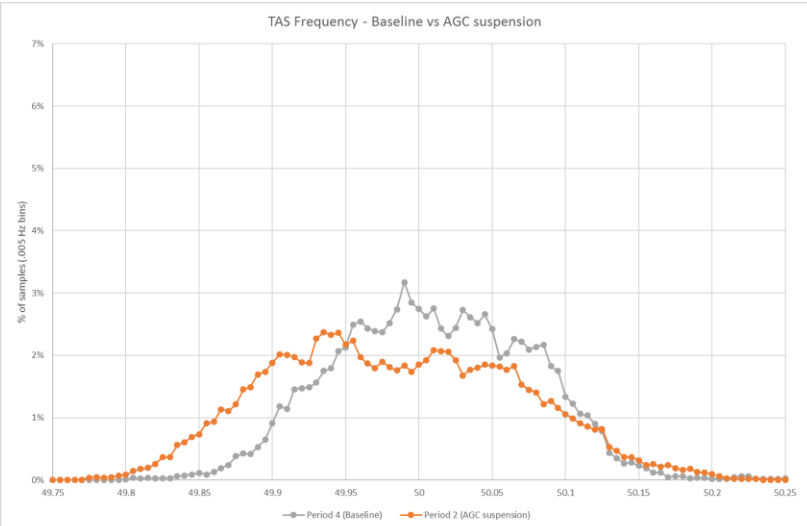

Figure 3.8 Frequency histograms for baseline and AGC suspended test periods

The results for the test periods with a dynamically calculated AGC bias and with permissive blocking are shown below. No dramatic change in frequency control performance is evident but the brief test periods were not long enough to distinguish between the influence of the settings changes or other factors. Further testing is required to observe changes in performance as a result of the AGC system settings changes. No adverse performance from the AGC system was noted during the testing.

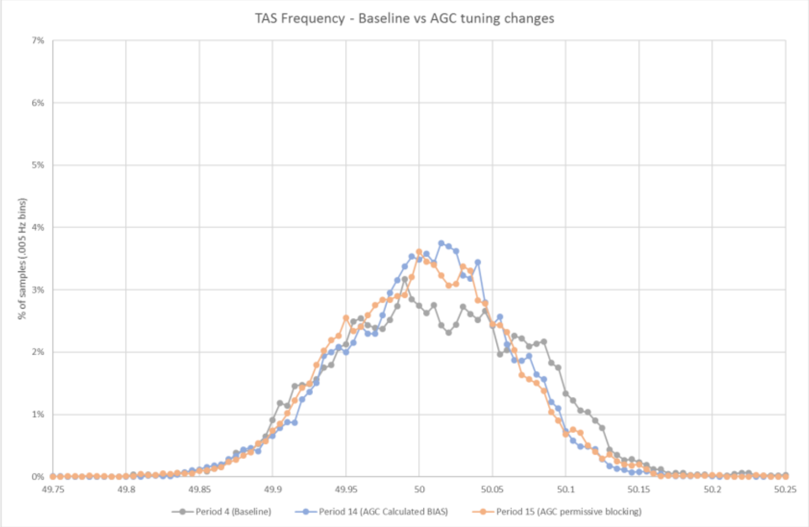

Figure 3.9 Frequency histogram for AGC settings changes and baseline tests

The dynamically calculated AGC bias setting during and either side of the test period is shown below. The bias setting is calculated based on Tasmanian system conditions, including demand and generator unit commitment.

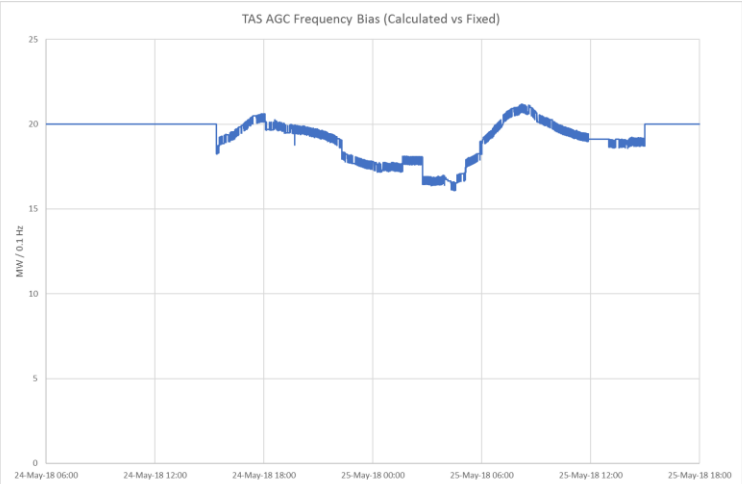

Figure 3.10 Normal and dynamically calculated AGC bias setting

3.4. Governor Activity

3.4.1. Deviation from Dispatched Load Setpoint

The changes in AGC system settings did not produce notable changes in load deviation statistics. However, there were clear differences when frequency deadbands were narrowed. As expected, narrowing the frequency deadband caused increased deviation in the generator's output away from its dispatched load setpoint. The deviations were relatively small however and did not cross thresholds for energy dispatch non-conformance to be monitored. The figures below show histograms for the deviation in load away from the dispatched setpoint. Figure 3.11 shows Cethana's histograms for period 4 (baseline with variable wind generation) and for period 13 (narrow deadbands with still wind generation). Figure 3.12 shows Tribute's histograms for period 4 and for period 8 (narrow deadbands with variable wind generations).

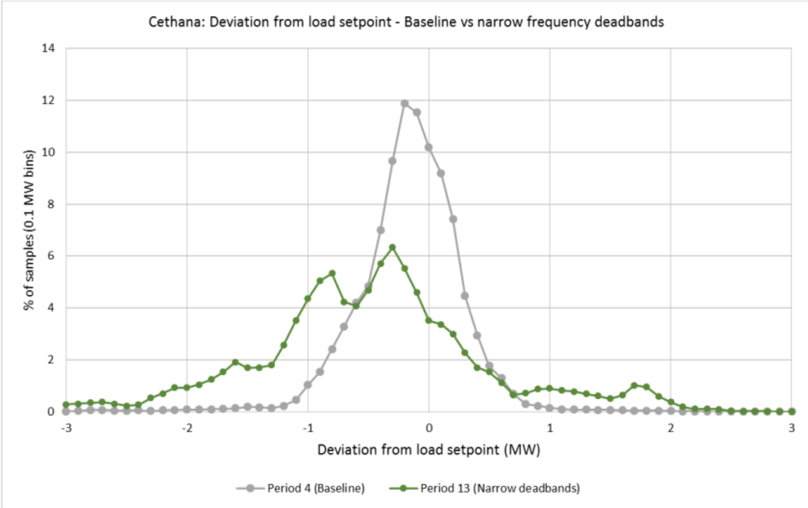

Figure 3.11 Cethana deviation from load setpoint histogram- baseline vs narrow deadbands

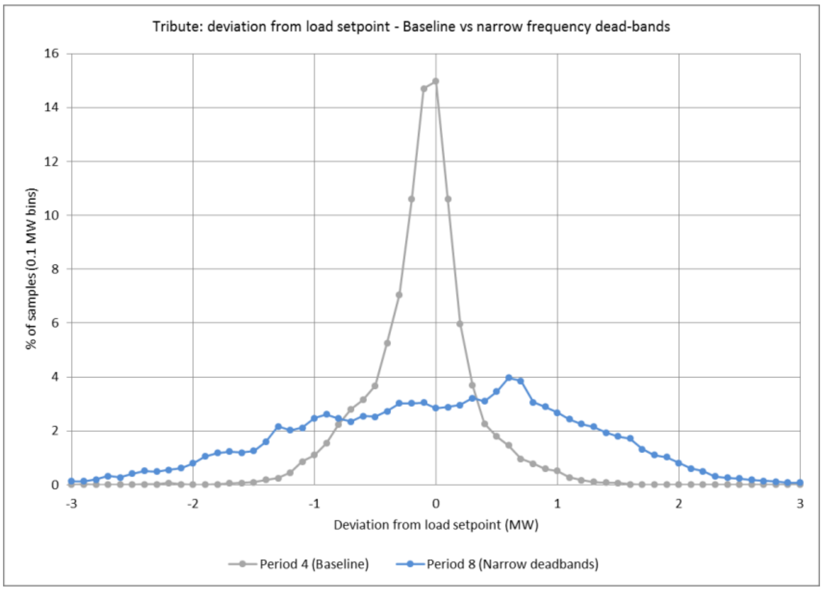

Figure 3.12 Tribute deviation from load setpoint histogram- baseline vs narrow deadbands

The statistics for several test periods are summarised below with 95th percentile figures for each of the monitored generators. Variable wind generation can be seen to generally increase the deviation from load setpoint. Note that for generators dispatched for regulation services, the load setpoint includes regulation commands.

