DYNAMIC STABILITY MONTHLY REPORT

NORTH ISLAND – MAY 2023

Transpower New Zealand Limited

May 2023

Keeping the energy flowing

TRANSPOWER

NOTICE

Version	Date	Change
1.0	18/03/2024	Final

	Position	Date
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Reviewed By:	Richard Sherry, Principal Engineer	18/03/2024

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 May 2023. This monthly report presents these findings for May 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 May 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 up to 40s in certain periods Relatively high number of occurrences
0.5 – 0.6 Hz	All-f BPE-p HAY-p	Possibly interarea modes	Decay time up to 15 s for a few periods Relatively low amplitude
1 Hz	All-f Most-p	Inter-area and Inter-station modes	Decay time up to 110 seconds in the power data Relatively low amplitude Relatively high number of occurrences
1.6 Hz	All-f All-p	Inter-station and Local modes	Decay time up to 100 seconds in the power data Relatively low amplitude
1.8 - 1.9 Hz	All-f All-p	Inter-station and Local modes	Relatively high amplitude in the power data Relatively well damped High number of occurrences

2.4-2.5 Hz	Most-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 May 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

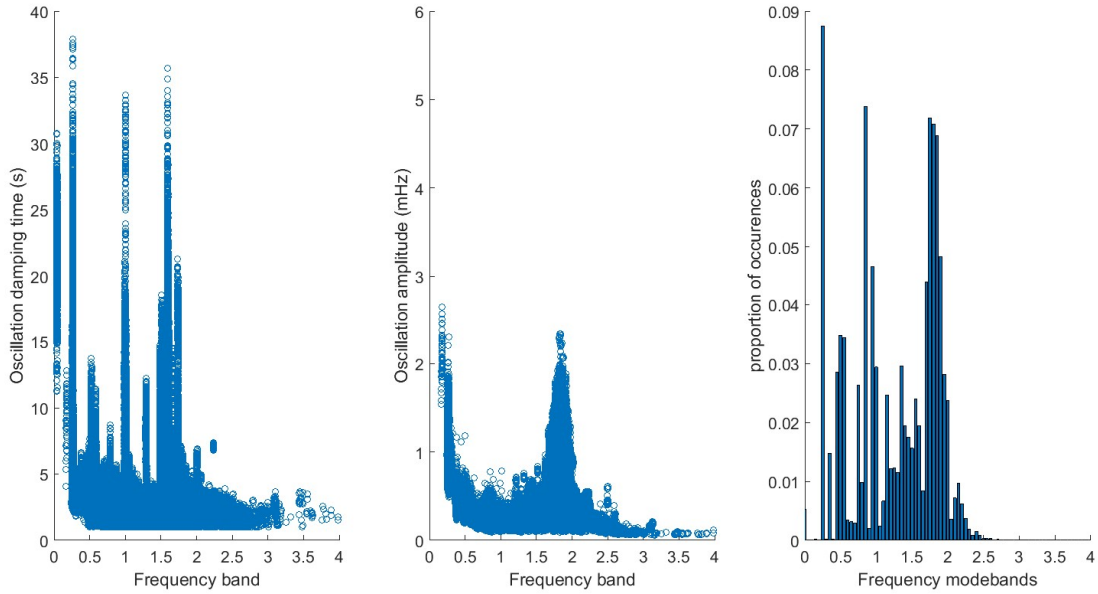


Figure 1: Bunnythorpe mode damping, mode amplitude, and frequency histogram using frequency data

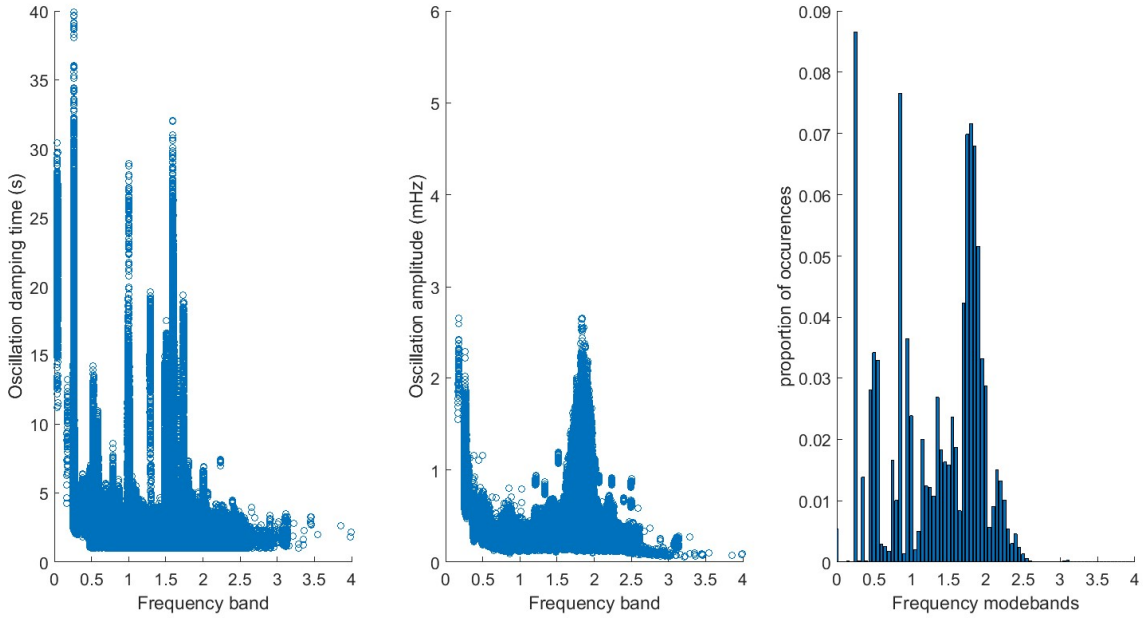


Figure 2: Haywards mode damping, mode amplitude, and frequency histogram using frequency data

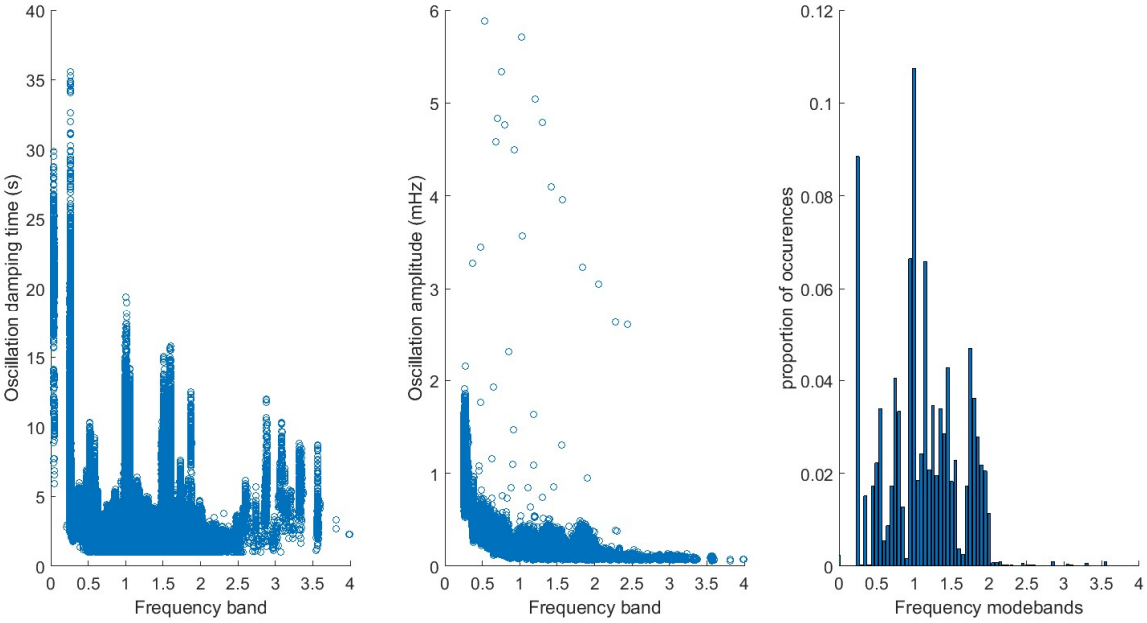


Figure 3: Huntly mode damping, mode amplitude, and frequency histogram using frequency data

