DYNAMIC STABILITY MONTHLY REPORT

NORTH ISLAND – MARCH 2023

Transpower New Zealand Limited

March 2023

Keeping the energy flowing




TRANSPOWER

NOTICE

Version	Date	Change
1.0	14/12/2023	Final

	Position	Date
Prepared By:	Jessie Fahey, Power Systems Engineer	14/12/2023
Reviewed By:	Richard Sherry, Principal Engineer	11/03/2024

Contents

1 Executive summary

1.1 Purpose

The low frequency dynamic oscillatory stability of the power system has been analyzed using phasor measurement unit data for the month of March 2023. This monthly report presents these findings for March 2023 and follows the same methodology as other monthly reports. Together these reports can be used to track significant changes over time specifically aimed at drawing attention to changes of oscillation behavior.

If some oscillation modes have changed significantly, a more detailed investigation should be required to identify the cause (e.g. load growth, generator, controller, topology, etc.)

1.2 Objectives

This monthly report's objective is to highlight significant modes on the network to help continuously assess the changes of the modes over time and changes in system conditions in order to trigger more detailed investigations in case of poor damping events.

2 Current status and observations

Mode freq.	Signal	Comments	Observations in March 2023
0.04 Hz	All-f All-p	Governor modes	Well-damped No significant change over the month
0.25 Hz	All-f Most-p	Likely control modes, and non-electromechanical	High decay time in certain periods, up to 50s in the frequency data Relatively high number of occurrences
0.5 – 0.6 Hz	Most-f	Possibly interarea modes	Decay time up to 15s in the frequency data Relatively low amplitude
0.9-1 Hz	Most-f Most-p	Inter-area and Inter-station modes	Damping time up to 50s in the power data Relatively low amplitude High number of occurrences
1.5 Hz	Most-f Most-p	Inter-station and Local modes	Decay time up to 35 seconds Relatively low amplitude
1.7-1.9 Hz	BPE-p HAY-p SFD-p	Inter-station and Local modes	Periods of relatively high amplitude High number of occurrences Relatively well damped

2.4-2.5 Hz	Most-f Most-p	Not yet identified	Low number of occurrences Well damped
3.5 Hz	HLY-f	Not yet identified	Low number of occurrences Well damped

The Wairakei PMU was disconnected from the start of 2023 through to 5th October.

3 Detailed plots for March 2023

3.1 Mode frequency histograms

Remark: the frequency histograms are shown for a frequency range [0.04 4Hz]

3.1.1 PMU Frequency Data

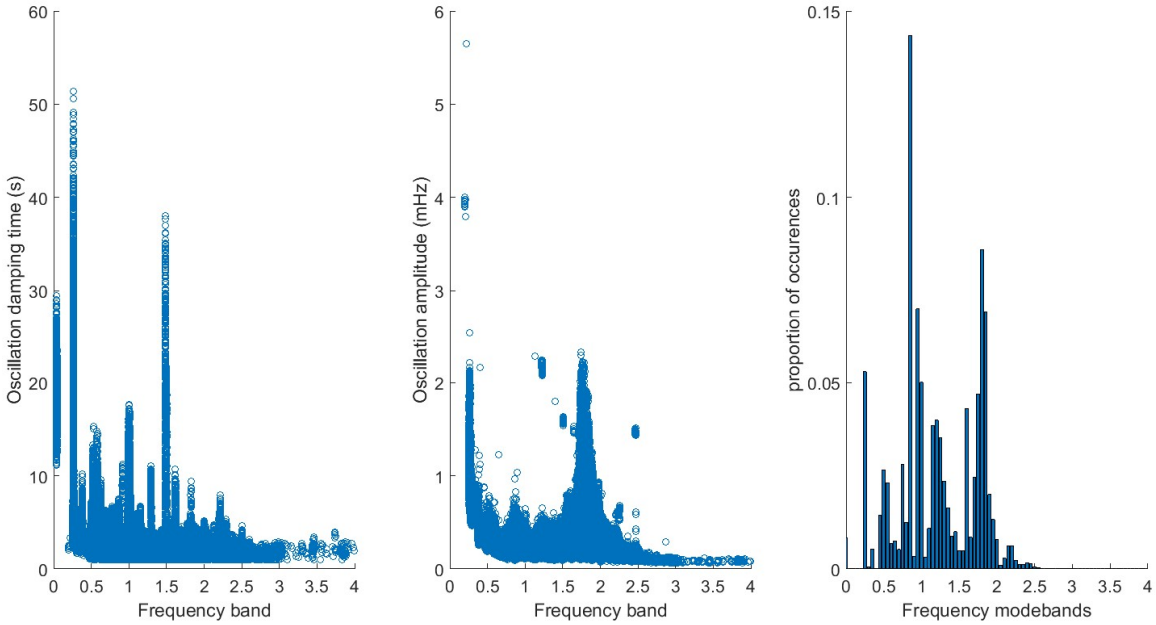


Figure 1: Bunnythorpe mode damping, mode amplitude, and frequency histogram using frequency data

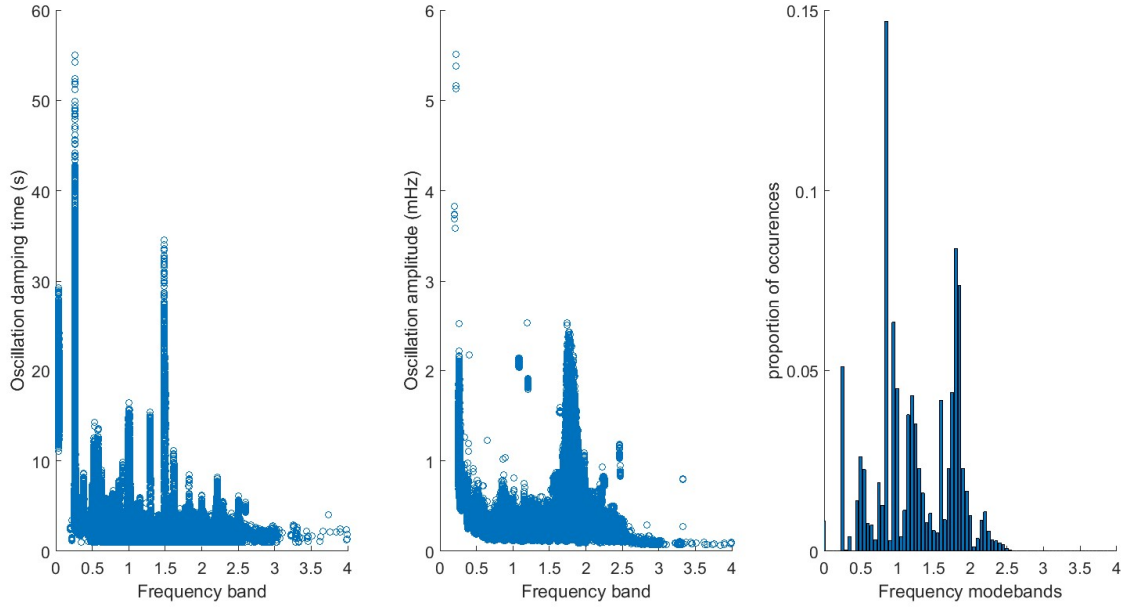


Figure 2: Haywards mode damping, mode amplitude, and frequency histogram using frequency data

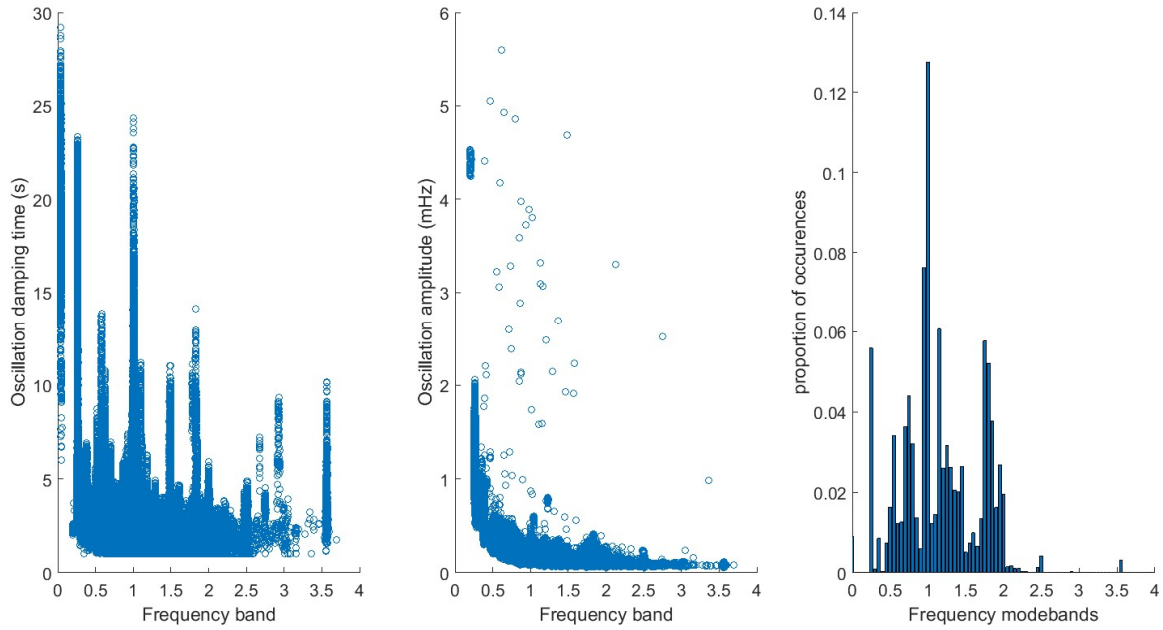


Figure 3: Huntly mode damping, mode amplitude, and frequency histogram using frequency data