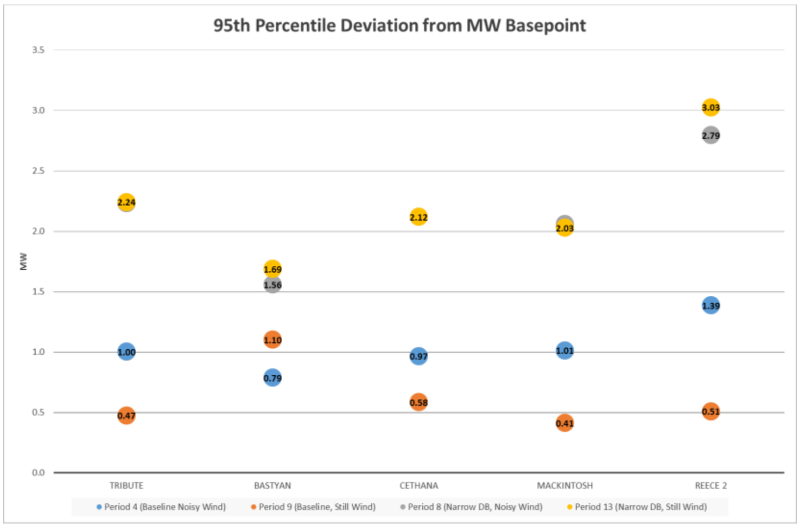

Figure 3.13 Deviation from load setpoint 95th percentiles

Analysis of regulation FCAS causer pays factors indicated that, if the test periods weren't excluded, there would have been limited impact as a result of the testing. Hydro Tasmania's scheduled generation factor would have improved by 0.2% if the test periods were not excluded.

3.4.2. Actuator Movement

Each of the monitored generators has a Francis hydro turbine which are controlled using guide vanes. The guide vane positions on five generators were monitored during the test periods and their movements analysed. Increased movement of the guide vanes has been taken as an indicator of potential increased wear and tear associated with providing continuous primary frequency control. Feedback from Hydro Tasmania indicated that while increased guide vane movement would be expected to lead to some increase in maintenance costs, the relationship is currently unknown.

The guide vane movements have been summarised as a total distance travelled per hour, averaged over each test period. Although some trends were clear, the guide vane movements of individual generators were seen to be influenced by a number of factors that were unrelated to the particular test condition, including:

1. If the generator was dispatched for regulation FCAS duty
2. If the generator was dispatched to full load
3. Wind generation variability

As no control of the market was attempted during the testing, these influences were not consistent across the test periods. The particular governor's tuning (speed of response) was also seen to heavily influence the guide vane movement results.

The influence of some of these factors can be seen in Figure 3.14 and Figure 3.15 below. Figure 3.14 compares the guide vane movements of the monitored generators across test period 9 which was a baseline period with flat wind generation. In this test period Reece 2 was dispatched to full load and provided energy only (no regulation FCAS) for the entire test period. Bastyan and Mackintosh were similarly dispatched but came online part of the way through the test period. All three of these units had steady guide vane positions and power output. Tribute and Cethana were dispatched at part load and for regulation FCAS services for the entire test period. The power output and guide vane positions varied considerably more on these units.

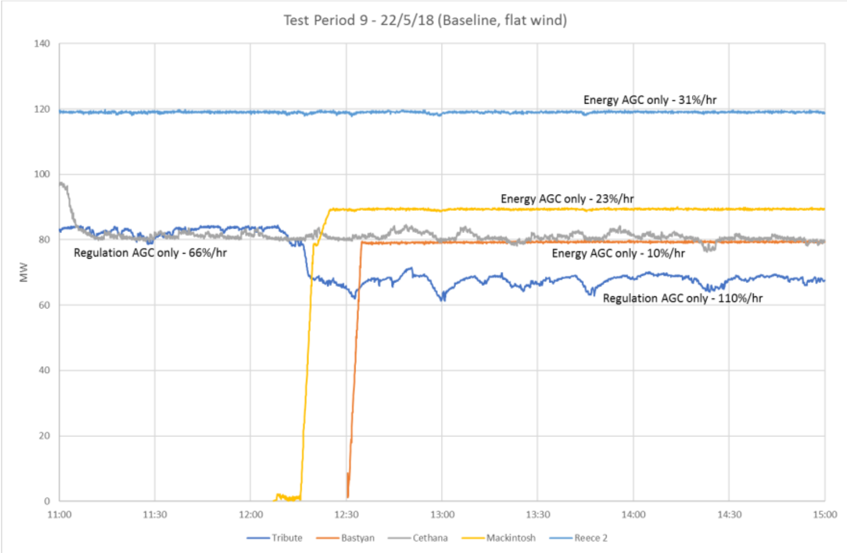

Figure 3.14 Power output of monitored generators for test period 9

The total guide vane movement for Reece 2 is separated into mileage figures for energy only dispatch and for regulation FCAS dispatch for several test periods below. Regulation dispatch can be seen to be a significant factor in the results. The amount of regulation service and whether raise and/or lower regulation is being provided are also factors.

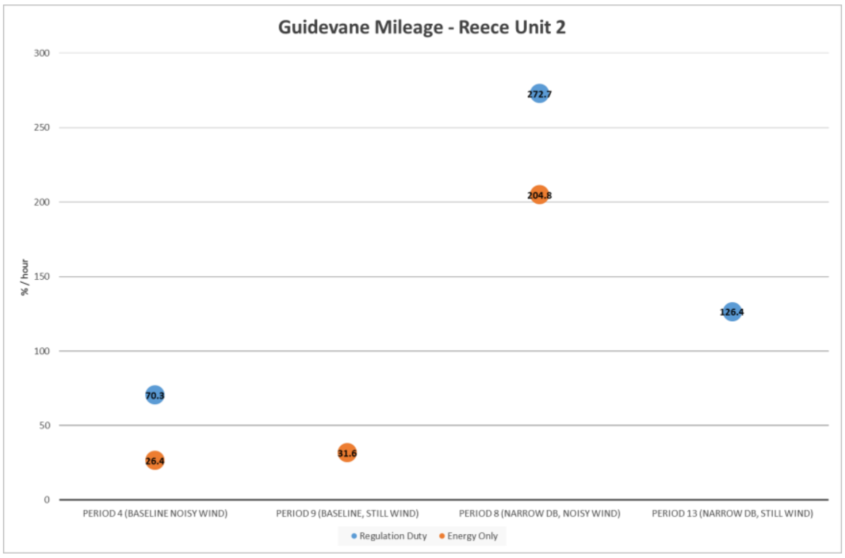

Figure 3.15 Reece 2 governor mileage for several test periods

The guide vane movement for all five monitored generators for two baseline and two narrow deadband test periods are shown below. For consistency, a mileage figure for either regulation or energy only dispatch is compared (whichever was more prevalent for the unit during the tests). It can be seen that test period 8 with narrow deadbands and varying wind generation produced the most guide vane movement. Period 13 with narrow deadbands and flat wind generation also produced increased guide vane movement in comparison to the baseline test periods.

The influence of governor tuning (speed of response) is also evident in the results. Bastyan and Mackintosh have slower responding governors and therefore lower guide vane mileage figures.

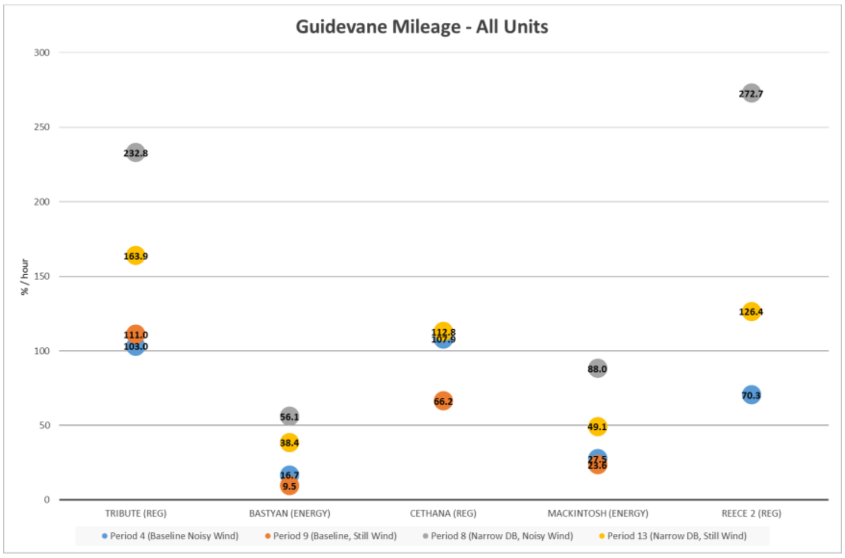

Figure 3.16 Governor mileage for all monitored generators

4. Conclusion

During the first half of 2018, the Basslink inter-connector between Tasmania and Victoria was out of service, removing the influence of the mainland on the Tasmanian power system. This presented an opportunity for performing tests into solutions to the degrading frequency control performance in the NEM during normal operation.

Tasmania is a comparatively small system when compared to the mainland NEM and currently has a single market generator, Hydro Tasmania, enabling tests to be quickly organised.

The tests were conducted on selected days during May 2018, predominantly from 11:00 to 15:00 when the system could be closely monitored and changes to the underlying Tasmanian demand are minimal. Several low risk settings changes were also left in service over night.

