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Regulation FCAS Report 1:

An analysis of AGC relative effectiveness of Tasmanian versus Mainland and an assessment of station performance and enablement

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Contents

1 Introduction

This Report follows the Preliminary Report "Are Regulation FCAS efficiently administered in the NEM". Evidence from the Preliminary Report suggested that the relative strength of AGC signals sent to Tasmanian units to provide regulation FCAS were significantly less than their Mainland counterparts, and as a result Mainland frequency was potentially compromised. The primary objective of this report is to answer this question more thoroughly by analysing several years of four second causer pays data. The Preliminary Report analysed only a random sample of times during April 2017.

The Preliminary Report also provided evidence that regulation FCAS performance varied materially from station to station. The second objective of this report is to analyse the four second causer pays data more thoroughly to determine if there is any systemic underperformance.

The third objective of this report is to apply "Big Data Analytics" in an attempt to correlate frequency deviations with a sample range of variables.

This report is limited and is by no means a comprehensive analysis of the causation of the alleged deterioration in frequency. Rather it should be viewed as the next step towards gaining an understanding of the underlying causes and effects.

2 Frequency

Figure 1 is a heat map where the x-axis represents each day over a year and the y-axis the within day dispatch intervals. Hence there are 365 by 288 cells across the x and y axis respectively. The greater the intensity of blue and red the greater the frequency deviates from the nominal frequency (normalised to 50Hz). The black arrow in Figure 1 shows when (on the 13th of June) there is a step change in the deviation of the average mainland frequency. This increase in the frequency deviation occurs at the same time Basslink returns to service.

Heat map of 2016 average mainland frequency per five minute interval

Basslink returns (arrow) coincides with an increase in the variation of frequency

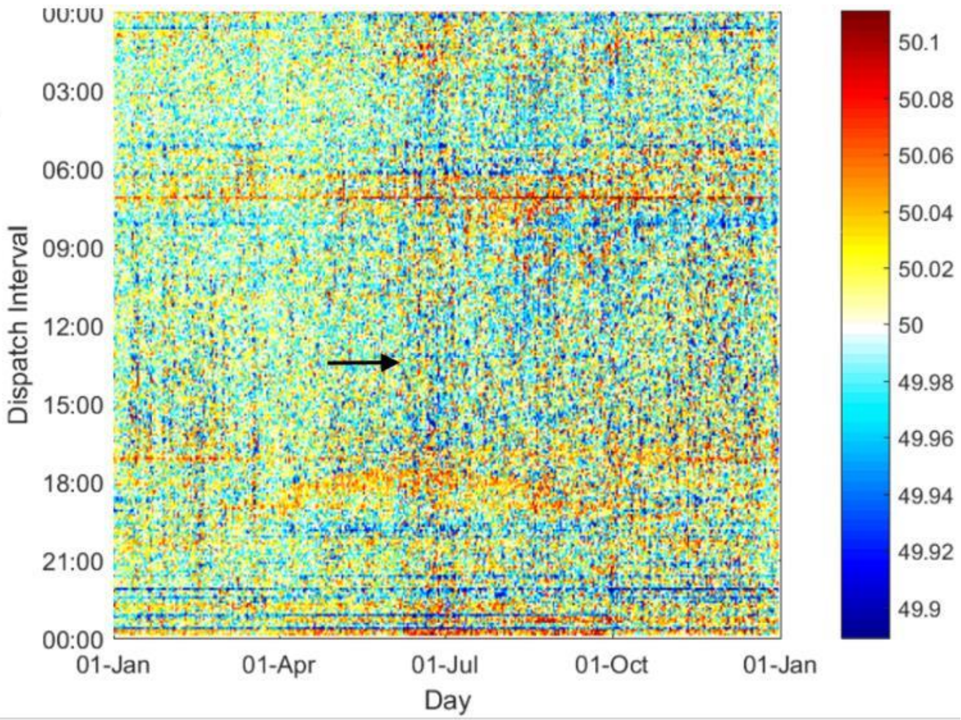


Figure 1.

Figure 1 also shows horizontal lines of colour. This suggests that there is a systemic error in the system dispatch resulting in under or over frequency for five minute periods at the same time of day. For example there is a very strong red line for dispatch interval ending 7:05. There is also a red "unhappy mouth" that appears to begin in April and ends in September that seems to coincide with the end of daylight and hence a high rate of change in demand as lighting is switched on.

Heat map of 2017 average mainland frequency per five minute interval

Frequency improves marginally in early May as shown by the arrow. There are other impacts on frequency that are as yet unidentified such as the apparent lighter band in mid-April (midway through The arrow).

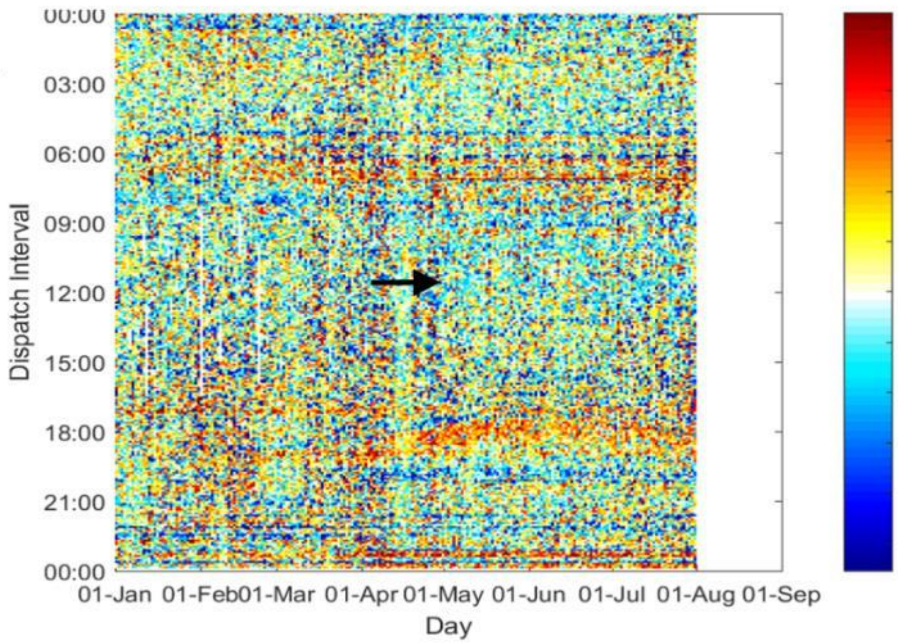


Figure 2

Figure 2 shows a slight improvement in frequency in early May 2015 (note that the pixels appear more pronounced compared to Figure 1 because only 7 months of data are shown). This coincides with changes to Tasmanian AGC calculated ratio of ACE over Hz deviation (refer to Section 3).

Figure 3 shows the frequency heat map for 2015. Interestingly frequency deviation was not greater prior to the Basslink outage (beginning 20th December 2015) although there may have been an increase in frequency variability that began sometime during mid to late November as shown by the arrow in Figure 3.

Heat map of 2015 average mainland frequency per five minute interval

For the most part the frequency did not vary during the year. However there appears to be a slight increase in the variation in frequency in mid to late November as shown by the arrow. However no cause was found.

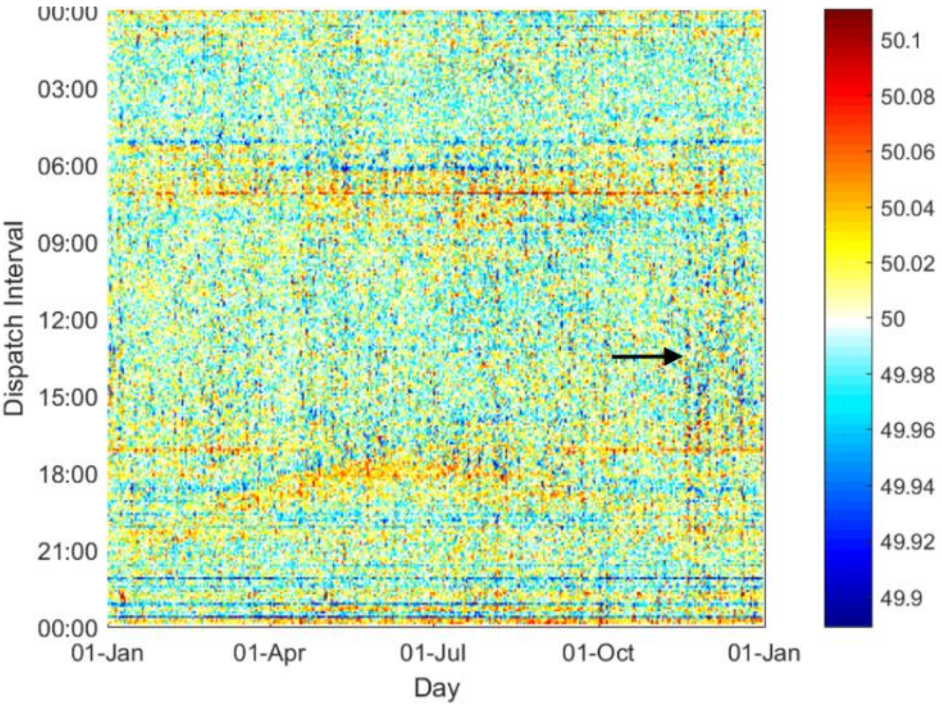


Figure 3

Appendix 1 shows the full history of these heat maps for years 2011 – 2017 (January to August). These heat maps show a steady increase in frequency variation over time however the step change when Basslink returned to service appears to be the most significant.

3 Tasmania and Mainland AGC analysis

Section 4 of the Preliminary Report "Are regulation FCAS efficiently administered and delivered in the NEM" outlined the theory and the analysis of the relative AGC instructions for units on the Mainland compared with units in Tasmania. For convenience this has been copied into Appendix 2 of this report.

The AGC analysis was extended in this report to cover January 2011 to August 2017. Roughly 2000 times the data volume was used in this report compared to the Preliminary Report. (The Preliminary Report used a random sample of 4 second data from April 2017.)

Figure 4 is a graph of the slope of "ACE filtered over HZ", **AoH**, against time for the Mainland (labelled NEM) and Tasmania. For completeness both North and South values are included (the AoH parameter represents the MW required to correct the frequency deviation, the AoH is a linear input of the Frequency Indicator which is a key input into the AGC instructions sent to individual units).

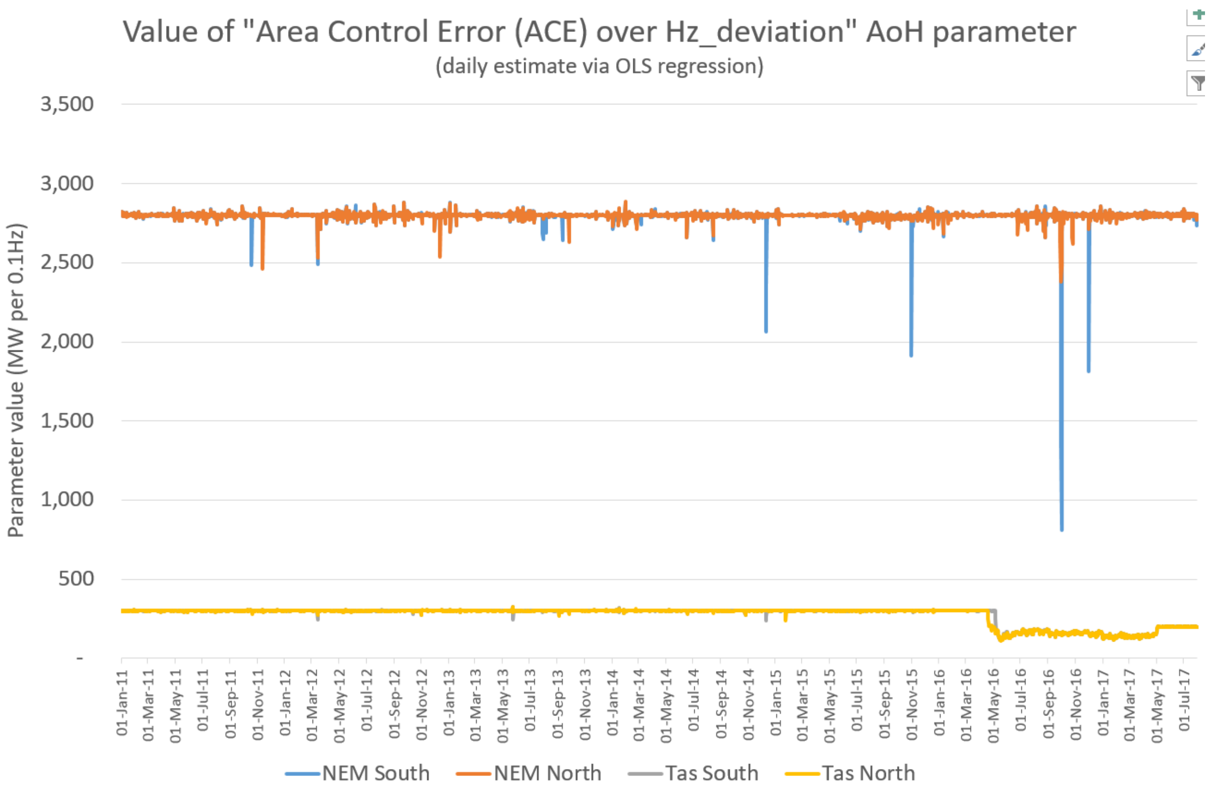


Figure 4

Figure 4 shows the Mainland AGC AoH value is consistently 2800 MW/Hz for AoH. (Note that the spikes are suspected anomalies in the data but this is not conclusive). Of interest is that the Tasmanian AoH dropped suddenly around May 2016.

Figure 5 rescales this graph to show Tasmania more clearly (bottom right corner of Figure 4 is zoomed).

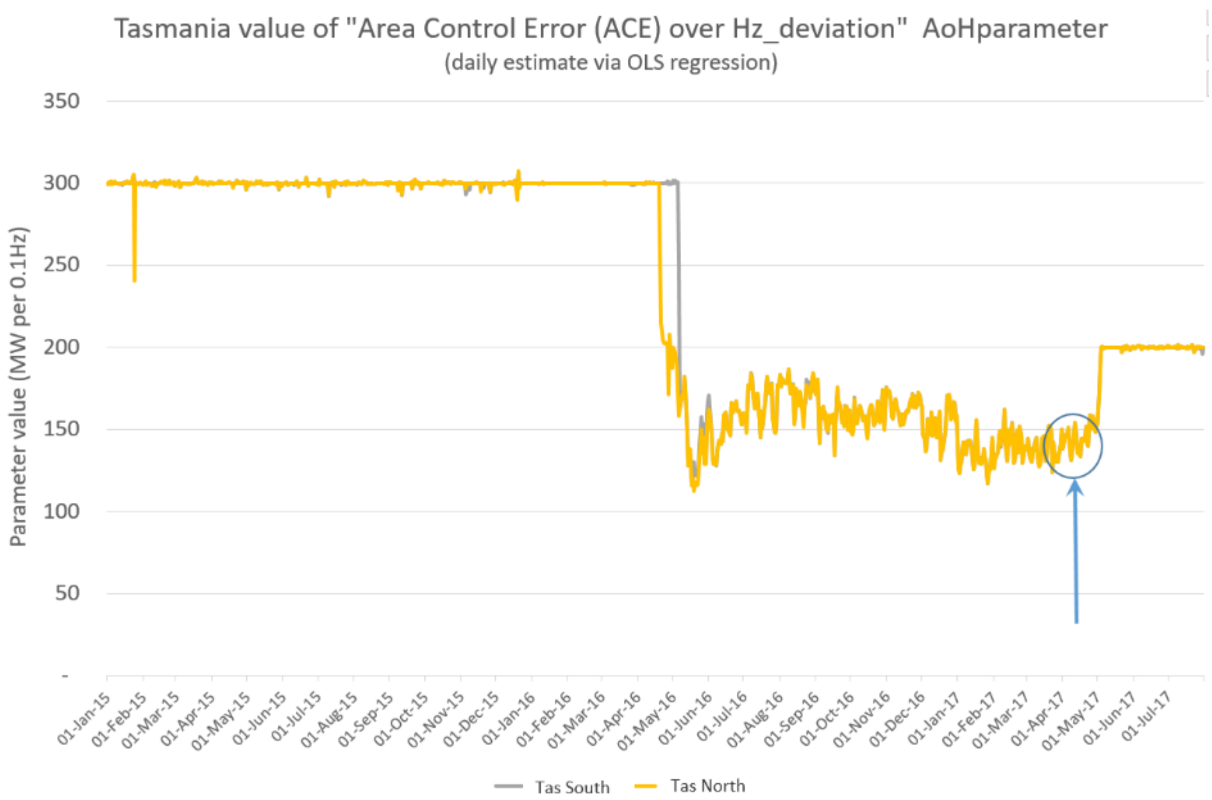


Figure 5

The blue circle in Figure 5 shows the sample period of data used to derive the value of 140 derived in our Preliminary Report.