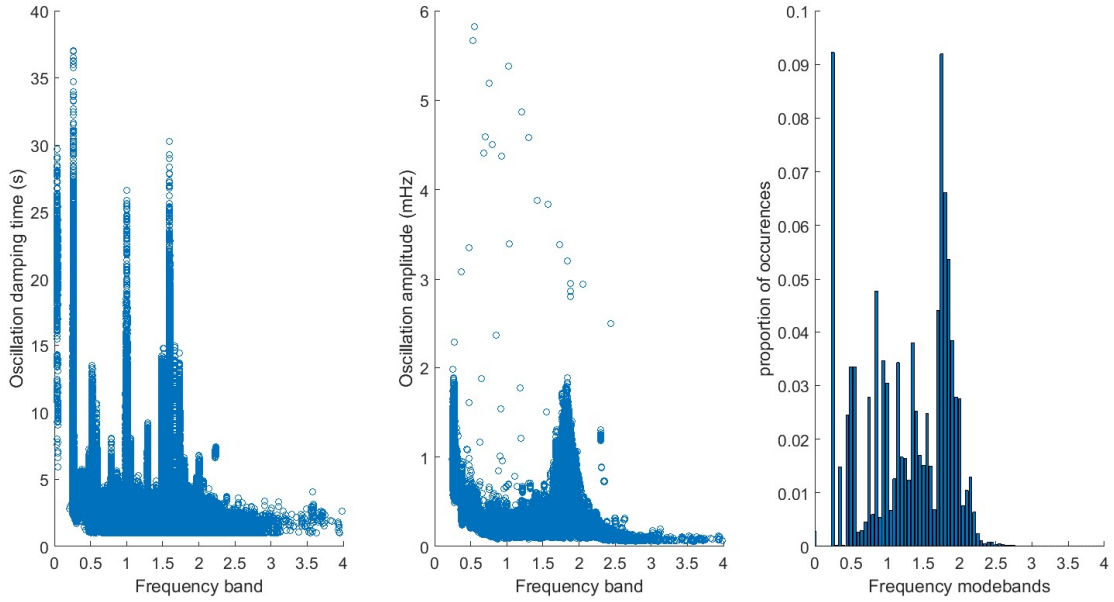


Figure 4: Stratford mode damping, mode amplitude, and frequency histogram using frequency data

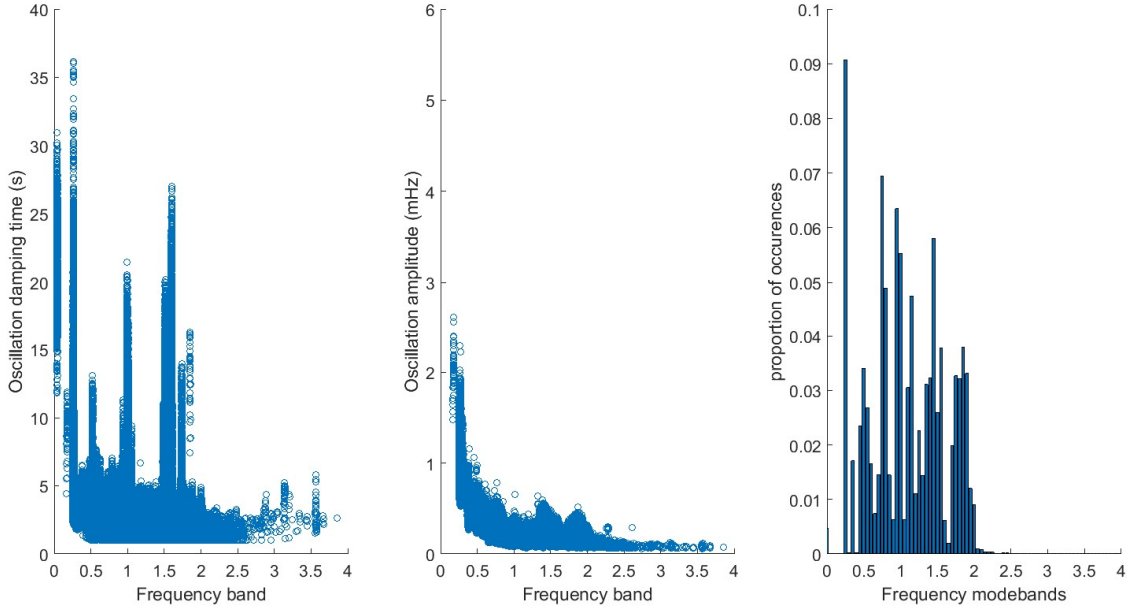


Figure 5: Whakamaru mode damping, mode amplitude, and frequency histogram using frequency data

3.1.2 PMU Active Power Data

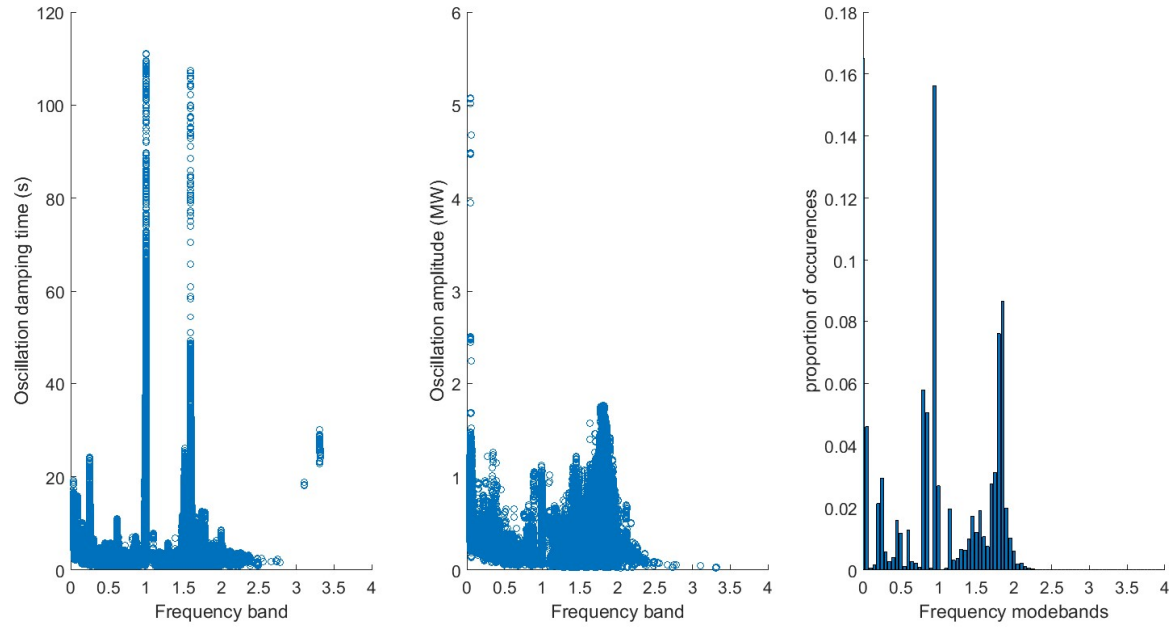


Figure 6: Bunnythorpe mode damping, mode amplitude, and frequency histogram using active power data

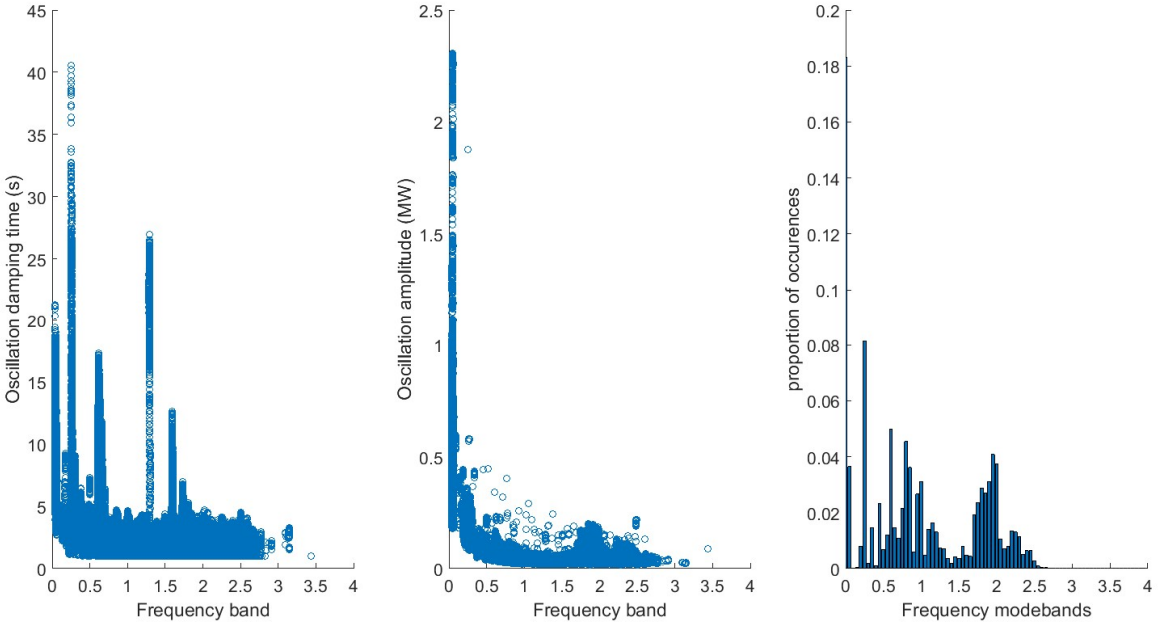


Figure 7: Haywards mode damping, mode amplitude, and frequency histogram using active power data

