Sub Synchronous Oscillation Novel Measurement Approach

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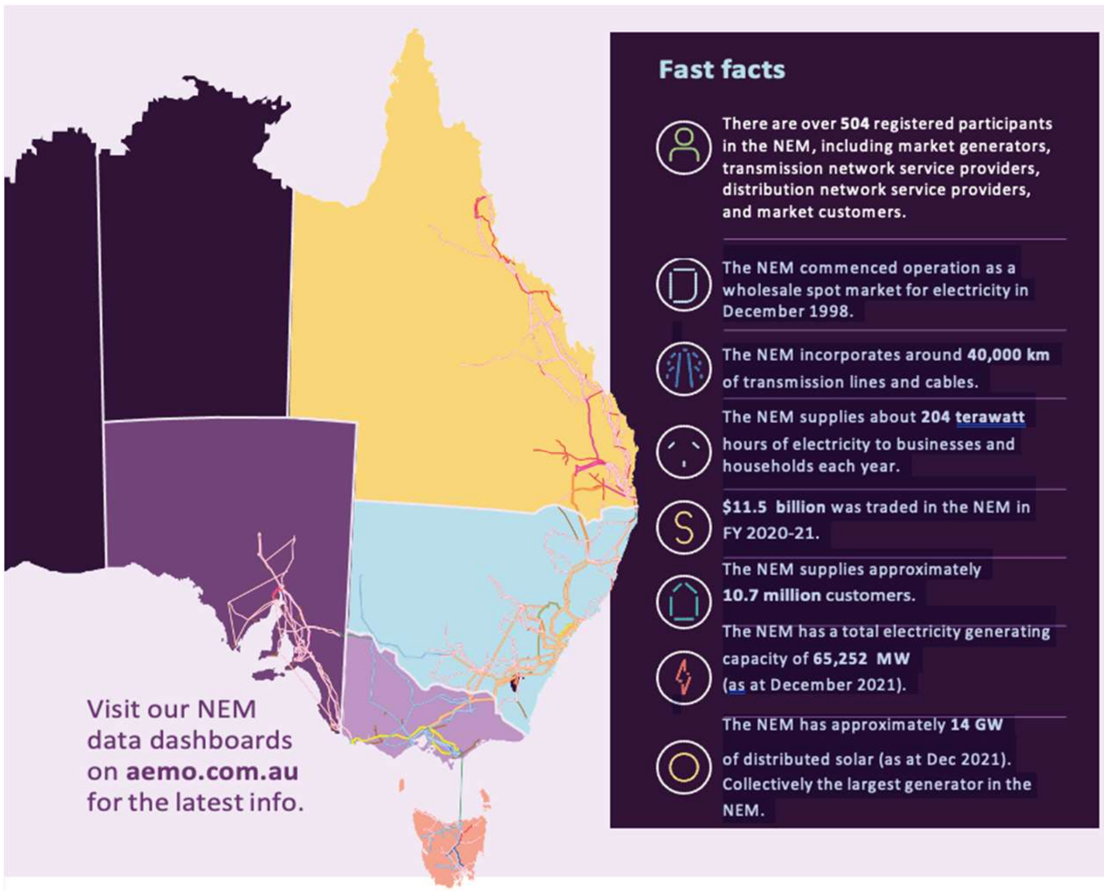
AGENDA