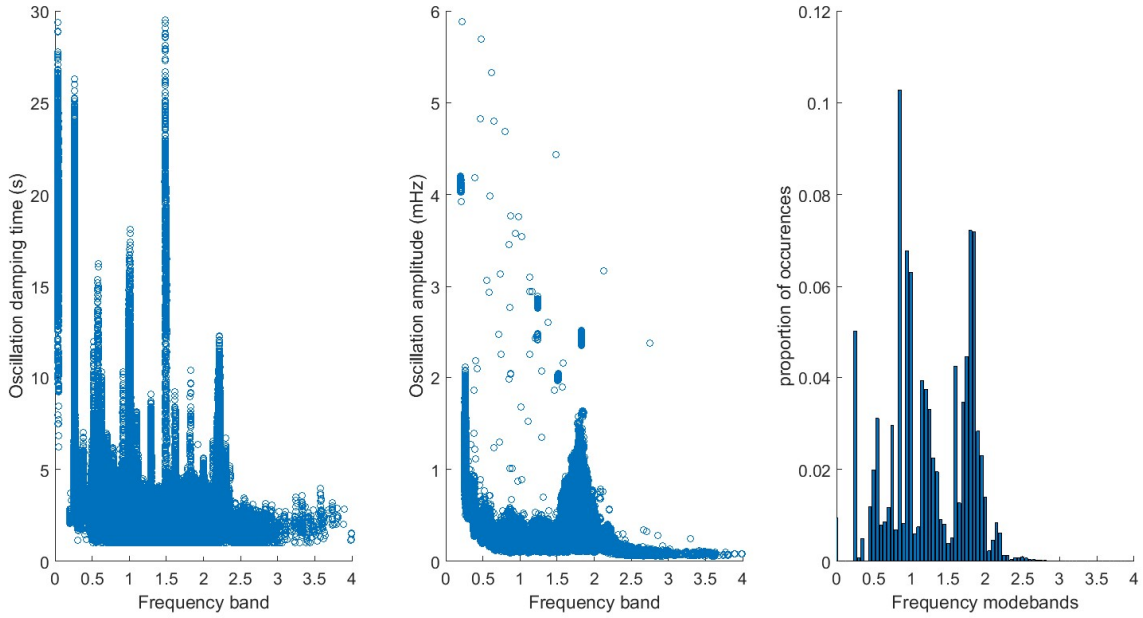


Figure 4: Stratford mode damping, mode amplitude, and frequency histogram using frequency data

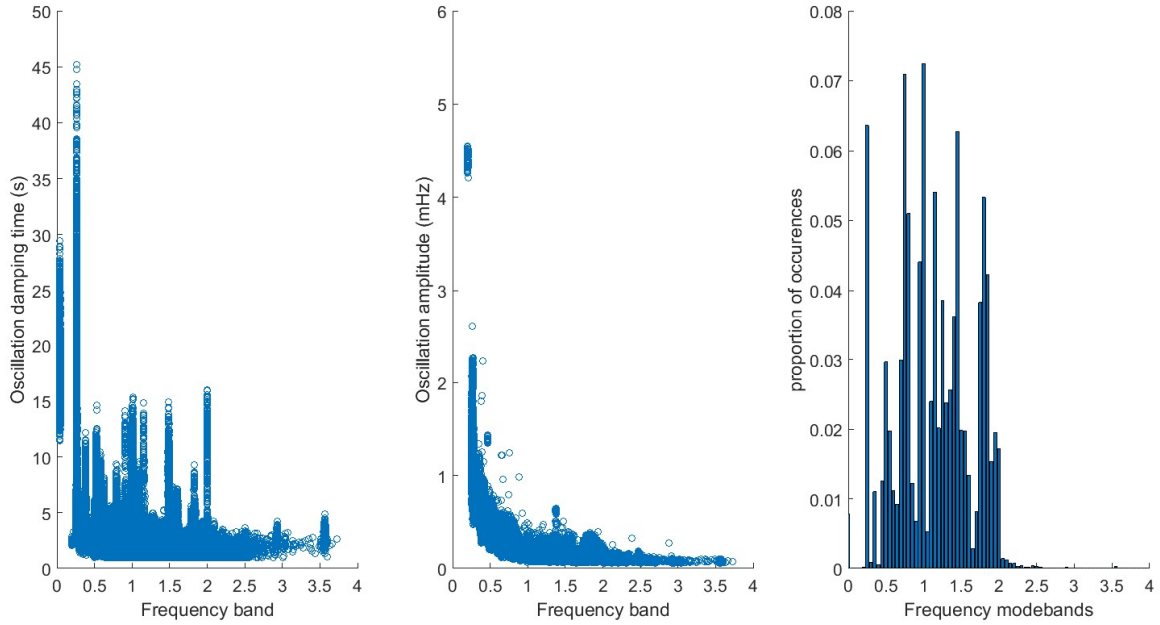


Figure 5: Whakamaru mode damping, mode amplitude, and frequency histogram using frequency data

3.1.2 PMU Active Power Data

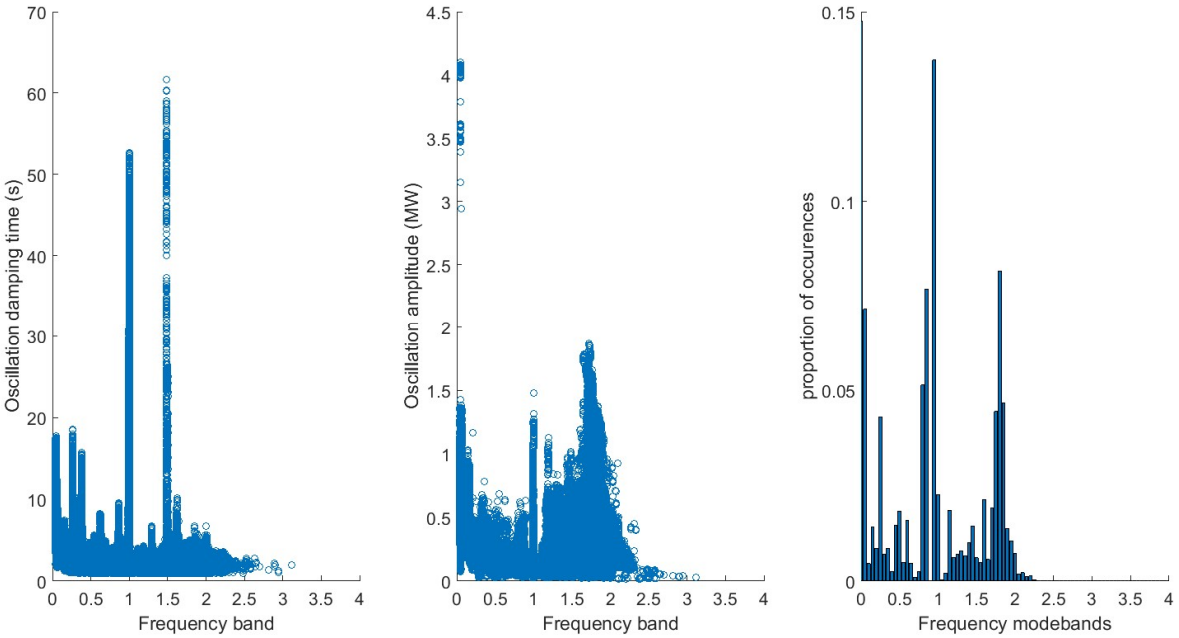


Figure 6: Bunnythorpe mode damping, mode amplitude, and frequency histogram using active power data