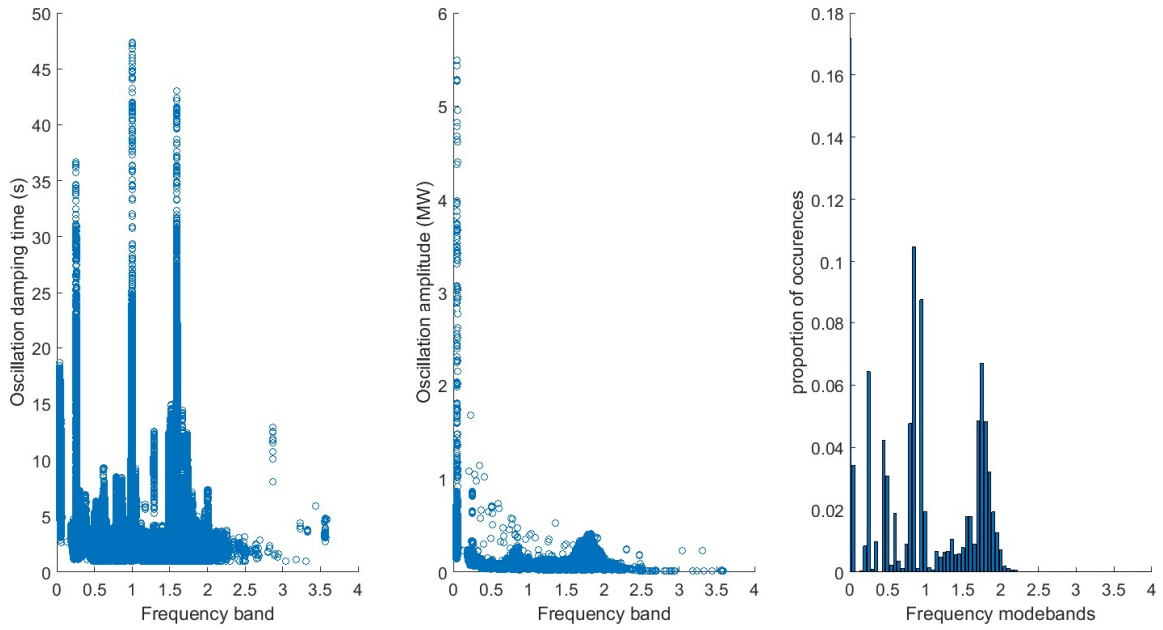


Figure 8: Huntly mode damping, mode amplitude, and frequency histogram using active power data

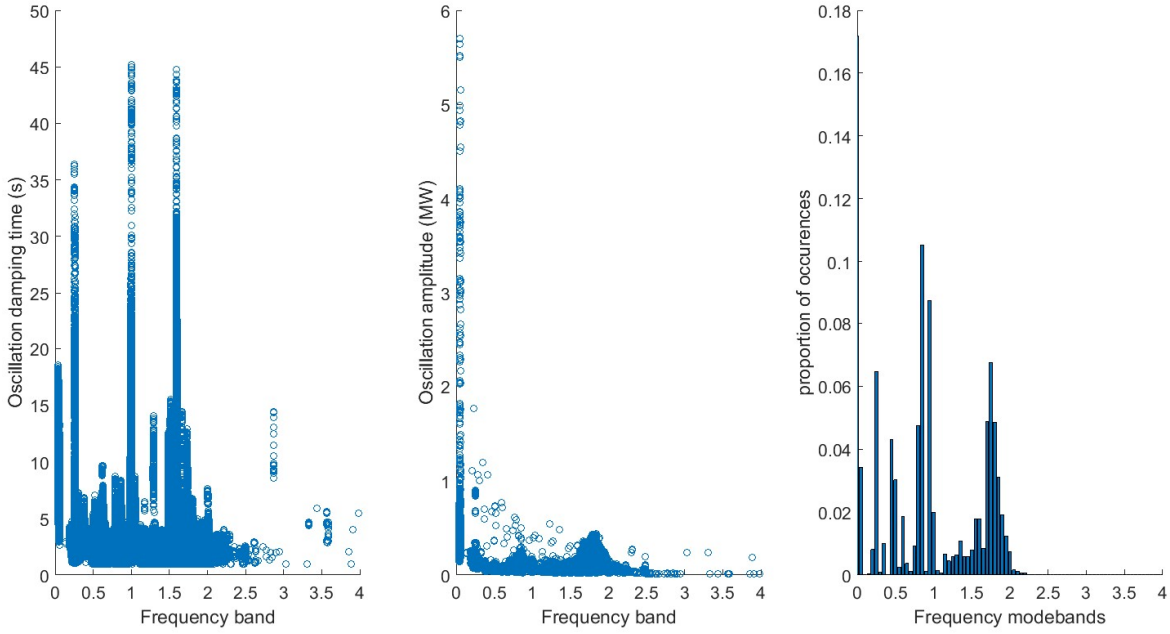


Figure 5: Stratford mode damping, mode amplitude, and frequency histogram using active power data

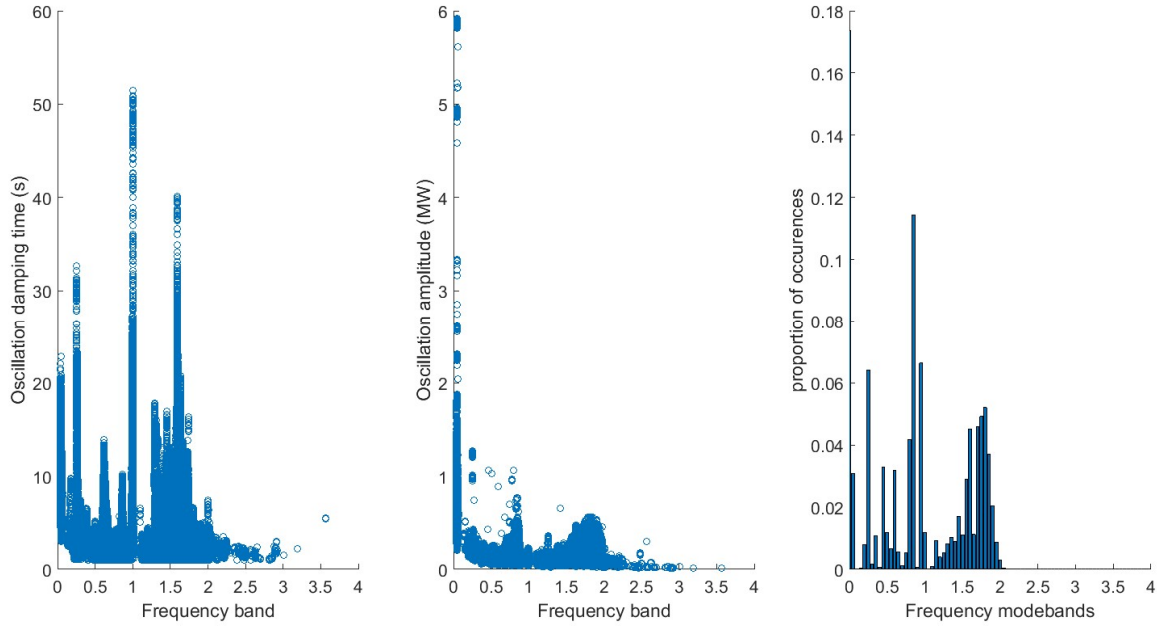


Figure 60: Whakamaru mode damping, mode amplitude, and frequency histogram using active power data

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 poorly damped modes at approximately 1 and 1.6 Hz can be observed in the May data, especially at Bunnythorpe.