Figure 5 shows a clear drop in the AoH in late April 2016 from 300 to around 150 +/-25. The AoH changed from 300 in Tas North on the 20th April 2016 and Tas South followed 17 days later. This can be seen by the drop in the yellow line (Tas North) in the middle of Figure 5 preceding the drop in the grey line (Tas South). We can only speculate why this is the case but presumably there was a change in the AGC settings for Northern Tasmania followed by Southern Tasmania 17 days later.

Both Tasmanian South and North AoH were increased to a steady value of 200 on the 3rd of May 2017. This day falls between the time when AEMO enforced a maximum Tasmanian regulation contribution of 34 MW on the 1st of May 2017 and increasing to 50MW on the 5th of May 2017. (See market notices 58459 and 58498 respectively).

There is no data available for the Frequency Indicator and it is assumed to be proportional to the AoH (there are gain settings that may have been changed that would impact the Frequency Indicator however we assume that gain settings do not change). Given this is true then the implication is that a reduction of the AoH for Tasmanian units results in a reduction in the AGC instructions for regulation services sent to Tasmanian units compared to Mainland units. For example if an instruction of 30MW was sent for an AoH of 300 then under the same values of ACE filtered (and ACE Integral) an instruction of only 20MW would be sent for an AoH of 200. As a consequence Tasmanian units provide a lower response to correct frequency.

The effective difference in AGC signals between Mainland and Tasmanian units was analysed. No significant and lasting bias was identified however our analysis is consistent with the discussion above. The bigger issue appears to be the independence of AGC and frequency control between Mainland and Tasmanian systems and how Basslink balances frequency. Appendix 4 discusses this, and the information required to analyse the effectiveness of Tasmanian AGC to correct Mainland frequency and time-error, in more detail.

4 Station Performance

The Preliminary Report showed Mount Piper Unit 2 providing virtually no response to AGC instructions (up to 60MW) on the 17th of January 2017. Figure 6 shows the performance of Mount Piper and Gladstone units during the afternoon of this day. It shows Mount Piper 2 is providing negligible response (data aggregated hourly).

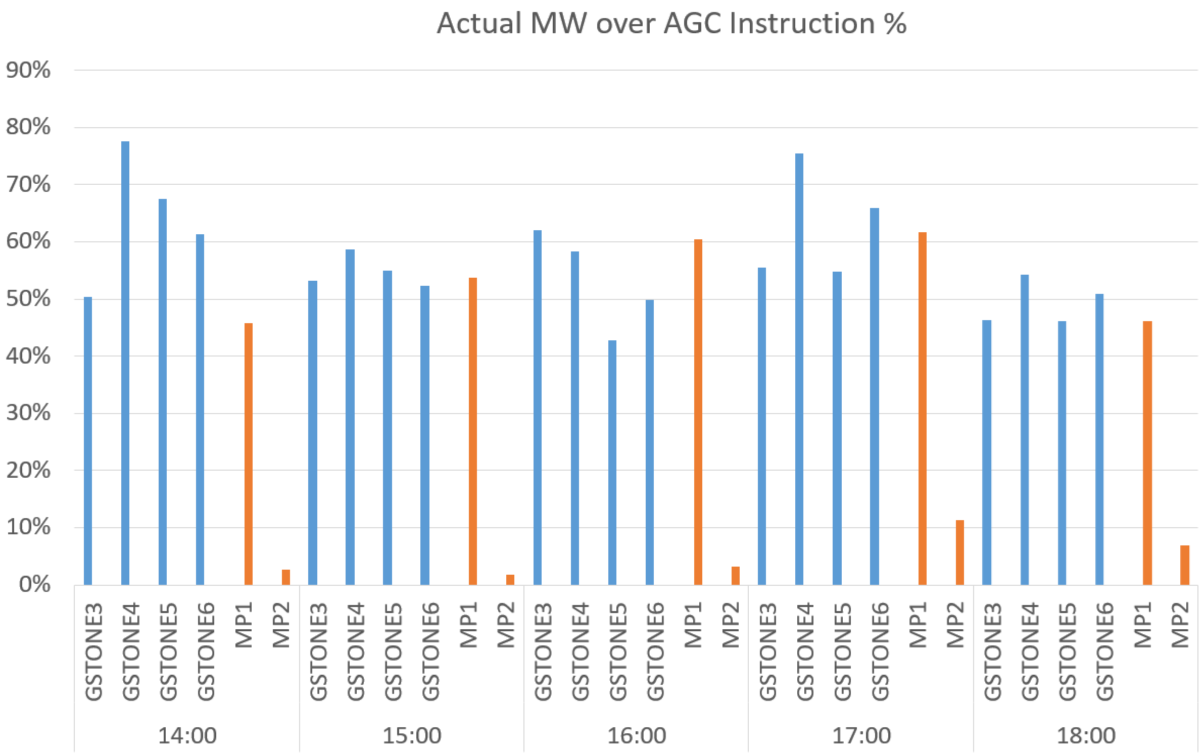


Figure 6.

Note that for any given 4 second interval, if the unit response is greater than the AGC instruction then we set the response to be equal to the AGC instruction. This capping of unit response reduces the calculated performance and hence performance values are necessarily less than or equal to one. If the response is not capped then performance can be overstated due to instructions dropping to zero when response exceeds enablement (this is discussed more thoroughly in Appendix 3). However capping the response then understates performance because of the delay between an instruction and a units response. We found that the results were more representative of performance when the response was capped.

Average daily performance of selected units for January 2017 is shown in Figure 7. It is important to note that the averaged data provides no information of enablement volumes and as such results can be distorted, nonetheless the averages presented include only significant daily volumes and where enablement is greater than 3MW for any given dispatch interval.

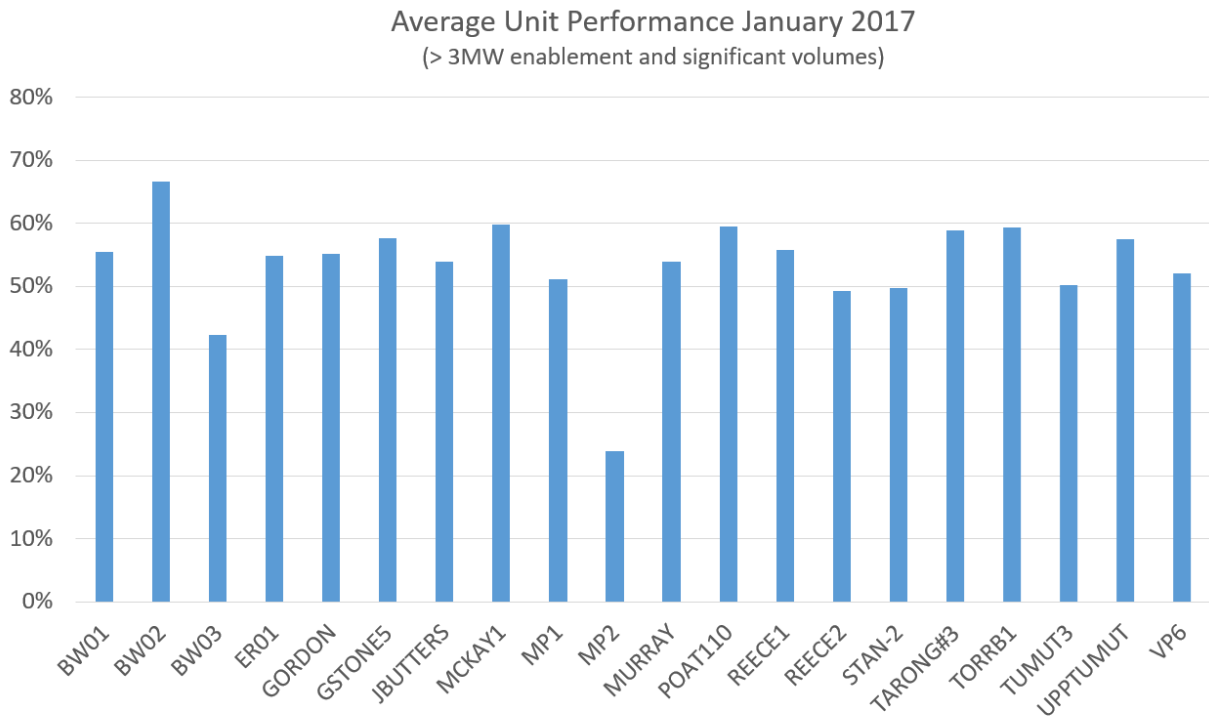


Figure 7.

Performance for all units was comparable for January 2017 with the exception of Bayswater 3, 42%, and Mount Piper 2, 24%. Average for the remaining units shown was 56%.

Figure 8 shows the monthly average daily performance of Mount Piper 2 and Bayswater 3. Mount Piper is enabled considerably less than Bayswater hence there are only five months where Mount Piper 2 meets the minimum volume requirements of our query (> 3MW enablement for any 5 minute dispatch interval and > 300MW hours of enablement in total). Bayswater 3 shows a slight systemic under performance (the average over the period is 39%).

With the exception of January Mount Piper 2 performance is above average at 64%. For January, Mt Piper 2 performance was low with an average of 10%.

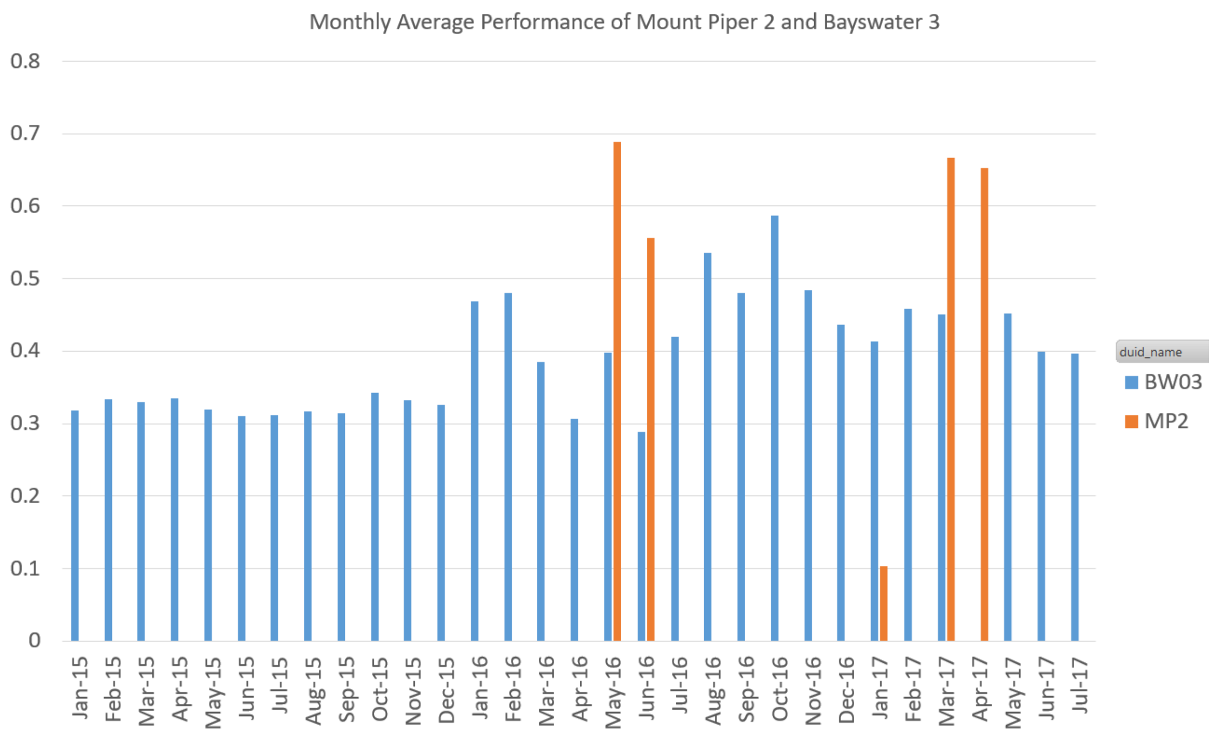


Figure 8.

Other stations and units were analysed however all provided comparable performance. Figure 9 shows average performance by station for the period from January 2015 to July 2017.

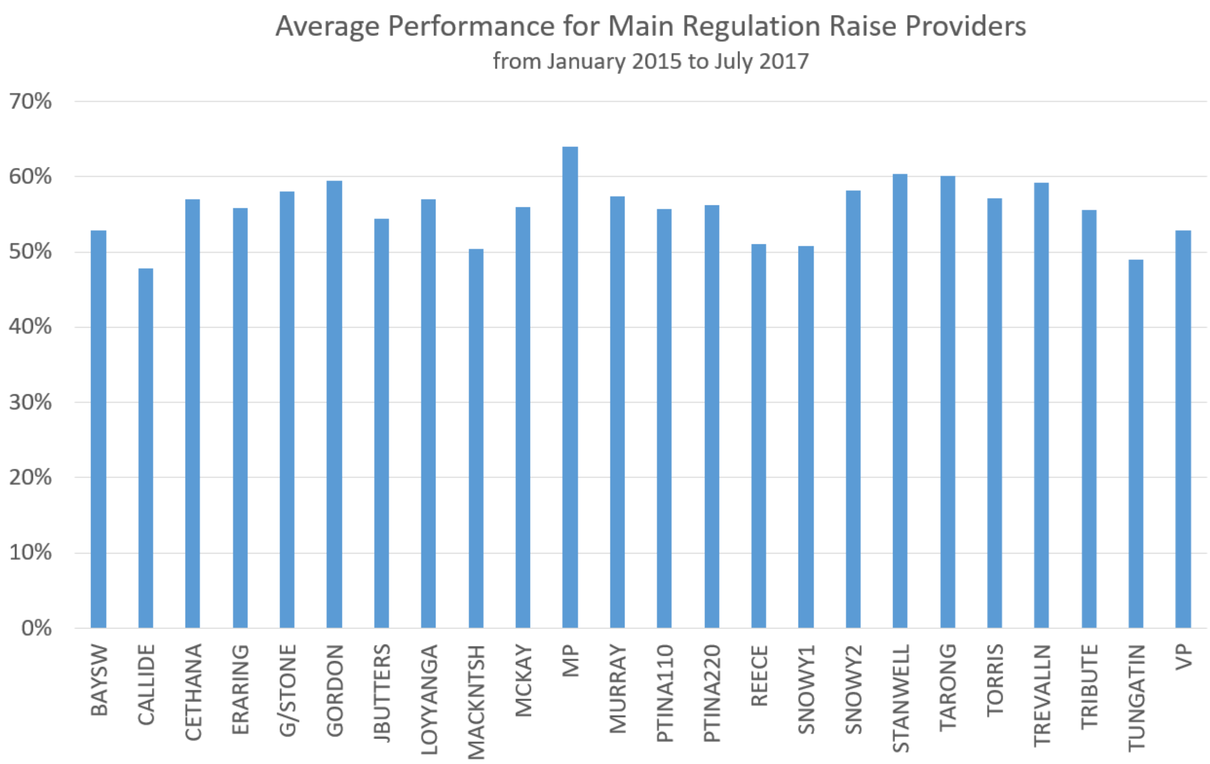


Figure 9.