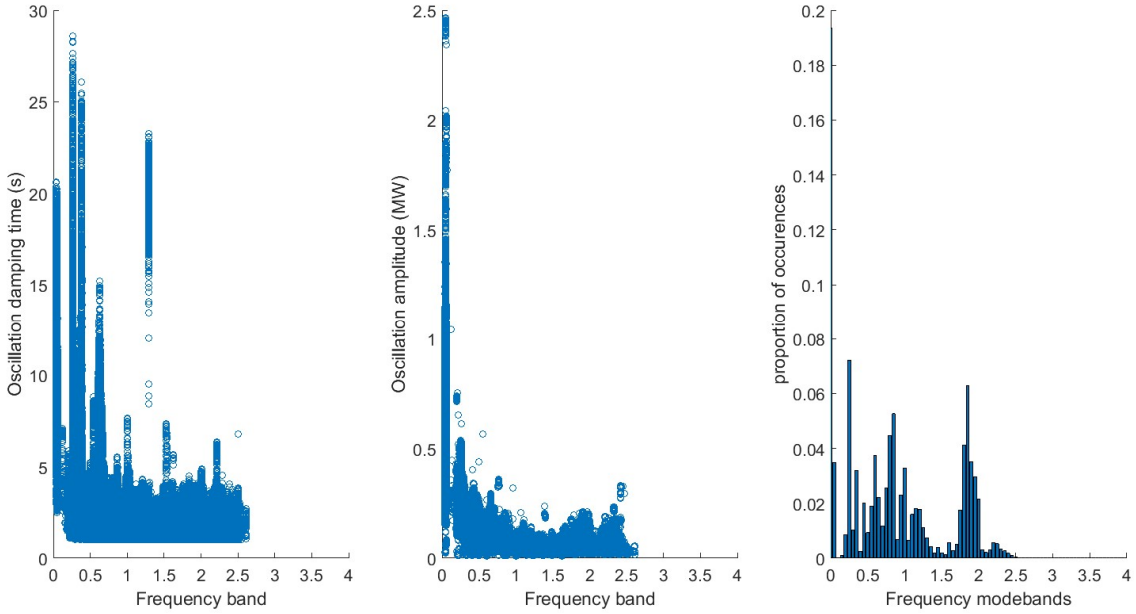


Figure 7: Haywards mode damping, mode amplitude, and frequency histogram using active power data

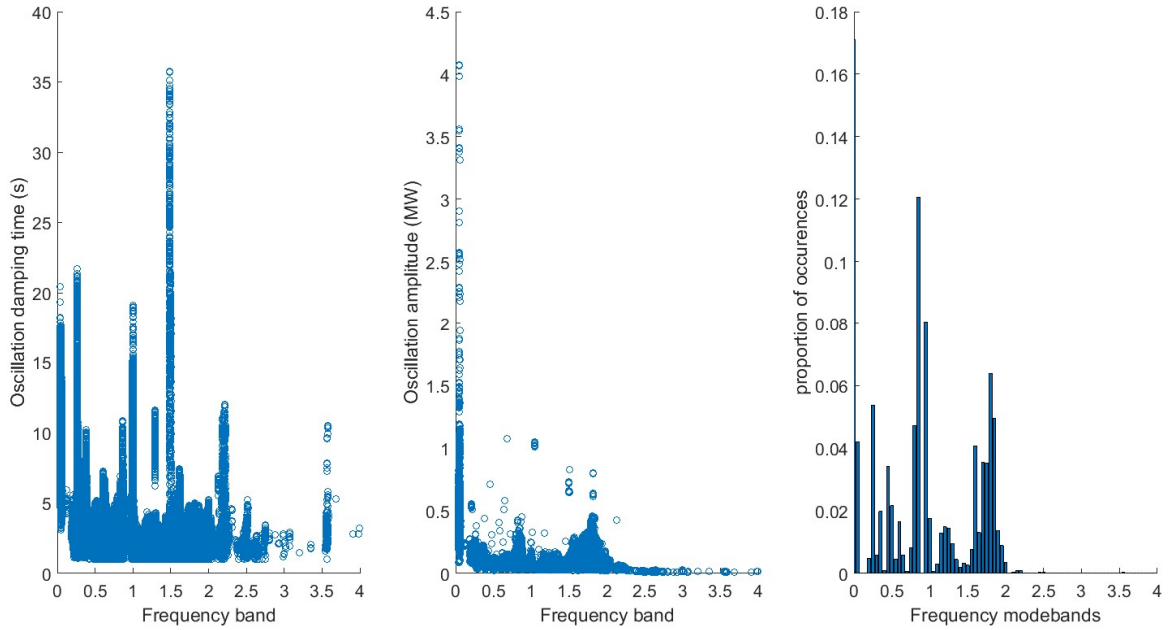


Figure 8: Huntly mode damping, mode amplitude, and frequency histogram using active power data

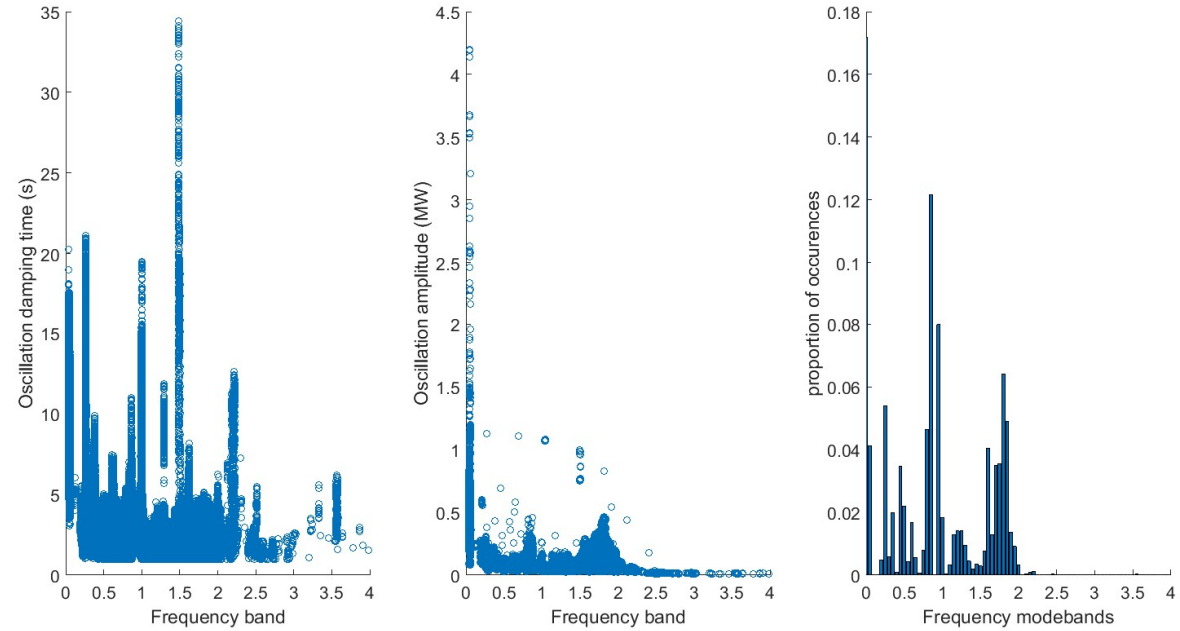


Figure 9: Stratford mode damping, mode amplitude, and frequency histogram using active power data

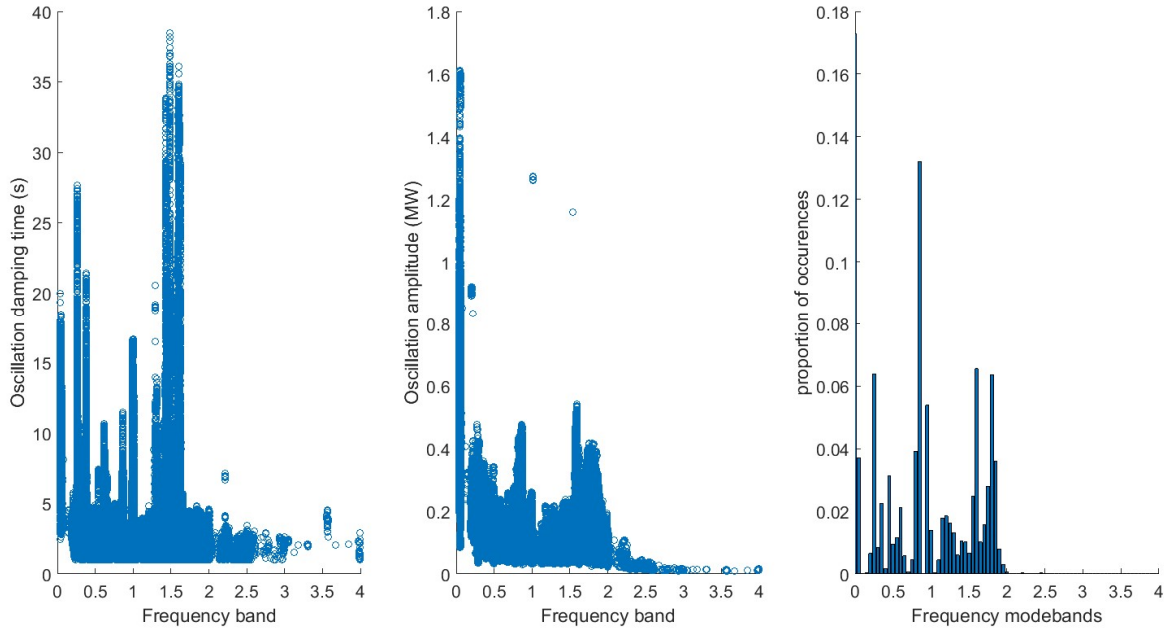


Figure 10: Whakamaru mode damping, mode amplitude, and frequency histogram using active power data

3.1.3 Observations using the frequency histograms

From the histograms, it can be observed that some modes have a large percentage of occurrences. Distinct modes at approximately 1 Hz and 1.8 Hz can be observed in the March data.

