# DYNAMIC STABILITY MONTHLY REPORT

NORTH ISLAND – FEBRUARY 2023

**Transpower New Zealand Limited**

February 2023

*Keeping the energy flowing*

TRANSPOWER

Transpower New Zealand Limited The National Grid

## NOTICE



| Version | Date | Change |
|---|---|---|
| 1.0 | 19/12/2023 | Final |

| | Position | Date |
|---|---|---|
| Prepared By: | Jessie Fahey, Power Systems Engineer | 19/12/2023 |
| Reviewed By: | Richard Sherry, Principal Engineer | 11/3/2024 |

# 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 February 2023. This monthly report presents these findings for February 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 February 2023 |
|---|---|---|---|
| 0.04 Hz | All-f<br>All-p | Governor modes | No significant change over the month<br>Well-damped |
| 0.25 Hz | All-f<br>Most-p | Likely control modes, and non-electromechanical | Relatively high number of occurrences<br>High decay time up to 70 seconds |
| 0.5 – 0.6 Hz | All-f<br>Most-p | Possibly interarea modes | Decay time up to 15 seconds.<br>Low amplitude. |
| 0.9-1 Hz | All-f<br>Most-p | Inter-area and Inter-station modes | Damping time up to 90 seconds.<br>Relatively low amplitude.<br>High number of occurrences. |
| 1.5-1.6 Hz | All-f<br>All-p | Inter-station and Local modes | Damping time up to 30 seconds<br>High amplitudes on some occasions (e.g 14th Feb) |
| 2-2.25 Hz | HAY-f<br>SFD-f<br>WKM-f<br>HAY-p | Possibly Intra-Plant modes | Decay time up to 35 seconds.<br>Relatively low amplitude.<br>Low number of occurrences. |

| | | | |
|---|---|---|---|
| 2.4-2.7 Hz | All-f<br>All-p | Not yet identified | Low number of occurrences<br>Well damped |
| 3, 3.5 Hz | Most-p,<br>HLY-f | Not yet identified | Low number of occurrences<br>Occasionally poorly damped<br>Low amplitude |