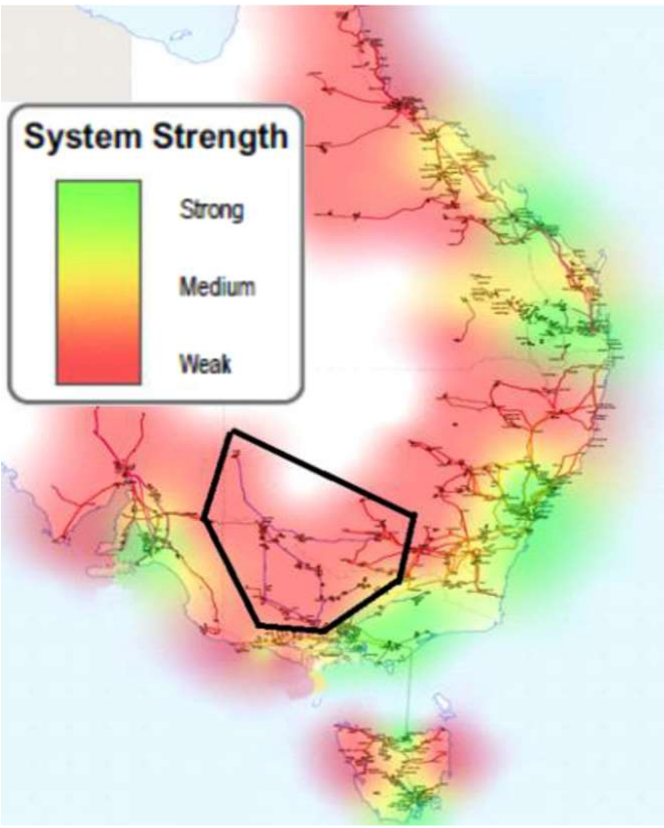
- National Electricity Market
- Oscillatory Stability
- System strength
- Sub-synchronous voltage oscillations
- Small Signal Analysis Tools
- Application
- Regulatory intervention

National Electricity Market (NEM)



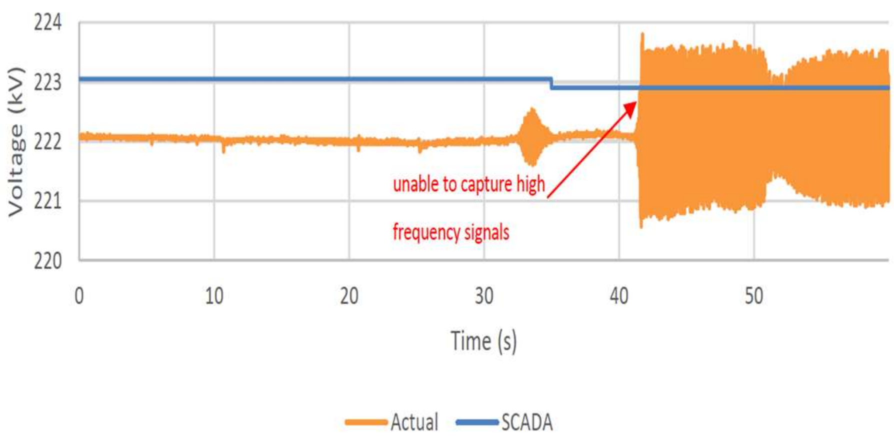
- The NEM is managed by AEMO (Australian Energy Market Operator)
- The longest interconnected power system in the world > 5,000km
- Small in capacity approx 50 GW
- Large load areas concentrated in capital cites separated by extremely long distances
- Very distinct inter- area modes of oscillations
- Very high penetration of inverter based resources including in very weak areas of the grid
- Never seen before challenges in managing system strength, inertia and frequency response.