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
- 0.5-0.6 Hz
- 1 Hz
- 1.6 Hz
- 1.8-1.9 Hz
- 3-3.5 Hz mostly observed at HLY

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]

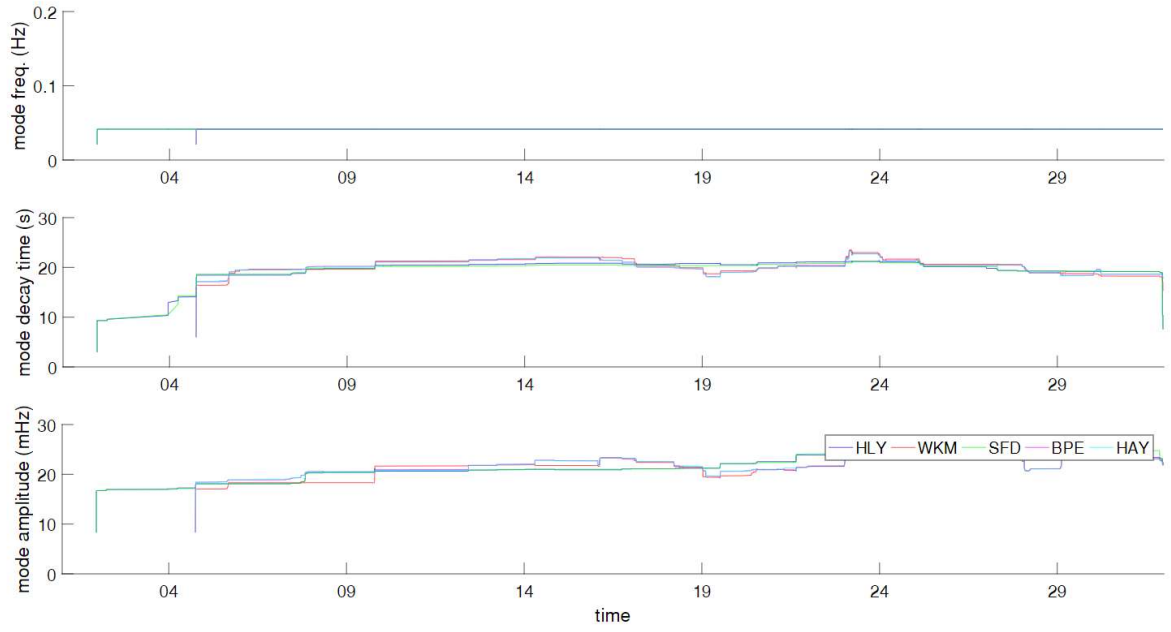


Figure 7: PhasorPoint results for the modeband [0.0 0.2 Hz] using PMU frequency data

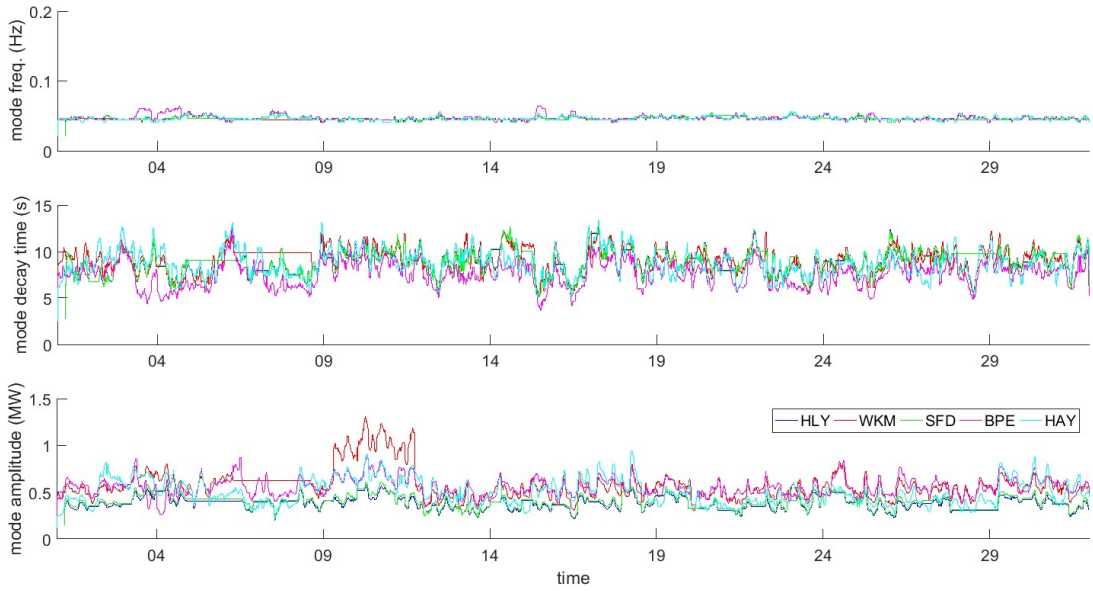


Figure 8: PhasorPoint results for the modeband [0.0, 0.2 Hz] using PMU active power data

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:

- 0.04-0.06 Hz mode observed
- Well damped

3.4 Mode band 2: [0.2 – 0.6 Hz]

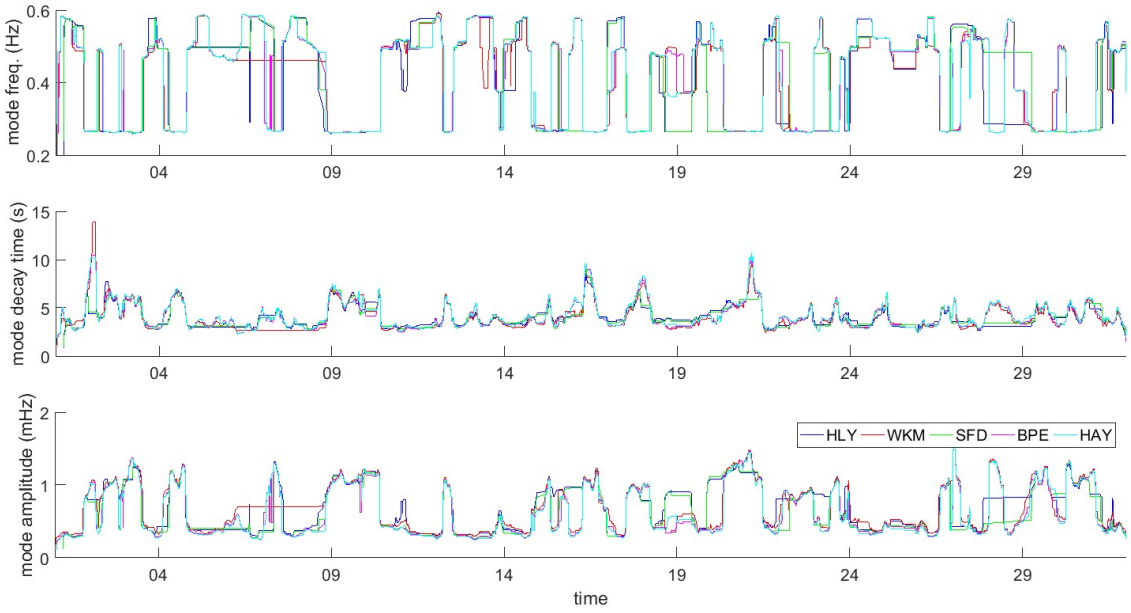


Figure 9: PhasorPoint results for the modeband [0.2, 0.6 Hz] using PMU frequency data

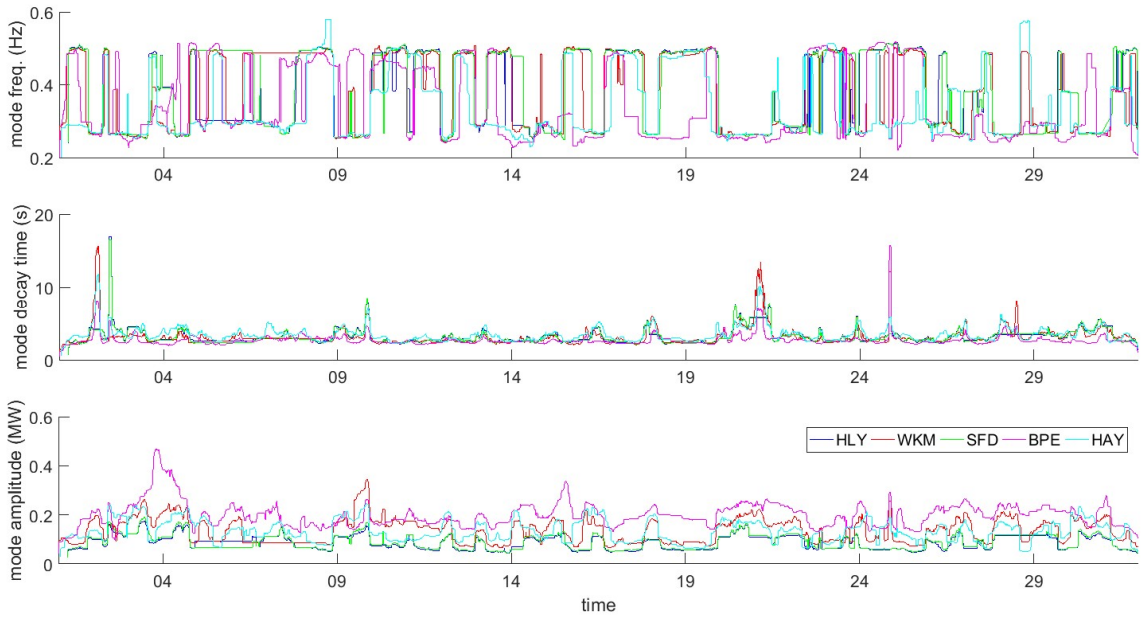


Figure 10: PhasorPoint results for the modeband [0.2, 0.6 Hz] using PMU active power data.