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

# 3 Detailed plots for February 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

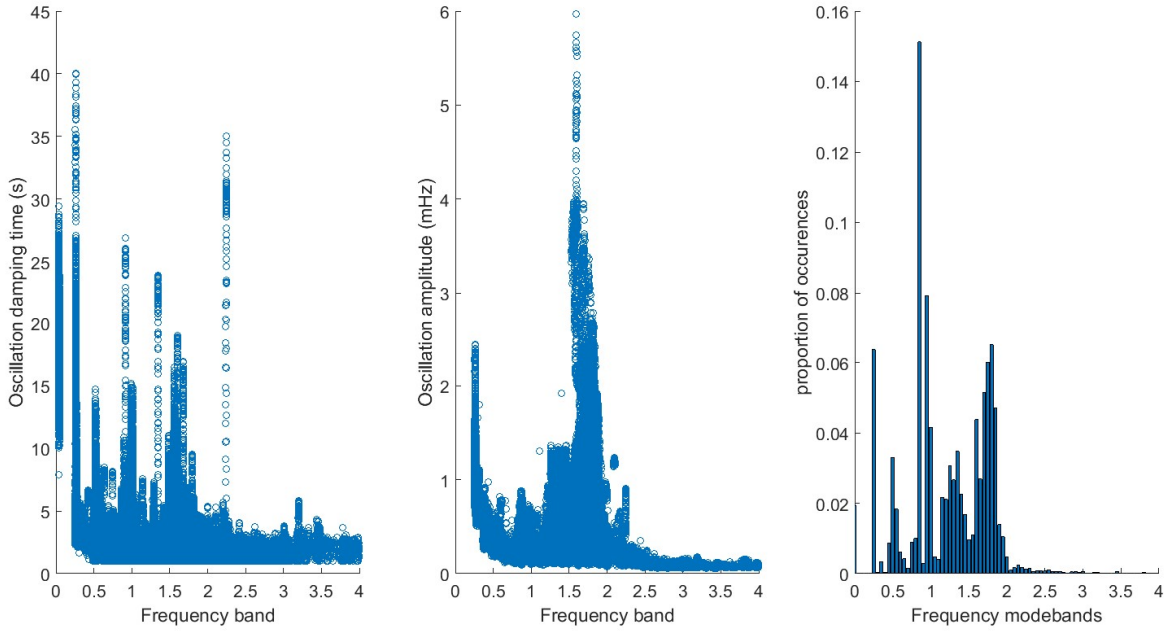



**Figure 1: Bunnythorpe mode damping, mode amplitude, and frequency histogram using frequency data**

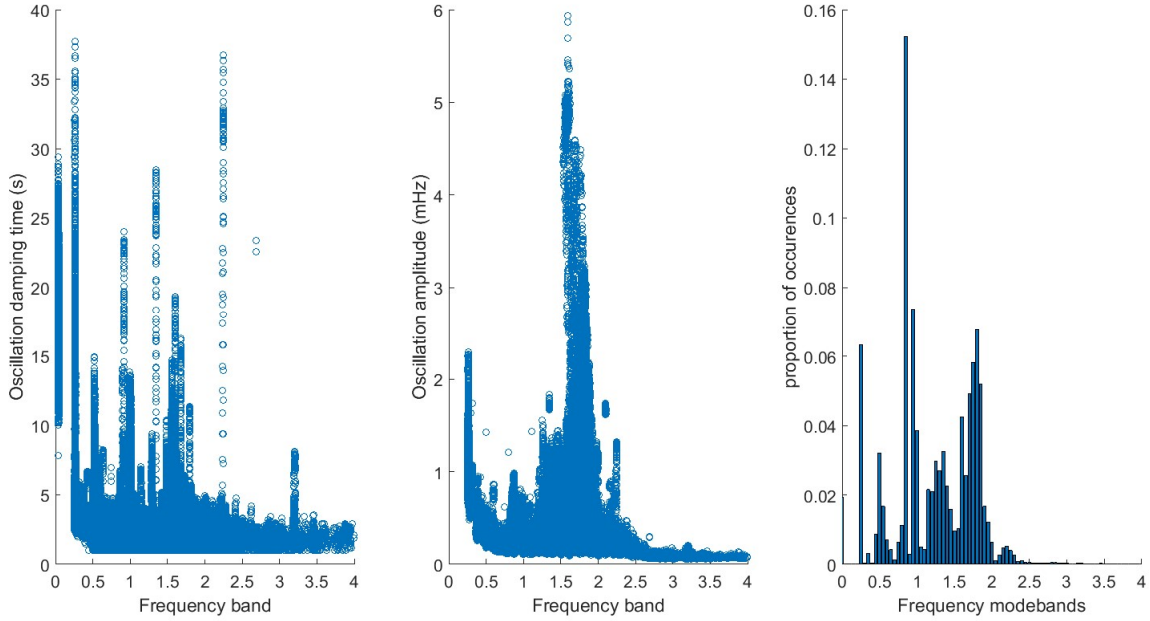



**Figure 2: Haywards mode damping, mode amplitude, and frequency histogram using frequency data**

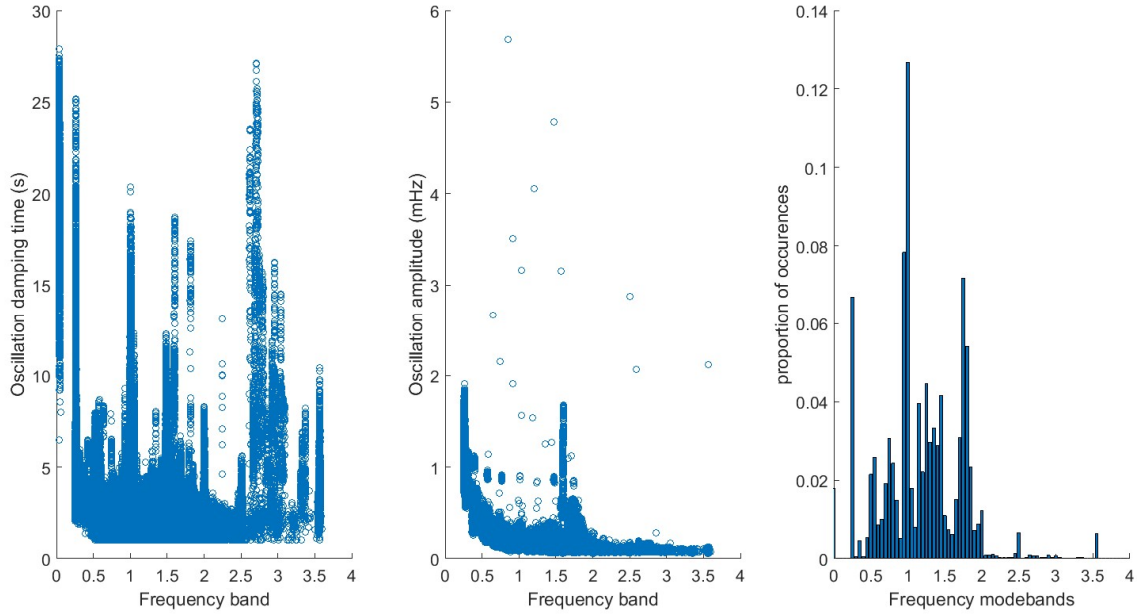



**Figure 3: Huntly mode damping, mode amplitude, and frequency histogram using frequency data**

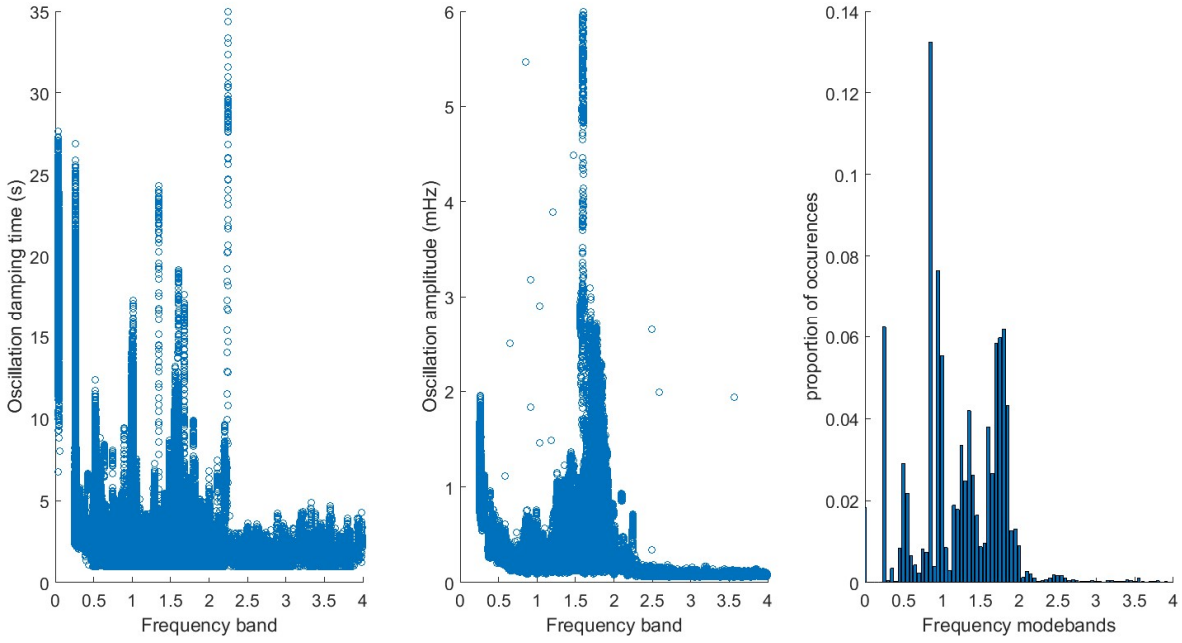



**Figure 4: Stratford mode damping, mode amplitude, and frequency histogram using frequency data**

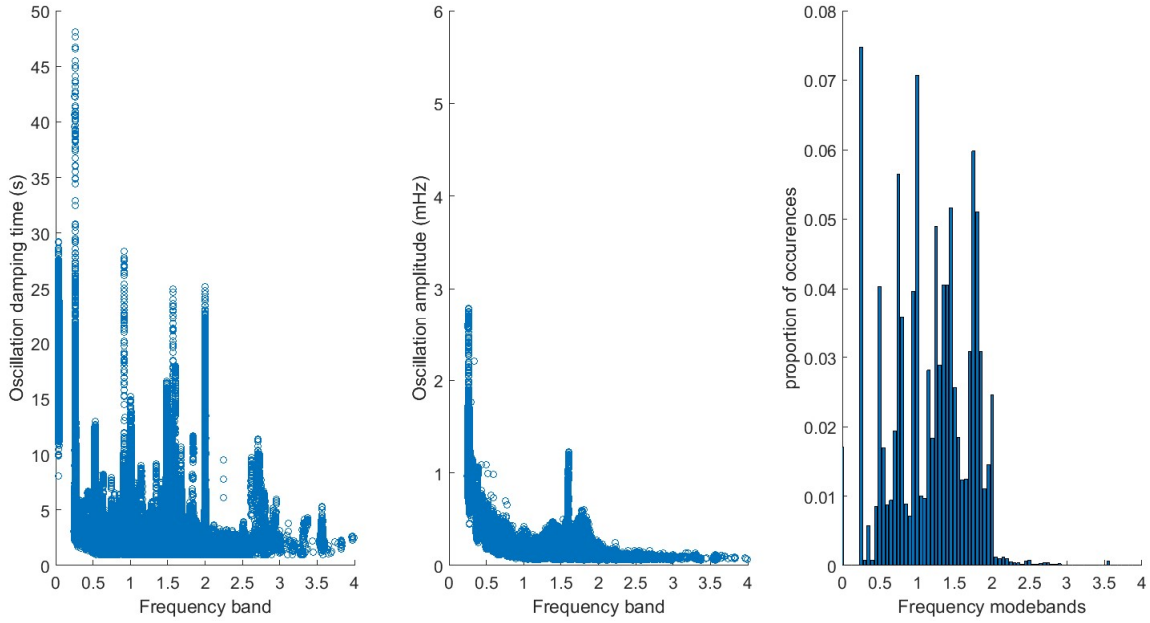