Oscillatory Stability



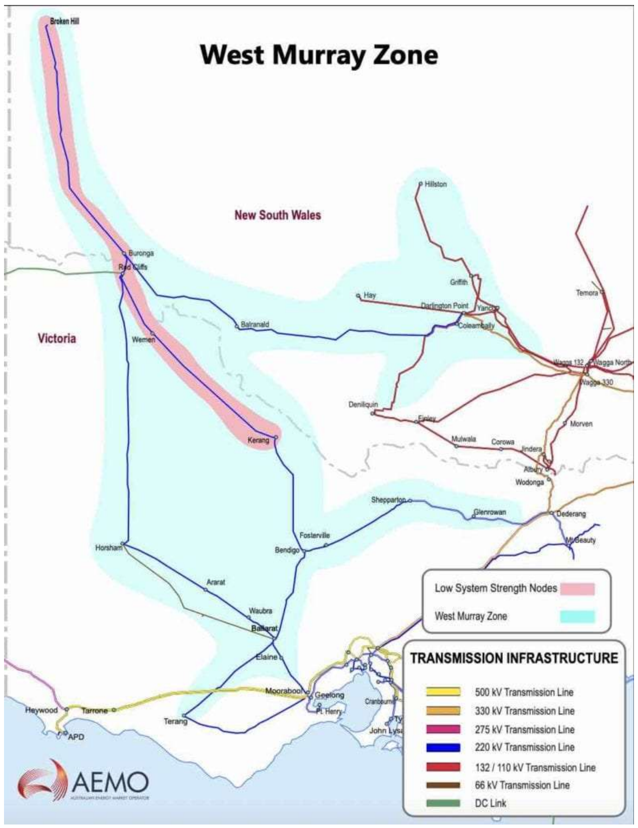
- The NEM has low damping due to the long distances between load and generation centers
- Loads, power system stabilisers and power oscillation provide damping for the NEM
- Oscillations are usually between two regions over an interconnector (Inter area)
- Low or negative damping can lead to protection on the interconnector operating resulting in cascading blackouts.
- This is the leading cause of blackouts around the world.
