AEMO WAMS Development Project

We acknowledge the Traditional Owners of country throughout Australia and recognise their continuing connection to land, waters and culture.

We pay respect to their Elders past and present.

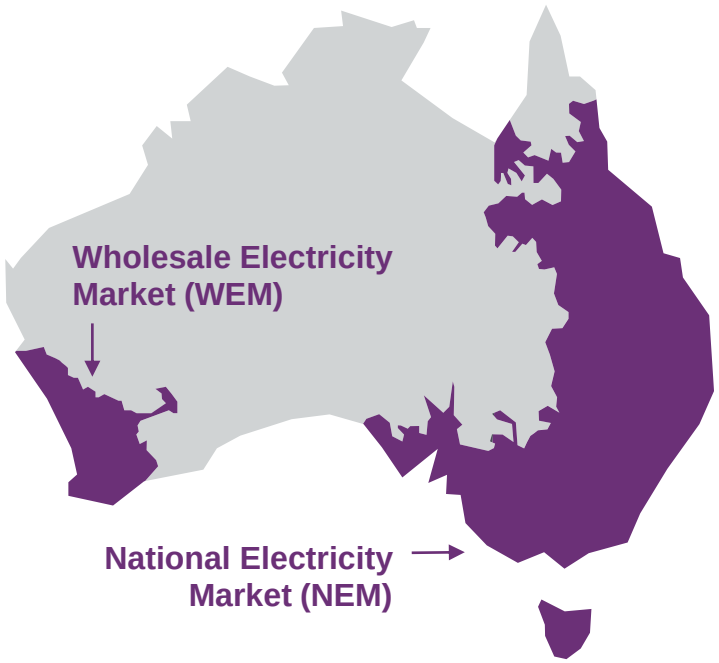
About AEMO

- AEMO is a member-based, not-for-profit organisation.
- We are the independent energy market and system operator for the National Electricity Market (NEM) and the WA Wholesale Electricity Market (WEM), and system planner for the NEM.
- We also operate retail and wholesale gas markets across south-eastern Australia and Victoria's gas pipeline grid.

AEMO SERVICES

AEMO Services is an independent subsidiary of AEMO, established in 2021 to enable the transparent provision of advisory and energy services to National Electricity Market jurisdictions.

Electricity



Gas

Declared Wholesale Gas Market (DWGM)

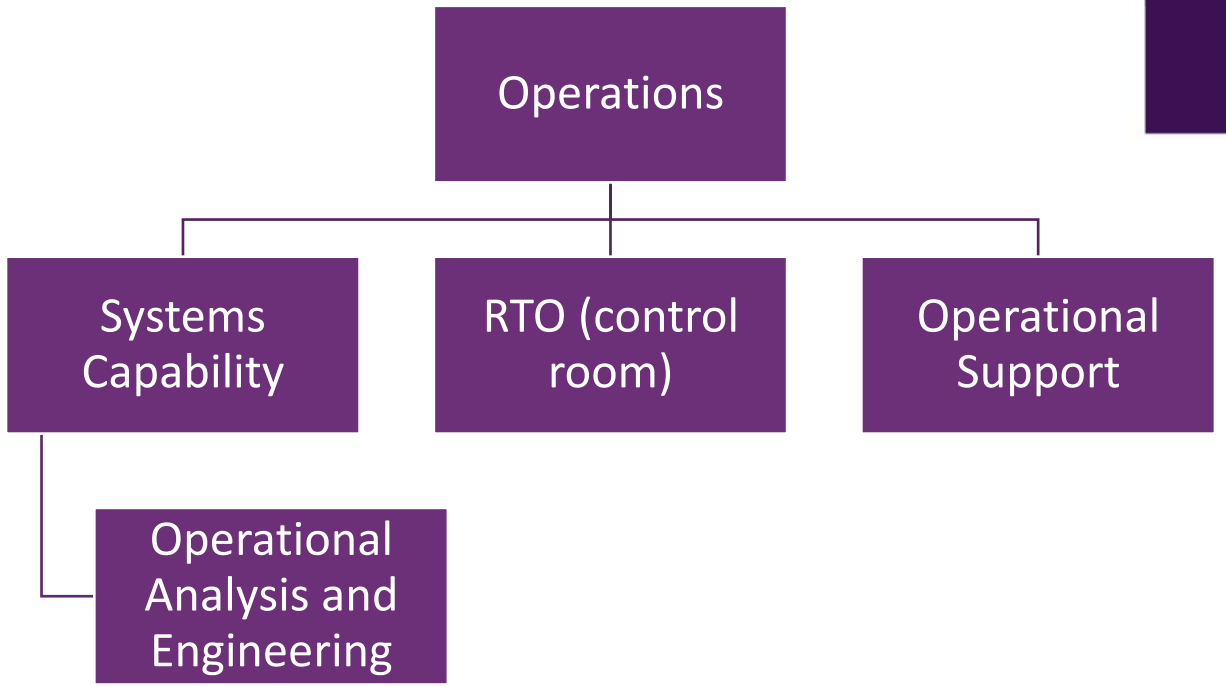
Short Term Trading Market (STTM)