The frequency histograms usually do not contain enough information to precisely define all modes of interest however, the following approximate modes are observed from the data:

- 0.25 Hz
- 0.9-1 Hz
- 1.5 Hz
- 1.8 Hz
- 2.25 Hz
- 3.5 Hz

3.2 Defining mode bands

Mode bands are used to separate the different oscillating modes. Nevertheless, using the mode frequency is not a restrictive enough criterion to separate modes. Hence, several modes can still coexist in the same frequency band.

The following mode bands are defined:

0.0-0.2 Hz	0.2-0.6 Hz	0.6-0.9 Hz	0.9-1.2 Hz	1.2-1.8 Hz	1.8-2.4 Hz	2.4-4 Hz

3.3 Mode band 1: [0.0 – 0.2 Hz]

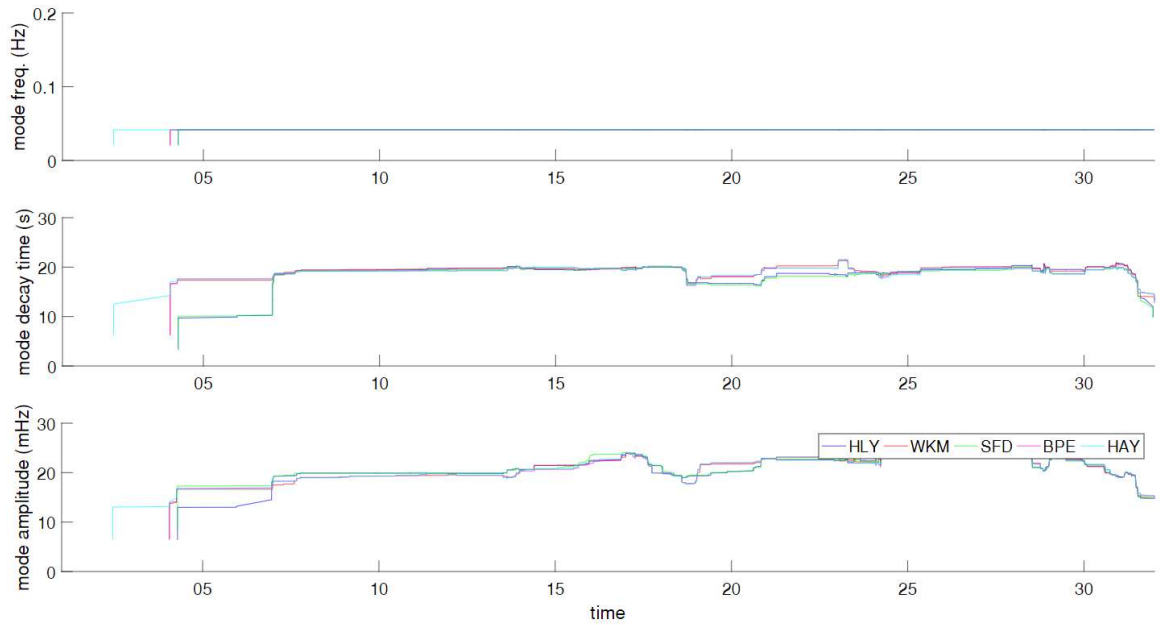


Figure 11: PhasorPoint results for the modeband [0.0 0.2 Hz] using PMU frequency data

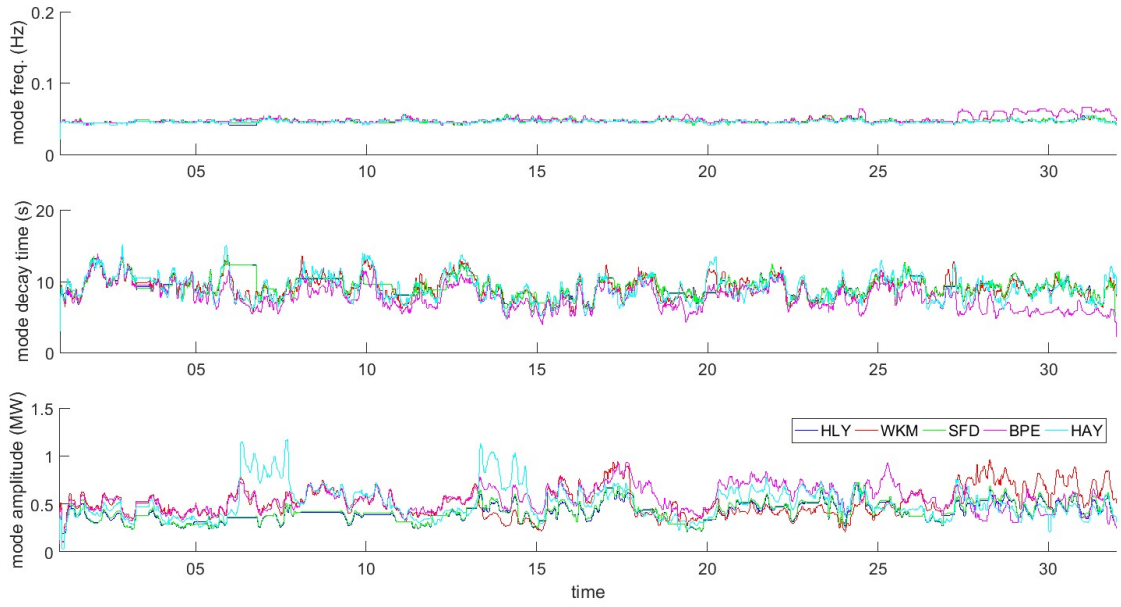


Figure 12: PhasorPoint results for the modeband [0.0, 0.2 Hz] using PMU active power data

Using PMU frequency:

- 0.04 Hz (governor) mode observed.
- For these persistent very low frequency modes the envelope decay times reported by the software are misleadingly short.

Using active power:

- 0.04-0.05 Hz mode observed.

3.4 Mode band 2: [0.2 – 0.6 Hz]

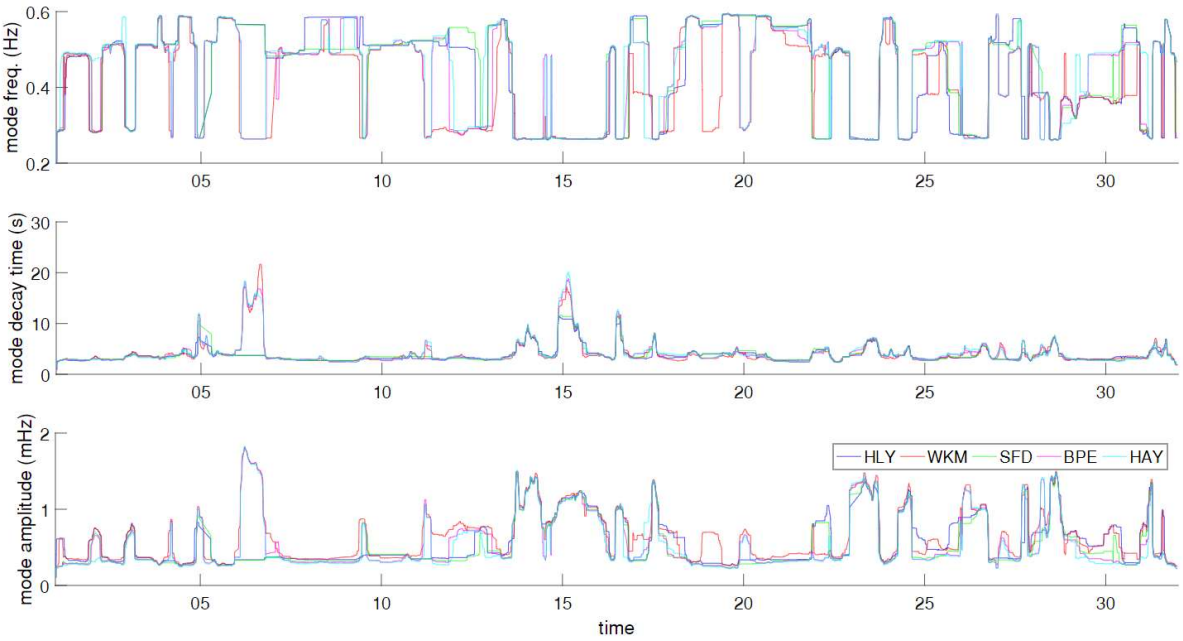


Figure 13: PhasorPoint results for the modeband [0.2, 0.6 Hz] using PMU frequency data