- Damping is getting worse as synchronous generation is decommissioned.

System Strength problem



- IBR controllers becoming unstable will result in voltage oscillations
- These oscillations are typically between 5-25 hz, and cannot be seen by SCADA
- They have been proved to exist by field tests and modelling
- With no visibility AEMO can only preemptively constrain or direct.

Sub-synchronous voltage oscillations



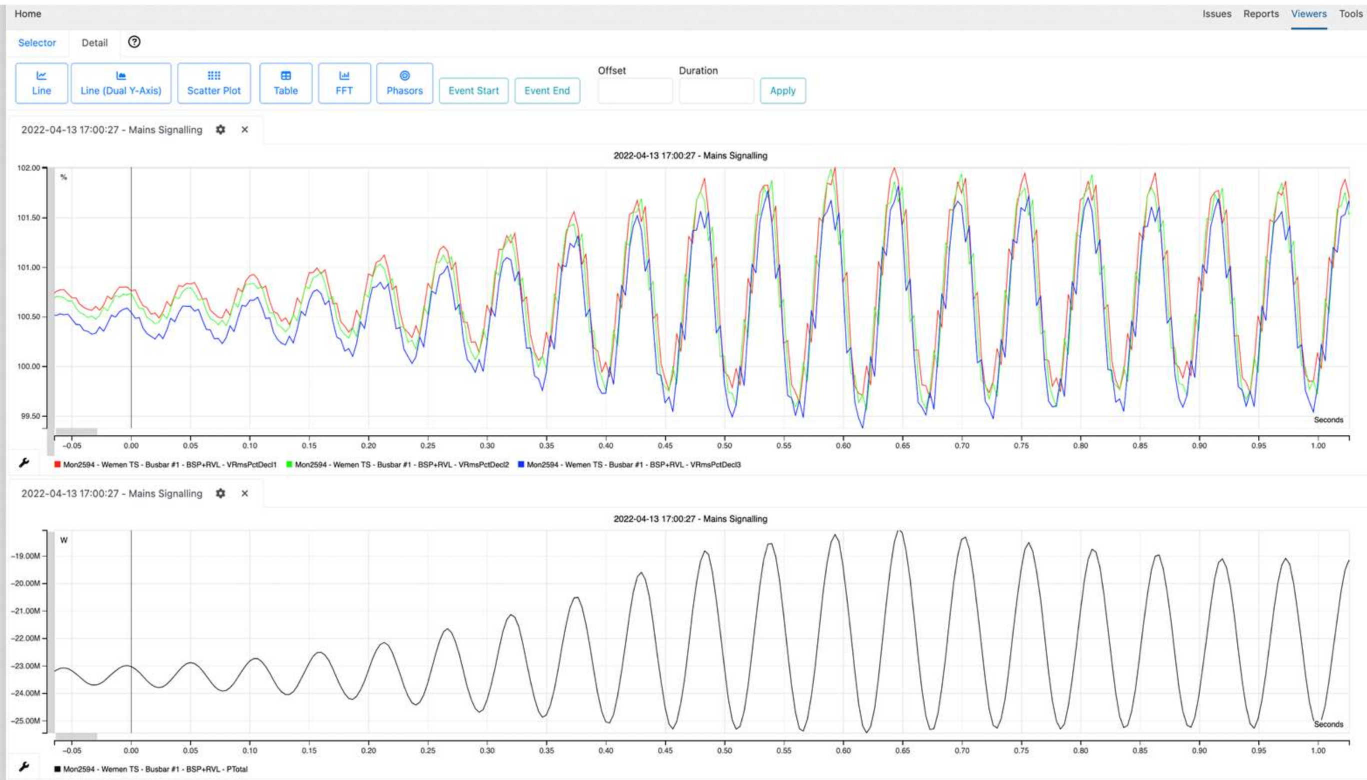
AEMO has observed intermittent power system oscillations in the West Murray area.