Figure 9 shows that all of the major regulation raise providers performed more or less equally on average (keeping in mind that the underlying volume of services varied by a factor of 20).

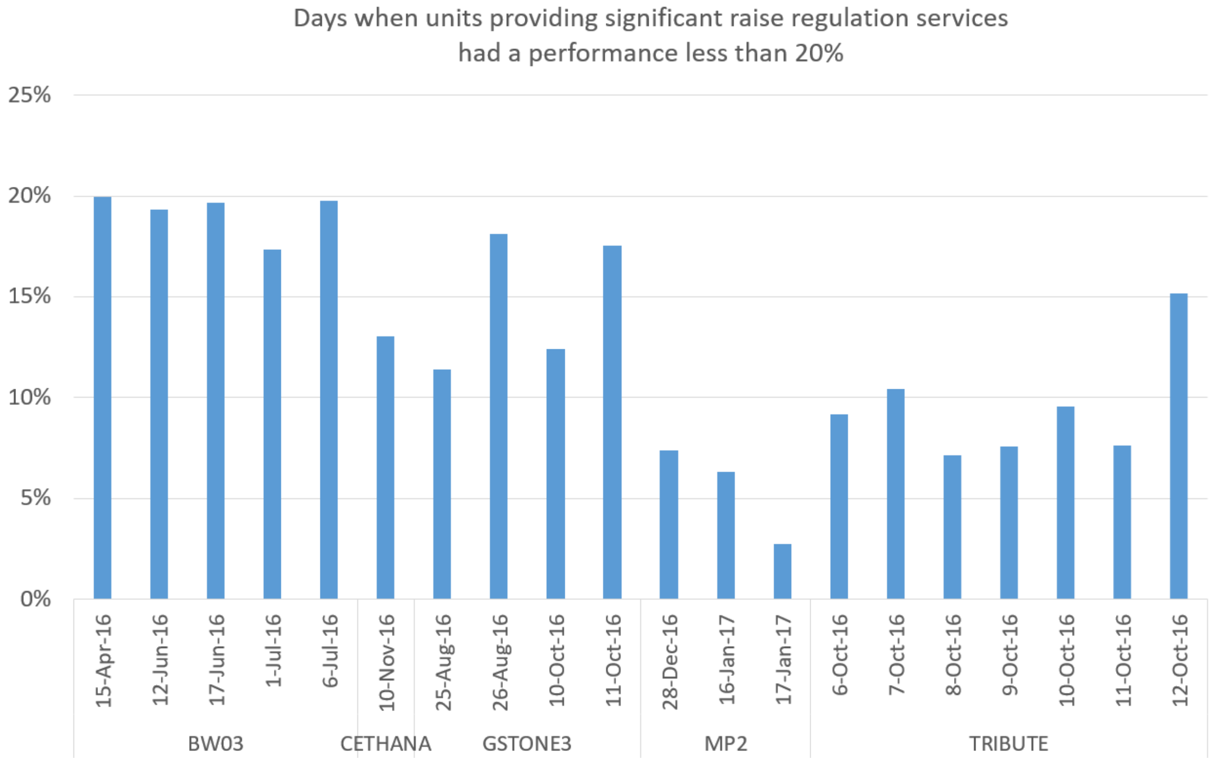


Figure 10.

Figure 10 shows a list of units and days from January 2016 to July 2017 when performance was less than 20% on average over the day. The results only include units that provided more than 40MWhrs of enablement over a day. Bayswater 3 has five days that were only just less than 20%. To hazard a guess I would suggest that these just happen to be days where the unit was performing particularly poorly compared to the unit's long term average of 42% shown in Figure 7. This is in contrast to Mount Piper 2 which appeared to have a control issue during January and late December. Although not shown, Mount Piper was enabled very little raise regulation FCAS in January other than on the days shown.

Tribute and Gladstone 3 both have poor performance on consecutive days. Perhaps there was a change in a control setting that did not prevent enablement of regulation services yet units were unable to respond to raise regulation AGC signals.

Figures 11 and 12 show a comparison of AGC instruction and response (termed deviation from energy target) for Gladstone 3 and Gladstone 4 on the 25th of August 2016. Gladstone 3 shows no obvious response to AGC signals other than for a short period during the late afternoon. However Gladstone 4 shows a strong correlation to AGC signal compared with the units response.

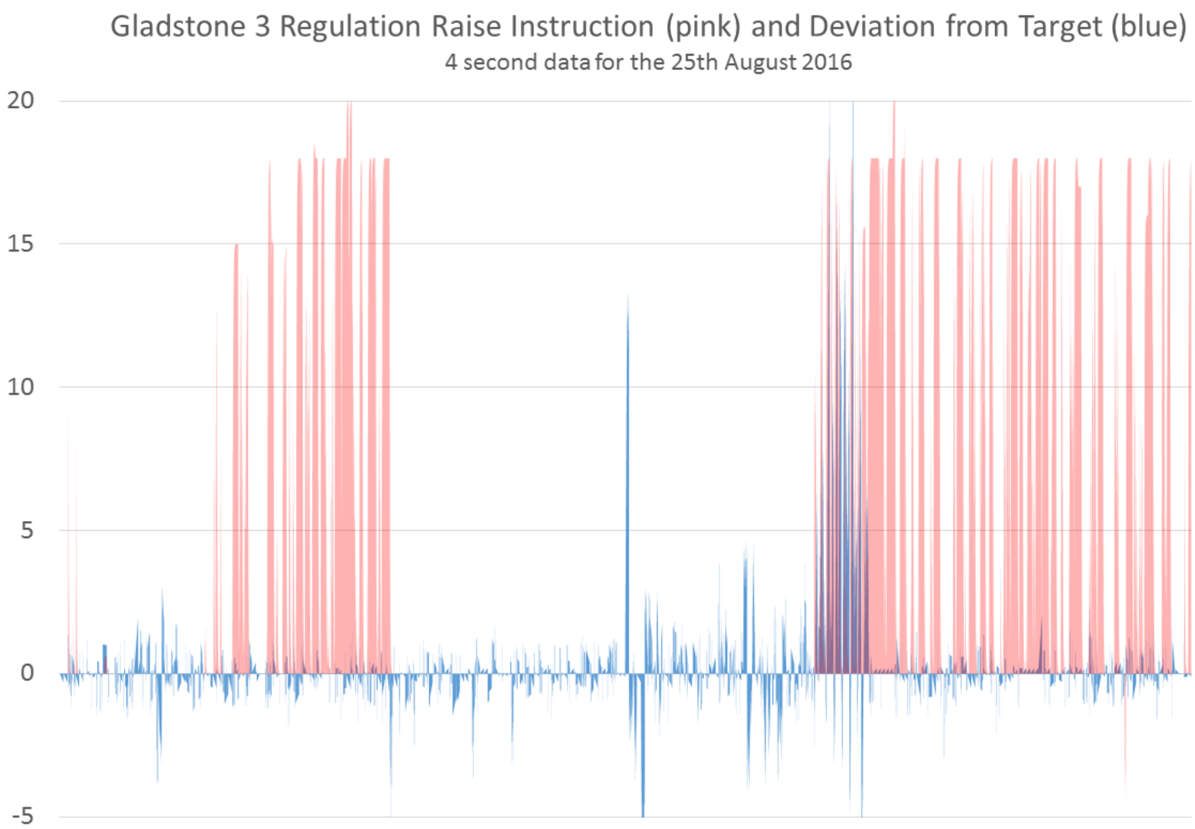

Gladstone 3 Regulation Raise Instruction (pink) and Deviation from Target (blue)
4 second data for the 25th August 2016
20
15
10
5
0
-5

Figure 11.

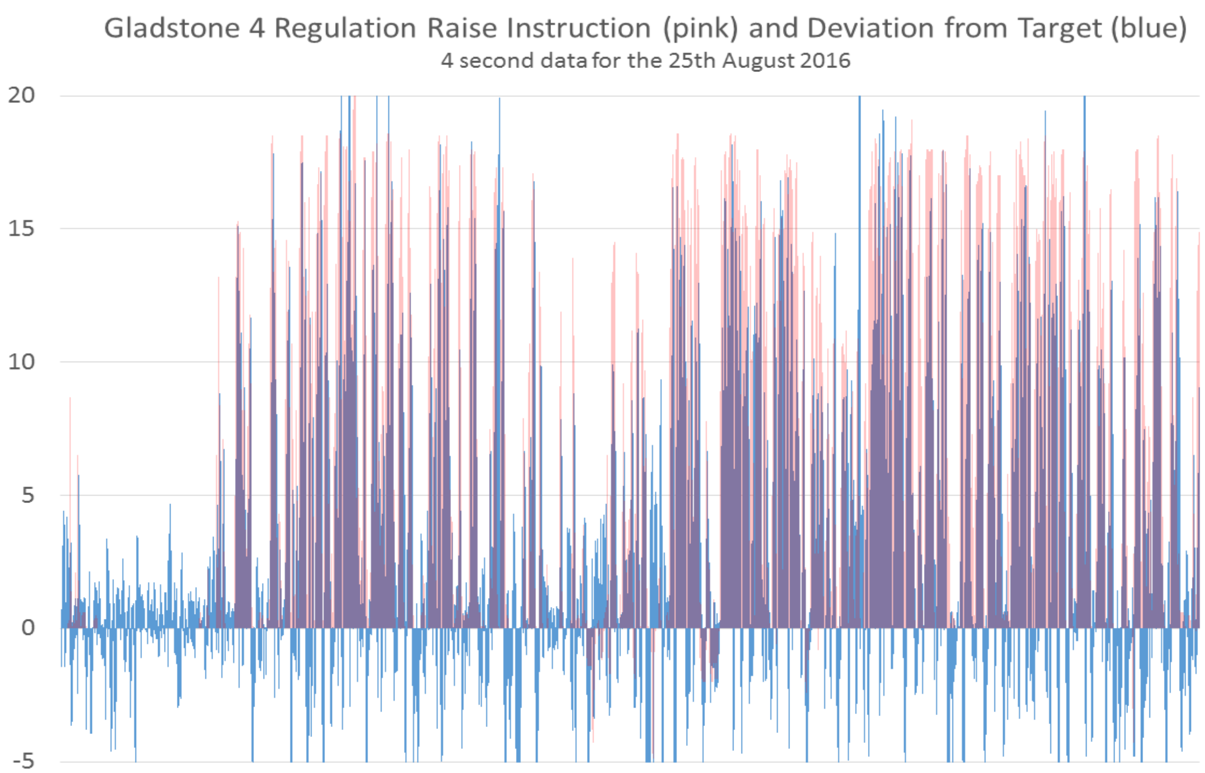

Gladstone 4 Regulation Raise Instruction (pink) and Deviation from Target (blue)
4 second data for the 25th August 2016
20
15
10
5
0
-5

Figure 12.

4 Machine Learning Results

To gain some insight into what variables (termed *features*) influence frequency in the NEM we applied a machine learning algorithm to seven years of data. Firstly we converted the 4 seconds Causer Pays data into summary 5 minute metrics such as "average frequency over 5 minutes" (avg_hz), "standard deviation of frequency over 5 minutes", "average effective raise enablement over 5 minutes" etc. We also gathered data from tables in the MMS database. Specifically, we used fields from the tables: DispatchRegionSum, DispatchLoad and DispatchInterconnectorRes.

With the 5 minute metrics we then used Random Forest Regression to try and fit the following models:

$$Average\_Hz\_5min = F(feature\ set)$$

$$Standard\ Deviation\_Hz\_5min = F(feature\ set)$$

whereby *F(feature set)* is a non-linear function of the variables/features listed in the table below. "Average Hz 5min" is simply the average frequency over the dispatch interval with positive and negative values netting out. "Standard deviation Hz 5min" is the standard deviation of frequency over the dispatch interval. Positive and negative values do not net out and hence is more representative of the rate of change of frequency. Possibly a better metric to use in future analysis would be to compare the rate of change of frequency between 4 second intervals.

We applied the two models above to the "NEM North" and "TAS North" regions. For each model, 1000 trees were fit with a maximum tree depth of 8.

Variable (also known as Feature)	**Data Source**
main_aggregatedispatcherror	MMS data field
tas_aggregatedispatcherror	MMS data field
tas_ace_hzdev_param	pdView defined as AoH
main_initialsupply	MMS data field
main_clearedsupply_minus_initial	MMS data fields (calculated)
main_effective_raise_enablement	pdView defined Appendix 3
tas_initialsupply	MMS data field
main_effective_lower_enablement	pdView defined Appendix 3
tas_clearedsupply_minus_initial	MMS data fields (calculated)
main_raisereglocaldispatch	MMS data field
main_fcast_error	MMS data fields = lead(initialsupply) – clearedsupply
tas_fcast_error	MMS data field =

	lead(initialsupply)-clearsupply
main_semischedule_clearedmw	MMS data field
tas_semischedule_clearedmw	MMS data field
main_acefil_param	pdView calculated estimate of average AGC ACEFIL gain parameter (daily)
main_totalintermittentgeneration	MMS data field
basslink_flow	MMS data field
tas_effective_raise_enablement	pdView defined Appendix 3
main_ace_hzdev_param	pdView defined as AoH
main_aceint_param	pdView calculated estimate of AGC aceint gain parameter (daily)
tas_totalintermittentgeneration	MMS data field
tas_effective_lower_enablement	pdView defined Appendix 3
tas_acefil_param	pdView calculated estimate of average AGC ACEFIL gain parameter (daily)
tas_raisereglocaldispatch	MMS data field
main_lowerreglocaldispatch	MMS data field
tas_lowerreglocaldispatch	MMS data field
tas_aceint_param	pdView calculated estimate of average AGC ACEINT gain parameter (daily)

Key variables not used that could be included but require work beyond the scope of this project include: Basslink Deadzone, System Inertia, and Frequency Indicator (this includes the unknown gain settings which have step changes in the settings depending on ACEfiltered and ACEintegral).

An output of Random Forest Regression is the "importance" of each variable/feature which is a measure of how much that variable helps to reduce the forecast variance.

Figure 13 shows the results for the frequency deviation, note that only the top 50% of variables are shown.