The specific aims of the tests were to assess:

1. The impact of AEMO's AGC system on Tasmanian frequency control performance
2. The system frequency performance improvement that could be achieved by reducing or removing the frequency deadband on selected generators
3. The change in governor activity caused by these modifications

Key findings from the tests were that:

1. Removal of the frequency deadband on selected generators produced a very clear and immediate improvement in frequency control performance
2. The frequency control in Tasmania was better than on the mainland during key test periods
3. The effect of changes to AEMO's AGC system were less clear; however, the primary test period was selected so as not to be challenging for AGC control
4. Governor activity was influenced by many factors, especially regulation duty, but could be seen to increase when the frequency deadband on a generator was removed

The impact of wind generation was also observable at times during the testing. The periods of more variable wind generation resulted in wider variations in system frequency and increased governor activity.

Appendix A. Test Result Figures

A.1. Test Period 2

15th May 2018: AGC system suspended, deadbands normal, noisy wind generation.

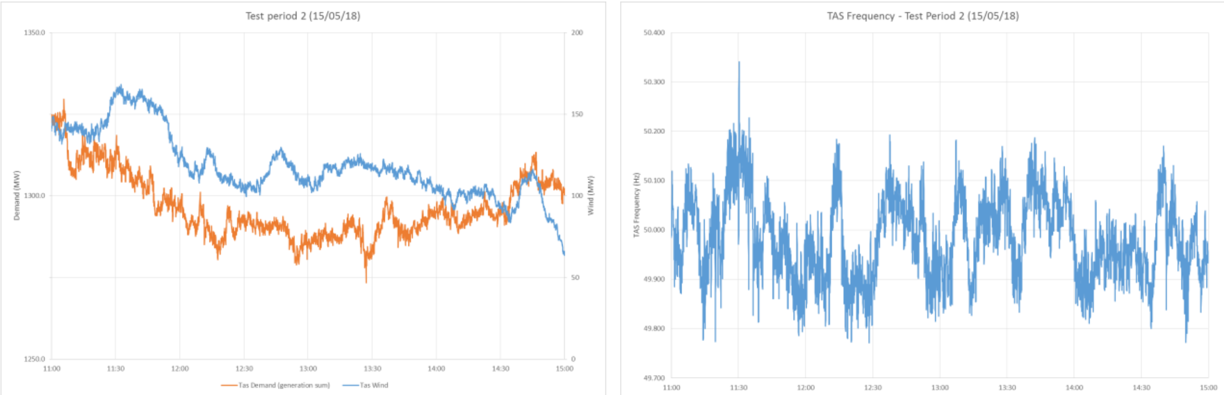

Figure A.1 Tasmanian demand, total wind generation and frequency - test period 2

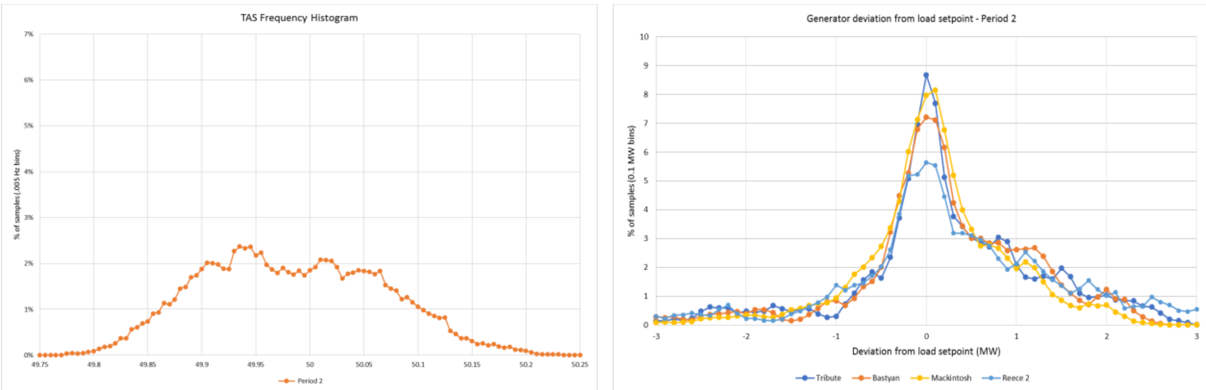

Figure A.2 Tasmanian frequency and deviation from load setpoint histograms - test period 2

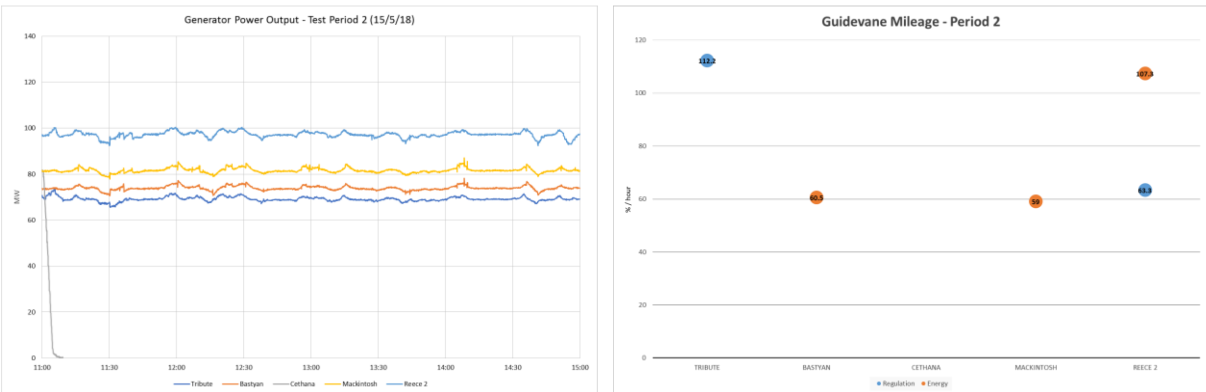

Figure A.3 Monitored generator power output and guide vane mileage - test period 2

A.2. Test Period 4

16th May 2018: Baseline monitoring period, noisy wind generation.

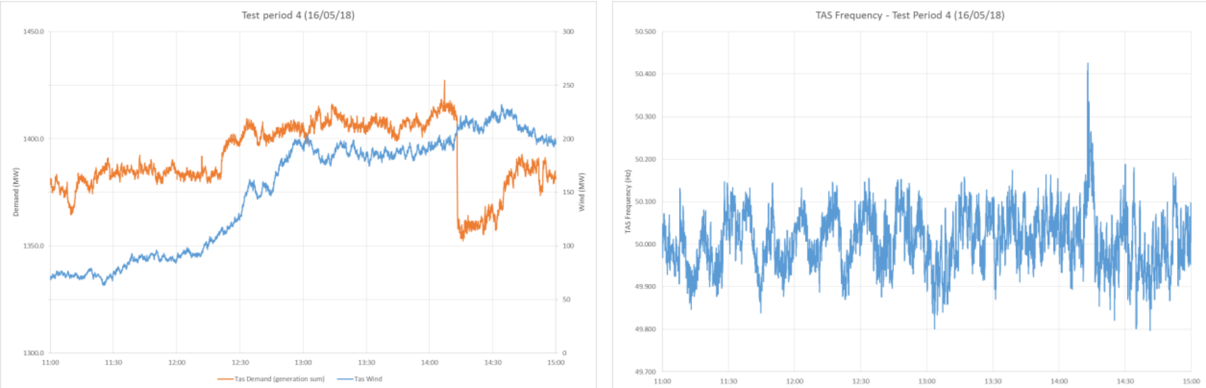

Figure A.4 Tasmanian demand, total wind generation and frequency - test period 4

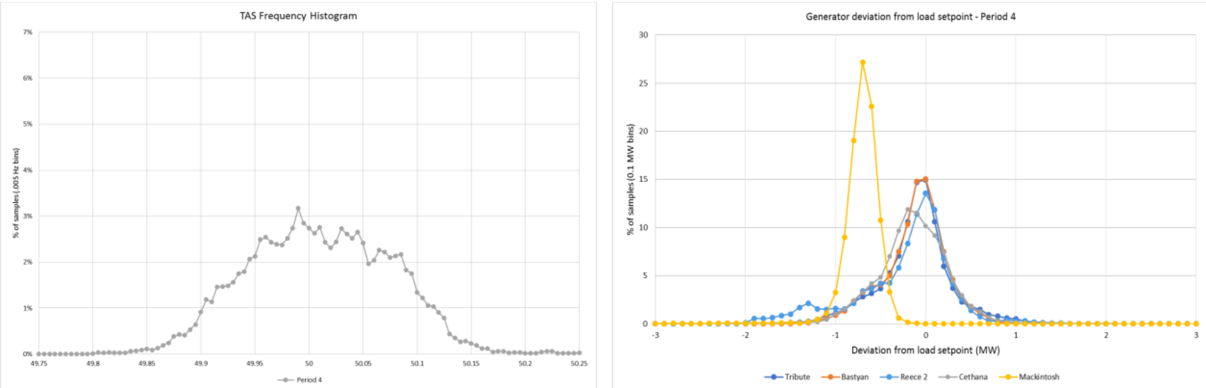

Figure A.5 Tasmanian frequency and deviation from load setpoint histograms - test period 4

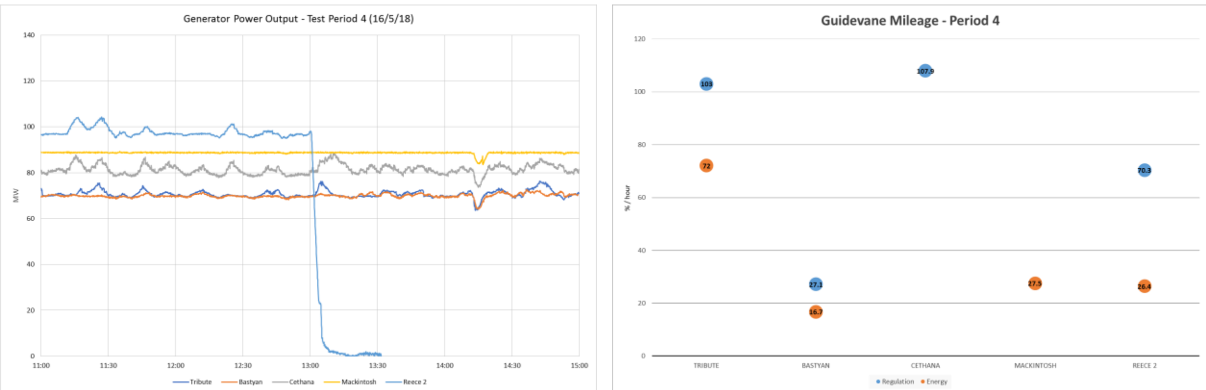

Figure A.6 Monitored generator power output and guide vane mileage - test period 4

A.3. Test Period 5

16th – 17th May 2018: Additional baseline data. Noisy wind generation in periods 5a – 5c. Smooth wind generation in period 5d.