19 Hz sub-synchronous voltage oscillations

4 analysers deployed to capture the events.

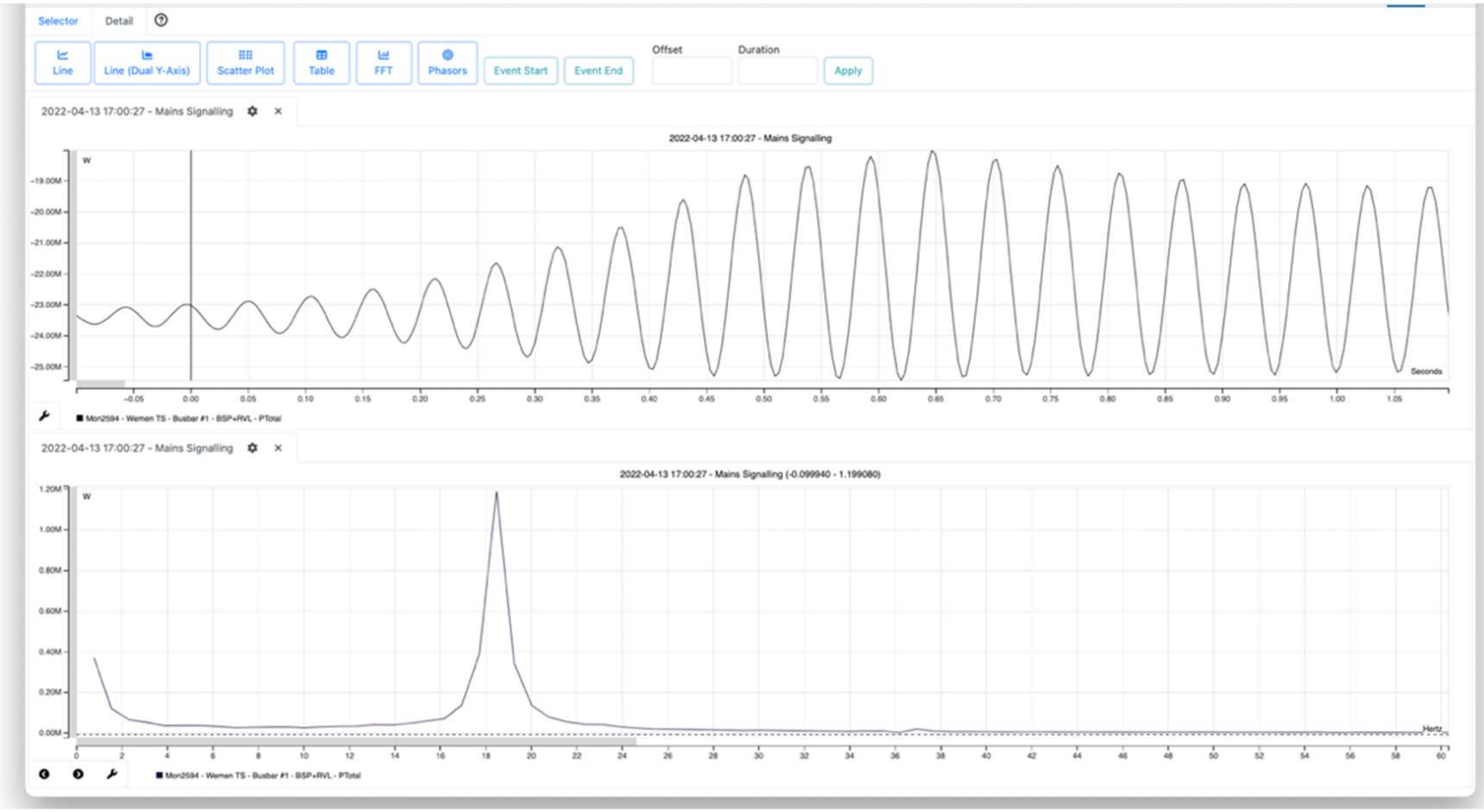
Investigation conducted by AEMO, AusNet, Powercor, CT LAB