and

Gas Supply Hub (GSH)

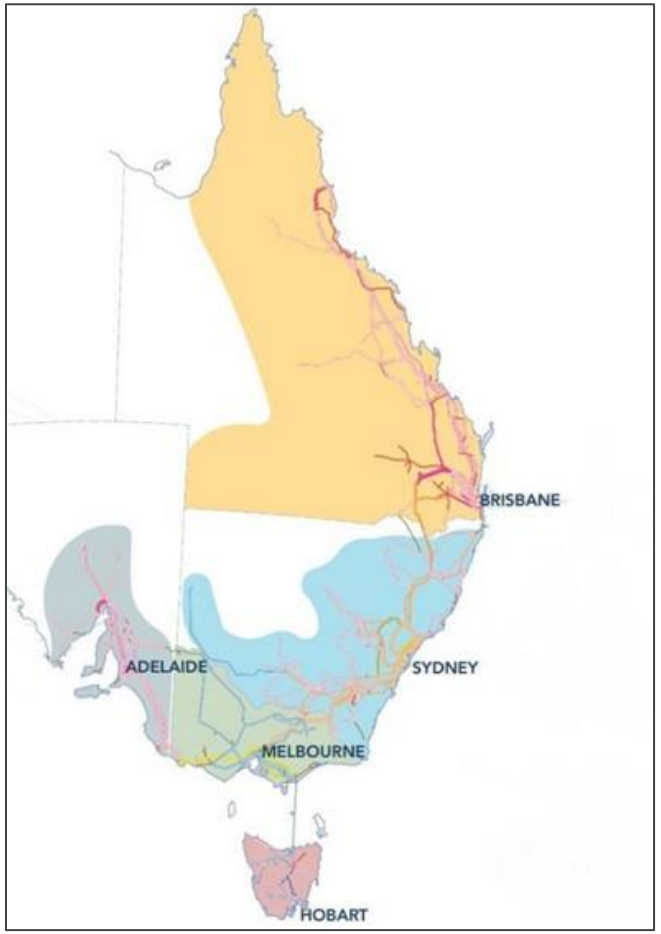
Operational Analysis and Engineering

- We provide ‘Expert Advice’ to the control room, Operational Support and other areas of operations
- We occasionally provide advice to transmission planning and externally to government and network service providers
- We specialise in the physics and dynamic behaviour of the east - Australian power system – the ‘NEM’
- To do this, we use world leading simulation techniques and data analytics