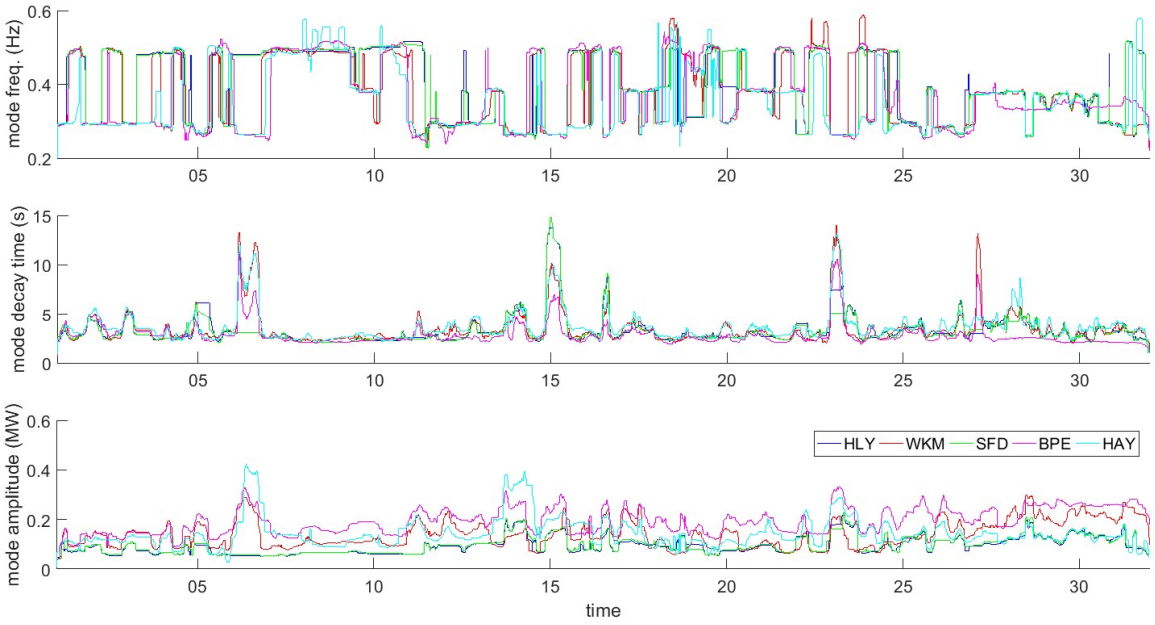


Figure 14: PhasorPoint results for the modeband [0.2, 0.6 Hz] using PMU active power data.

Using PMU frequency:

- 0.25 Hz mode. Decay time around 3 seconds, increasing to 10-20 seconds at times throughout the month.
- 0.5 Hz-0.6 Hz. Decay time around 3-5 seconds throughout the month.

Using active power:

- 0.25-0.3 Hz, 0.4 Hz and 0.5-0.6 Hz modes at most sites, all low amplitude.
- 0.25 Hz mode decay time between 3-15 seconds.
- 0.5-0.6 Hz mode decay around 5 seconds when dominant.

3.5 Mode band 3: [0.6 – 0.9 Hz]

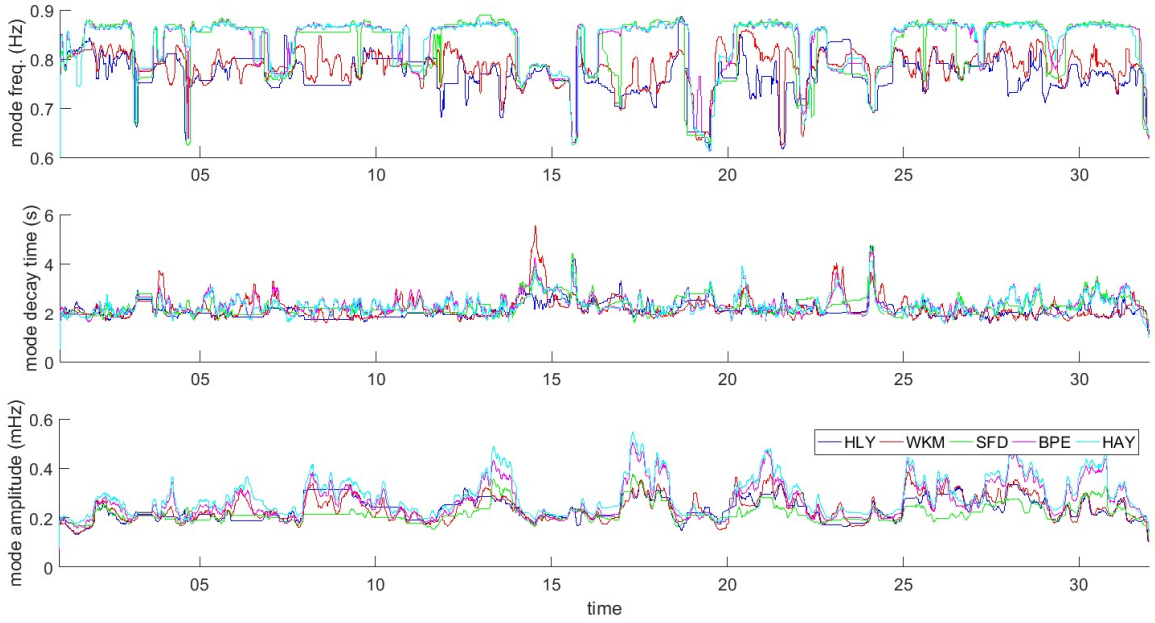


Figure 15: PhasorPoint results for the modeband [0.6, 0.9 Hz] using PMU frequency data

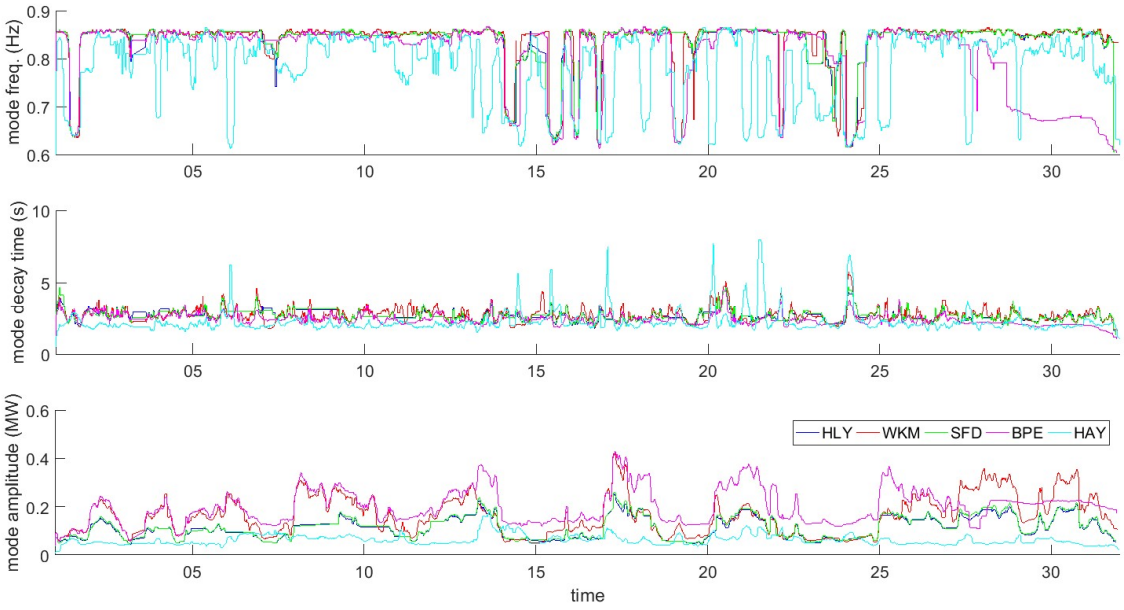


Figure 16: PhasorPoint results for the modeband [0.6, 0.9 Hz] using PMU active power data

Using PMU frequency:

- Mode around 0.6 Hz, and 0.7 Hz – 0.9 Hz observed.
- Decay time less than 5 seconds.
- Maximum amplitude ~0.5 mHz.

Using active power:

- Modes around 0.65 Hz and 0.85 Hz observable.
- Decay time less than 5 seconds at most sites (except Haywards where frequency and decay time varies more but on very low amplitude data).
- Maximum amplitude at Bunnythorpe ~400kW.