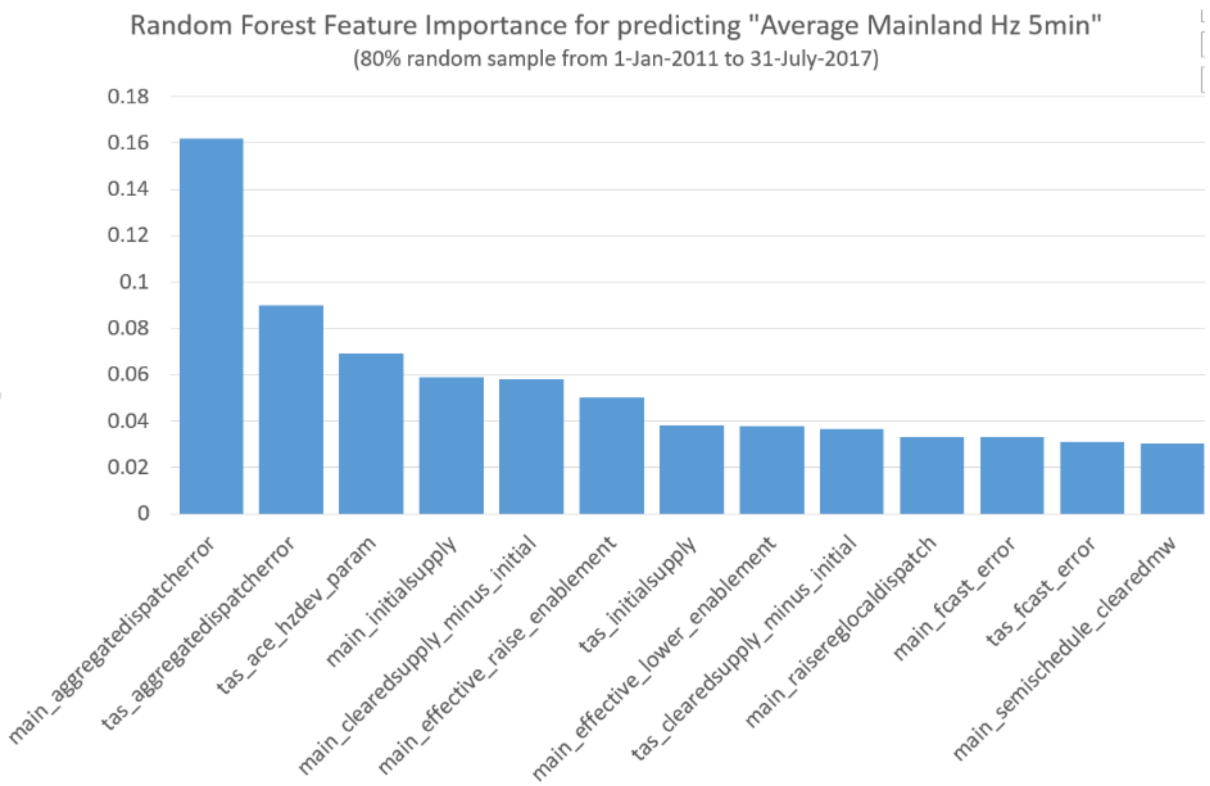


Figure 13.

The two variables that have the greatest impact on the Average Mainland Frequency are Aggregate Dispatch Error for the Mainland and Tasmania respectively. The third most impactful variable is the Tas_Ace_hzDev_parameter which is the AoH shown in Figures 4 and 5. This result supports the case that changes to AoH prior to Basslink return to service, and changes on the 3rd of May 2017, had a significant impact on frequency deviation.

Figure 14 shows the average aggregate dispatch error for the last seven years.

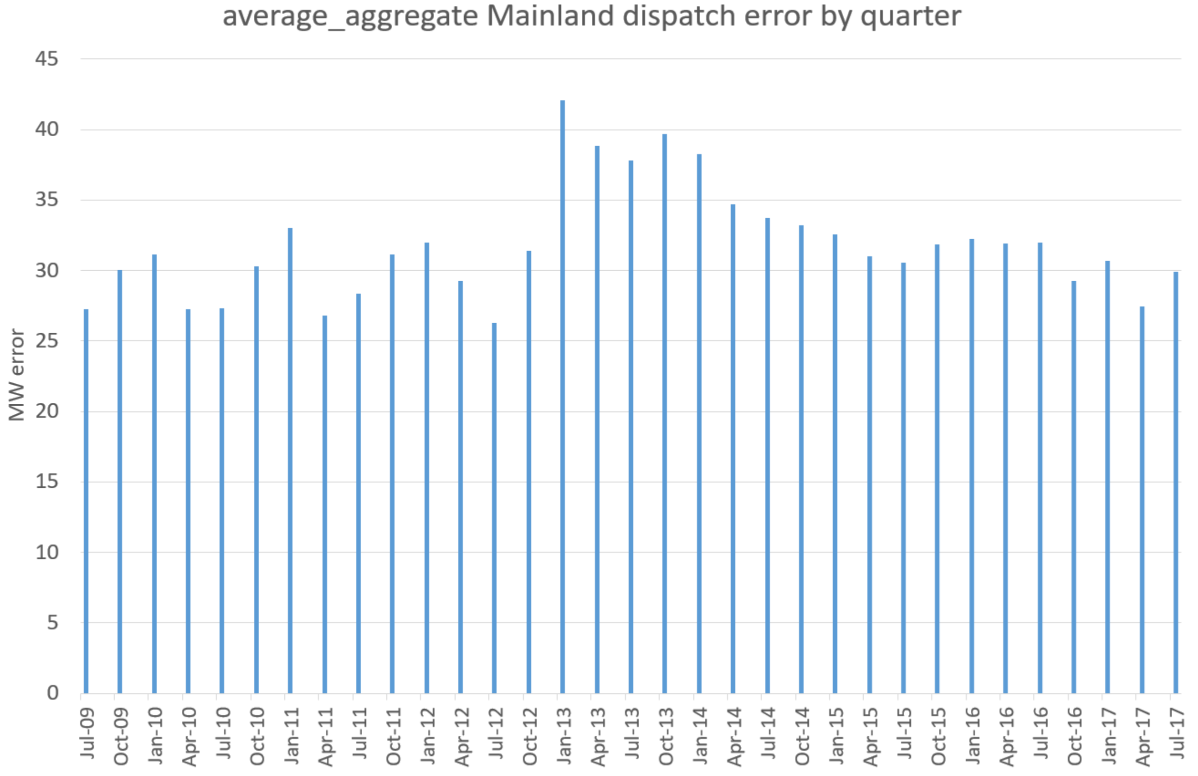


Figure 14.

Although the aggregate dispatch error increases for 1st quarter of 2013, the long term average has remained around 30MW.

Figure 15 shows the Random Forest results for frequency standard deviation.

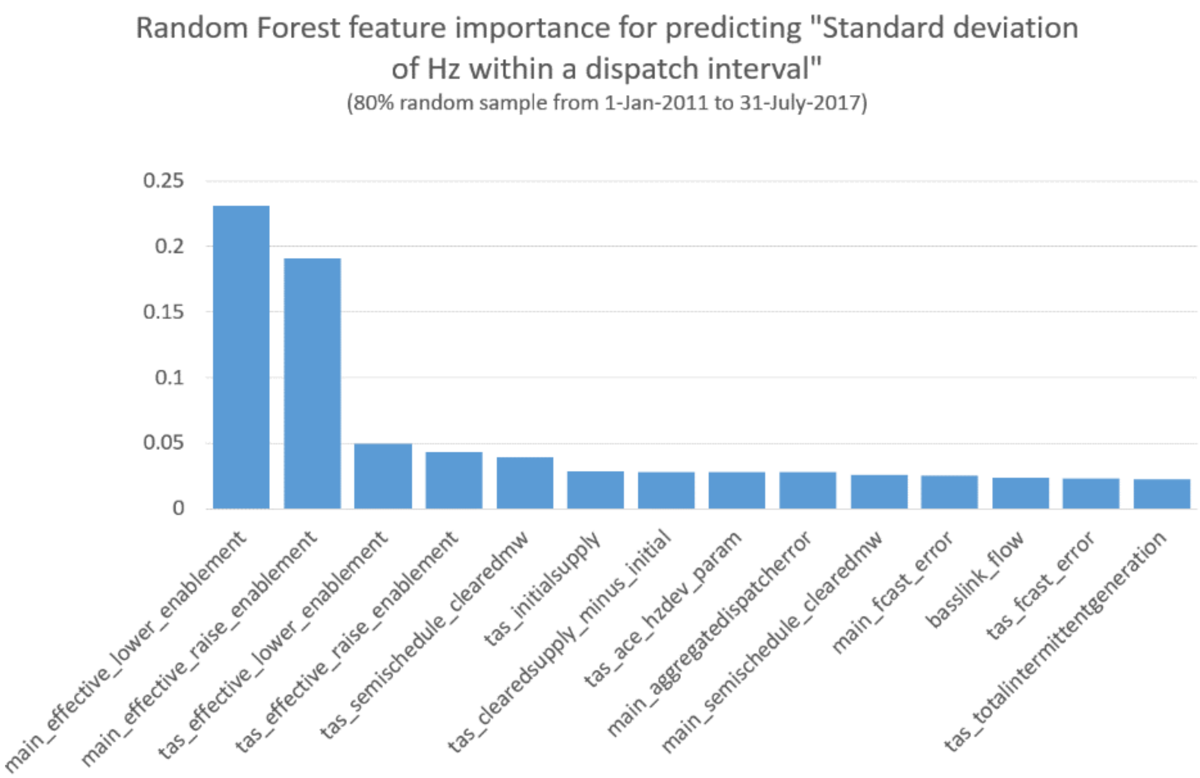


Figure 15.

Frequency standard deviation is caused mostly by the "effective enablement" (effective enablement is described in Appendix 3) which takes into account the impact of units with a material difference between their initialMW and their energy target.

Figure 16 shows the average effective enablement as a percentage of dispatched enablement.

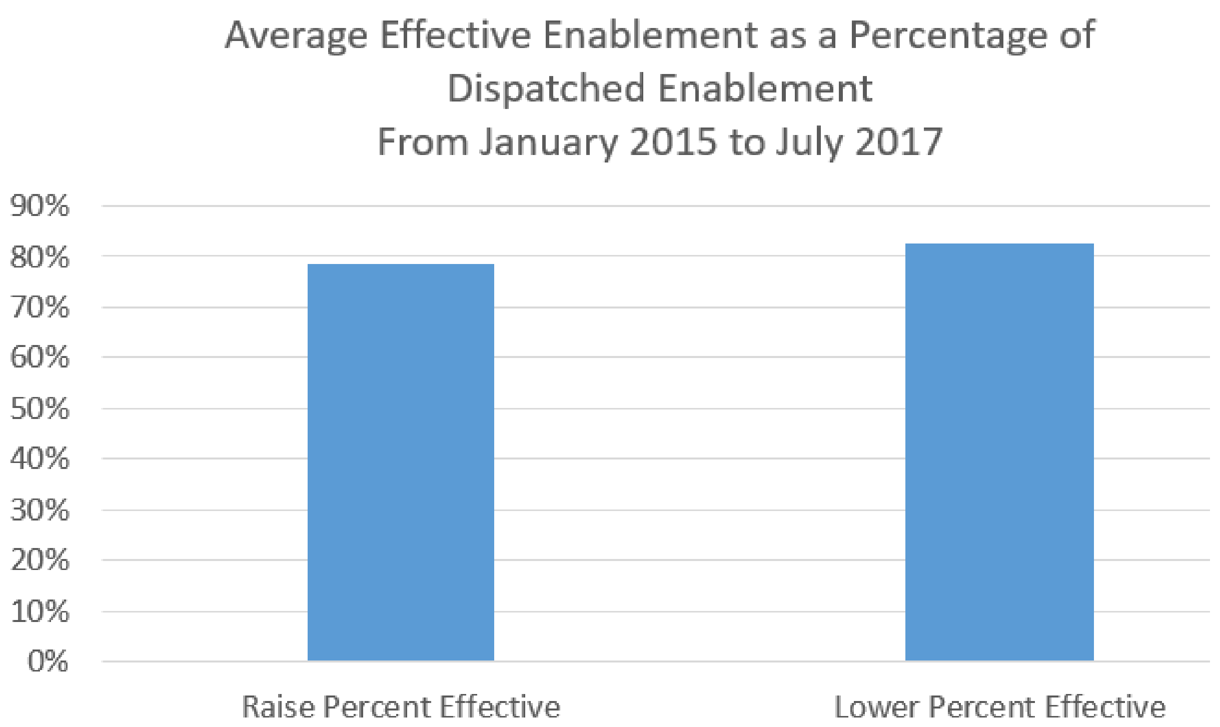


Figure 16.

By our definition of effective enablement, raise and lower regulation is on average only 78% and 83% of total enablement.

Figure 17 shows the distribution of Effective Enablement as a percentage of total enablement for 2017.

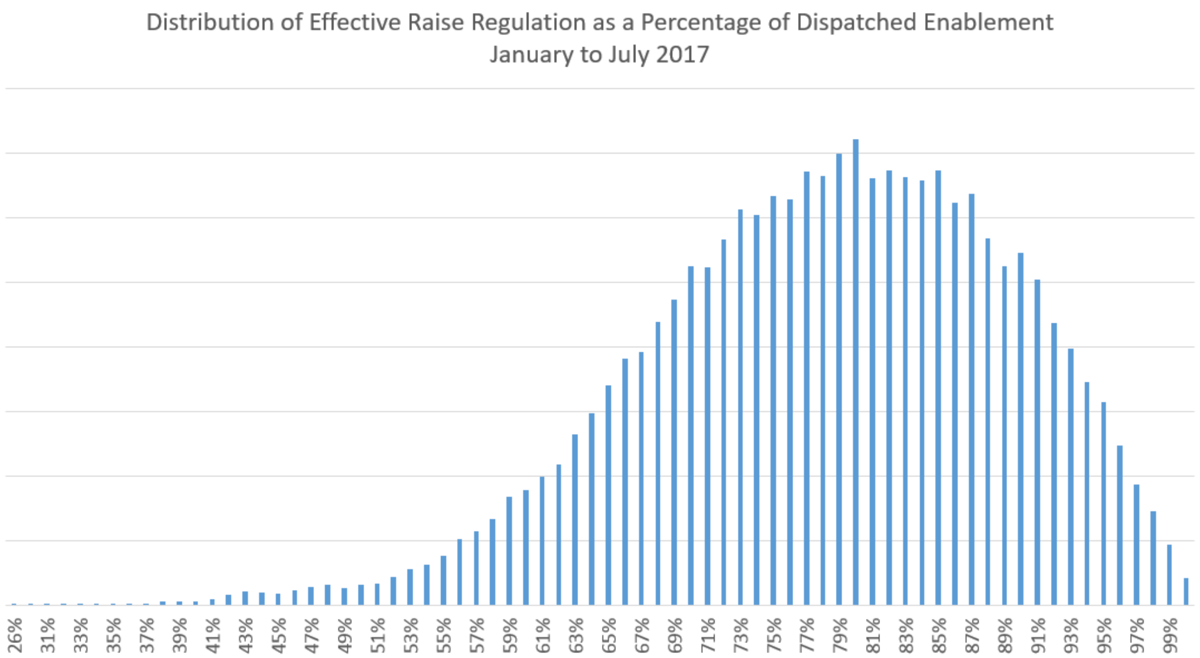


Figure 17.

This distribution raises two issues, first that there is never as much effective enablement as dispatched enablement, and second that there are times when the effective enablement is less than half what is otherwise believed to be available.

The Random Forest Regression results (Figure 16) show that frequency standard deviation is impacted the most by variations in the effective regulation. Figure 11 shows that the effective (raise) regulation has a broad distribution. The conjecture is that when the effective enablement is low relative to dispatched enablement it is more likely that there will not be sufficient volume of regulation services to correct frequency.