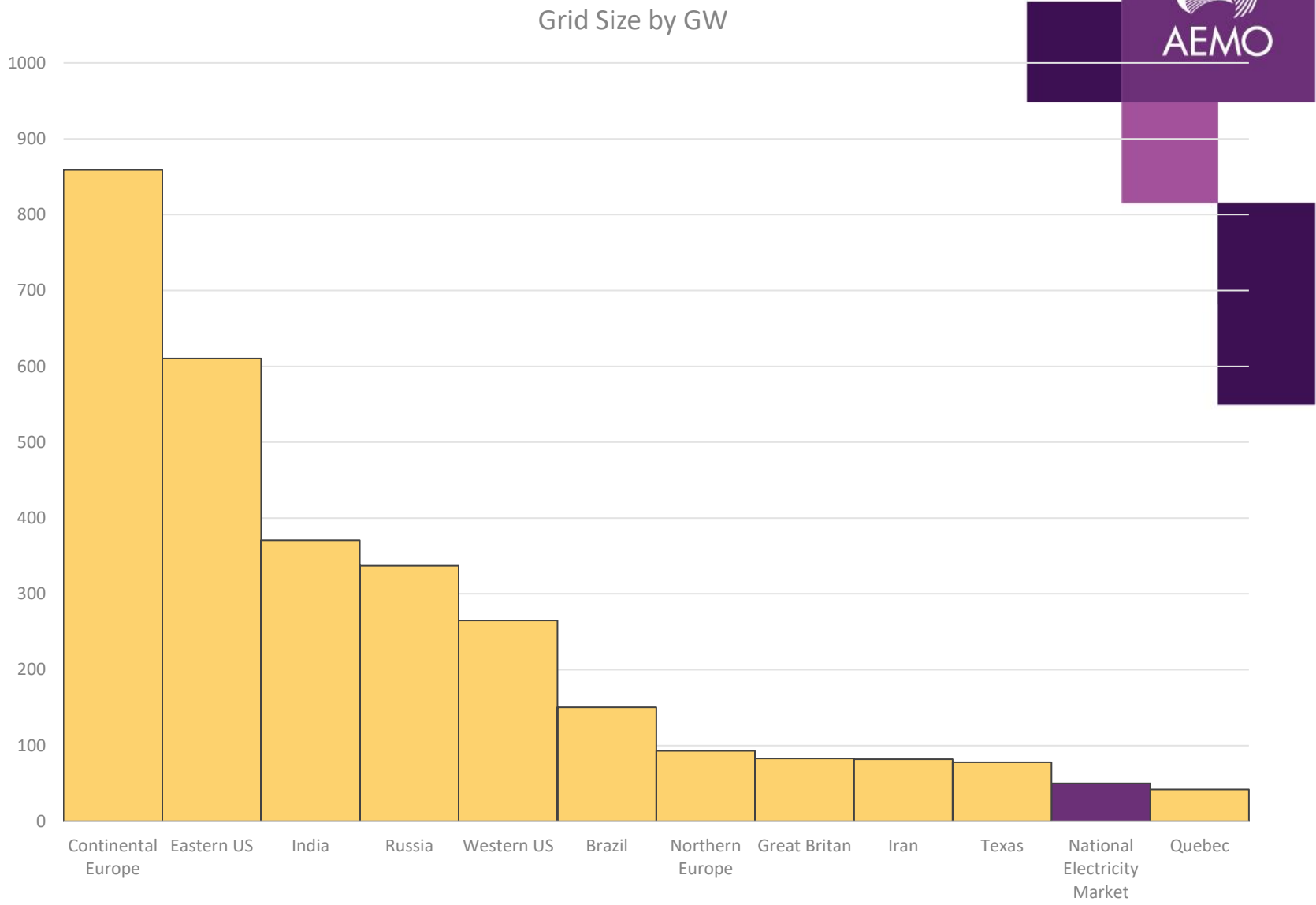
What is the NEM?

- The largest interconnected power system in the world by geographical size: >5000km from Port Douglas (QLD) to Port Lincoln (SA)
- Despite this relatively small by capacity: ~50GW
- Large load areas concentrated at the capital cities separated by extremely long distances
- Very distinct inter-area modes of oscillation
- 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