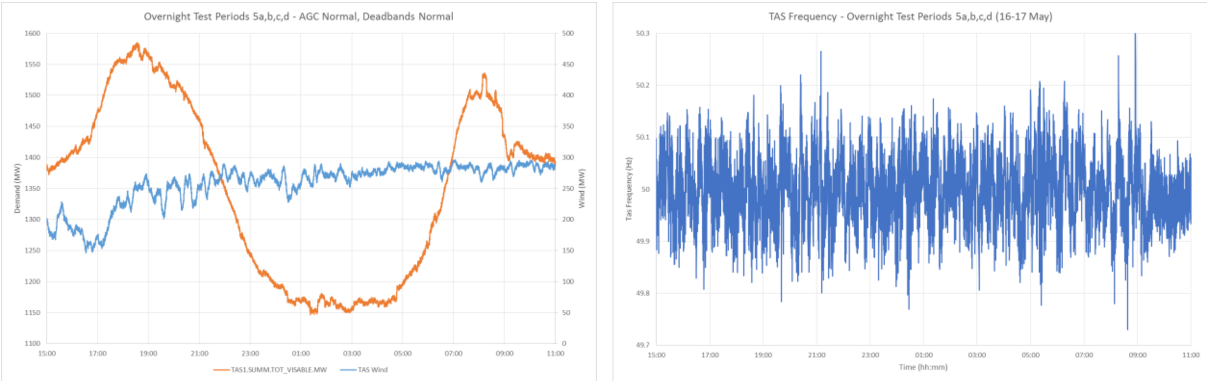

Figure A.7 Tasmanian demand, total wind generation and frequency - test period 5

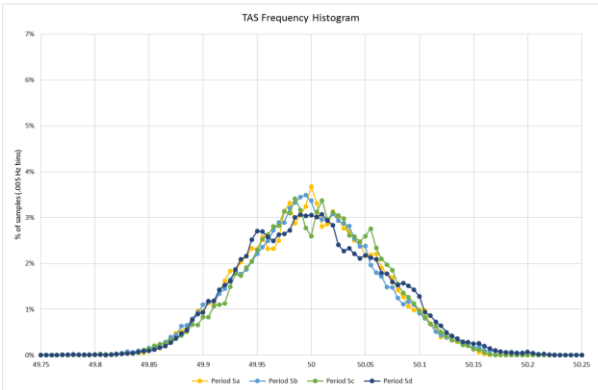

Figure A.8 Tasmanian frequency histograms - test period 5

A.4. Test Period 6

17th May 2018: AGC system suspended, deadbands narrow, smooth wind generation.

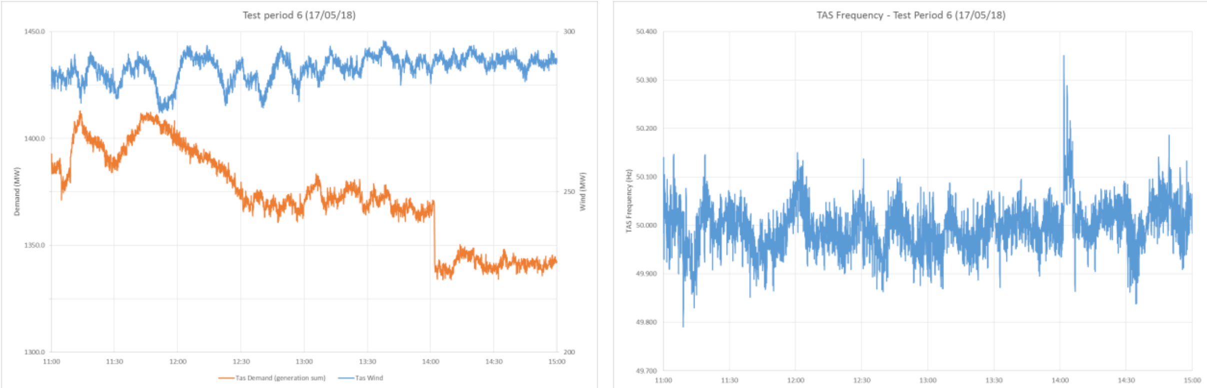

Figure A.9 Tasmanian demand, total wind generation and frequency - test period 6

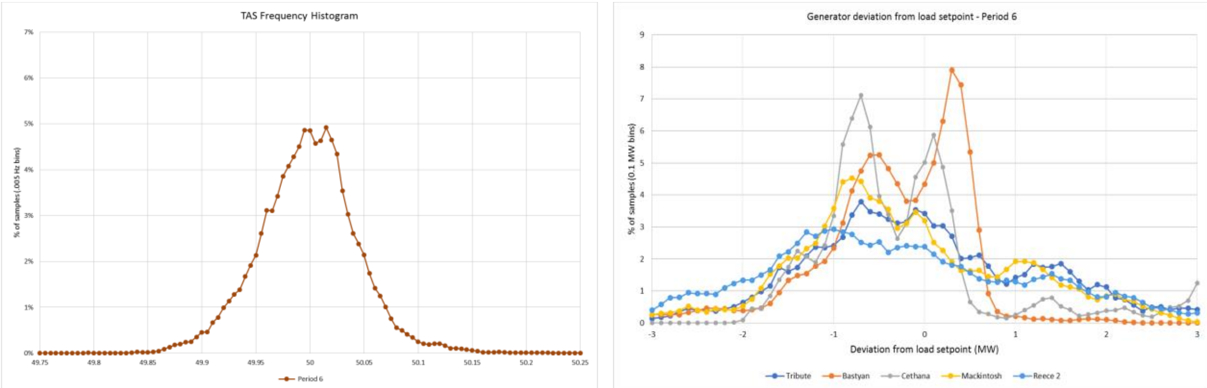

Figure A.10 Tasmanian frequency and deviation from load setpoint histograms - test period 6

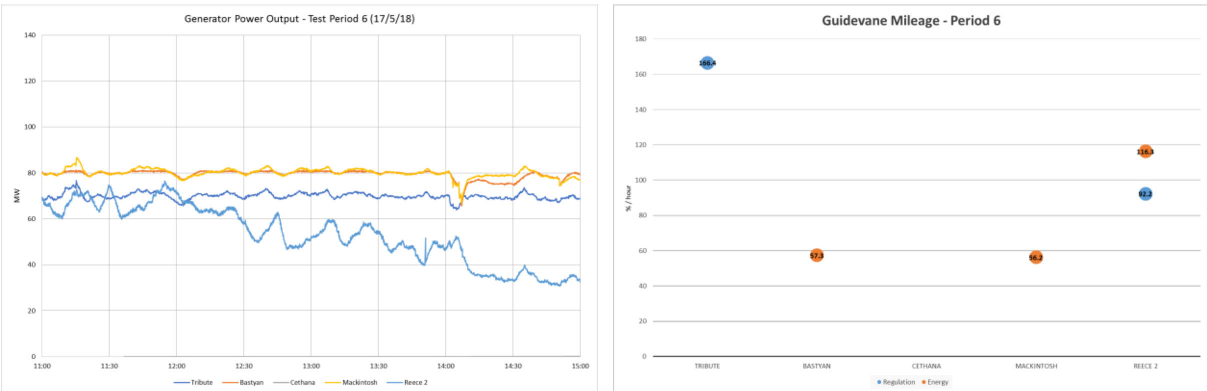

Figure A.11 Monitored generator power output and guide vane mileage - test period 6

A.5. Test Period 7

17th – 18th May 2018: Additional monitoring period with AGC system normal and narrow deadbands. Wind generation noisy in periods 7c and 7d, smoother in periods 7a and 7b.