5 Conclusion

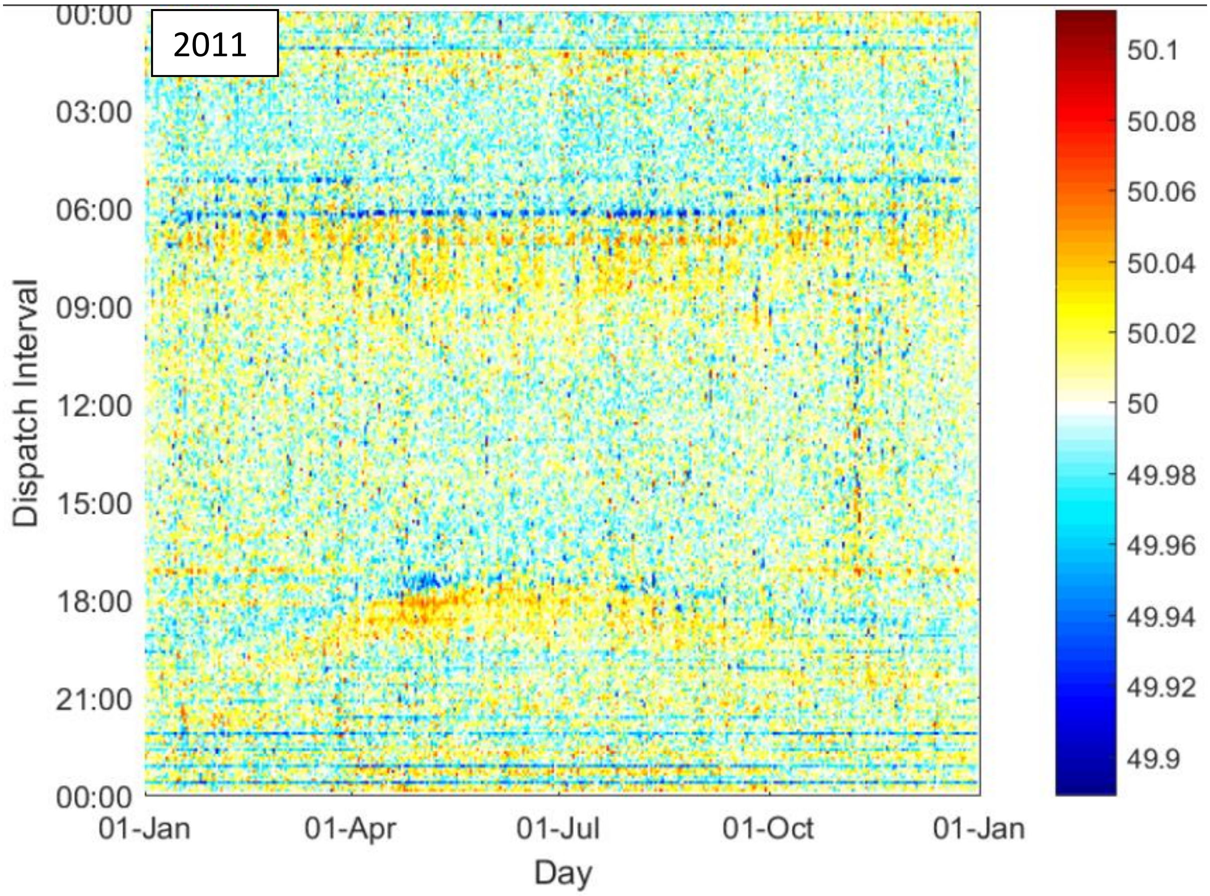
The data provide several key findings.

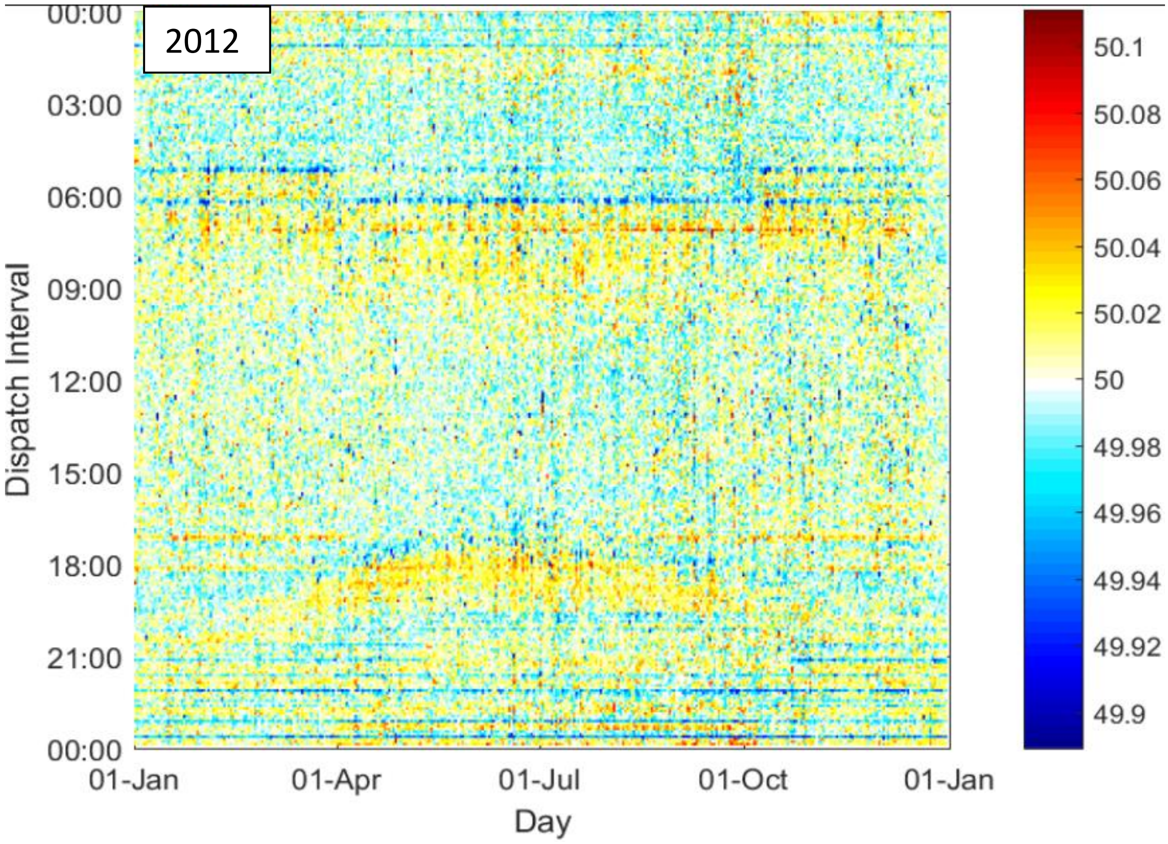
1. Average 5 minute frequency has become more variable since 2011 however a significant and sustained increase in variability occurred when Basslink returned from an extended outage on the 13th of June 2016.
    a. The increase in variability coincided with a decrease by a factor of 2 in the AoH for Tasmania units (which we believe linearly impacts the AGC pulses for Tasmanian units).
    b. Tasmanian units do not always provide the same level of Mainland frequency recovery as Mainland units.
2. Unit performance is on average consistent between stations. However there are occasions where performance is negligible and there appears to be no feedback between a units capacity to provide regulation FCAS and market dispatch.
3. There can be a significant difference between the effective enablement and the dispatch enablement and that this difference has a high correlation with frequency standard deviation.

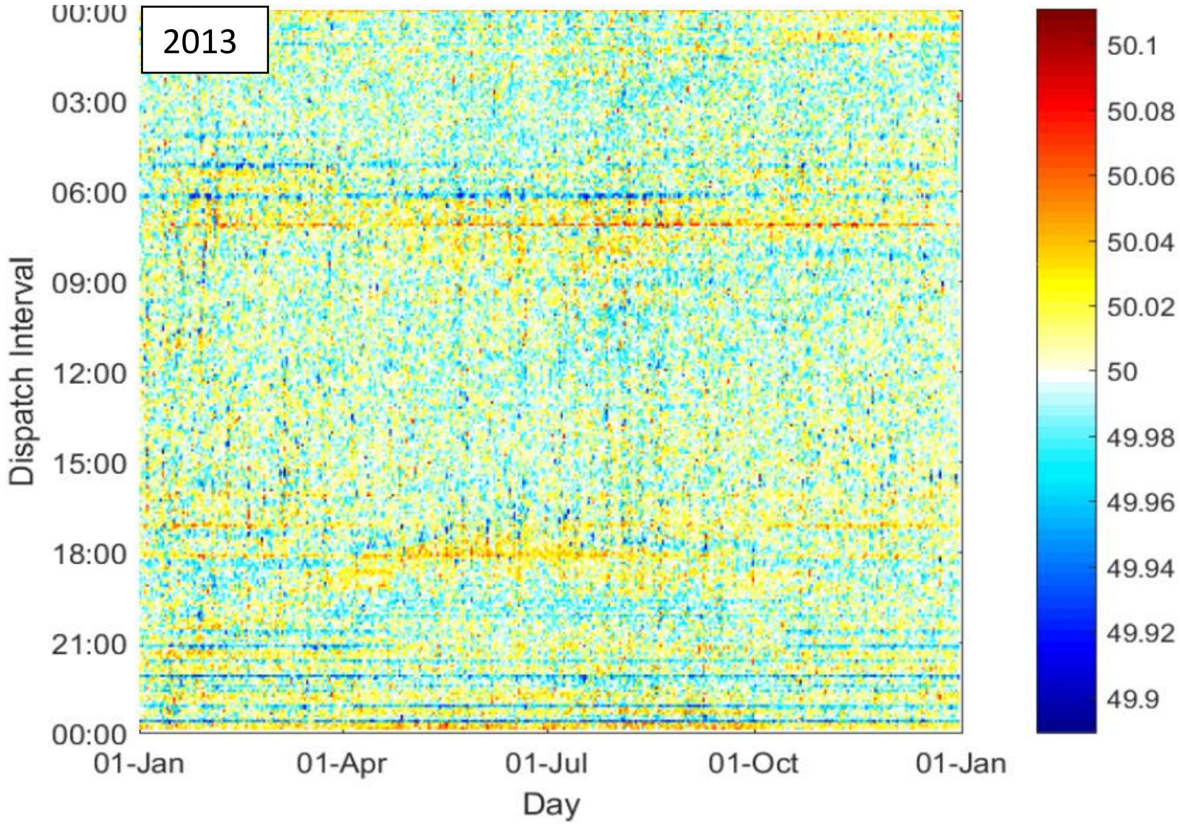
Appendix

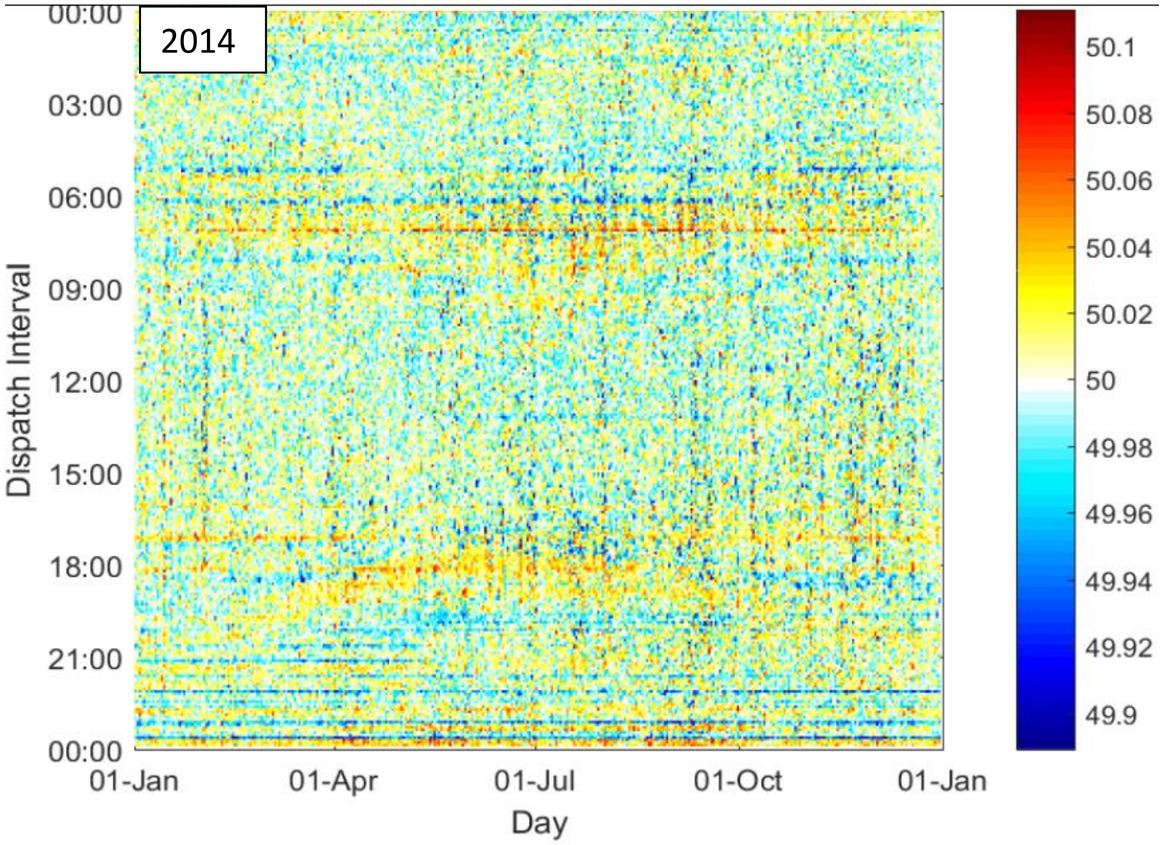
Appendix 1 Frequency Deviation Heat Maps for All Years

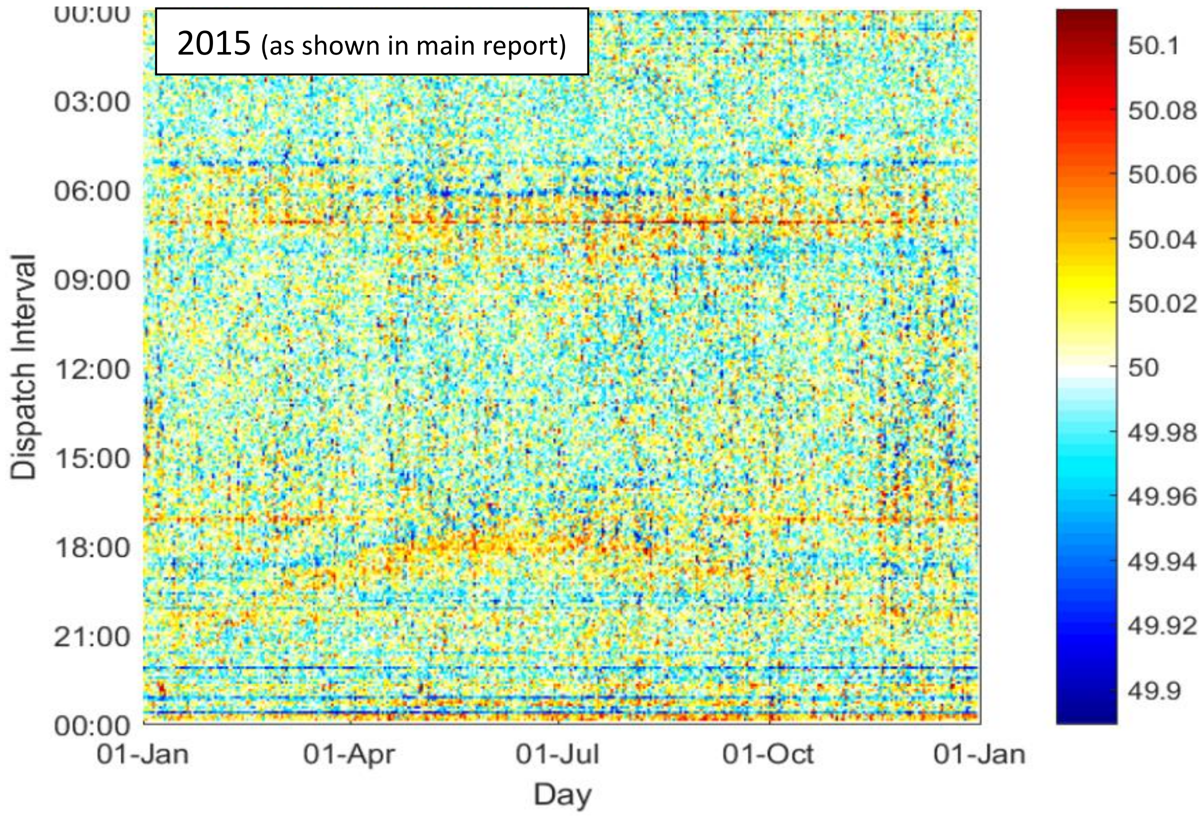
All of the heat maps showing the average frequency for every 5 minute dispatch interval from 2011 to 2017 (January to August) are shown below.