Size of the NEM

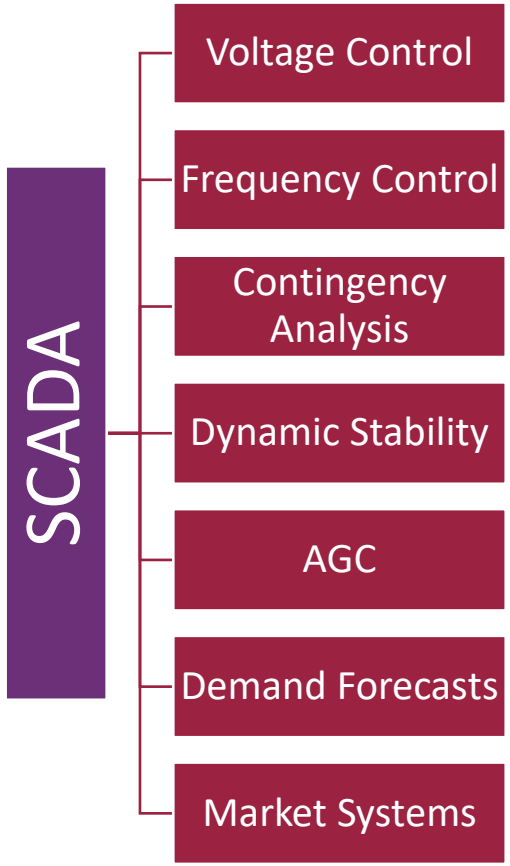
Source:
en.wikipedia.org/wiki/Wide_area_synchronous_grid



How NOT to Operate a Power System

24th January 2021 – Total Loss of Visibility of the NEM

Visibility Is CRITICAL to Operations!



Power System Monitoring

Quantities we use at AEMO

Power	Reactive Power	Voltage	Current
Frequency	Inertia	Power Quality / Harmonics	Tap changer positions
	Plant status	Environmentals	

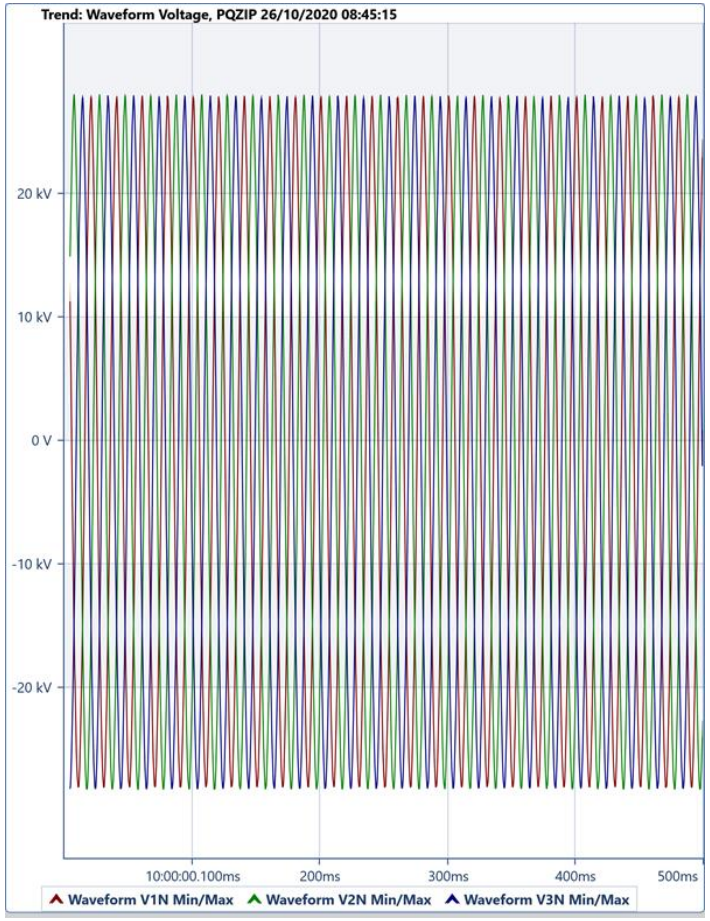
What we can measure

- Instrumentation transformers step down the voltage to safe levels but preserve the shape of the signal
- Current: Measured by Current Transformers
- Voltage: Measured by Voltage Transformers

Voltage Transformer (input only)

Current transformer (input and output)