**Figure 5: Whakamaru mode damping, mode amplitude, and frequency histogram using frequency data**

### 3.1.2 PMU Active Power Data

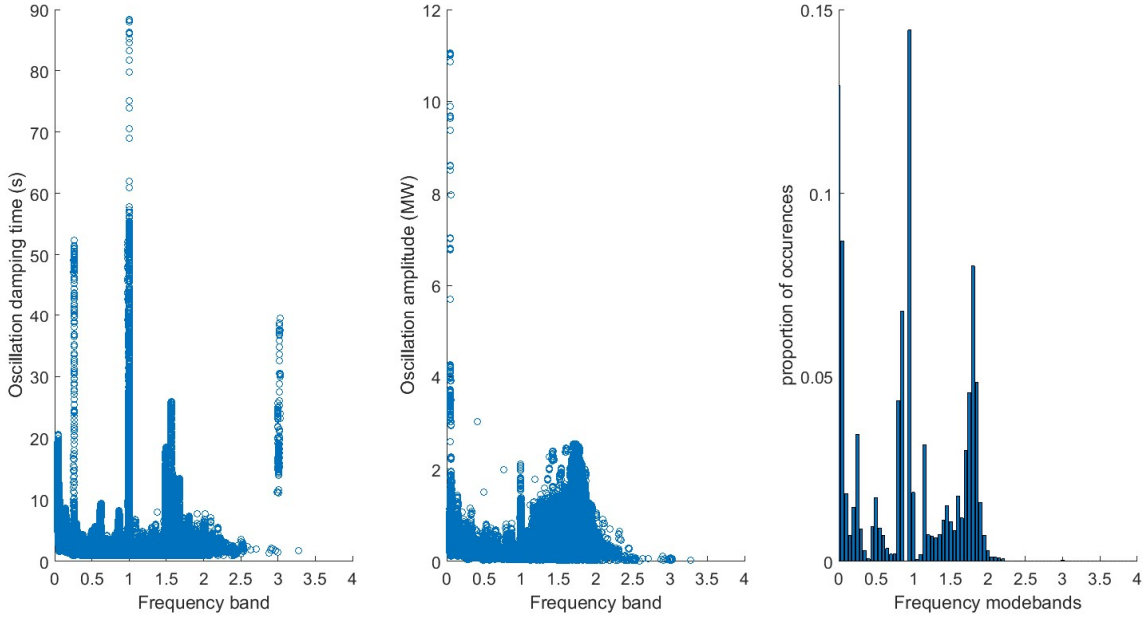



**Figure 6: Bunnythorpe mode damping, mode amplitude, and frequency histogram using active power data**

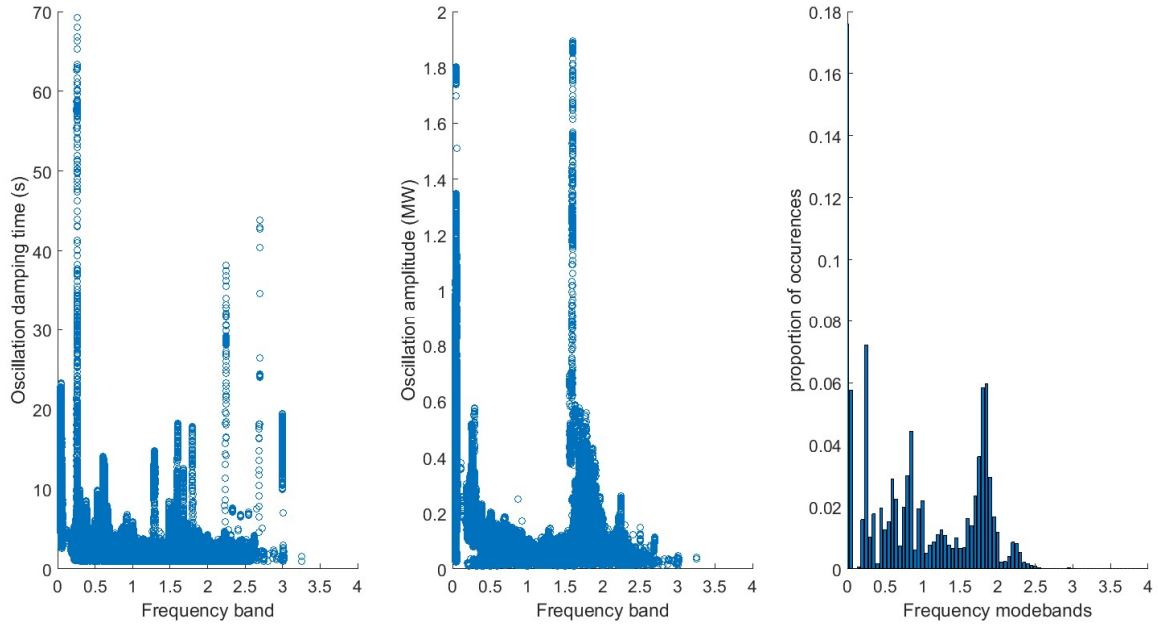



**Figure 7: Haywards mode damping, mode amplitude, and frequency histogram using active power data**

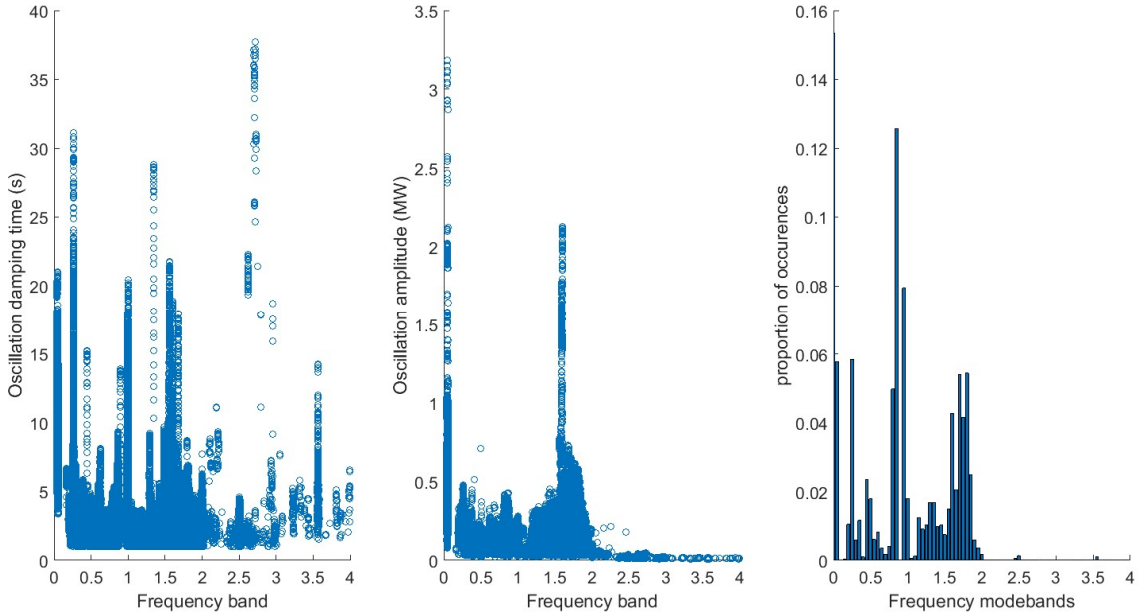



**Figure 8: Huntly mode damping, mode amplitude, and frequency histogram using active power data**

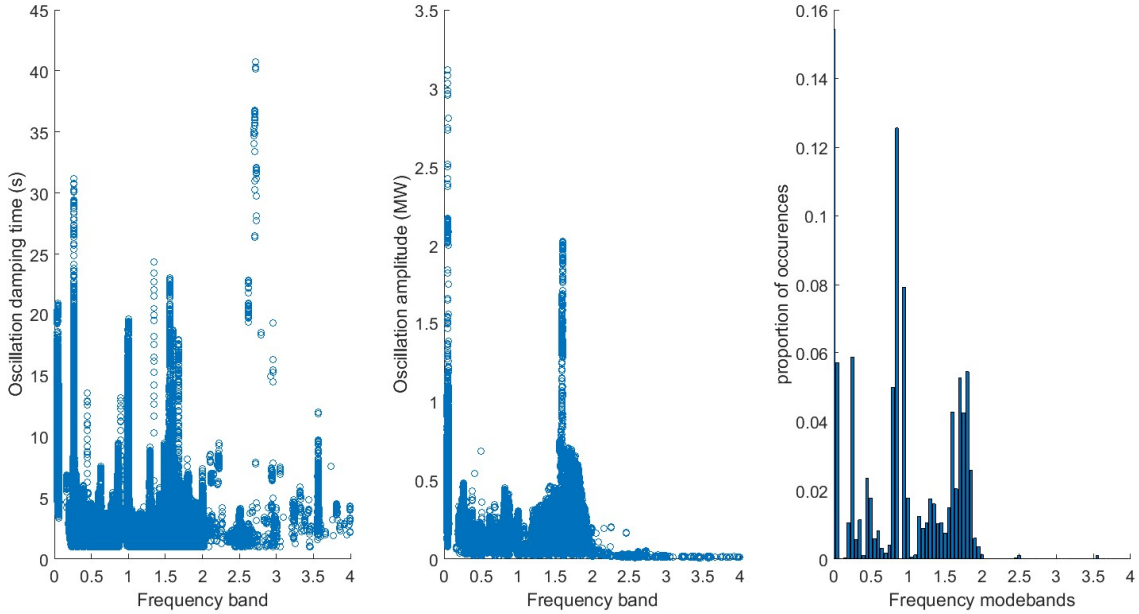



**Figure 9: Stratford mode damping, mode amplitude, and frequency histogram using active power data**

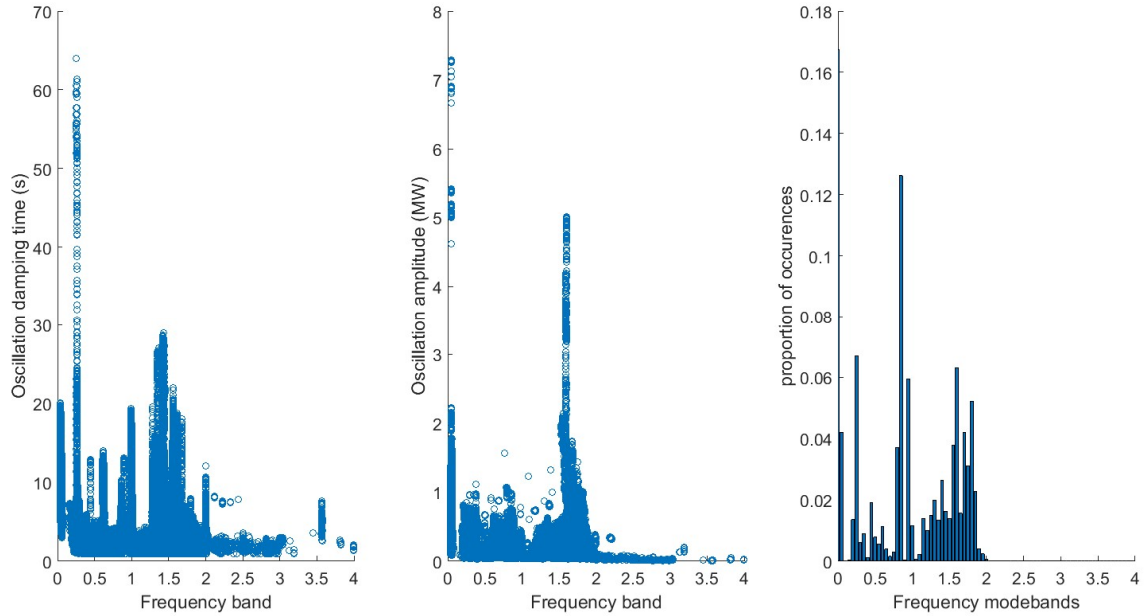