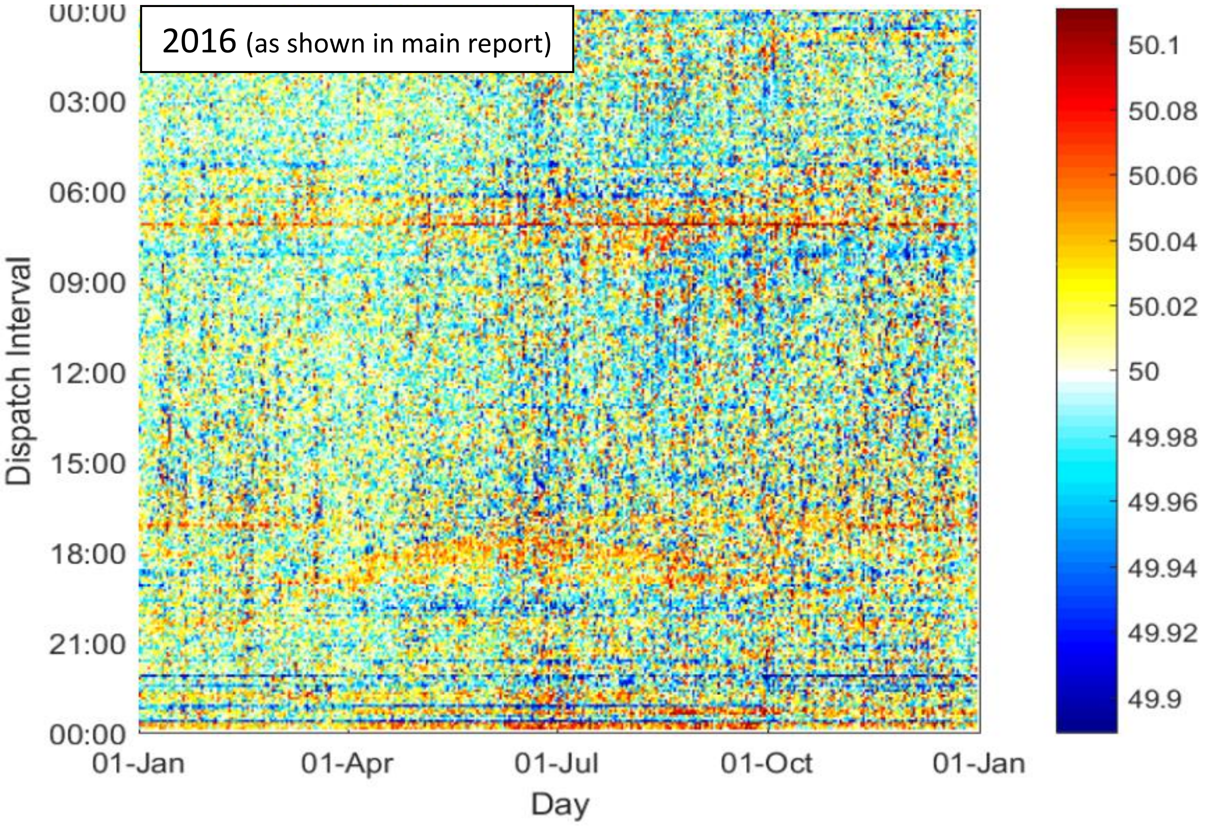


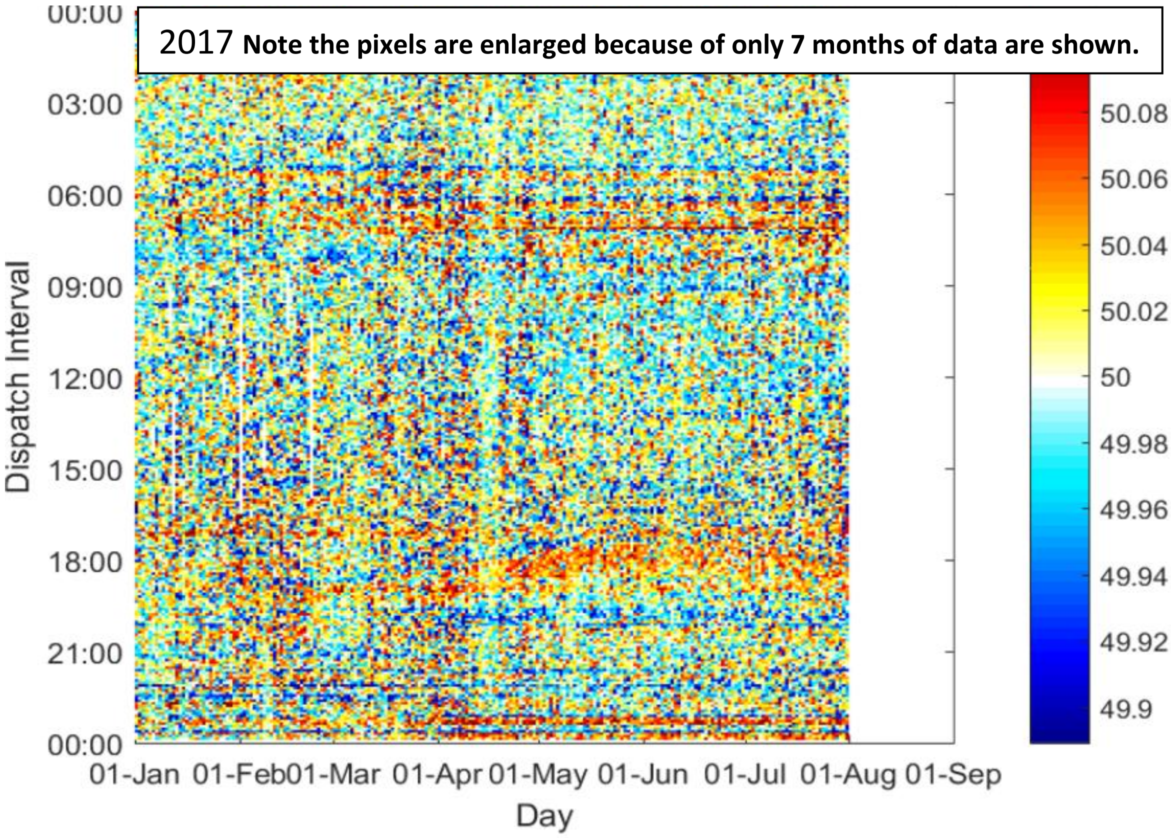

2012
Dispatch Interval
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
01-Jan
01-Apr
01-Jul
01-Oct
01-Jan
Day
50.1
50.08
50.06
50.04
50.02
50
49.98
49.96
49.94
49.92
49.9


2013
Dispatch Interval
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
01-Jan
01-Apr
01-Jul
01-Oct
01-Jan
Day
50.1
50.08
50.06
50.04
50.02
50
49.98
49.96
49.94
49.92
49.9


2014
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
Dispatch Interval
01-Jan
01-Apr
01-Jul
01-Oct
01-Jan
Day
50.1
50.08
50.06
50.04
50.02
50
49.98
49.96
49.94
49.92
49.9


2015 (as shown in main report)
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
Dispatch Interval
01-Jan
01-Apr
01-Jul
01-Oct
01-Jan
Day
50.1
50.08
50.06
50.04
50.02
50
49.98
49.96
49.94
49.92
49.9


2016 (as shown in main report)
Dispatch Interval
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
01-Jan
01-Apr
01-Jul
01-Oct
01-Jan
Day
50.1
50.08
50.06
50.04
50.02
50
49.98
49.96
49.94
49.92
49.9


2017 Note the pixels are enlarged because of only 7 months of data are shown.
Dispatch Interval
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
01-Jan
01-Feb
01-Mar
01-Apr
01-May
01-Jun
01-Jul
01-Aug
01-Sep
Day
50.08
50.06
50.04
50.02
50
49.98
49.96
49.94
49.92
49.9

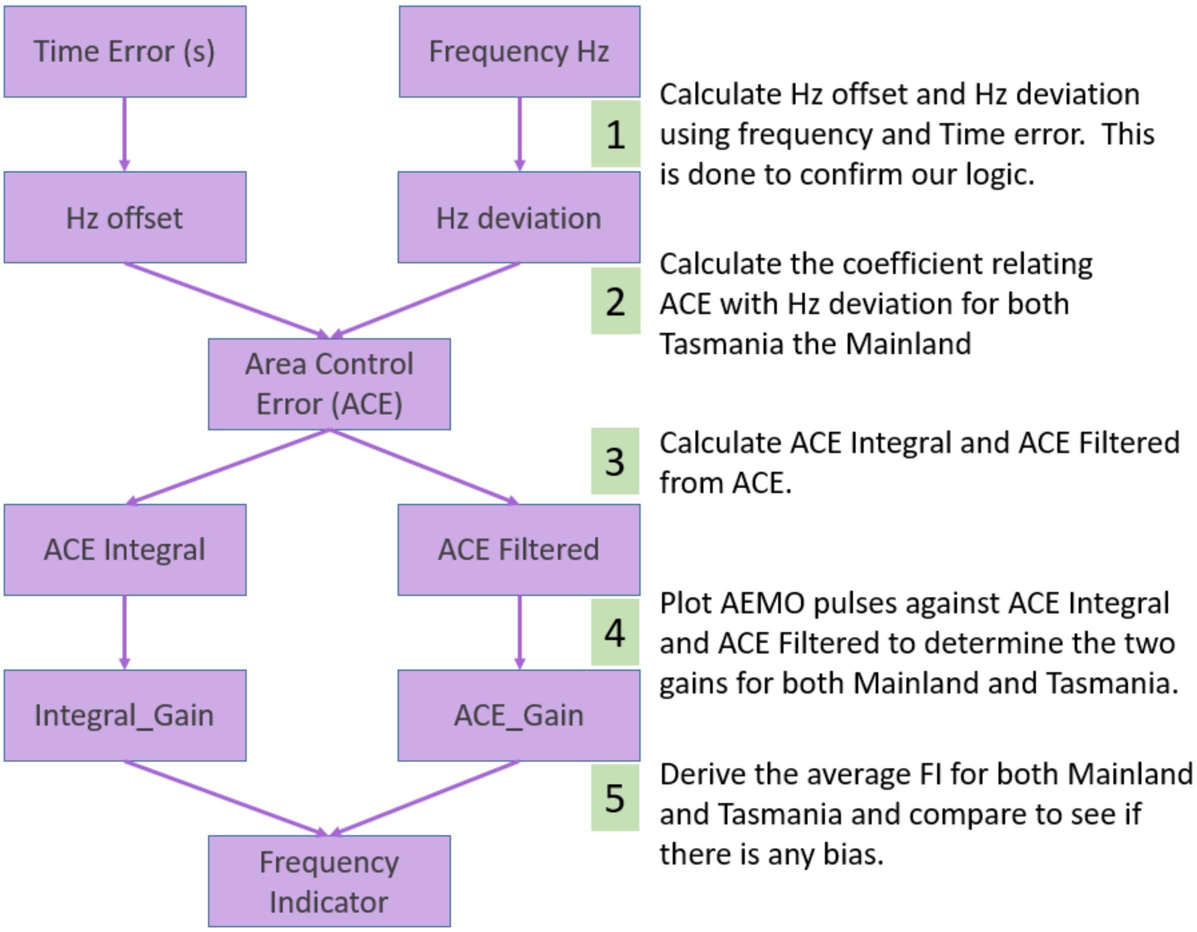
Appendix 2 From the Preliminiary Report – Statistical analysis of Tasmanian versus Mainland AGC instructions

This section outlines the method and the results of applying a statistical analysis of the 4 second causer pays data.

We understand, although have not confirmed, that AGC instructions are closely related to the Frequency Indicator (FI) which is known to be defined as follows[i]:

FI = (ACE_Filtered * ACE_Gain) + (ACE_Integral * Integral_Gain)

The aim of this section is to derive an average value of ACE_Gain and Integral_Gain and ACE and ACE_Integral thereby estimate an average FI for both the Mainland and Tasmanian units and compare these values to see if there is any bias between signals sent to the Mainland compared to signals sent to Tasmania. The following flow diagramme summarises the process to achieve this aim.



Moving through the steps.

1. Let's just say that step 1 worked since the values are otherwise available. We did this to check the data and our logic.

2. The following two plots (Chart 8 and Chart 9) show that a plot of *ACE* (with units of MW) vs. *Hz_Deviation – Hz_Offset* has a gradient of 2800 MW/Hz and 140 MW/Hz for the Mainland and Tasmania respectively. Note also that the fit is perfect and so we are 100% confident that this is how AEMO calculate *ACE*. Hence, for the purposes of comparing FI between the Mainland and Tasmania ***ACE* can be set to 2800MW per Hz for the Mainland and 140MW/HZ for Tasmania.**