Using PMU frequency

- 0.25 Hz mode. Decay time around 5 seconds, increasing to 5-15 seconds at times throughout the month, amplitude about 1 mHz typically
- 0.5 Hz-0.6 Hz. Decay time around 5-10 seconds throughout the month, low amplitude.

Using active power:

- 0.25 Hz mode at all sites, mode decay time between 3-15 seconds.
- 0.5-0.6 Hz mode decay around 3-5 seconds when dominant.
- Maximum oscillation amplitude ~500kW, typically 200kW.

3.5 Mode band 3: [0.6 – 0.9 Hz]

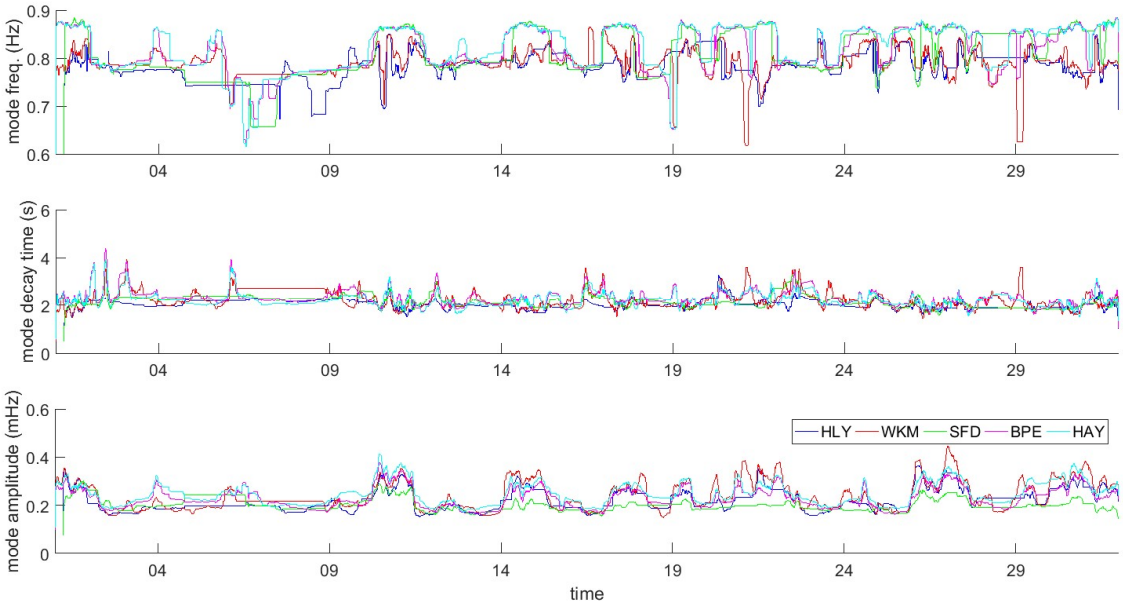


Figure 11: PhasorPoint results for the modeband [0.6, 0.9 Hz] using PMU frequency data

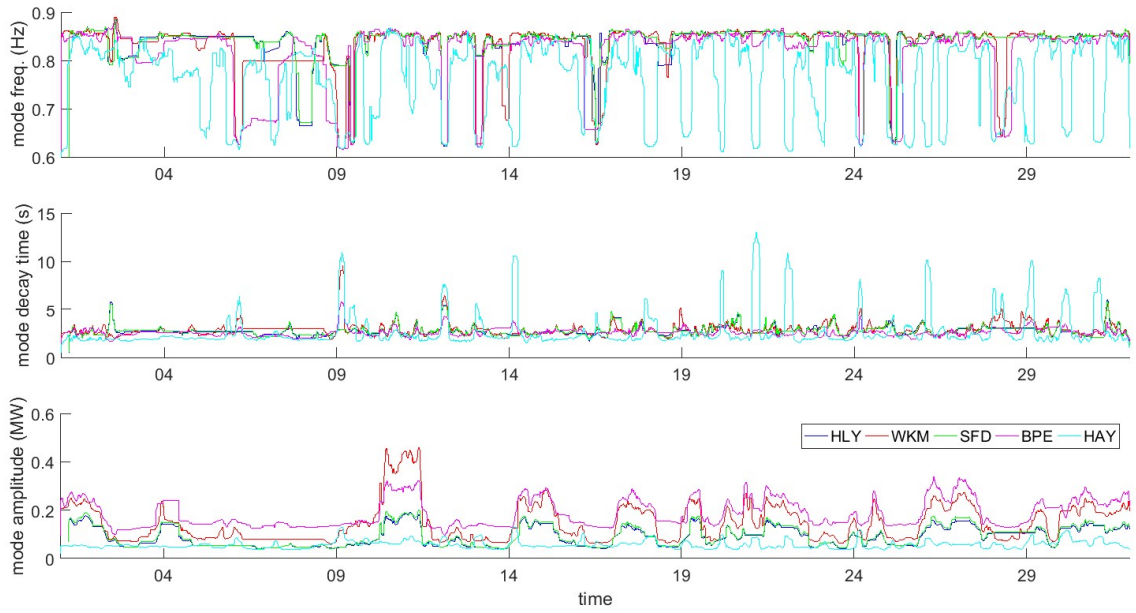


Figure 12: PhasorPoint results for the modeband [0.6, 0.9 Hz] using PMU active power data

Using PMU frequency:

- Mode around 0.7 Hz – 0.9 Hz observed.
- Decay time typically less than 5 seconds at most sites.

- Maximum amplitude ~0.4 mHz.

Using active power:

- Modes around 0.6 Hz (mostly for HAY) and 0.85 Hz (all) reported.
- Decay time less than 10 seconds at most sites except Haywards where decay time ranges from 2-13 seconds throughout the month.
- Maximum amplitude at Whakamaru ~500 kW, typically 200kW.

3.6 Mode band 4: [0.9 – 1.2 Hz]

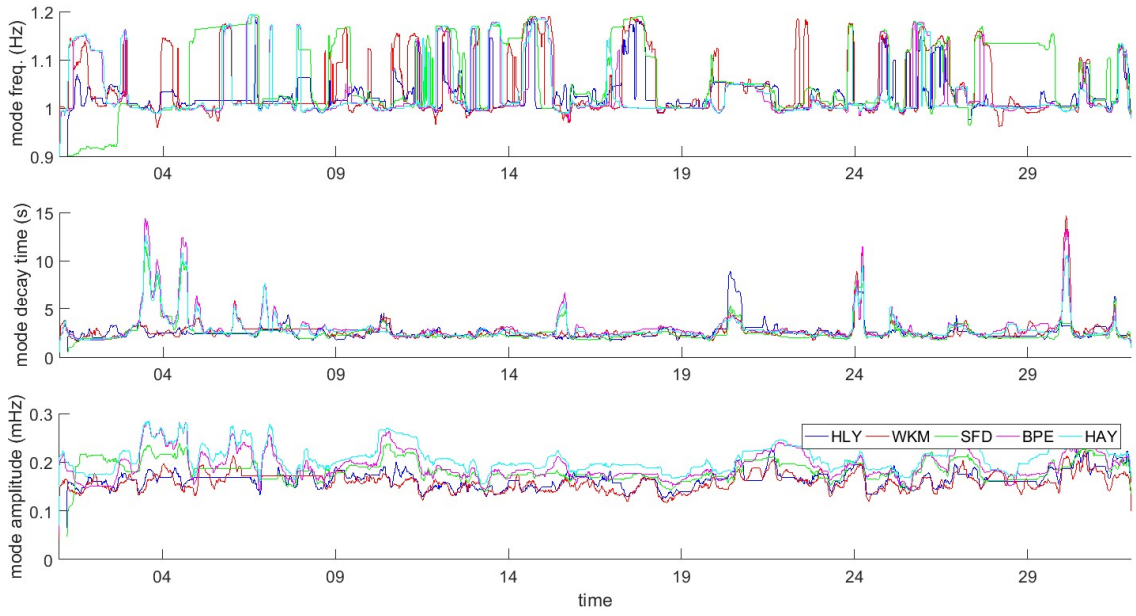


Figure 13: PhasorPoint results for the modeband [0.9, 1.2 Hz] using PMU frequency data