**Figure 5: Whakamaru mode damping, mode amplitude, and frequency histogram using active power data**

### 3.1.3 Observations using the frequency histograms

From the histograms, it can be observed that some modes have a large percentage of occurrences. One distinct mode at approximately 1.5-1.6 Hz can be observed in the February 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
- 1.5-1.6 Hz
- 2-2.25 Hz
- 2.7 Hz
- 3 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]

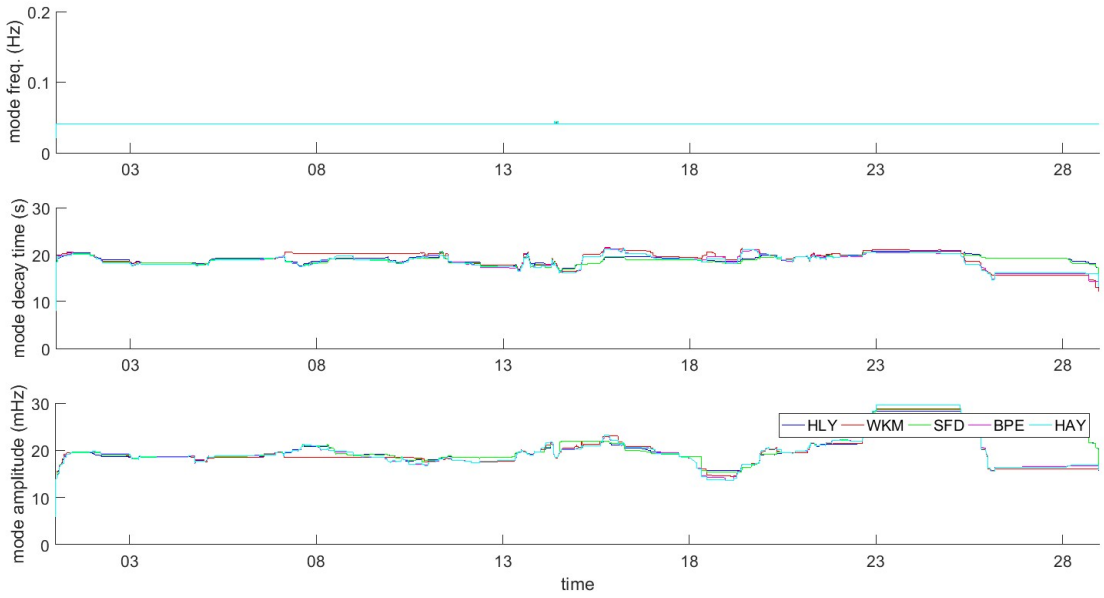



**Figure 6: PhasorPoint results for the modeband [0.0 0.2 Hz] using PMU frequency data**

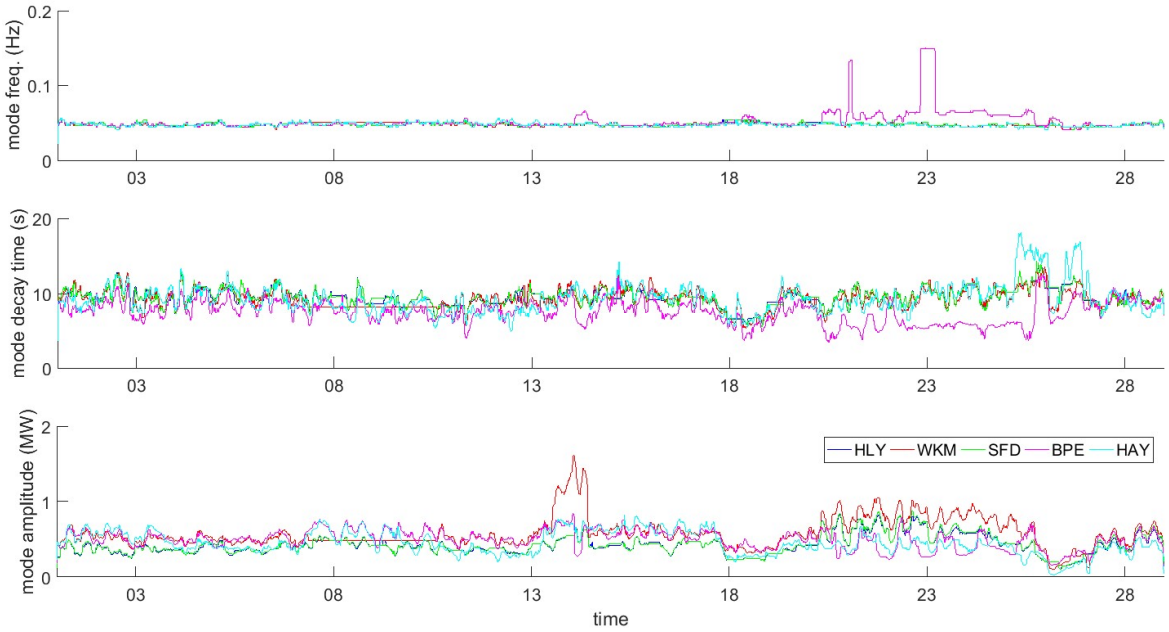



**Figure 7: PhasorPoint results for the modeband [0.0, 0.2 Hz] using PMU active power data**

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 Hz mode observed.
- 0.15 Hz also observed briefly at Bunnythorpe. This was well damped.