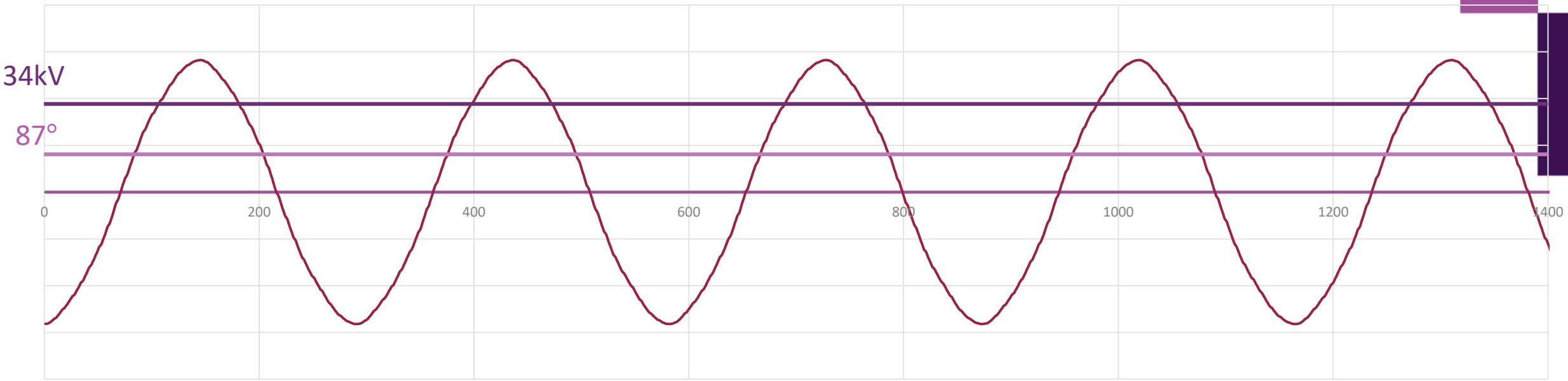
AC Power



½ a second of waveform data

- We use ‘alternating current’
- Voltage and current are fluctuating back and forth 50 times a second
- Bandwidth requirement to send waveform measurements for *every* element in the power system is not achievable
- Raw waveform data does not provide useful information to operators in real-time without extensive filtering and complex online data analysis (still a new field of research)