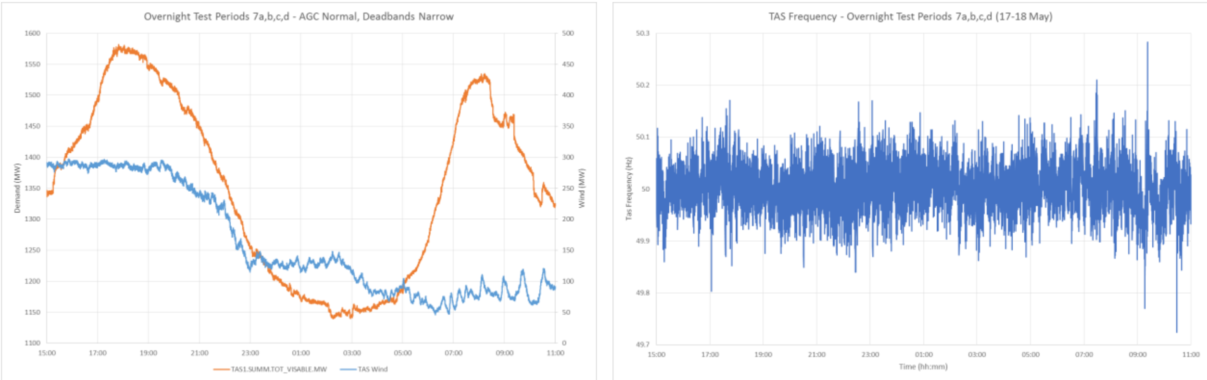

Figure A.12 Tasmanian demand, total wind generation and frequency - test period 7

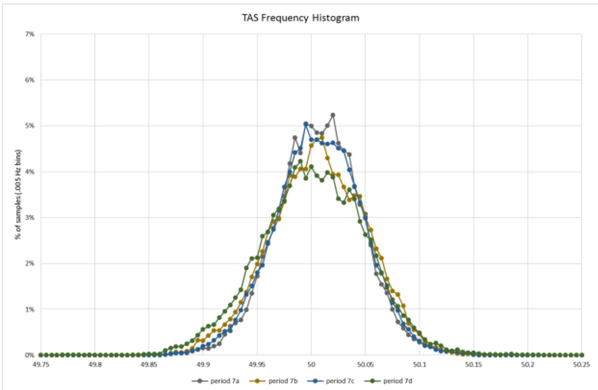

Figure A.13 Tasmanian frequency histogram - test period 7

A.6. Test Period 8

15th May 2018: AGC system normal, deadbands narrow, noisy wind generation.

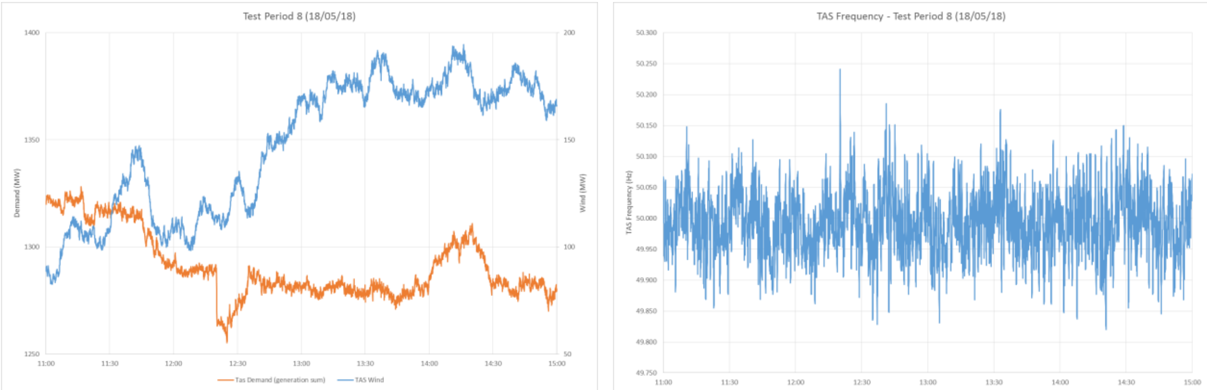

Figure A.14 Tasmanian demand, total wind generation and frequency - test period 8

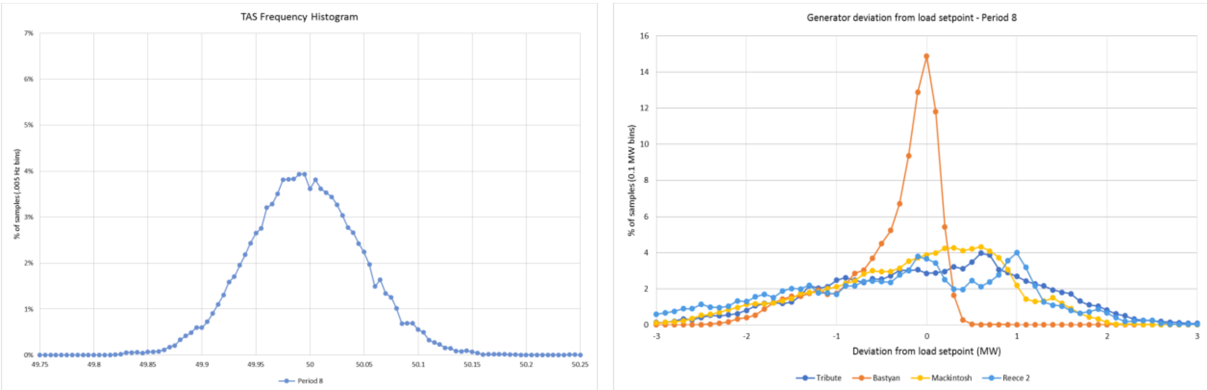

Figure A.15 Tasmanian frequency and deviation from load setpoint histograms - test period 8

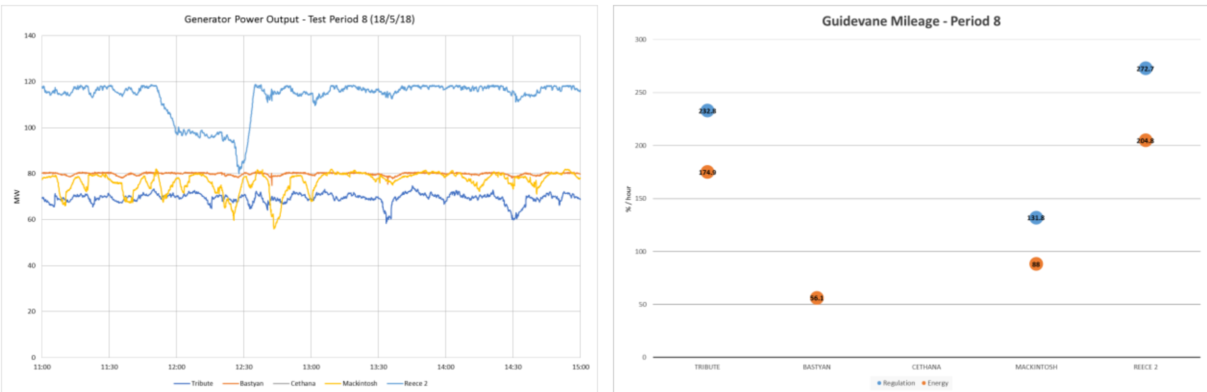

Figure A.16 Monitored generator power output and guide vane mileage - test period 8

A.7. Test Period 9

22nd May 2018: Baseline monitoring period, smooth wind generation.

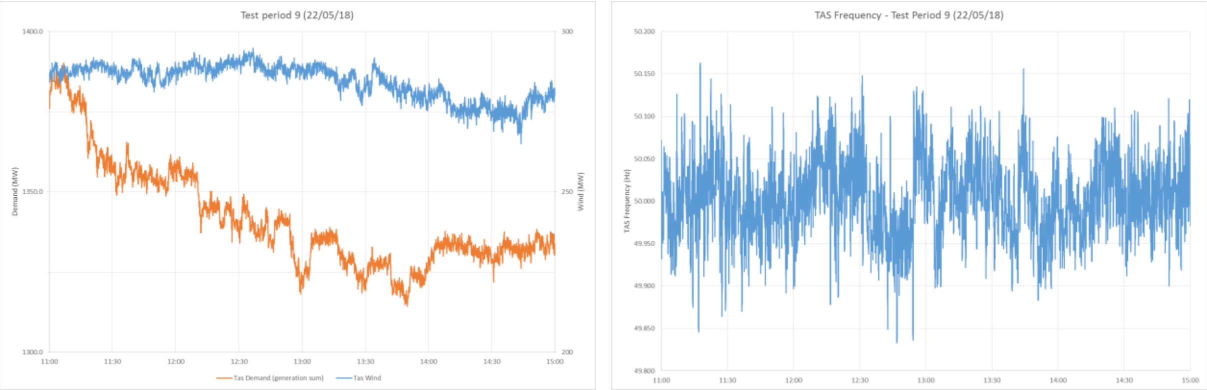

Figure A.17 Tasmanian demand, total wind generation and frequency - test period 9