## 3.4 Mode band 2: [0.2 – 0.6 Hz]

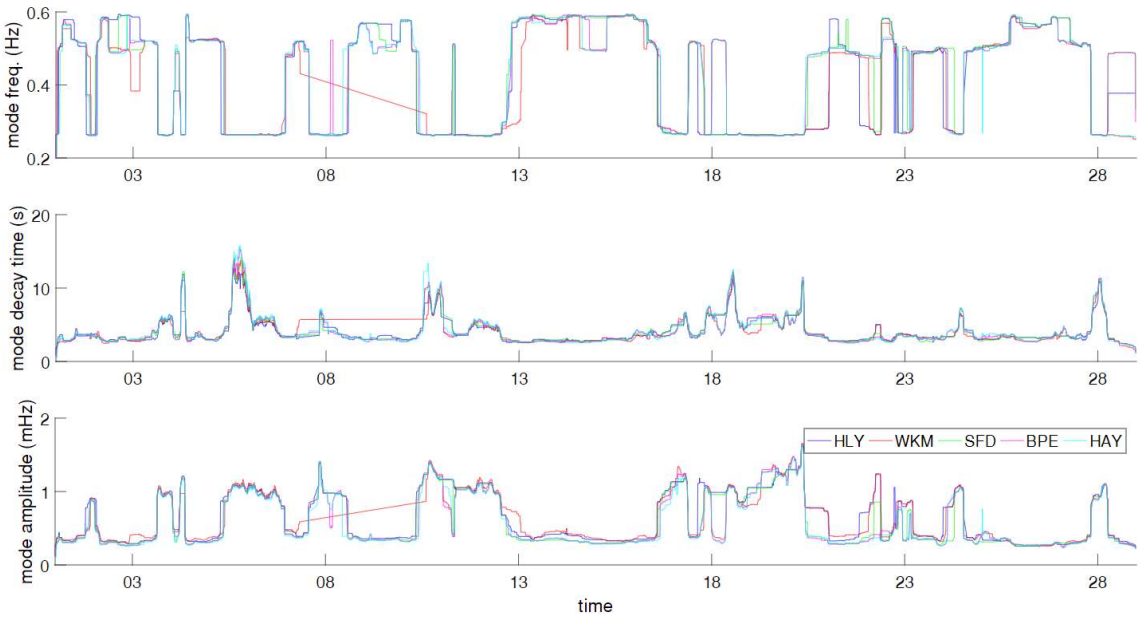



**Figure 8: PhasorPoint results for the modeband [0.2, 0.6 Hz] using PMU frequency data**

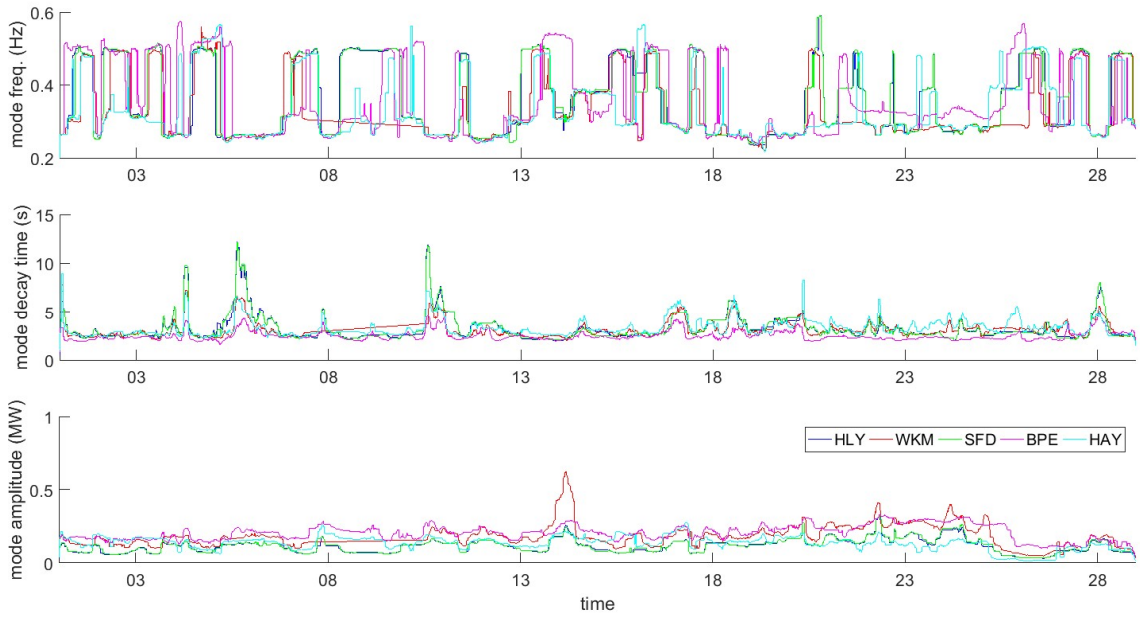



**Figure 9: PhasorPoint results for the modeband [0.2, 0.6 Hz] using PMU active power data.**

Using PMU frequency:

- 0.25 Hz mode. Decay time around 5 seconds, increasing to 5-15 seconds at times throughout the month.
- 0.5-0.6 Hz mode. Decay time around 5-10 seconds throughout the month.
- Both modes will be present continuously at low amplitude, the trend plots just show the largest within the mode band at any particular time

Using active power:

- 0.25 Hz and ~0.5-0.6 Hz modes observed at all sites, and ~0.4 Hz at most sites.
- 0.25 Hz mode decay time between 3-12 seconds.
- 0.4 Hz and 0.5-0.6 Hz mode decay times around 3-5 seconds when dominant.

## 3.5 Mode band 3: [0.6 – 0.9 Hz]

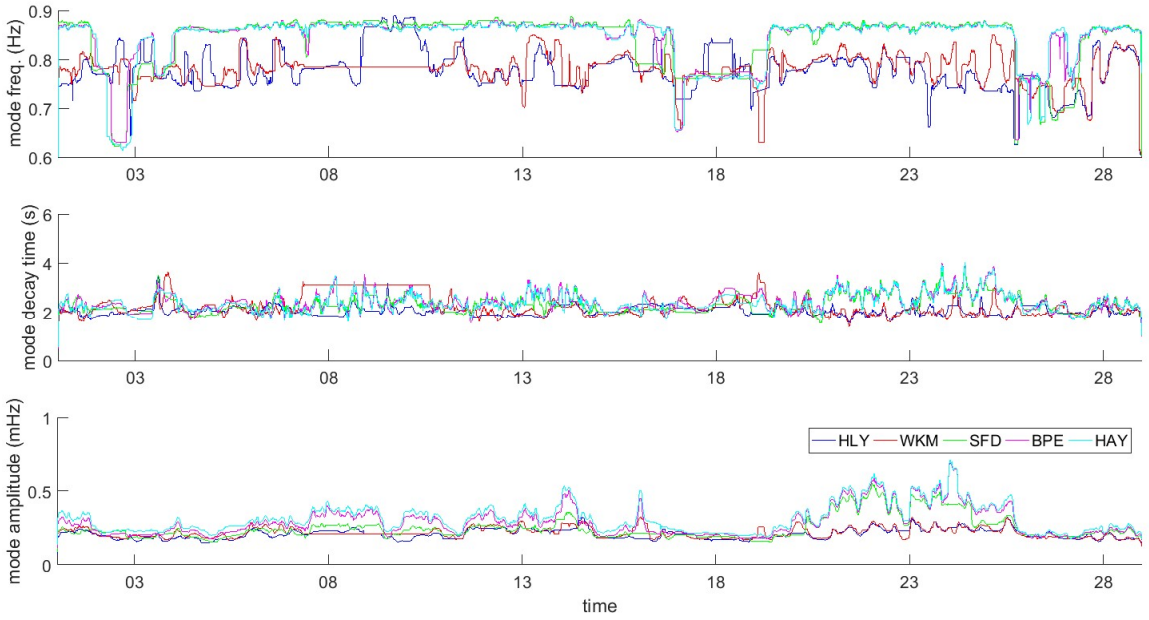



**Figure 10: PhasorPoint results for the modeband [0.6, 0.9 Hz] using PMU frequency data**

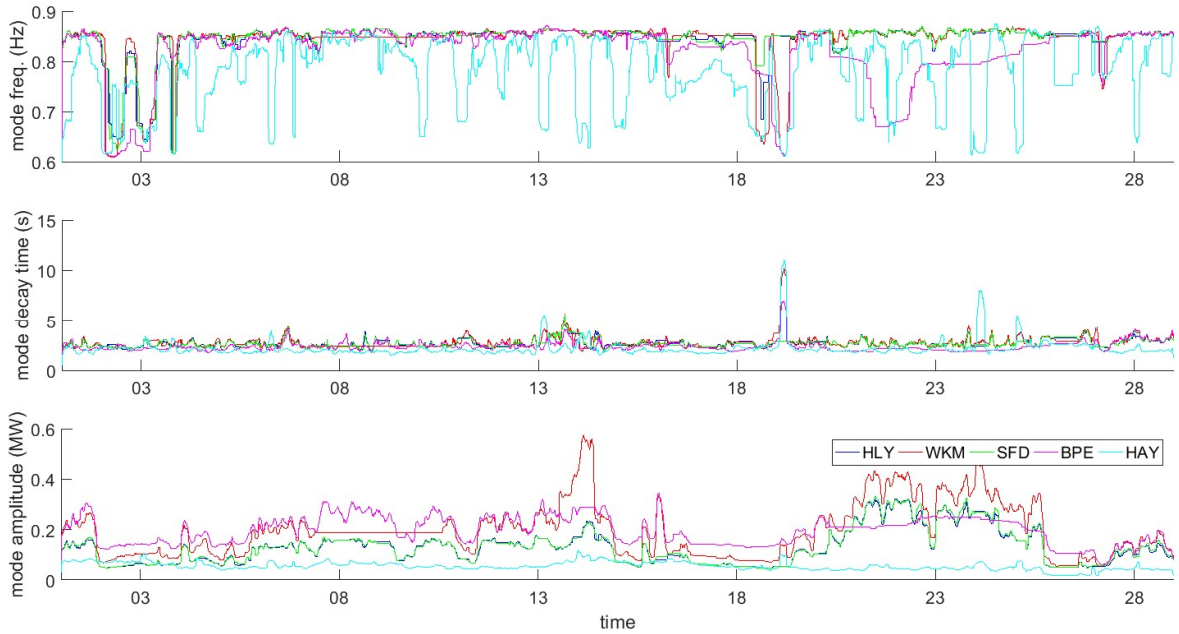



**Figure 11: PhasorPoint results for the modeband [0.6, 0.9 Hz] using PMU active power data**

Using PMU frequency:

- Modes around ~0.6 Hz, ~0.8 Hz and at 0.85 Hz observed at very low amplitudes.
- Decay time less than 4 seconds at all sites.
- Maximum amplitude ~0.7 mHz, typically 0.3 mHz or less

Using active power:

- Mode around 0.6 Hz and 0.7 Hz – 0.85 Hz observable. 0.85 Hz mode is persistent and highest amplitude
- Decay time less than 5 seconds at all sites except Whakamaru and Haywards where decay time peaks at 10 seconds once for the ~0.6 Hz mode.
- Maximum amplitude at Whakamaru ~600 kW.