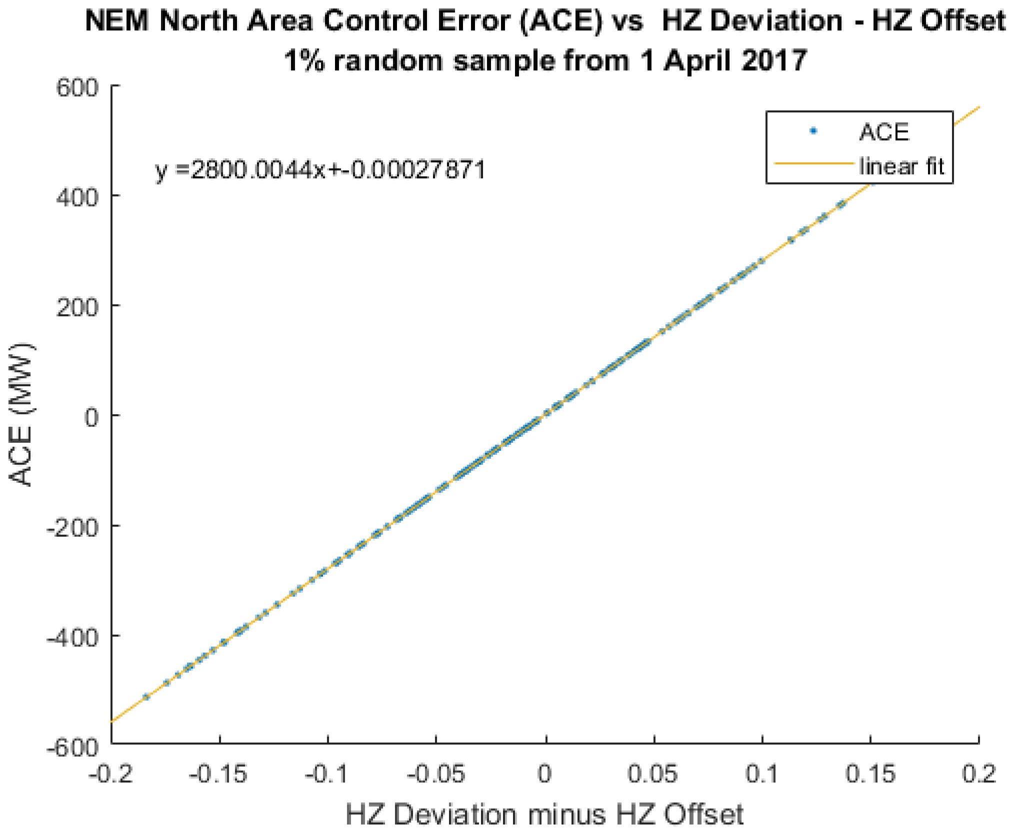


Chart 8

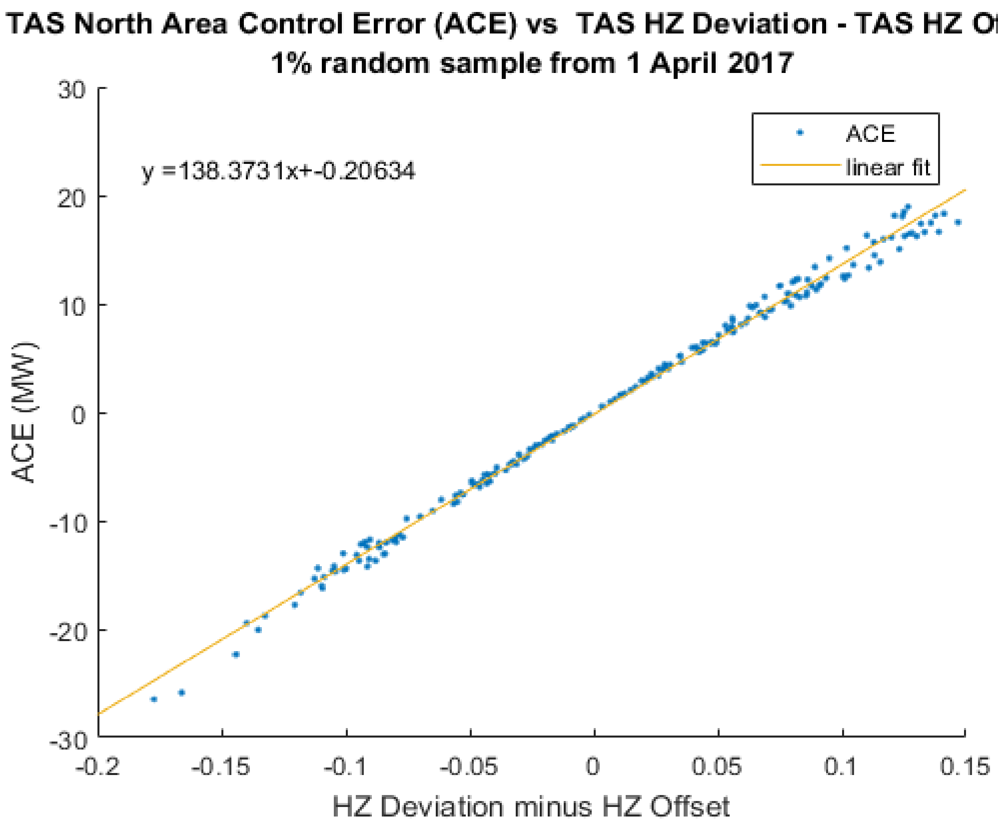


Chart 9

3. *ACE Filtered* was found to simply be *ACE* that had been exponential smoothed (not shown). *ACE Integral* was found to be equal to the previous *ACE Integral* + (*current ACE*/(60*60/4)). Working not shown.
4. The following two plots (Chart 10 and Chart 11) are used to derive estimates of *ACE_Gain* for both the Mainland and Tasmania. (The same can be done for *Integral_Gain* however there is little correlation, see Chart 12 – this raises further questions regarding the purpose of the Integral_Gain however such questions are beyond the scope of this analysis.)

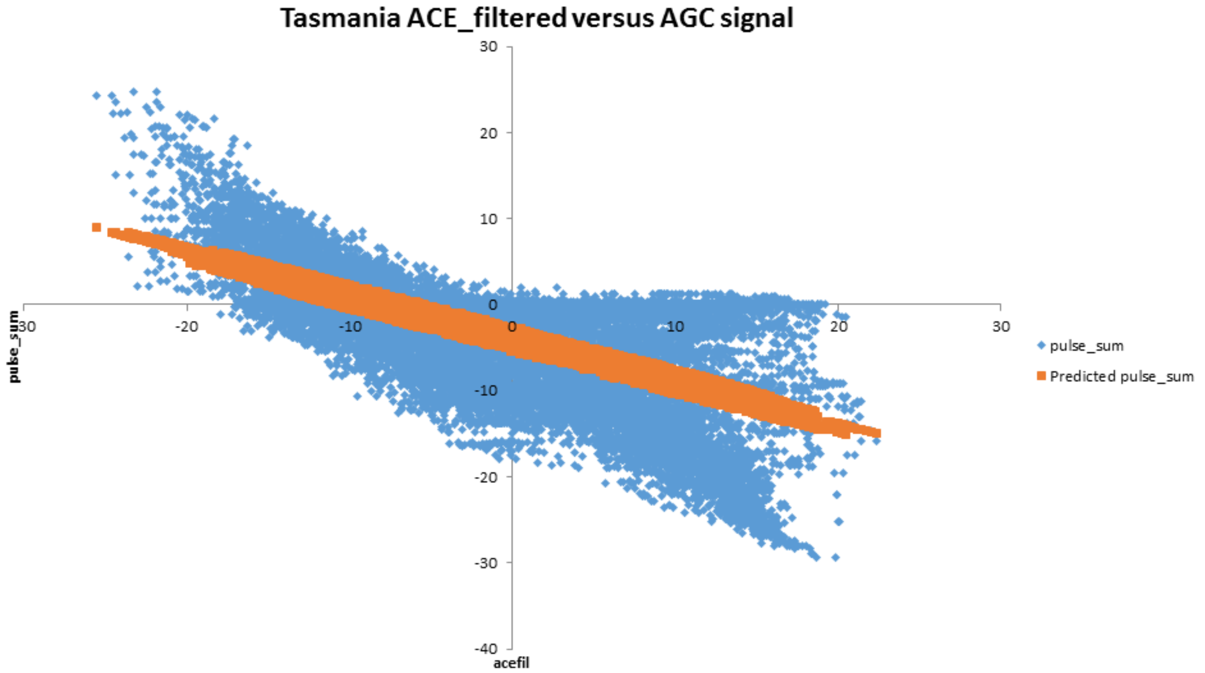


Chart 10

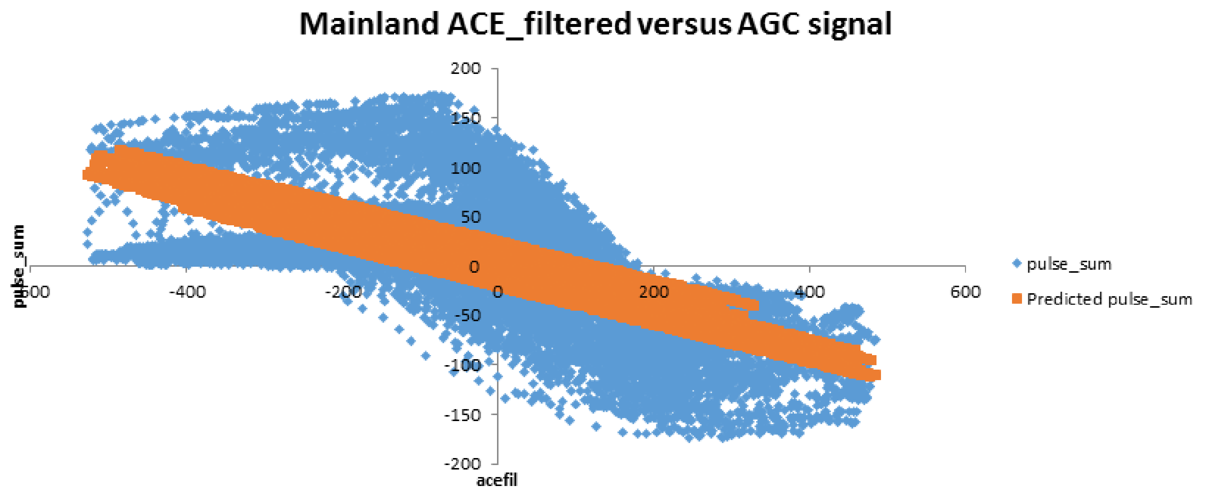


Chart 11

The slope of two graphs which represents the *ACE_Gain* is 0.19 and 0.5 for the Mainland and Tasmania respectively.

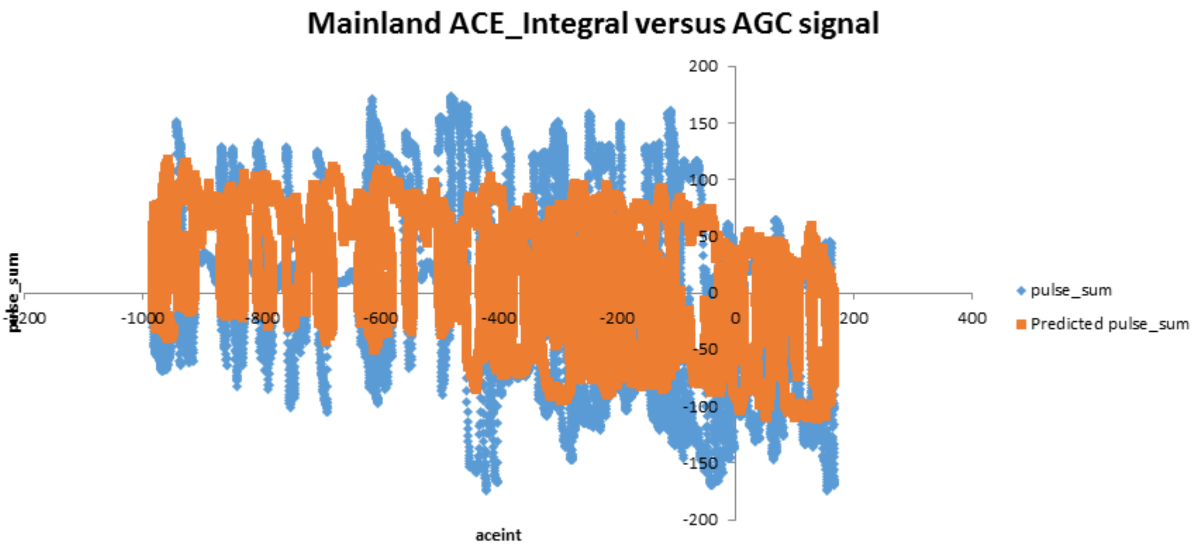
5. Derive the FI (or AGC signal) for both the Mainland and Tasmania and compare results.

FI (or AGC signal)	=	ACE_Filtered * ACE_Gain	
FI for Tasmania	=	140 * 0.5	= 70
FI for Mainland	=	2800 * 0.19	= 532

Note that FI is not published by AEMO and so the above is only an estimated average over the entire day.

From the above, the ratio of the two signals is: 532/70 = 7.6 or conversely 13%. This translates to a Mainland AGC signal being 7.6 times greater on average than a Tasmanian AGC signal. Or alternatively the Tasmanian signal is 13% of the Mainland signal on average. Note that this value is consistent with the estimated value of 17% derived using Chart 6 and Chart 7.

For completeness the following chart shows AGC_Integral versus AGC signal which shows no obvious correlation hence it was no included in the calculation.



Appendix 3 Description of Effective Regulation Enablement

"A Priori Effective Enablement" is a term that we defined and included as a variable in our Random Forest Regression analysis (heretofore Effective Enablement). The results from this regression suggested that the variable most correlated with the standard deviation of frequency was Effective Enablement. For this reason we included our results as discussed in Section 4. This Appendix aims to define this term and why we thought it worth investigating.

During our exploration of the 4 second data we observed the Generator Regulation Component (the AGC regulation Instruction) dropping to zero when actual generation exceeded a particular value during a given dispatch interval. This value coincided with the totalcleared target plus the regulation raise enablement.

We conjecture that although AGC instruction is equal to the unit basepoint plus the regulation raise instruction, the regulation raise instruction is set to zero anytime the actual generation is greater than *totalcleared* plus regulation raise enablement. This constraint is logical insofar as it prevents a situation where a unit could otherwise diverge significantly from its energy target over a number of dispatch intervals. However implicit in this logic is that regulation volume is required more at the end of a dispatch interval than at the beginning. This would be true if the supply and demand were in balance at the beginning of every dispatch interval.

Figure A3.1 aims to define “A Priori Effective (Raise) Enablement”.

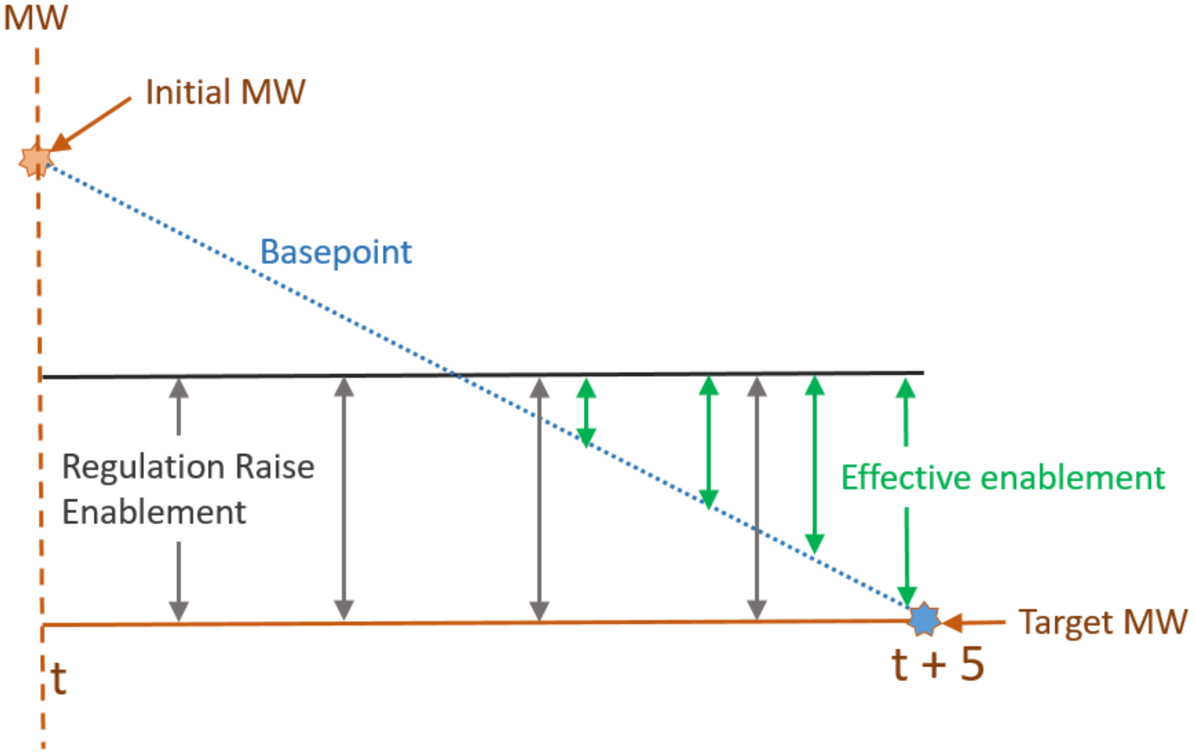


Figure A3.1

Figure A3.1 shows a scenario where the initialMW of a unit is significantly greater than the energy targetMW (assume that the energy target does not change from the previous dispatch interval). The unit’s basepoint is the linear trajectory from the initialMW to the TargetMW. Figure A3.1 shows the Regulation Raise Enablement (over and above the Target MW). We define the Effective Raise Enablement as shown by the area in green in Figure A3.1. Note that the Regulation Raise Enablement is considerably larger as shown by the area in black.

If our conjecture is true then in the example shown in Figure A3.1, the unit cannot receive any AGC raise regulation instructions at the beginning of the dispatch interval, nor can it receive any until the actual generation is less than the totalcleared plus regulation raise enablement (the black line) and that the results from Section 4 suggest that this effect has a significant correlation with frequency deviations.

Appendix 4 The effective difference in AGC regulation FCAS signals between Mainland and Tasmanian units

This appendix aims to highlight the shortfalls in our understanding of the independence between Tasmanian and Mainland AGC control systems and Basslink frequency balancing control system. These shortfalls were illuminated from our analysis of the effective difference in AGC regulation FCAS signals between Mainland and Tasmanian units.