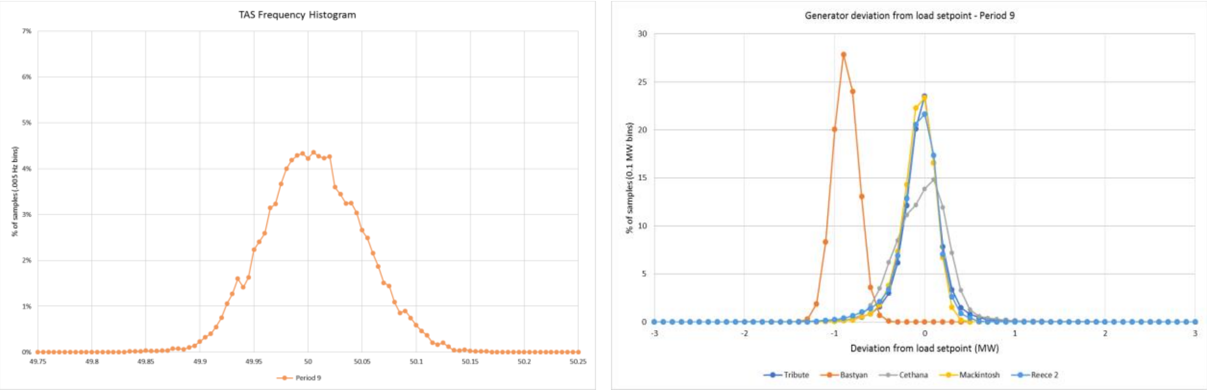

Figure A.18 Tasmanian frequency and deviation from load setpoint histograms - test period 9

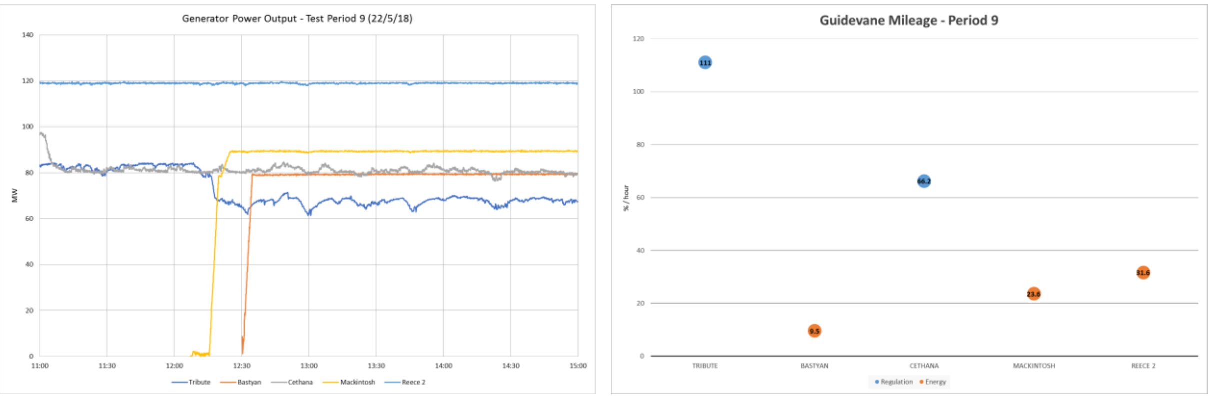

Figure A.19 Monitored generator power output and guide vane mileage - test period 9

A.8. Test Period 10

22nd – 23rd May 2018: Additional baseline data. Noisy wind generation in periods 10a – 10c, smoother in period 10d.

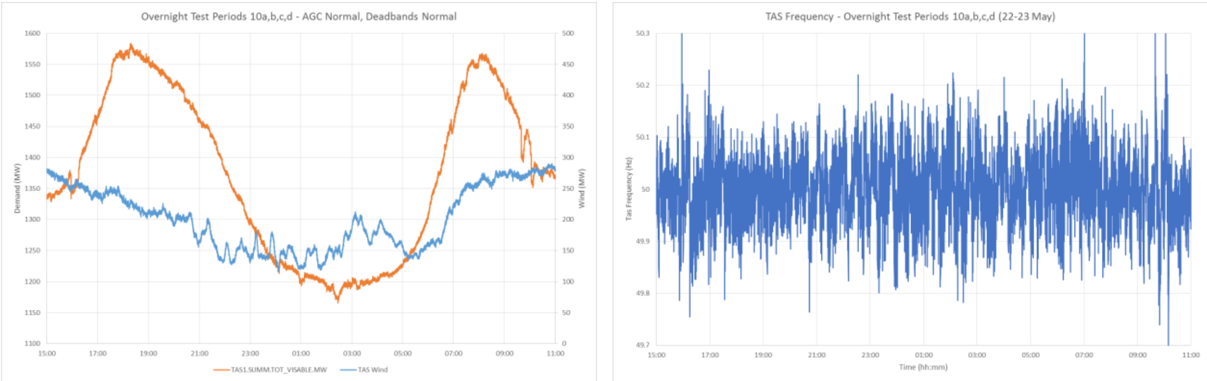

Figure A.20 Tasmanian demand, total wind generation and frequency - test period 10

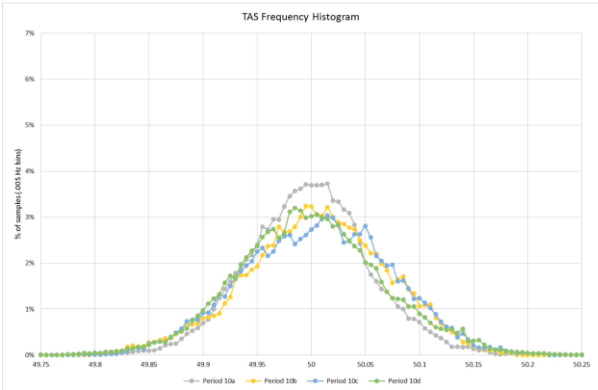

Figure A.21 Tasmanian frequency histograms - test period 10

A.9. Test Period 11

23rd May 2018: AGC system suspended, deadbands narrow, smooth wind generation.

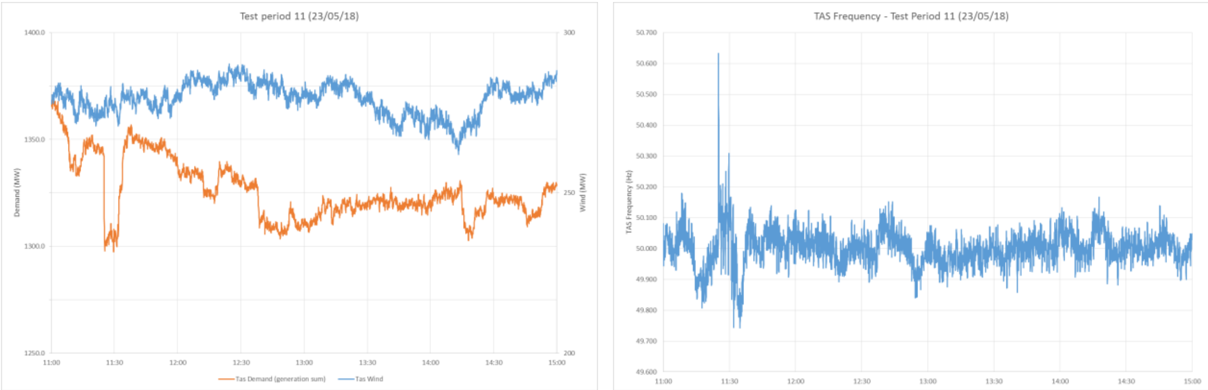

Figure A.22 Tasmanian demand, total wind generation and frequency - test period 11

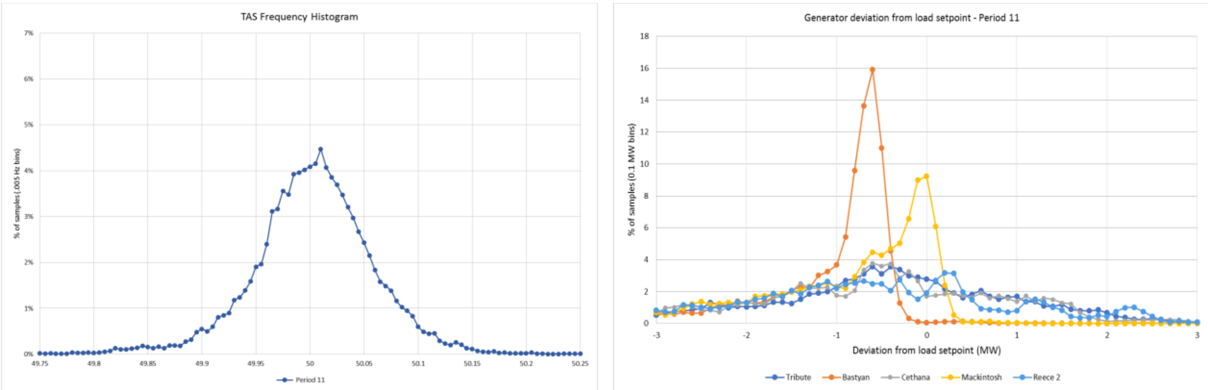

Figure A.23 Tasmanian frequency and deviation from load setpoint histograms - test period 11

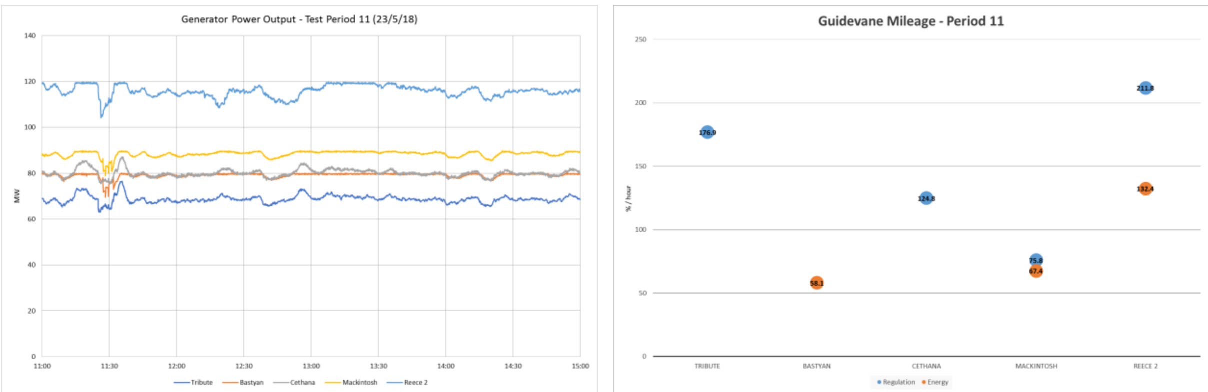

Figure A.24 Monitored generator power output and guide vane mileage - test period 11

A.10. Test Period 12

15th May 2018: Additional monitoring period with AGC system normal, deadbands narrow. Noisy wind generation in periods 12a – 12c, smoother in period 12d.