Small Signal oscillation



- Oscillations are spurious
- voltage (±1%),
- power oscillations in excess of 5MW on a 20MW

Small Signal oscillation



- FFT done on the EMT data

Conventional PMU Phasor Estimation

- PMU standard calls for two types of PMU accuracies
  - P-Class – Fast Response (max 2/Fs) – less accurate
  - M-Class – Slower Response (max 5/Fs) – more accurate
- Both classes requires more than 1 cycles of waveform data to accurately estimate phasors
- The maximum theoretical detectable oscillation frequency is <25Hz (Nyquist limitation) for P-class devices – (Much lower for M-Class devices)
- Real-world oscillation measurement bandwidth and accuracy is often limited frequencies <10Hz
- However – oscillation frequencies present in modern highly penetrated IBR networks can be as high as 18-19 Hz.

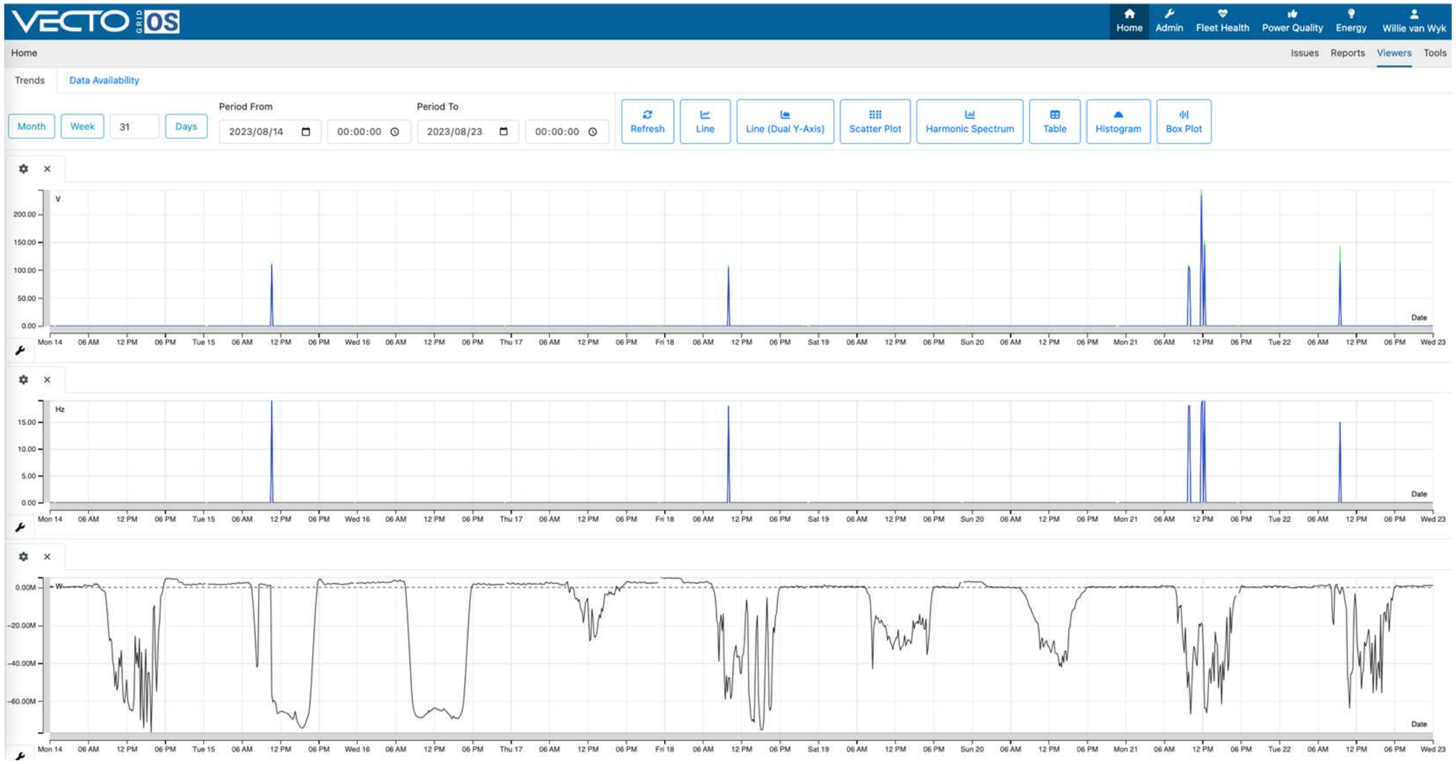
VECTO System Sub Synchronous Oscillation Measurement Options

- 50/60Hz Micro Synchrophasor Data Stream – Class P&M
  - Exceeds Class-M accuracy within Class-P response time
  - Very high phase and amplitude accuracy – detecting very small oscillations
  - Used for Sub Synchronous Analysis of frequencies <10Hz
- 1-Sec interval Sub Synchronous Spectrum (1Hz resolution – DC-60Hz)
  - Directly calculated from raw waveform data
  - Obtain both amplitude and phase angle of oscillation phasor
  - Used for Sub Synchronous Analysis of frequencies <25Hz
- 10-Sec interval Sub Synchronous Spectrum (0.1Hz resolution)
  - Higher frequency resolution, but lower update rate
  - Obtain only 60 phasors @ 0.1Hz Resolution (6Hz window)
    - The user can define the position of the window

Low Data Rate Oscillation Detection Tool

- Retain the amplitude & frequency of the highest detected oscillation on a 10-min interval
- Permanently enabled
- Used to detect oscillations throughout the grid
  - Requiring very little data to be transferred
  - Once detected – More tools are available to analyse events