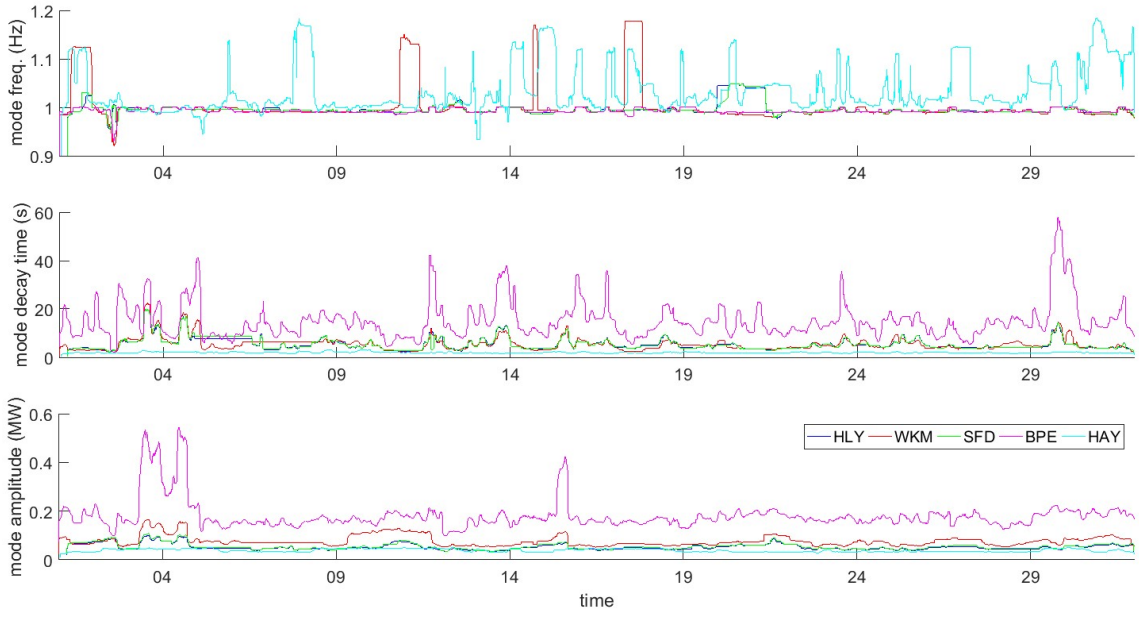


Figure 18: PhasorPoint results for the modeband [0.9, 1.2 Hz] using PMU active power data

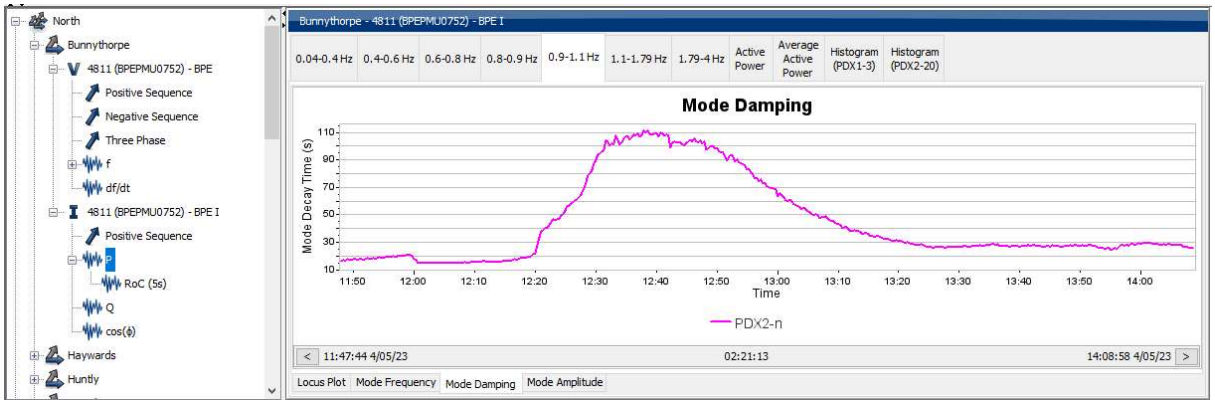
Using PMU frequency:

- Distinct modes at ~0.9 Hz, 1.00 Hz, 1.05 Hz, and 1.18 Hz.
- Highest mode amplitude ~0.3 mHz occurring for various frequencies. Most decay times are under 10 seconds.
- Mode 1 Hz peaks around 15 seconds observed from Bunnythorpe, Huntly and Whakamaru at certain periods.

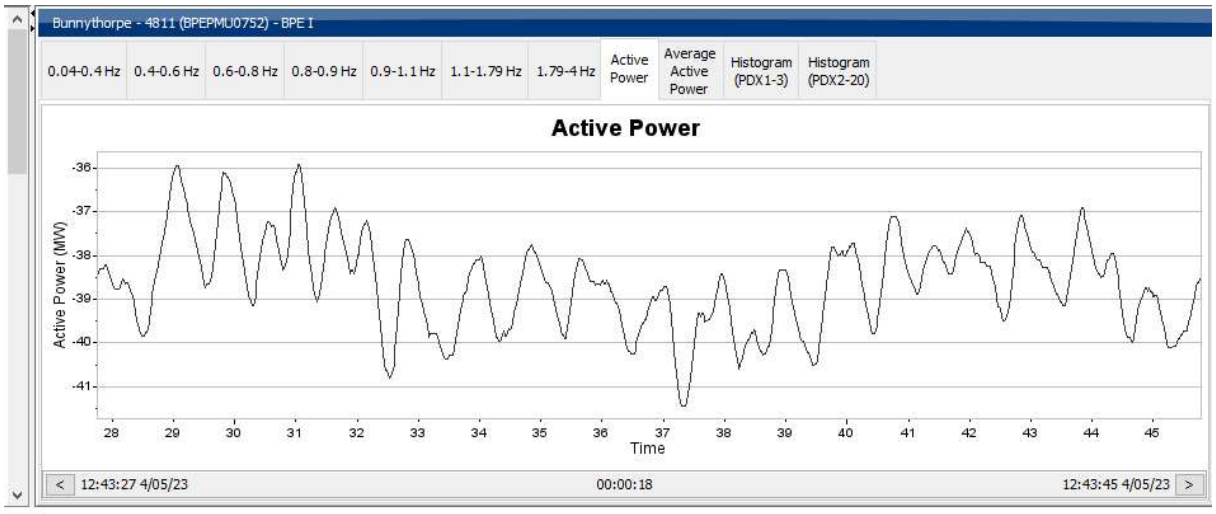
Using active power:

- Most modes are typically well damped. Modes at Bunnythorpe have a high damping time, peaking at ~60 seconds for the 1 Hz mode later in the month.
- All modes in this band have low oscillation amplitudes reported in the trends. Maximum amplitude is ~500 kW observed at Bunnythorpe earlier in the month.

The periods of very low damping identified in the histograms at 1 Hz are not obvious in the trends due to the sampling technique used tending to remove short duration phenomena. For example, on the 4th May 12:30 pm there was 0.9MW magnitude, 1 Hz mode observed at BPE with a very long decay period for about 30 minutes



The presence of a 1 Hz component is clear in the real time MW traces



As this particular frequency is close to a local mode for most generators it is unsurprising to find it persisting for 30 minutes at a more significant amplitude.

However, for other frequencies this could be much more significant in terms of requiring some investigation, and we are looking at ways to refine the trending algorithm to at least ensure the trend does display the outliers identified in the histograms.