## 3.6 Mode band 4: [0.9 – 1.2 Hz]

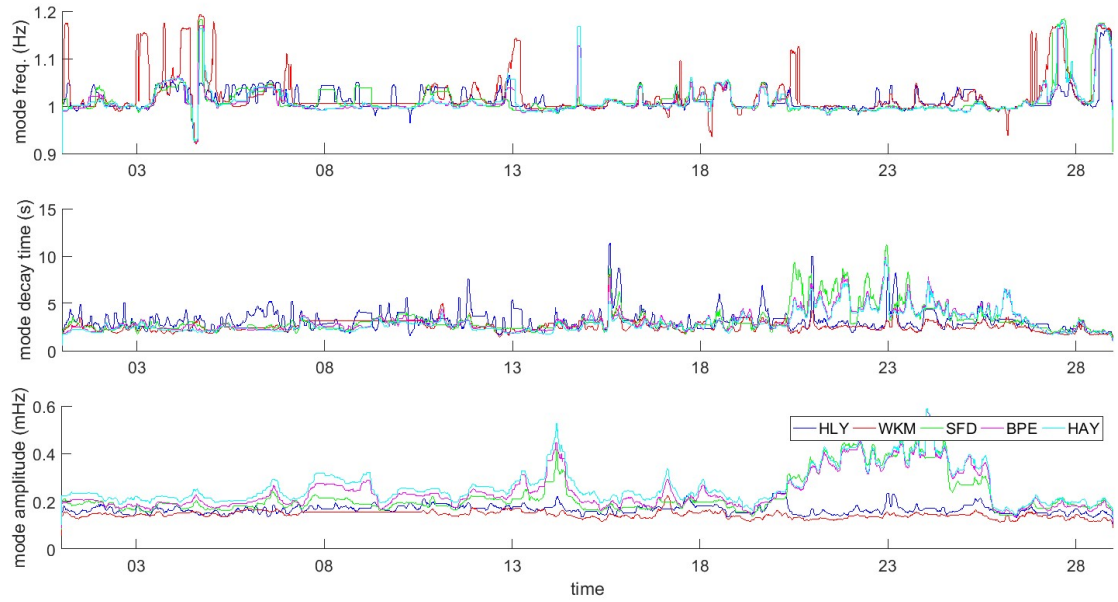



**Figure 12: PhasorPoint results for the modeband [0.9, 1.2 Hz] using PMU frequency data**

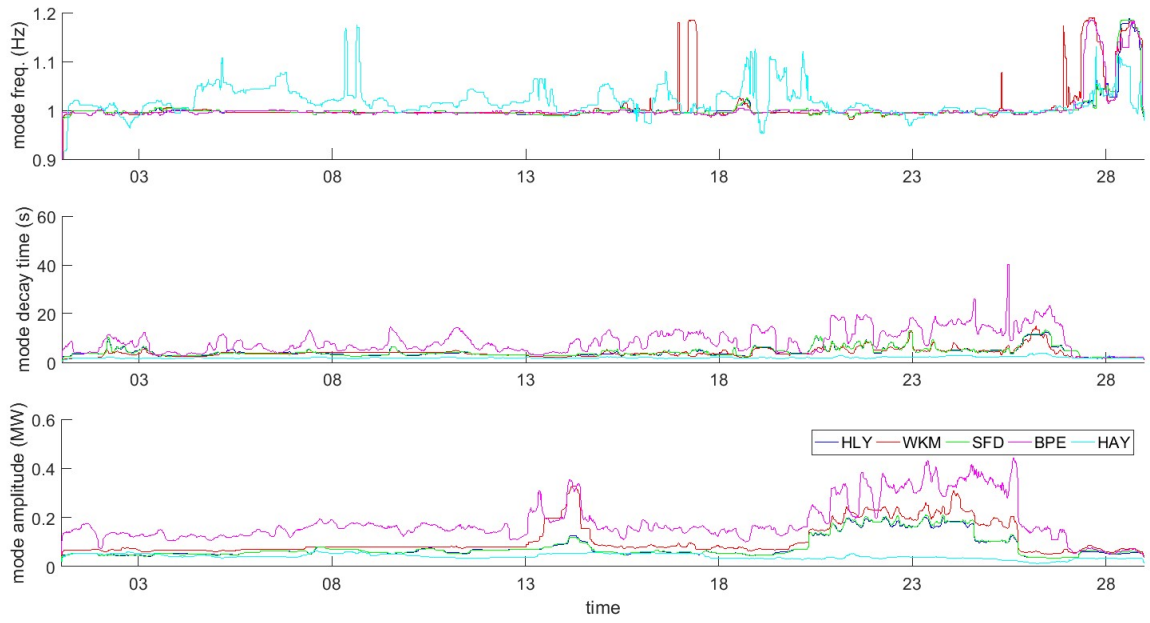



**Figure 1813: PhasorPoint results for the modeband [0.9, 1.2 Hz] using PMU active power data**

Using PMU frequency:

- Distinct modes at ~0.93 Hz, 1.00 Hz, 1.05 Hz, and 1.18 Hz.
- Highest mode amplitude observed to be ~0.6 mHz. Most decay times are under 10 seconds.
- Mode 1 Hz peaks around 12 seconds observed from Huntly.

Using active power:

- Most modes are typically well damped. However, the 1 Hz mode at Bunnythorpe displays some higher decay times towards the end of the month.
- All modes in this band have relatively low oscillation amplitudes (less than 500 kW).