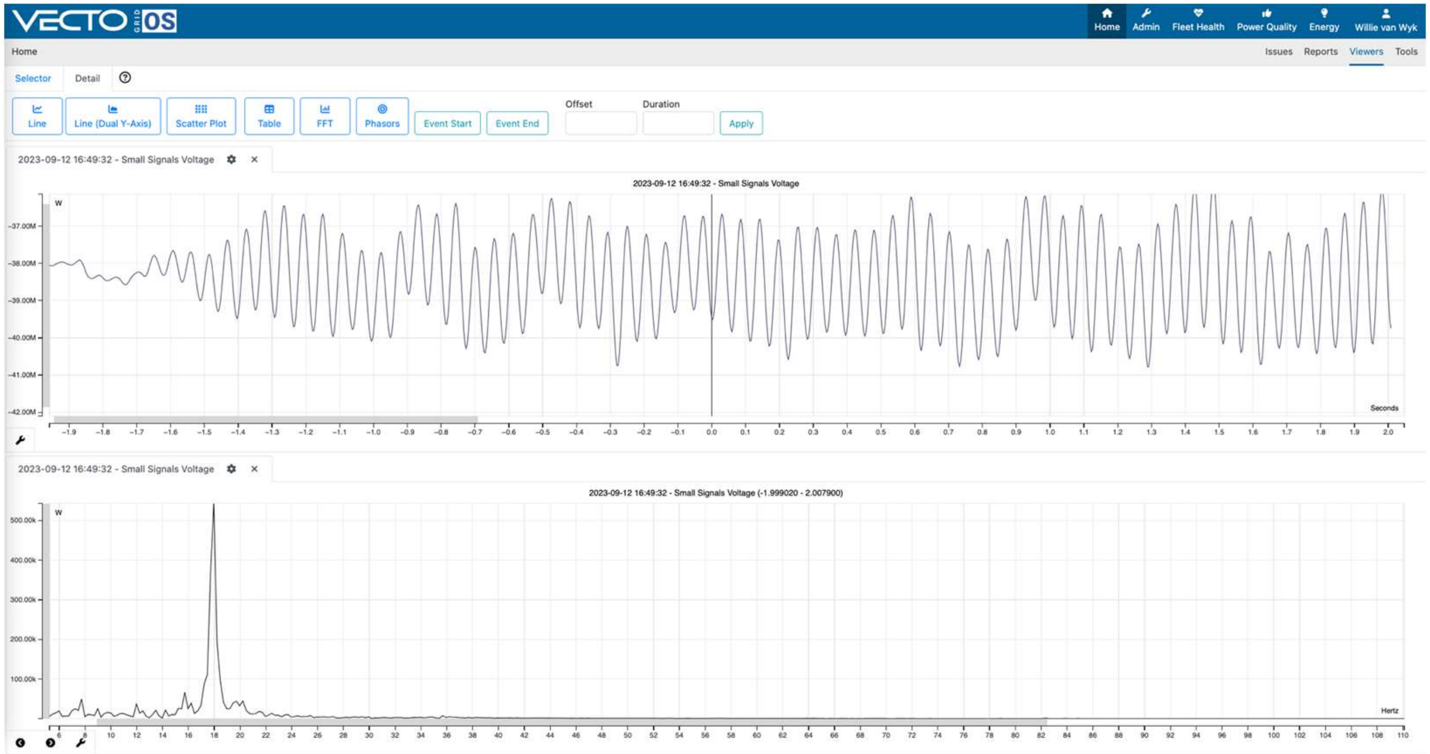
Example of 10-min interval Peak Oscillation Data stream



Small Signal Event Capturing Tool

- Define a trigger threshold on either voltage or current oscillations
- Once triggered we store:
  - Raw waveform (EMT) data stream with long pre-and post
  - RMS data stream – Updated 6 x per cycle
  - Synchrophasor data stream – Updated once per cycle
  - Small Signal Spectrum – Updated once per second

Example of Small Signal Event & FFT



Improve system strength with Syncon

- The 190 MVAr Kiamal Synchronous Condenser is the largest synchronous condenser installed in Australia and is currently in in operation
- Located near Ouyen, North West Victoria, the 221 ton Synchronous Condenser will contribute to the protection of the electricity grid connected to the Kiamal 256 MWp Solar Farm.
- Without the Synchronous Condenser plant output is limited to 50 %

AEMO issues caution regarding Oscillations

Note: West Murray Zone

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

28 June 2023

Torsional mode excitation in synchronous condensers in West Murray Zone

AEMO publishes this information for the general awareness of developers and operators of synchronous generators or condensers installed in areas of the National Electricity Market (NEM) power system where sub-synchronous oscillations may be present or likely.

AEMO has been closely monitoring the presence of sub-synchronous oscillations in the West Murray Zone (WMZ) since 2019 and most recently has published the following documents on the AEMO website:

- A comprehensive report on WMZ power system oscillations.
- A high level summary of observations from August 2020 through December 2021.
- A review of oscillations that occurred on 16 November 2021.