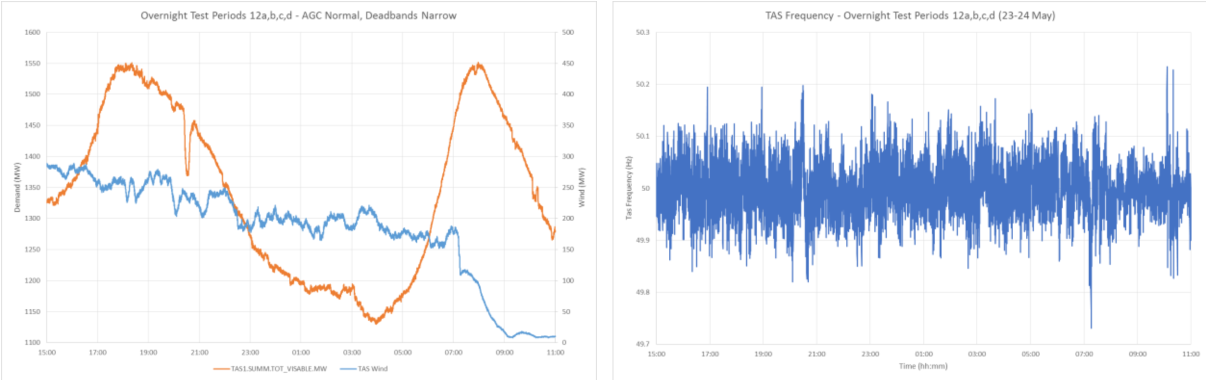

Figure A.25 Tasmanian demand, total wind generation and frequency - test period 12

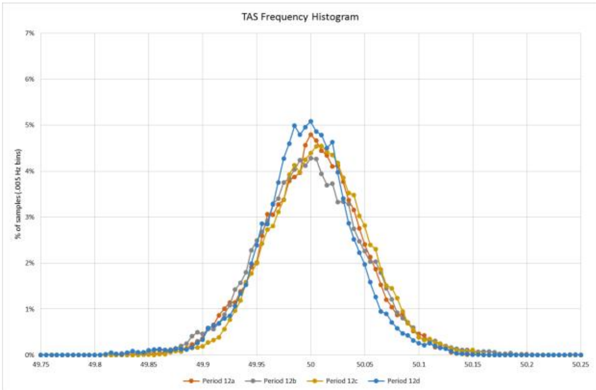

Figure A.26 Tasmanian frequency histograms - test period 12

A.11. Test Period 13

24th May 2018: AGC system normal, deadbands narrow, smooth wind generation.

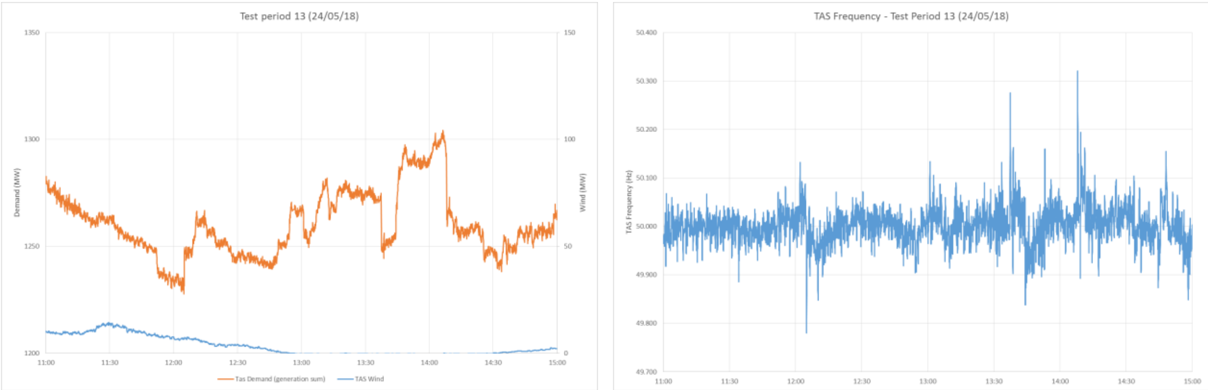

Figure A.27 Tasmanian demand, total wind generation and frequency - test period 13

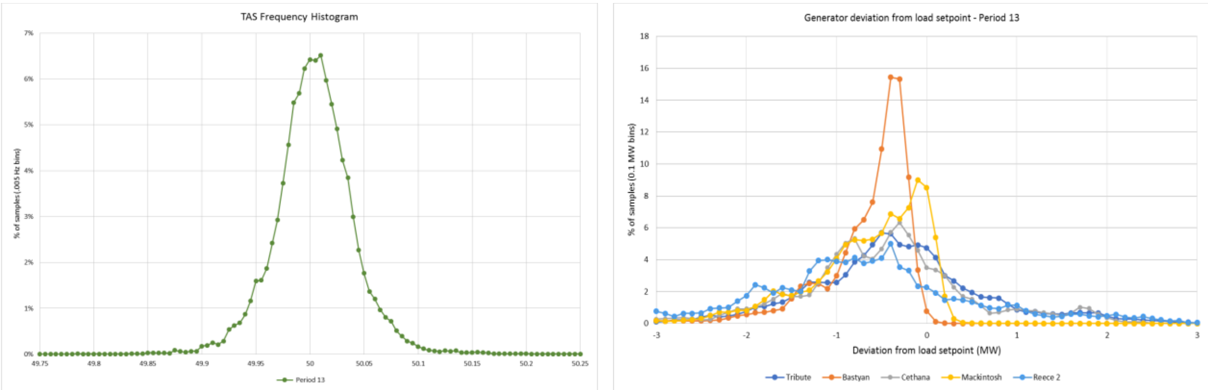

Figure A.28 Tasmanian frequency and deviation from load setpoint histograms - test period 13

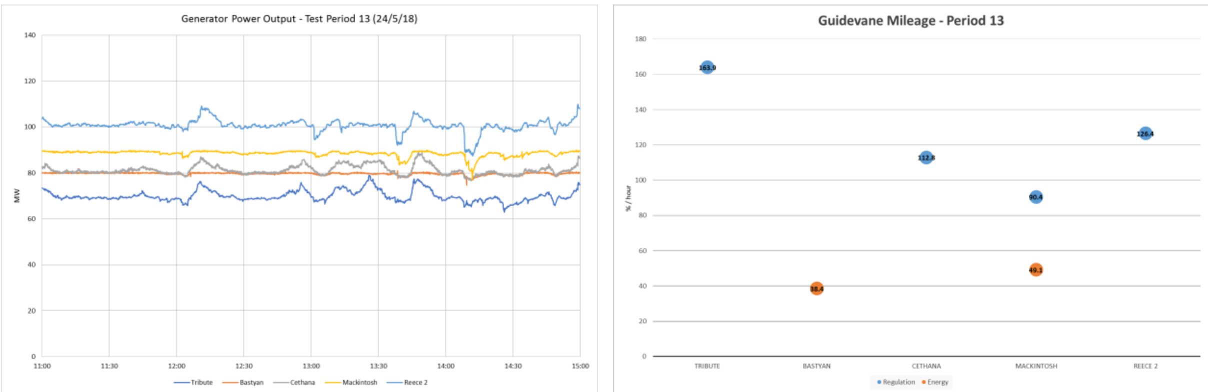

Figure A.29 Monitored generator power output and guide vane mileage - test period 13

A.12. Test Period 14

25th May 2018: AGC calculated bias, deadbands normal, smooth wind generation.