3.6 Mode band 4: [0.9 – 1.2 Hz]

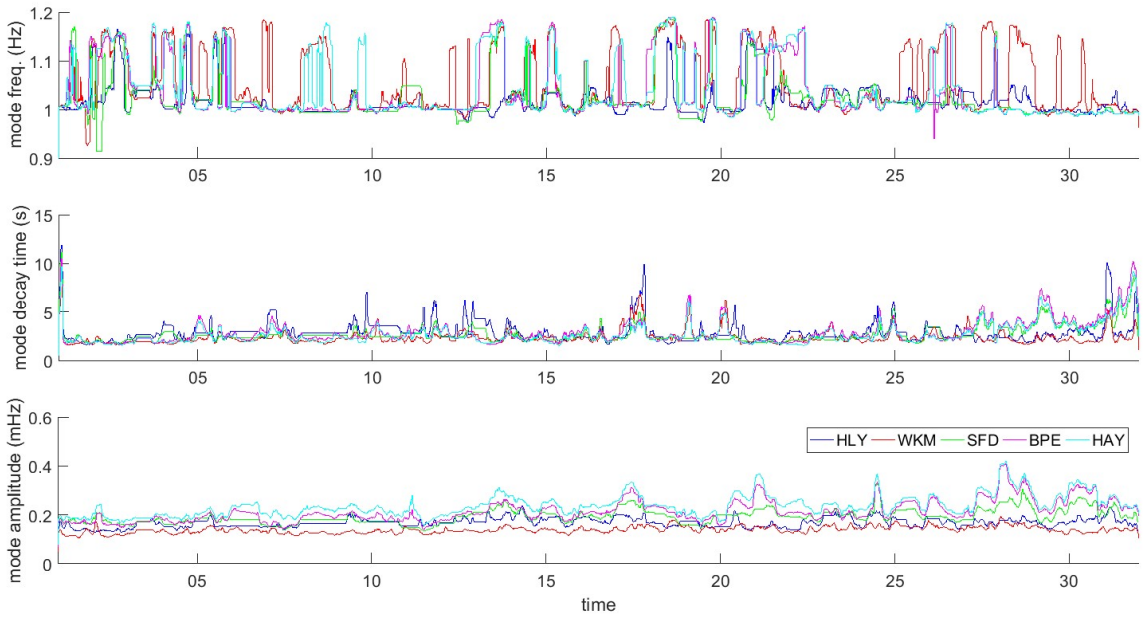


Figure 17: PhasorPoint results for the modeband [0.9, 1.2 Hz] using PMU frequency data

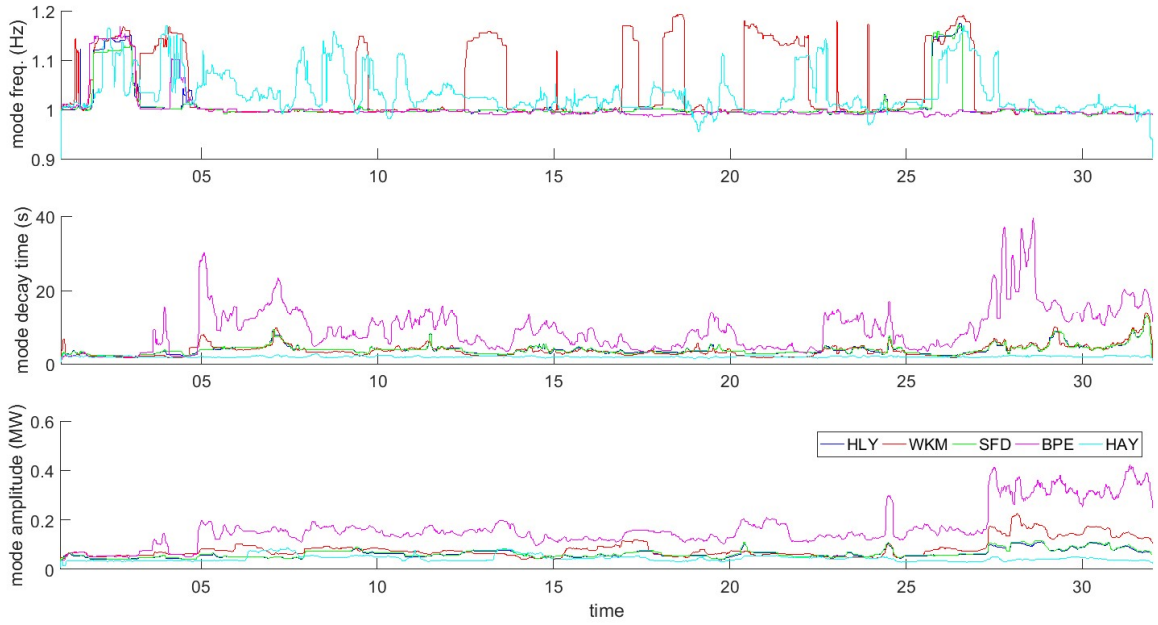


Figure 18: PhasorPoint results for the modeband [0.9, 1.2 Hz] using PMU active power data

Using PMU frequency:

- Distinct modes at 1.00 Hz and 1.1-1.15 Hz.
- Most decay times are under 12 seconds.
- Highest mode amplitude ~0.4 mHz.

Using active power:

- Most modes are typically well damped. However, Bunnythorpe shows a decay time up to 40 seconds for the 1 Hz mode at the end of the month.
- All modes in this band have relatively low oscillation amplitudes.

3.7 Mode band 5: [1.2 - 1.8 Hz]

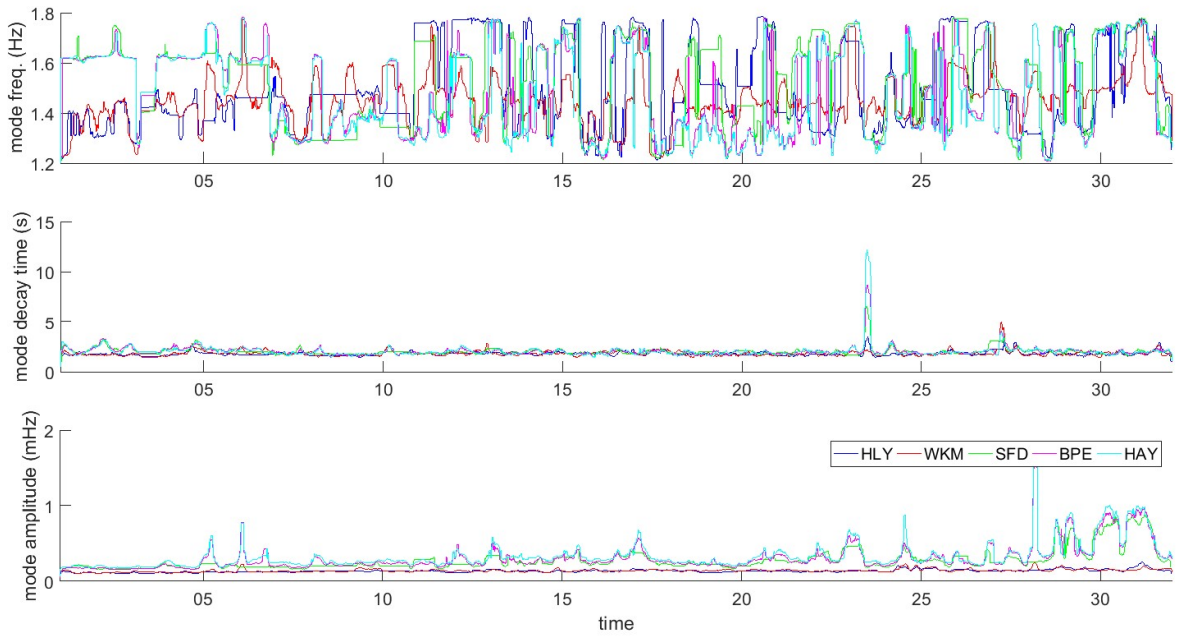


Figure 19: PhasorPoint results for the modeband [1.2, 1.8 Hz] using PMU frequency data