## 3.7 Mode band 5: [1.2 - 1.8 Hz]

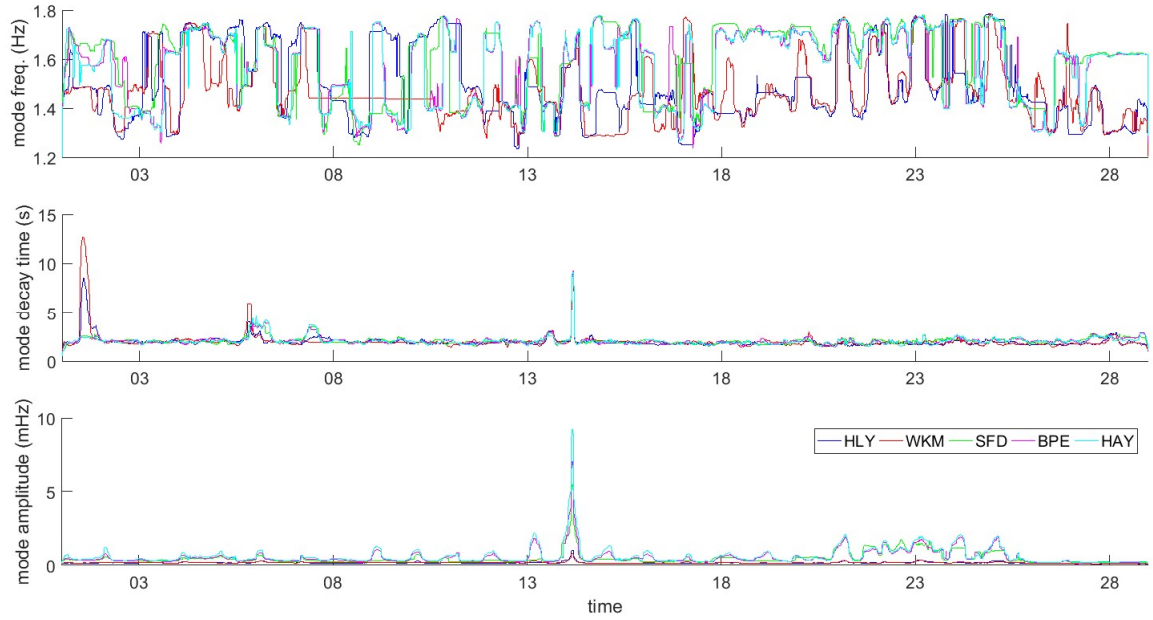



**Figure 19: PhasorPoint results for the modeband [1.2, 1.8 Hz] using PMU frequency data**

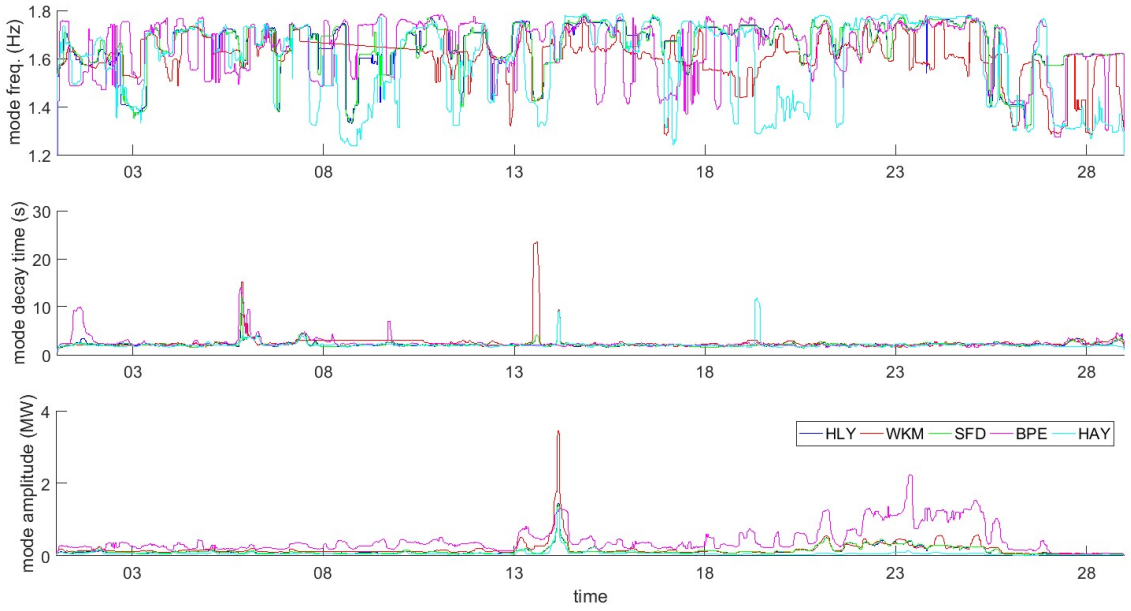



**Figure 20: PhasorPoint results for the modeband [1.2, 1.8 Hz] using PMU active power data**

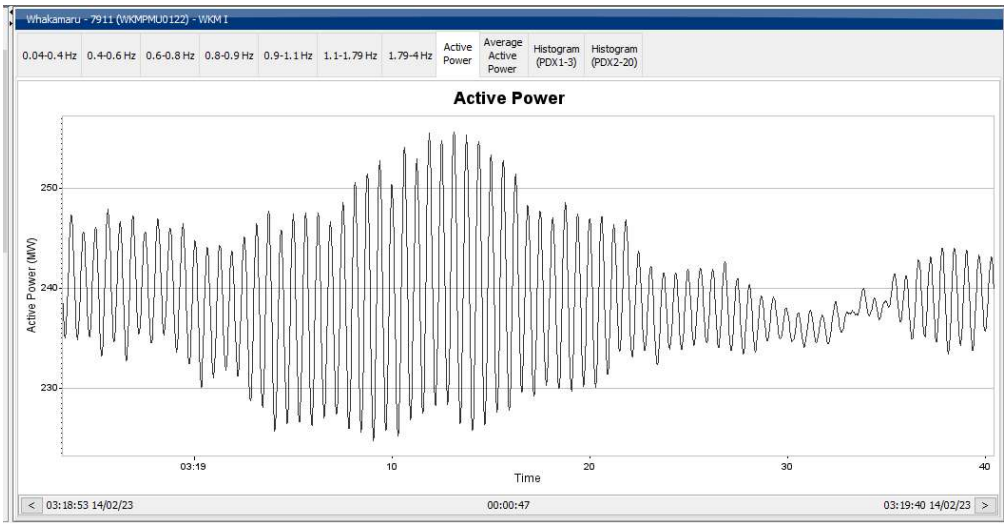
Using PMU frequency:

- Distinct modes around ~1.3 Hz, 1.5 Hz, 1.6, and ~1.7 Hz.
- Maximum decay time ~12 seconds observed at Whakamaru at the start of the month. Most of the month the decay time is less than 5 seconds for all modes.
- Maximum amplitude ~10 mHz observed at Haywards for ~1.7 Hz. Most mode amplitudes were observed to be less than 2 mHz throughout the month.

Using active power:

- Most modes relatively well damped except a briefly reported peak decay time of ~25 seconds at 1.6 Hz at Whakamaru on 14th of February 03:00 to 04:30.
- Maximum amplitude 3.5 MW briefly observed for ~1.6 Hz at Whakamaru on 14th of February, otherwise low amplitude although Bunnythorpe reports around 1 MW at 1.7 Hz

Amplitude spikes in the trend plots usually do indicate significant short-term behaviour (the smoothing methodology used removes short duration out-liers). In this mode band there were bursts of quite large magnitude power oscillations observed in the central north island in the early hours of 14th February. None were sustained longer than a minute – one example




Off line modal analysis shows that 1.6 Hz is a very common inter-station mode among the central north island hydro. No further investigation has been conducted.