Synchrophasors



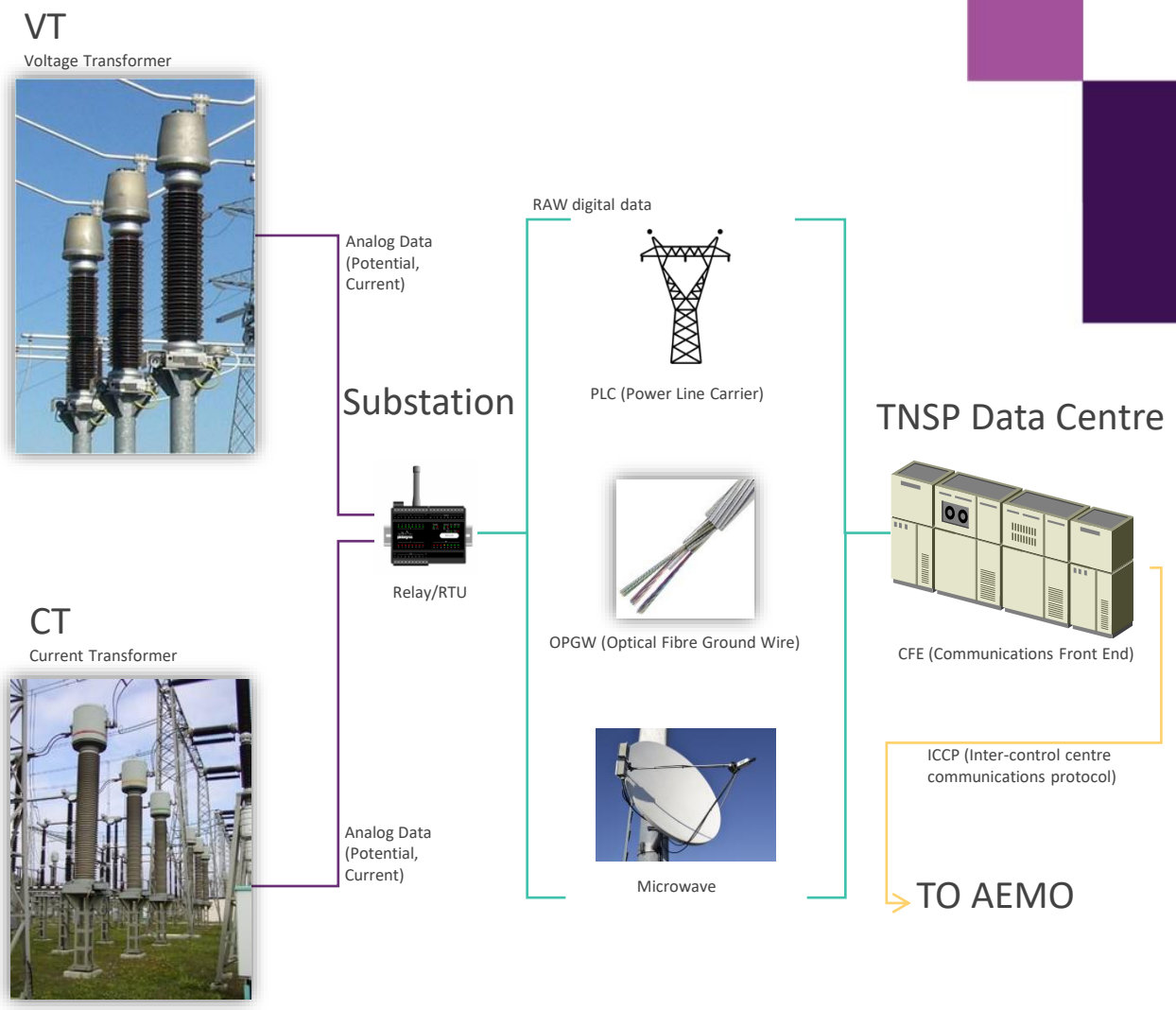
$$V(t) = \sqrt{2} \times V_{rms} \times \sin(2\pi \times 50 \times t + \emptyset)$$