In 2019, AEMO observed sub-synchronous oscillations in the frequency range of 7-10 Hz in the WMZ. AEMO, network service providers (NSPs), generators and the original equipment manufacturer (OEM) worked together to implement solar farm tuning solutions to address observed oscillations.

During August 2020, AEMO observed lower magnitude sub-synchronous oscillations in the WMZ, and has since been closely monitoring this area. The oscillation magnitude has generally been less than 1% peak-peak (measured at 220 kilovolt transmission node in WMZ) and mostly in the frequency range of 15-20 Hz based on root-mean-square (RMS) data. The processing of high-resolution waveform data for a few incidents identified a presence of dominant 33 Hz and 67 Hz components in voltage and current in addition to the 50 Hz fundamental component.

In May 2023, AEMO was made aware of a hypothesis that the mechanical torsional modes of a synchronous condenser could be susceptible to the presence of these sub-synchronous power system oscillations, which may have contributed to mechanical shaft damage.

The potential effects of sub-synchronous oscillations on conventional synchronous generators have been documented[1]. During this phenomenon, the electrical oscillations in the power system induced by the presence of series capacitors or high voltage direct current (HVDC) control modes could interact with the sub-synchronous complement of the turbine-shaft natural mechanical modes and result in damage to the turbine-shaft. However, electro-mechanical interaction due to low-level oscillations resulting in torsional vibrations of the mechanical shaft in synchronous condensers has not been widely reported. As more synchronous condensers (with and without flywheels) are being installed in the NEM, further investigation of this possibility is warranted.

[1] P. M. Anderson, et al., Subsynchronous Resonance in Power Systems, Wiley-IEEE Press, 1990 , at https://ieeexplore.ieee.org/book/5264388

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Proposed Regulatory Change for Generator connection requirements

In the AAS, specify that a generating system or IRS, for its asynchronous units:

- Must have system that can detect an instability in voltage, reactive power and active power
- Must have a protection system capable of disconnecting for oscillatory behaviour
- On detection of oscillations, execute a hierarchy of actions based on configurable trigger conditions, thresholds and timeframes, agreed with the NSP and AEMO, where – Any action to disconnect is based on contribution to the oscillations
- Actions are automatically and promptly actioned
- For synchronous and asynchronous production systems 100 MW or greater, must have a PMU and capability to receive information about contribution to oscillations from an AEMO central system (in a form nominated by AEMO)

The MAS requires:

- Where the plant, considering its reactive power range under S5.2.5.1, can change the voltage at the connection point, for system normal or planned outage conditions, by more than 1%, – The plant must have capability to detect an oscillation of voltage, reactive power and, where relevant, active power
- For asynchronous production systems a process agreed with the NSP and AEMO to manage oscillations promptly
- For synchronous production units and synchronous condensers a protection system to disconnect the plant for sustained pole slipping, if required by the NSP
- • If required by AEMO or the NSP, for production systems with active power capability 100 MW or greater and synchronous condensers 100 MVA a PMU, and capability to receive data on contribution to an oscillation in a form nominated by AEMO;

There is still more to learn

- The investigation is on going
- Additional 8 analysers to be installed next month

- *With the recent developments in renewable energy generation and addition of power electronic devices, power system dynamics have become extremely complex. A continuing challenge faced due to this transition is the sub synchronous oscillations caused by the interaction of renewable energy sources and various components of the power grid. Recently reported incidents due to sub synchronous oscillations highlight the need of monitoring and suppression of these harmful oscillations in real time.*

Class-A PQI Device
Class 0.2 Billing
PMU Device
Merging Unit
SCADA Transducer
Small Signal Analyser

500kHz Sampling Rate
Built-in Cellular Modem
Secure IP Based Comms
Linux Based Platform
Flexible Interfaces

GRID-MONITORING EDGE COMPUTER

Questions