## 3.8 Mode band 6: [1.8 – 2.4 Hz]

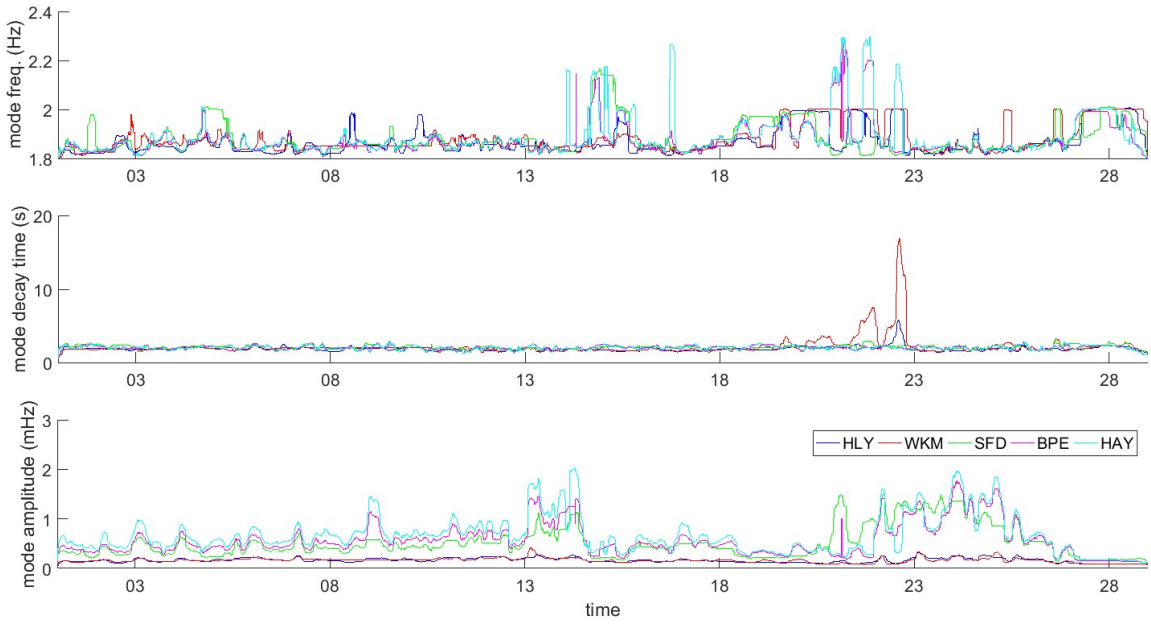



**Figure 21: PhasorPoint results for the modeband [1.8, 2.4 Hz] using PMU frequency data**

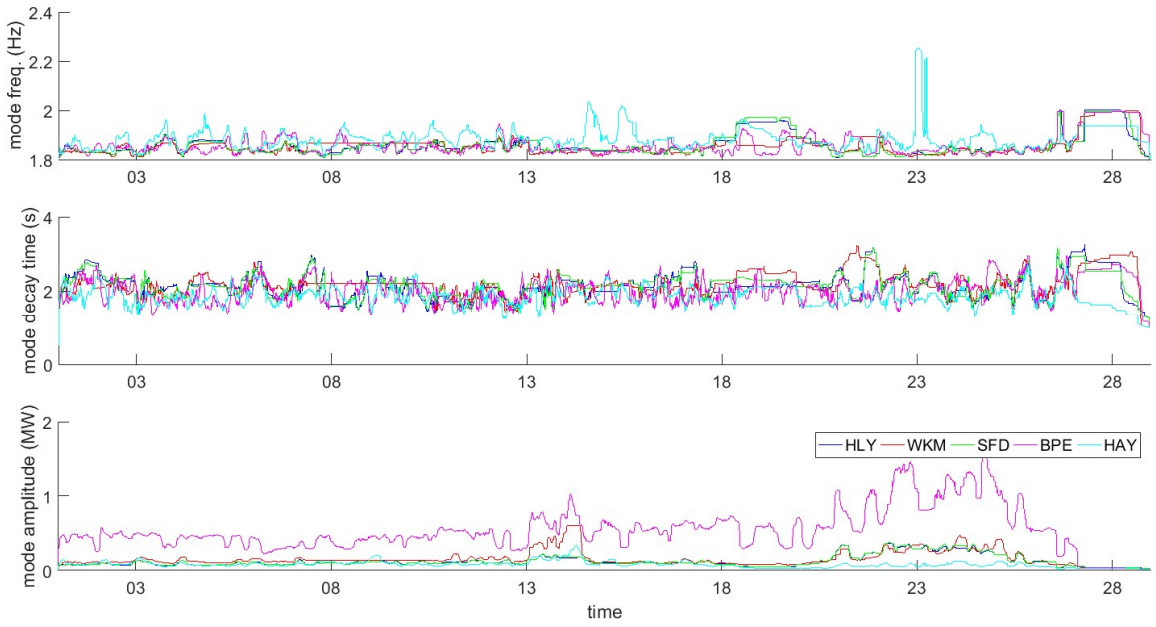



**Figure 142: PhasorPoint results for the modeband [1.8, 2.4 Hz] using PMU active power data**

Using PMU frequency:

- Modes observed at 1.8 hz and 2 Hz at most sites, and 2.2 Hz at Haywards and Bunnythorpe.
- Most modes in this band are relatively well-damped. However, a decay time of ~17 seconds was observed at Whakamaru for the 2 Hz mode at very low amplitude.
- Maximum amplitude observed to be ~2 mHz in the 1.8 Hz mode.

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 towards the end of the month but well damped.

## 3.9 Mode band 7: [2.4 – 4 Hz]

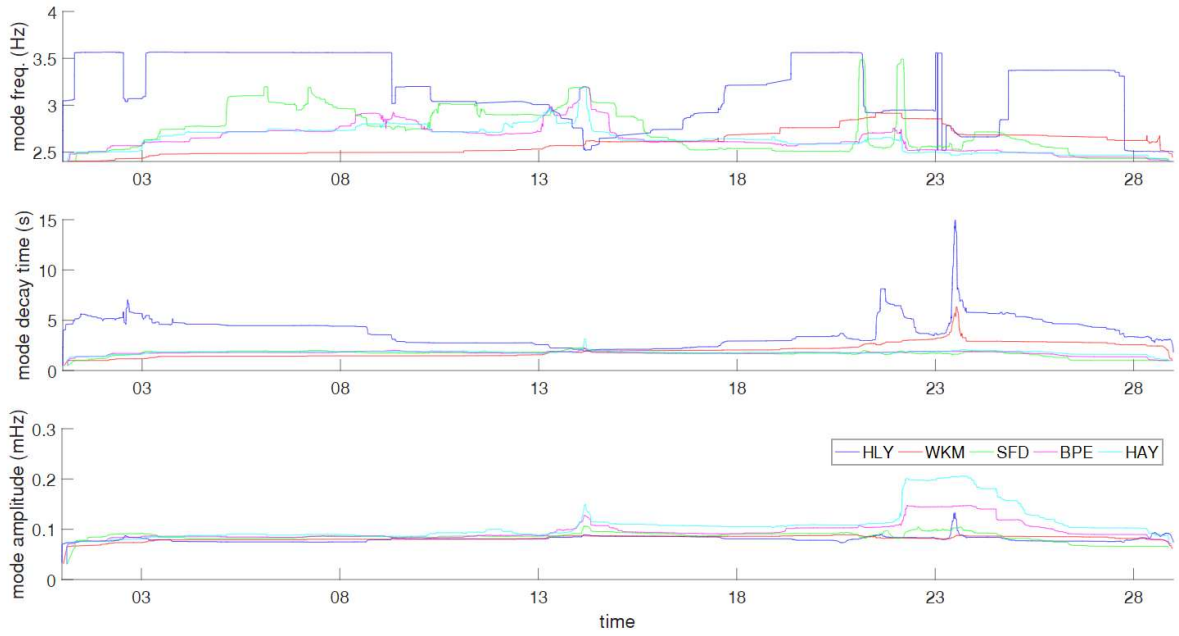



**Figure 23: PhasorPoint results for the modeband [2.4, 4 Hz] using PMU frequency data**

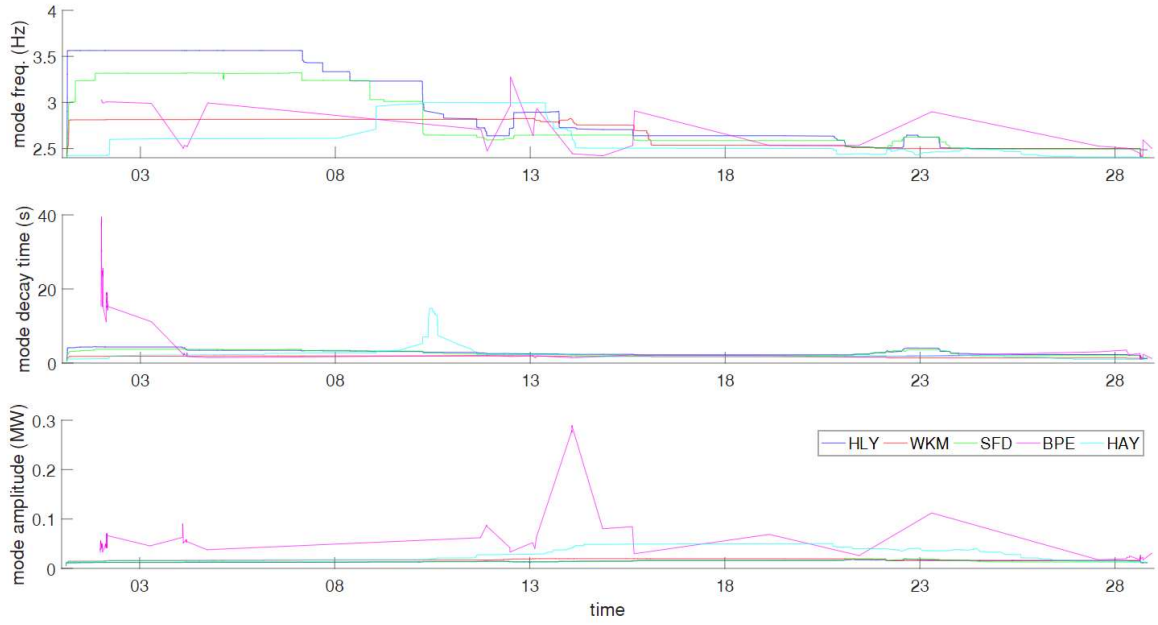



**Figure 24: PhasorPoint results for the modeband [2.4, 4 Hz] using PMU active power data**

Using PMU frequency:

- Modes observed at 2.4-2.5 Hz, ~2.7 Hz, 3 Hz and 3.5 Hz.
- All modes in this band are very low magnitude and relatively well-damped in the frequency data. Decay times usually below 5 seconds.

Using active power:

- All modes are low amplitude and well damped in the power data.
- Maximum oscillation amplitude for this mode band is ~0.3 MW, visible at Bunnythorpe for the 2.4 Hz mode.