Constant

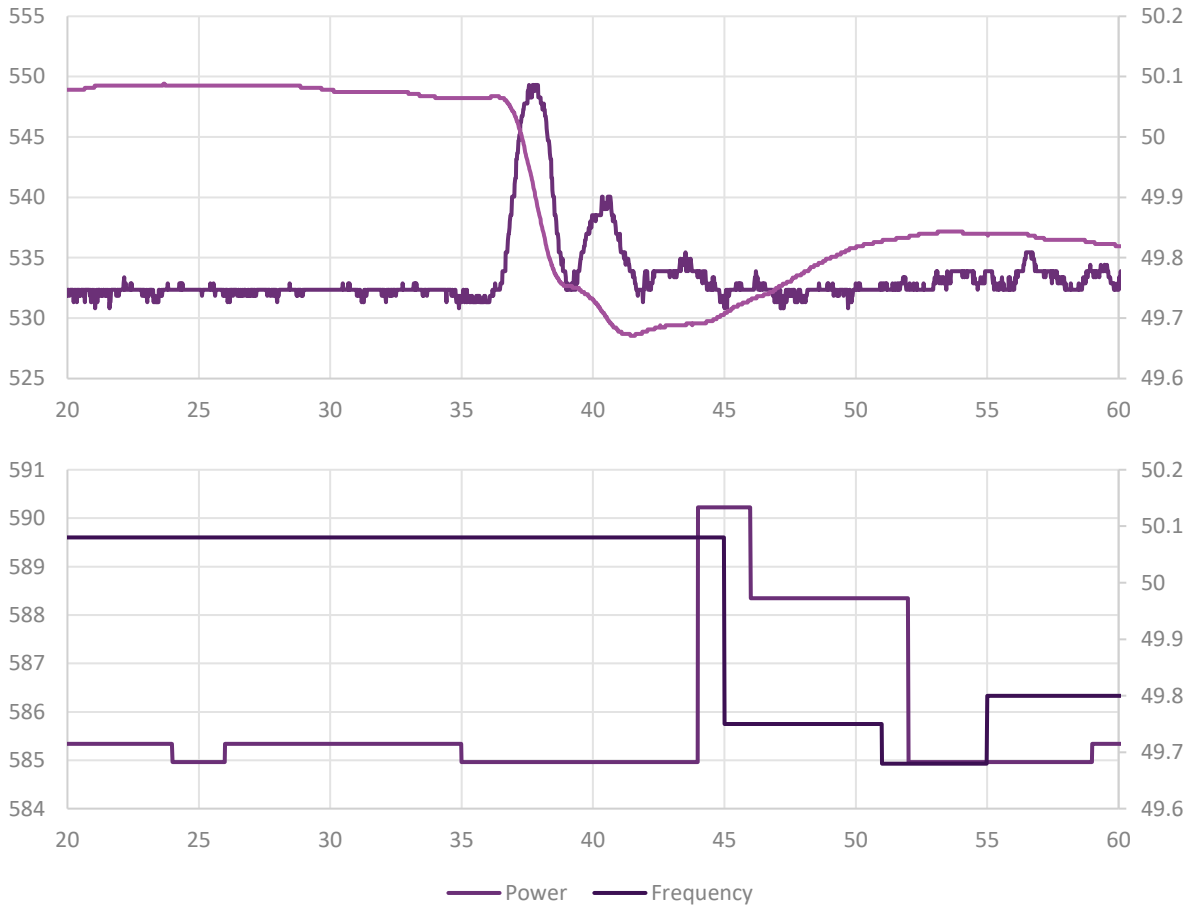
Constant

SCADA

- Supervisory Control and Data Acquisition
- Data is transmitted from a Remote Terminal Unit once every 4 seconds
- Data goes from the substation to a datacentre via the TNSPs comms network, then to AEMO over the internet (through a secure channel)
- Data is presented in our GE Energy Management System
- From EMS it is passed on to other applications such as PI, Forecasting systems and Market systems

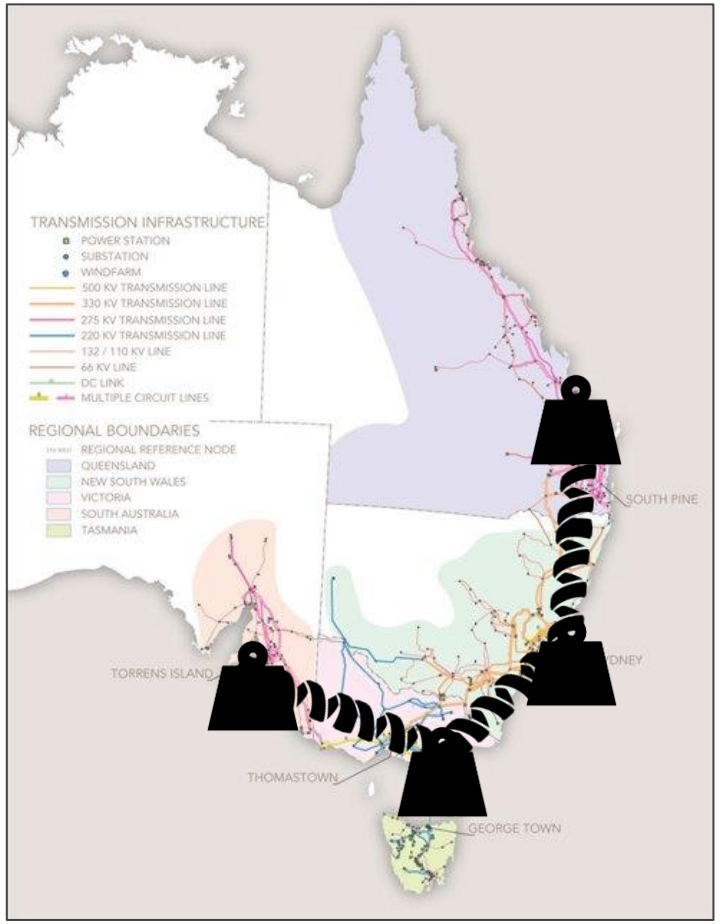


Limitations of SCADA



- Data is not time stamped – values received are assumed to be ‘right now’
- Speed of the communications network can have a huge impact – some signals could be up to 15 seconds old when they reach AEMO!
- One measurement every 4 seconds is too slow to capture frequency response, inter-area oscillations and phenomena driven by low system strength