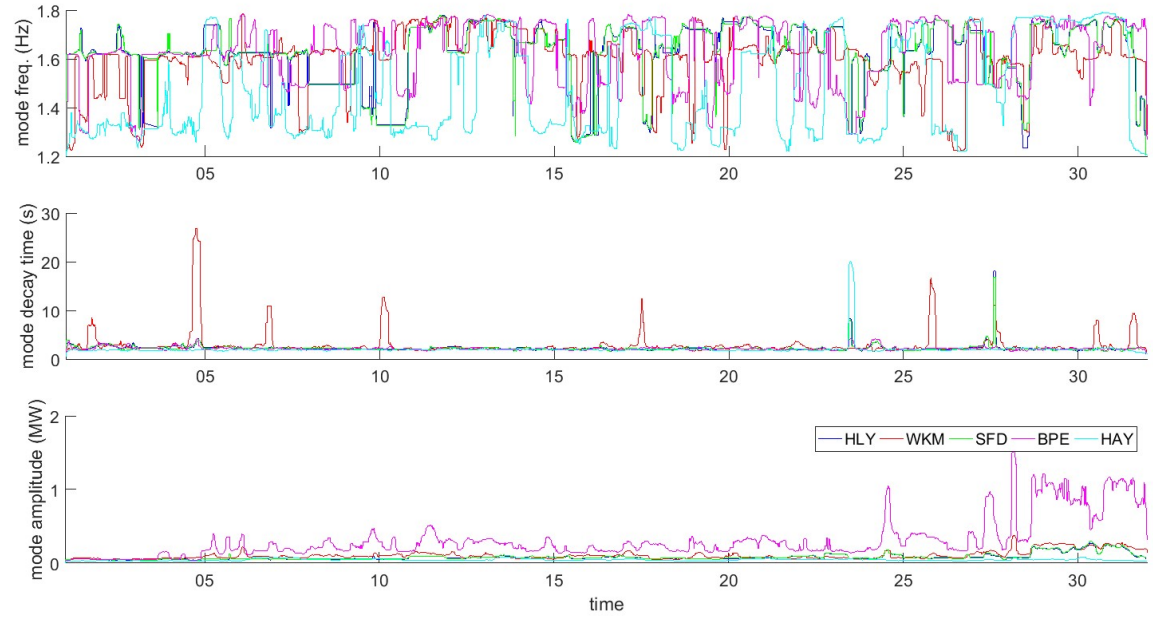


Figure 20: PhasorPoint results for the modeband [1.2, 1.8 Hz] using PMU active power data

Using PMU frequency:

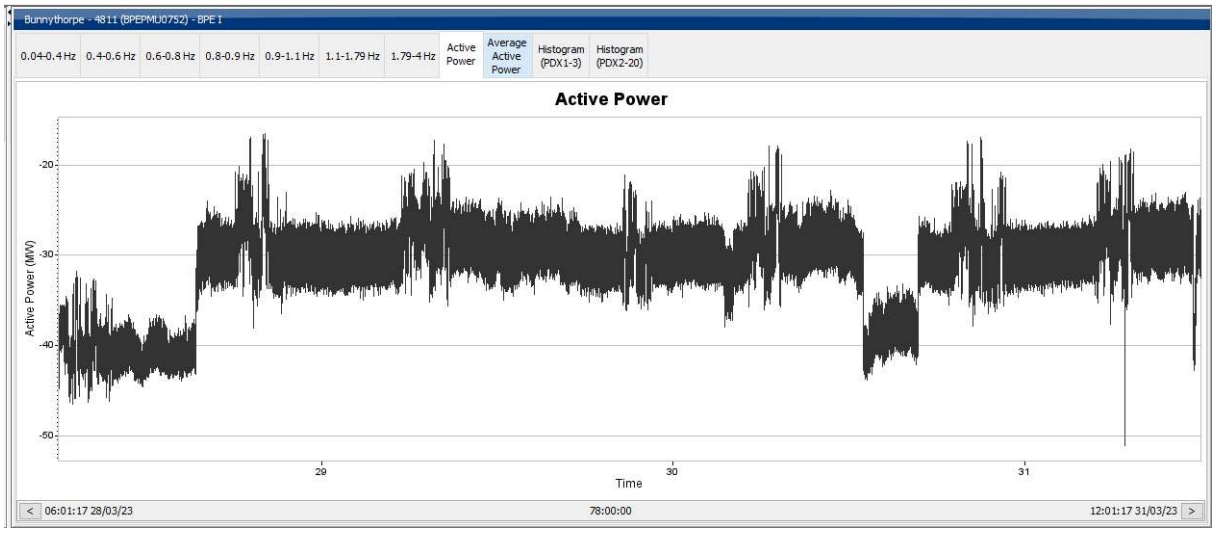
- Modes around ~1.2-1.4 Hz, 1.5 Hz, 1.6, and ~1.8 Hz.
- Maximum decay time ~12 seconds observed at Haywards. Most of the month the decay time is less than 5 seconds for all modes.
- Maximum amplitude ~1.5 mHz observed at Haywards for ~1.8 Hz. Most mode amplitudes observed to be less than 1 mHz throughout the month.

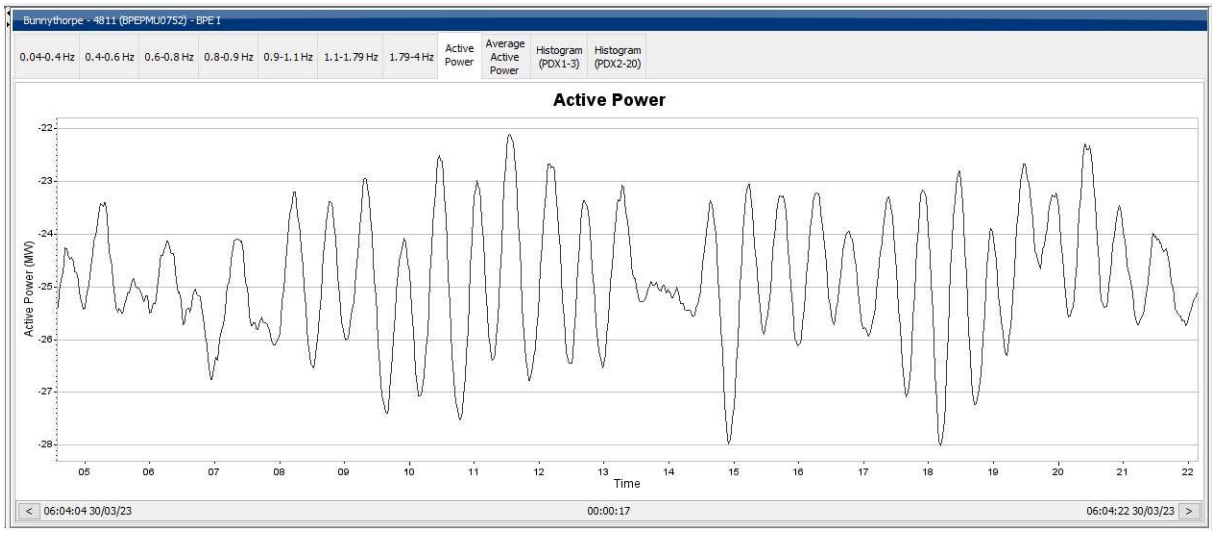
Using active power:

- Most modes appear to be relatively well damped except mode 1.6 Hz where the peak decay time observed ~25 seconds at Whakamaru at certain periods.
- Maximum amplitude ~1.5 MW observed for 1.8 Hz at Bunnythorpe however appeared relatively well damped. Modes at other sites were all low amplitude.

The magnitude of the 1.8 Hz oscillation at Bunnythorpe is evident from the power measurements. The behaviour often has a 'beat' pattern to it and this is not always reported as poorly damped despite being a sustained oscillation.

The behaviour has been observed regularly and has previously been correlated to rapidly fluctuating load being supplied at Tangiwai, which also appears to be the cause here.





3.8 Mode band 6: [1.8 – 2.4 Hz]

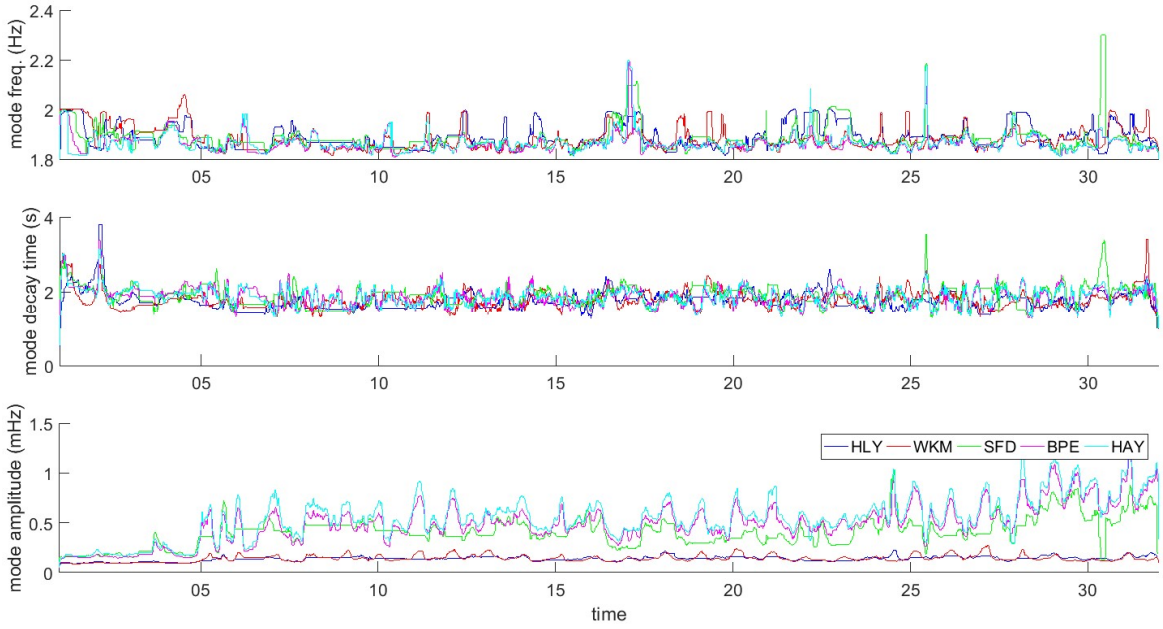


Figure 21: PhasorPoint results for the modeband [1.8, 2.4 Hz] using PMU frequency data