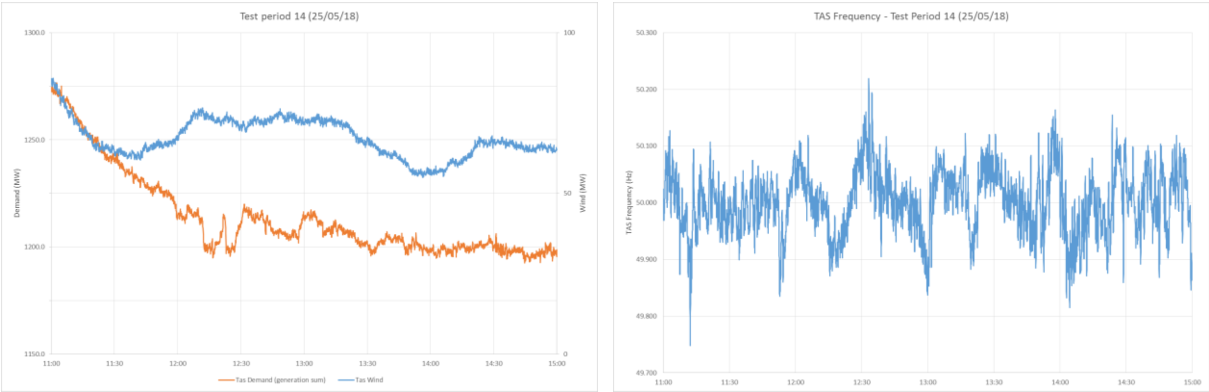

Figure A.30 Tasmanian demand, total wind generation and frequency - test period 14

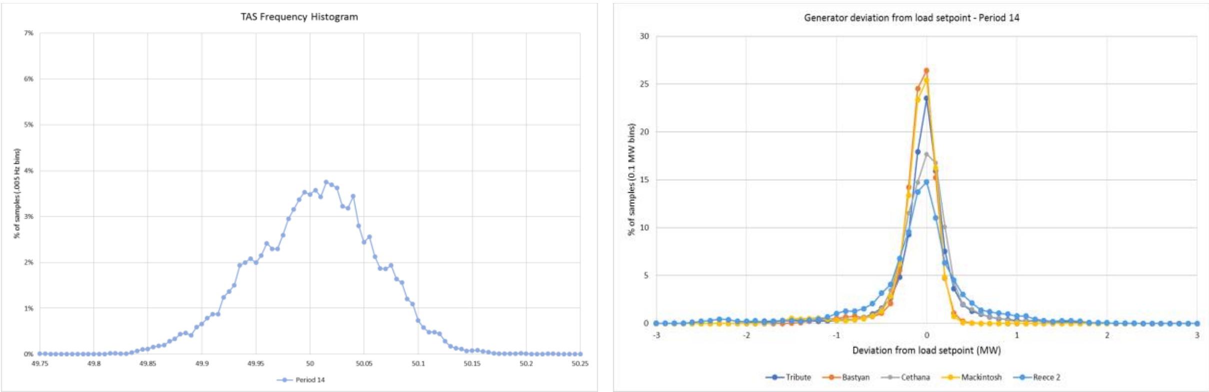

Figure A.31 Tasmanian frequency and deviation from load setpoint histograms - test period 14

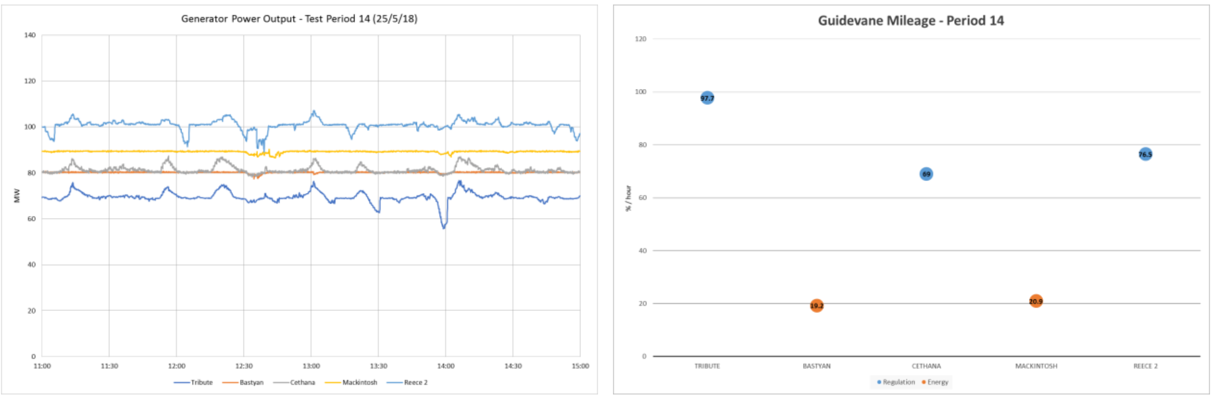

Figure A.32 Monitored generator power output and guide vane mileage - test period 14

A.13. Test Period 15

28th May 2018: AGC permissive blocking, deadbands normal, smooth wind generation.

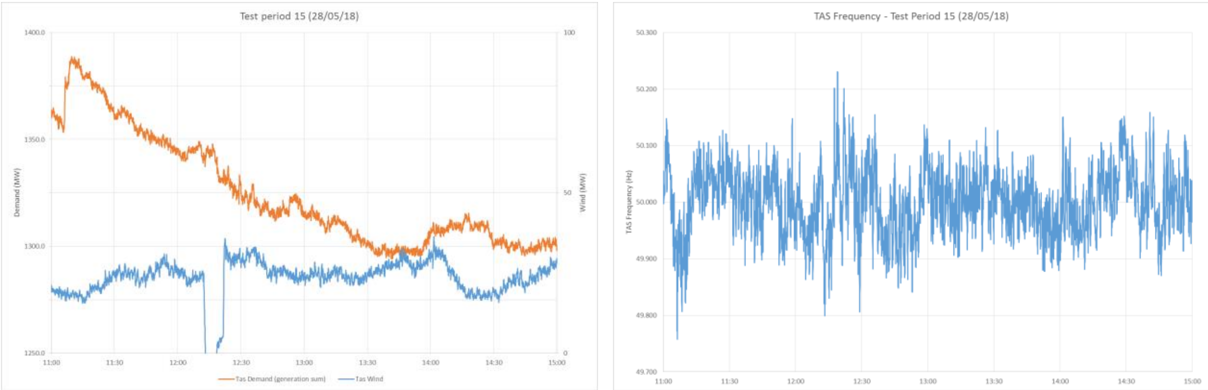

Figure A.33 Tasmanian demand, total wind generation and frequency - test period 15

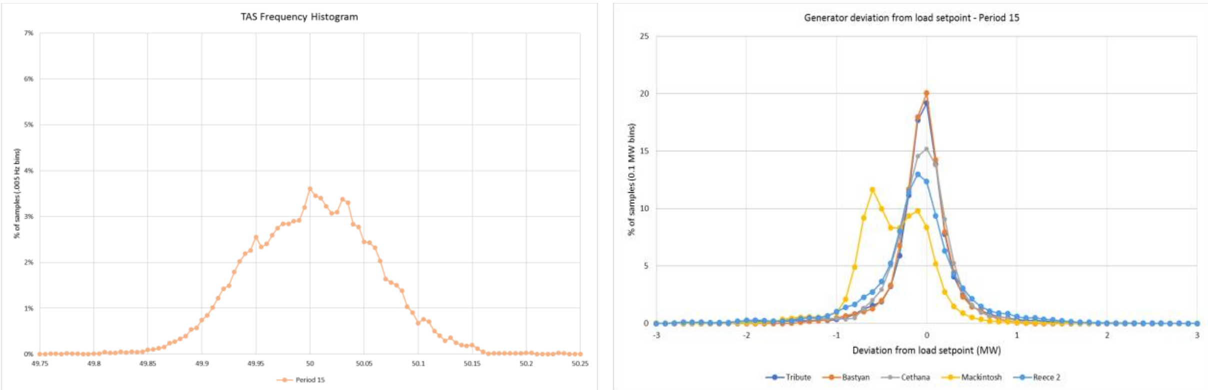

Figure A.34 Tasmanian frequency and deviation from load setpoint histograms - test period 15

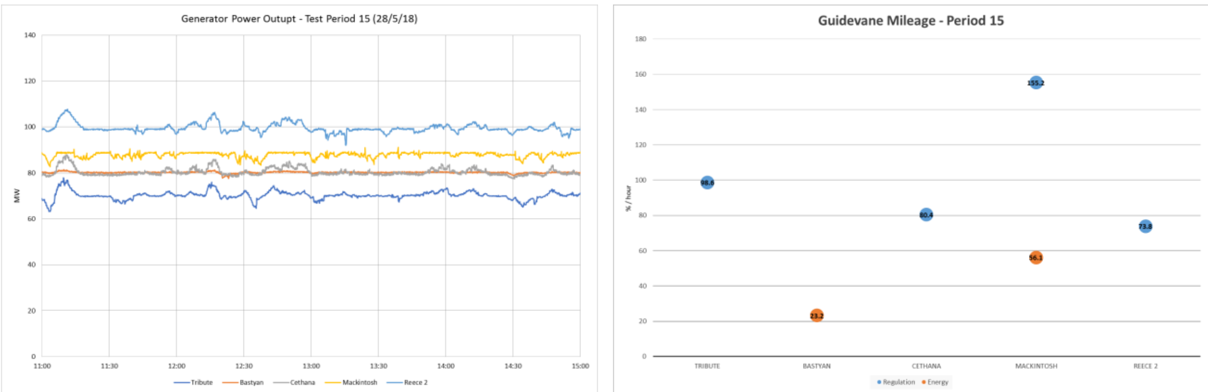

Figure A.35 Monitored generator power output and guide vane mileage - test period 15

This page is blank