3.7 Mode band 5: [1.2 - 1.8 Hz]

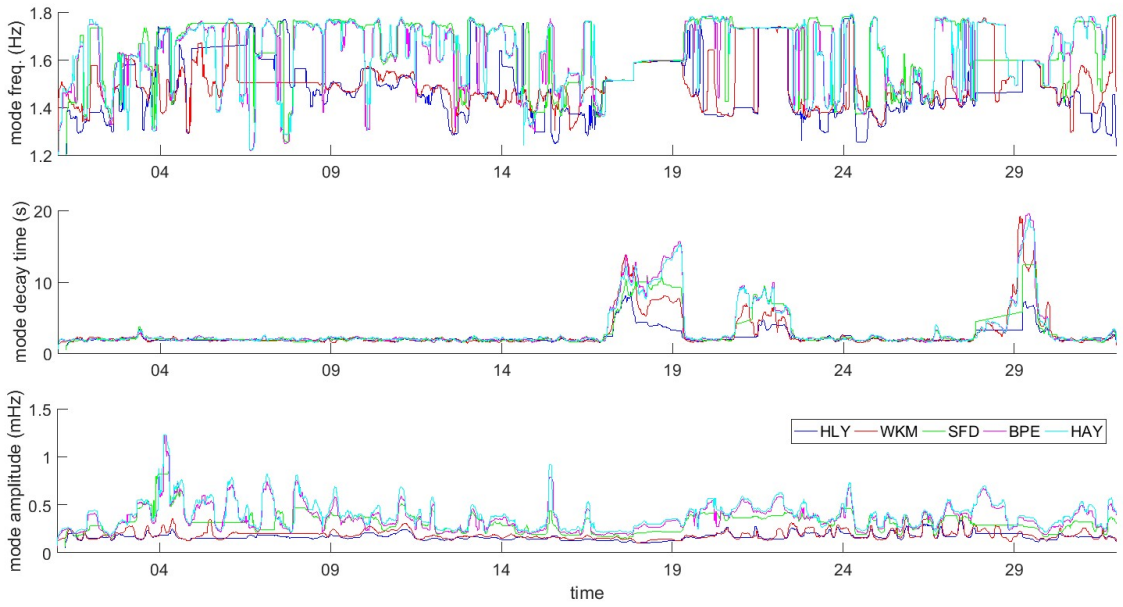


Figure 19: PhasorPoint results for the modeband [1.2, 1.8 Hz] using PMU frequency data

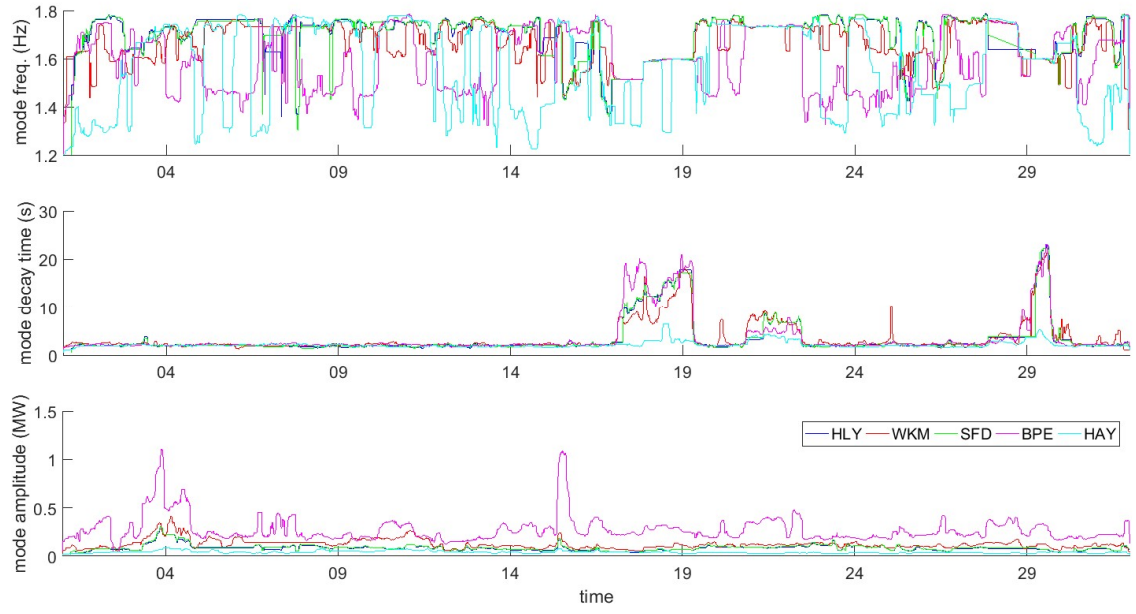


Figure 140: PhasorPoint results for the modeband [1.2, 1.8 Hz] using PMU active power data

Using PMU frequency:

- Distinct modes around ~1.3 Hz, 1.5 Hz, 1.6, and ~1.75 Hz.

- Maximum decay time ~20 seconds for the 1.6 Hz mode. Most of the month the decay time is less than 5 seconds for all modes.
- Maximum amplitude ~1.25 mHz observed at Huntly, Bunnythorpe and Haywards. Most mode amplitudes were observed to be less than 0.75 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 ~20 seconds for most stations at certain periods.
- Maximum amplitude ~1 MW observed for 1.6 Hz at Bunnythorpe however appeared relatively well damped when the magnitude was significant. Periods of very low damping reported in the histograms were associated with very low magnitudes and not of any concern.

3.8 Mode band 6: [1.8 – 2.4 Hz]

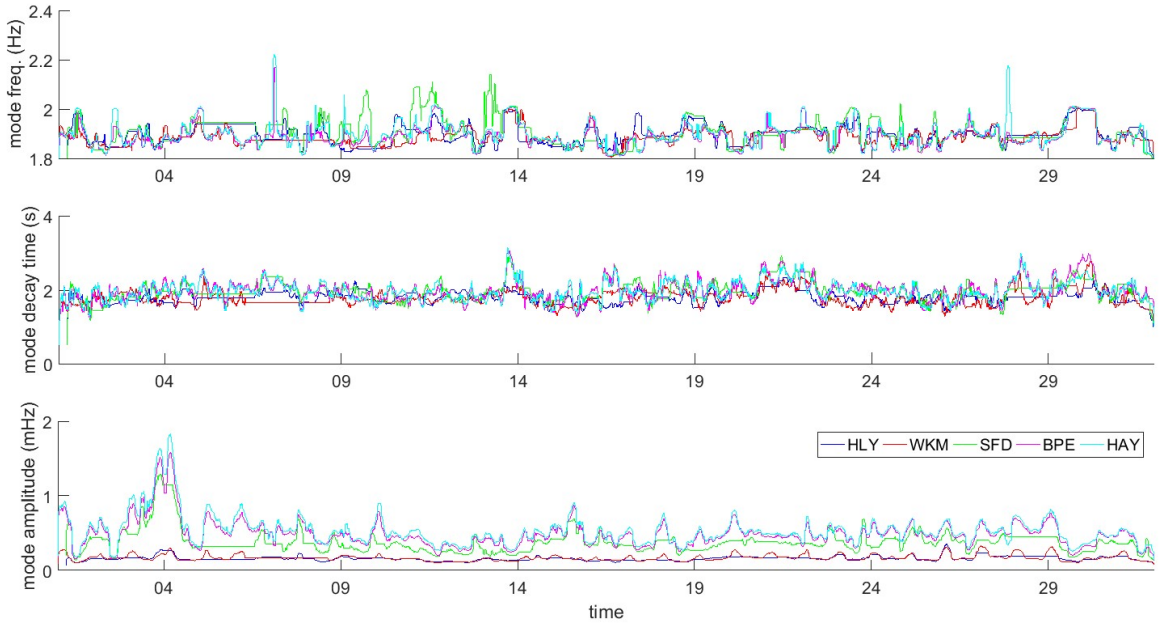


Figure 151: PhasorPoint results for the modeband [1.8, 2.4 Hz] using PMU frequency data