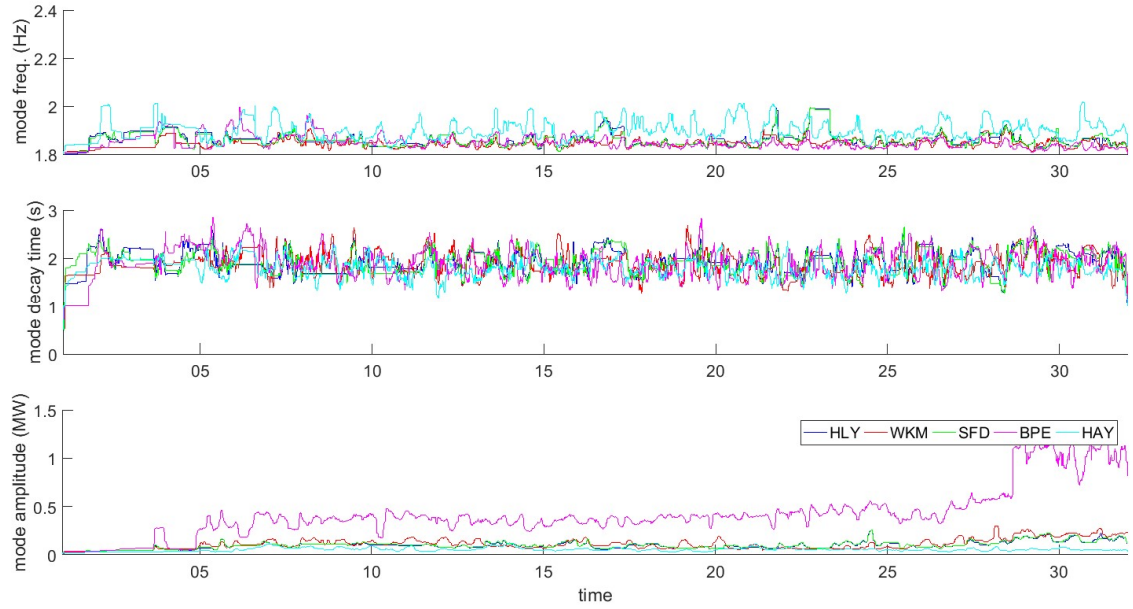


Figure 22: PhasorPoint results for the modeband [1.8, 2.4 Hz] using PMU active power data

Using PMU frequency:

- Modes at ~1.8 Hz, 2 Hz, and 2.2 Hz observed.
- All modes in this band are relatively well-damped and under 4 seconds.

Using active power:

- All modes in this band are relatively well-damped.
- Maximum oscillation amplitude for this mode band ~1 MW particularly visible at Bunnythorpe towards the end of the month. Similar to the mode reported below

1.8 Hz this mode just above 1.8 Hz is the same power oscillation at Bunnythorpe; the software detects the frequency as just above or just below 1.8 Hz at different times.

3.9 Mode band 7: [2.4 – 4 Hz]

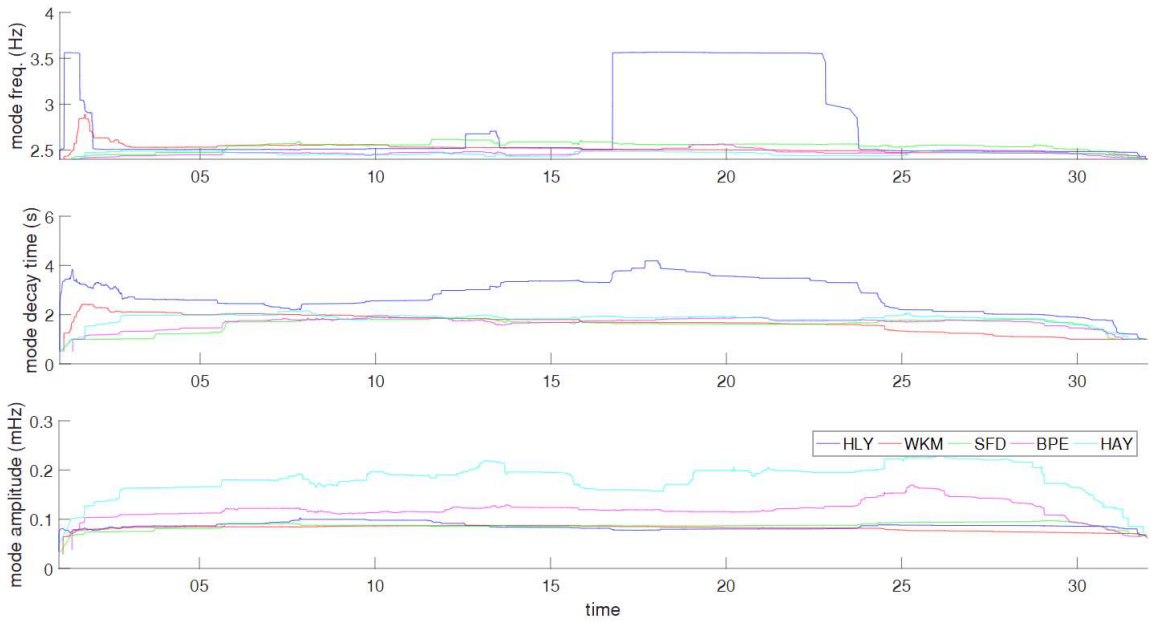


Figure 23: PhasorPoint results for the modeband [2.4, 4 Hz] using PMU frequency data

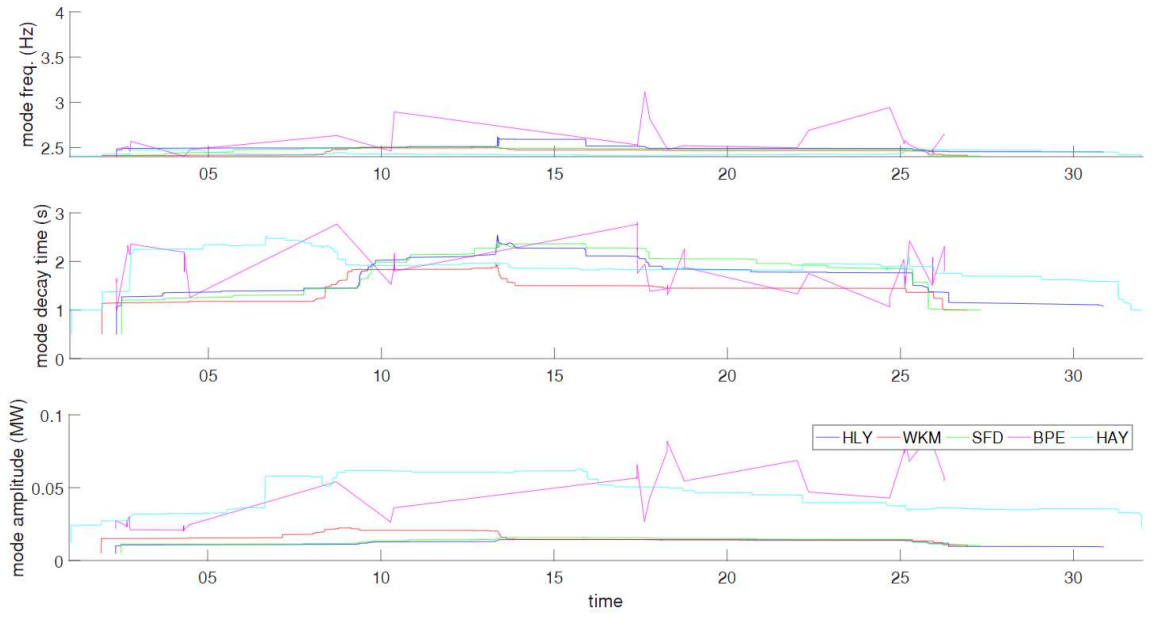


Figure 24: PhasorPoint results for the modeband [2.4, 4 Hz] using PMU active power data

Using PMU frequency:

- Modes observed at 2.4-2.5 Hz and 3.5 Hz.
- All modes in this band are well-damped and low amplitude in the frequency data.

Using active power:

- The 2.5 Hz mode is reported, but at very low amplitude in the power data.