We term a metric for the effective difference in AGC signals as the “Tasmanian to Mainland AGC Signal Utilisation Ratio” and it is defined as follows:

Let: "Sum Tasmanian AGC regulation FCAS signals (MW)" / "Sum Tasmanian Enablement (MW)"

= Tasmanian AGC Utilisation

And: "Sum Mainland AGC regulation FCAS signals (MW)" / "Sum Mainland Enablement (MW)"

= Mainland AGC Utilisation

Then: Tasmanian AGC Utilisation / Mainland AGC Utilisation

= **"Tasmanian to Mainland AGC Signal Utilisation Ratio"** or **AGC Signal Ratio** for short

The aim of this metric is to determine if, on average and relative to enablement volume, there is a AGC signal bias between Tasmanian and Mainland units. A value close to 1 (or 100%) would imply there is no bias. Figure A4.1 shows the monthly average AGC Signal Ratio from Jan 2015.

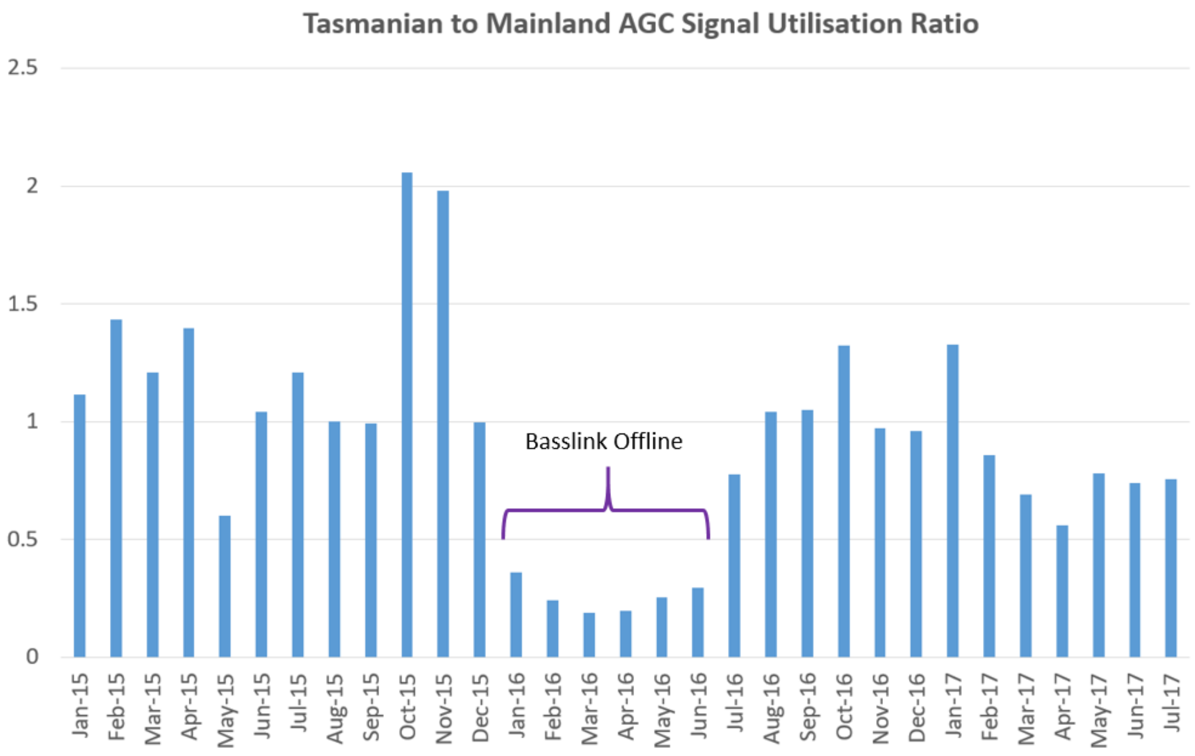


Figure A4.1

When Basslink was offline the Tasmanian units received only 25% of the relative AGC signals compared with the Mainland (the average Ratio during Basslink's outage is 0.25). This is expected since Tasmania is a smaller and more variable system and hence requires a relatively larger enablement level however less of the regulation service is utilised on average.

Prior and after Basslink's outage the average Ratio was 1.27 and 0.91 respectively. This is consistent with our claim that AoH for Tasmania was reduced just prior to Basslink's return to service hence the drop in the average Ratio. It should be noted that these values are close to one and hence there is no obvious bias. Furthermore even on a monthly basis the average Ratio varies considerably.

Figure A4.2 shows the Hourly Average 5 minute AGC Signal Ratio from 2nd – 4th May 2017.

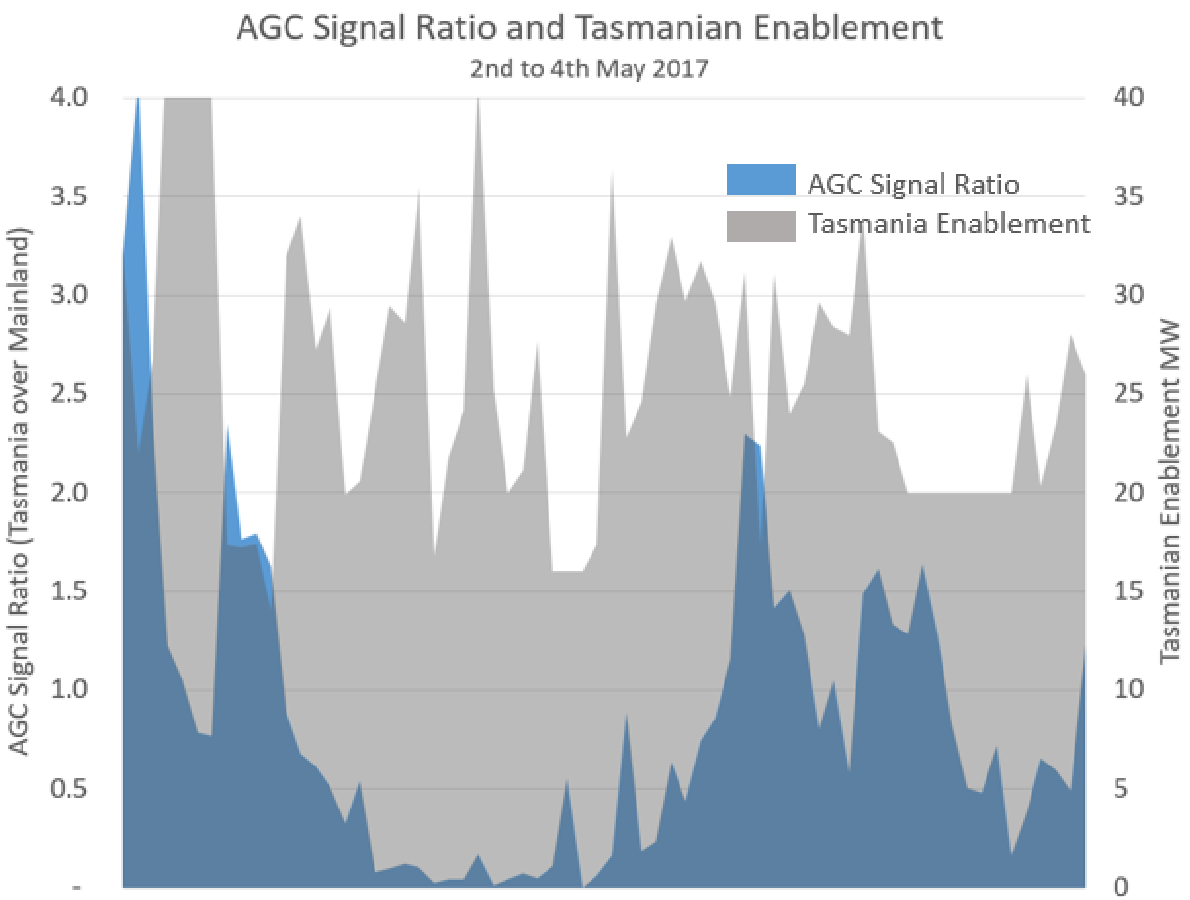
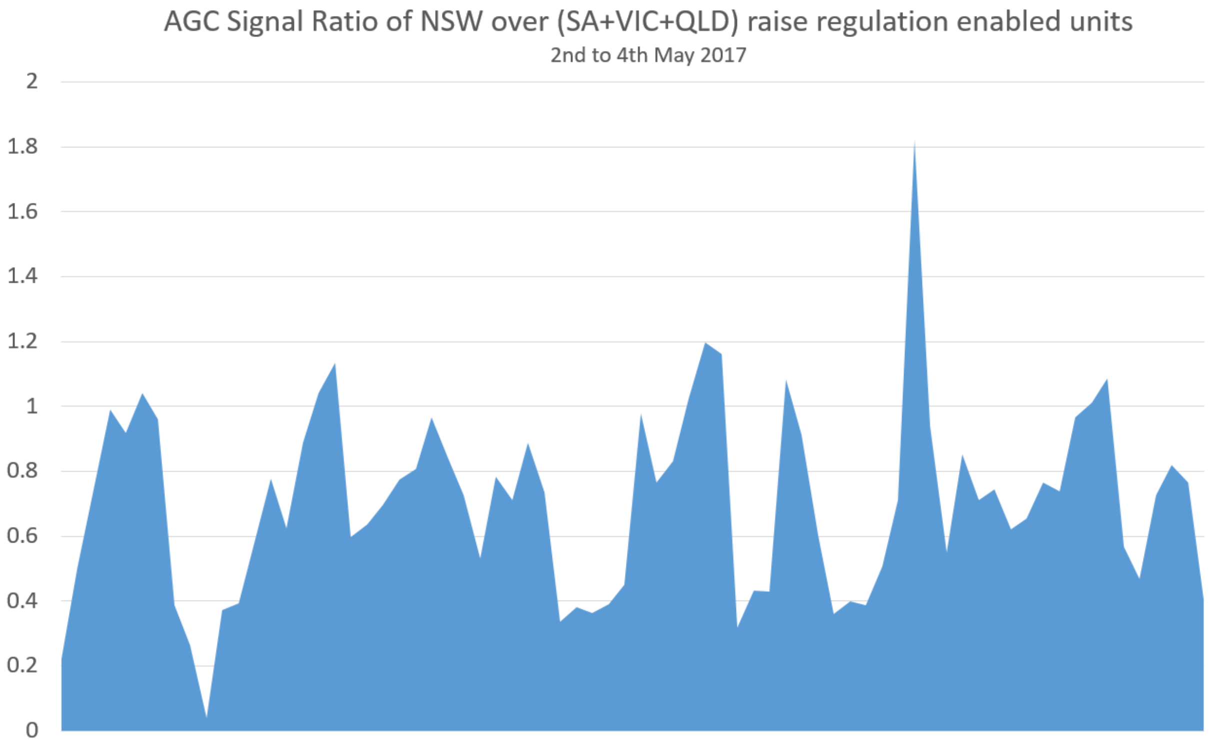


Figure A4.2

Tasmanian Enablement varied between 15 and 35MW for most of the 3 days shown. However the AGC Signal Ratio varied from almost zero to 4 (or 400% more of Tasmanian units enablement was utilised compared with Mainland units).

This raises more questions than answers – one question that comes to mind for us is whether the Basslink frequency controller response time is sufficient to effectively equalise frequency between the Mainland and Tasmania. If response time was instantaneous (like an AC power line connecting two regions) then the AGC Signal Ratio should be closer to one.

Figure A4.3 shows the same graph as Figure A4.2 however the ratio compares NSW with SA, VIC and QLD raise enabled units combined.



Although there is considerable variability in the AGC Signal Ratio there is certainly not the variability when compared with Tasmanian units. Note that "effective enablement" as described earlier could be a contributing factor to the variability in the AGC Signal Ratios.

In an attempt to understand what is the relationship between the independent AGC systems (for Mainland and Tasmania) and Basslink, Figure A4.4 and A4.5 aims to visualise this relationship (note that this visualisation is not necessarily representative of the system).

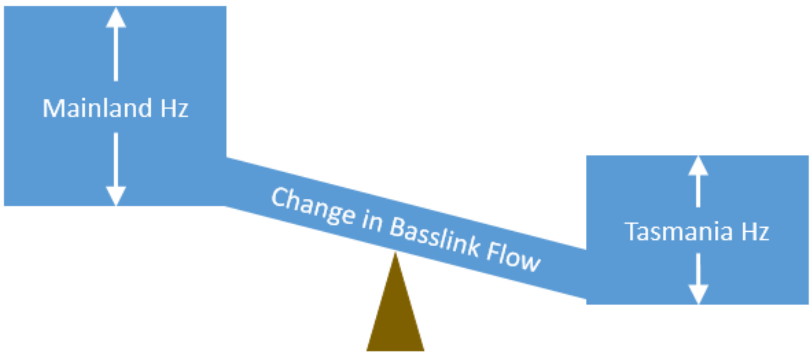


Figure A4.4

Figure A4.4 attempts to show the Basslink frequency controller. In short, if Mainland Hz is greater than Tasmania Hz (plus the deadband of 0.01Hz) then the Change in Basslink Flow increases towards Tasmania.

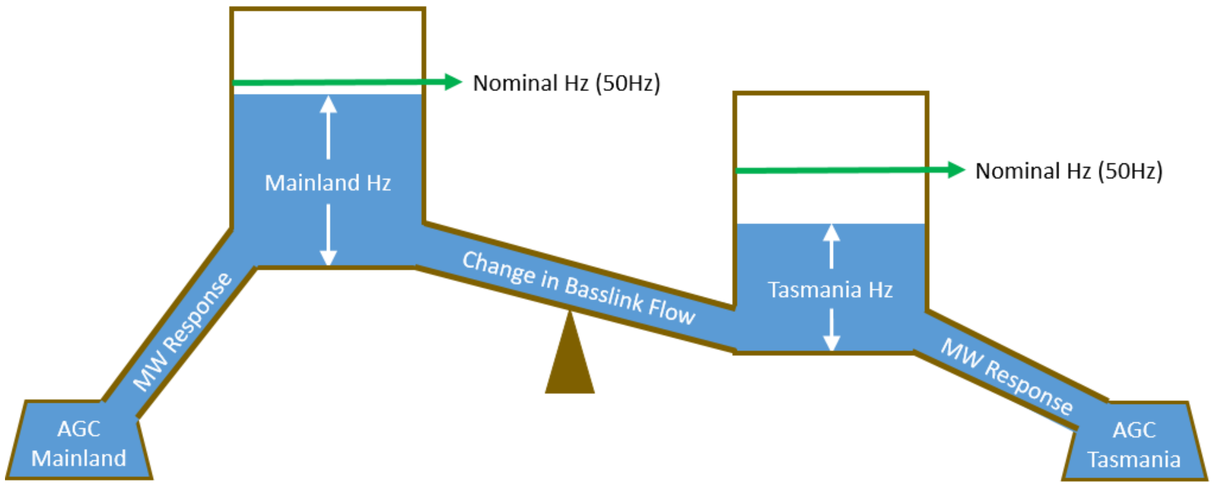


Figure A4.5

Figure A4.5 adds the AGC systems for the Mainland and Tasmania. These AGC systems are independent. If the Mainland frequency is less than Nominal frequency (usually 50Hz unless there is material time error) then MW response will be positive from raise regulation enabled Mainland units. Similarly for Tasmania.

How effective this control system balances frequency is a question which, at this time, we have insufficient data and knowledge to answer. In our view the variability of the AGC Signal Ratio shown in Figure A4.2 would suggest that further investigations are warranted.

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[i] Kate Summers, "Fast Frequency Service – Treating the symptom not the cause?" Submission Paper to Licensing Inverter Connected Generators. 8th February 2017