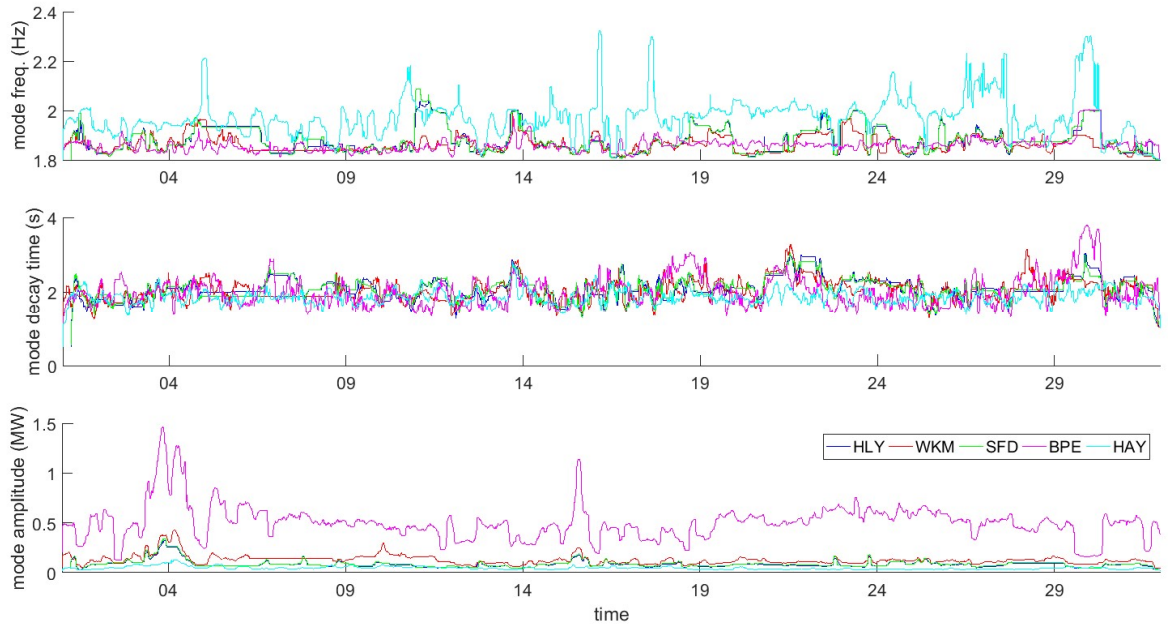


Figure 162: PhasorPoint results for the modeband [1.8, 2.4 Hz] using PMU active power data

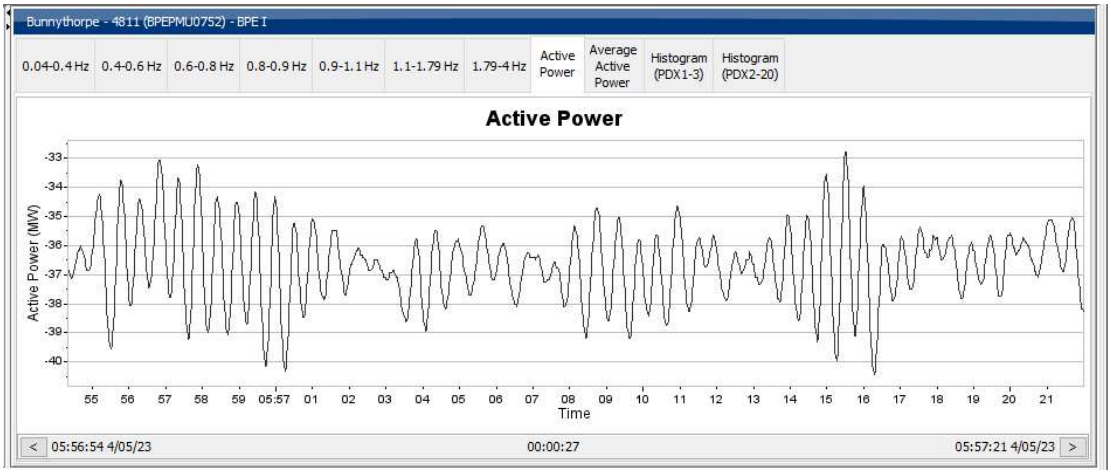
Using PMU frequency:

- All modes in this band are relatively well-damped.
- The maximum mode amplitude was just under 2 mHz for the 1.8 Hz mode observed at Bunnythorpe and Haywards on the 4th May.

Using active power:

- All modes in this band are relatively well-damped.
- Maximum oscillation amplitude for this mode band ~1.5 MW particularly visible at Bunnythorpe on the 4th May.

The 1.8 Hz behaviour is known to be due to a disturbing load at Tangiwai, the oscillatory component is persistent but manifests as a 'beat' pattern on the time domain traces as the oscillation interacts with other oscillatory modes at Bunnythorpe.



3.9 Mode band 7: [2.4 – 4 Hz]

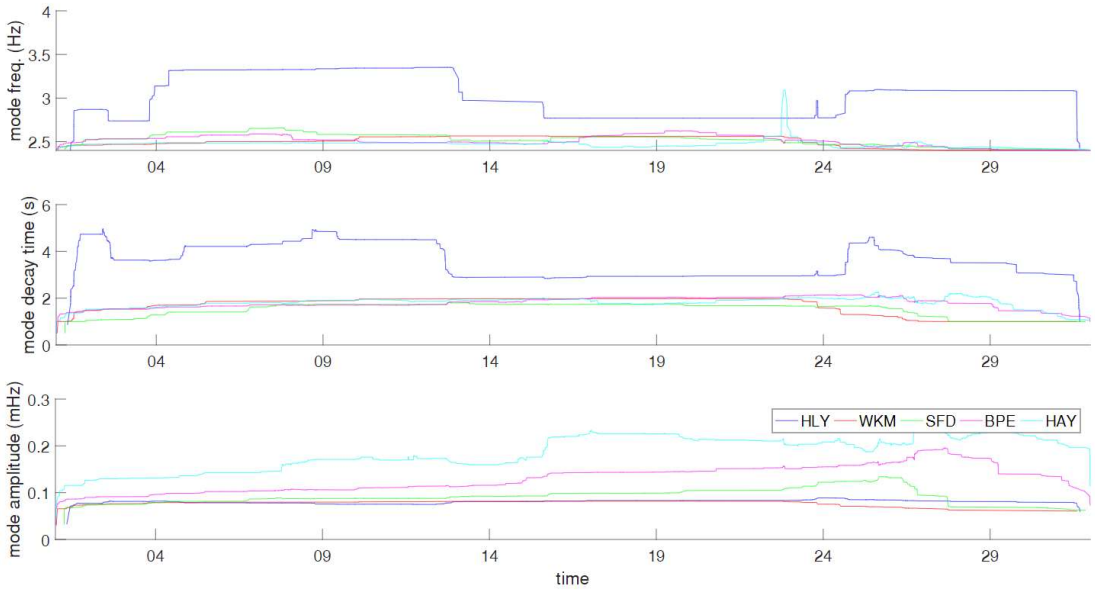


Figure 23: PhasorPoint results for the modeband [2.4, 4 Hz] using PMU frequency data

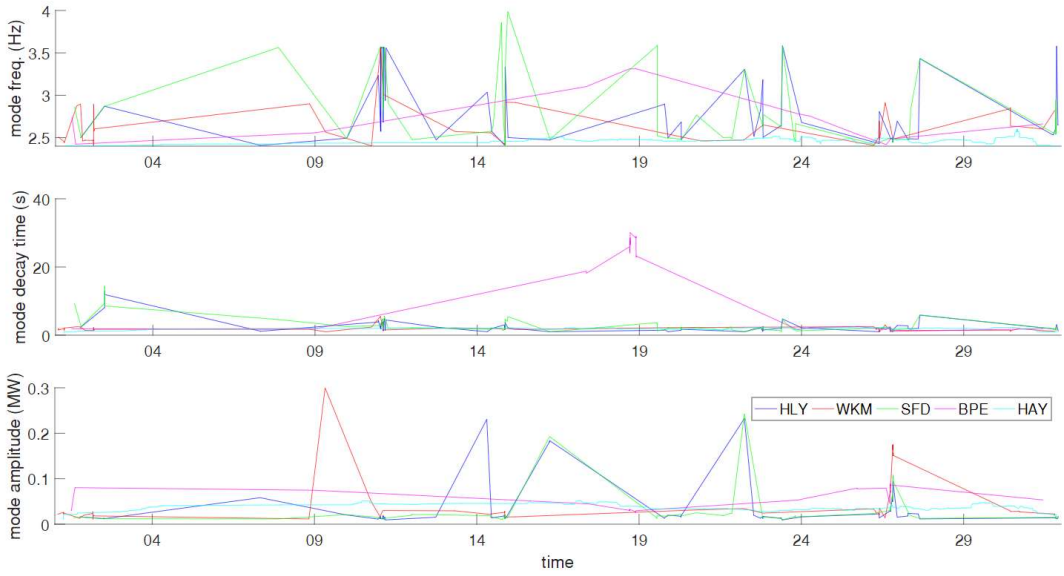


Figure 24: PhasorPoint results for the modeband [2.4, 4 Hz] using PMU active power data

Using PMU frequency:

- Modes observed at 2.4-2.5 Hz at most sites, and ~2.8 Hz and 3.4 Hz at Huntly.
- All modes in this band are well-damped in the frequency data.

Using active power:

- Few data points are recorded for this mode band.
- All modes in this band are low amplitude in the power data.