Oscillatory Stability



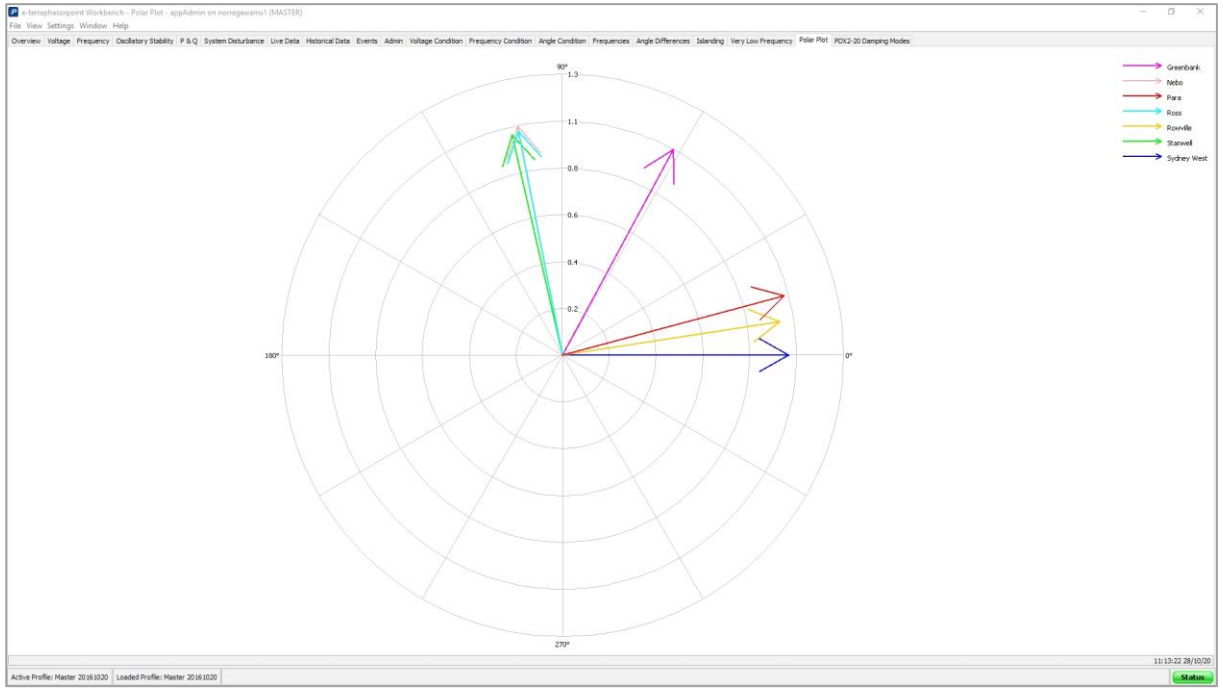
- Due to electro-mechanical coupling of *synchronous* generators, we can think of the power system as a series of connected masses and springs
- A spring will oscillate indefinitely unless there is a frictional *damping* force
- The NEM has low damping due to the long distances between load / generation centres
- Loads, power system stabilisers and power oscillation dampers provide damping for the NEM

Oscillatory Stability

- Oscillations are usually between two regions over an interconnector (inter-area oscillations)
- Low or negative damping can lead to protection on the interconnector operating, resulting in cascading blackouts
- This is the leading cause of large scale blackouts around the world
- Damping is getting worse as synchronous generation is decommissioned

The Tacoma Narrows Bridge collapsed in 1940 due to poorly damped oscillations

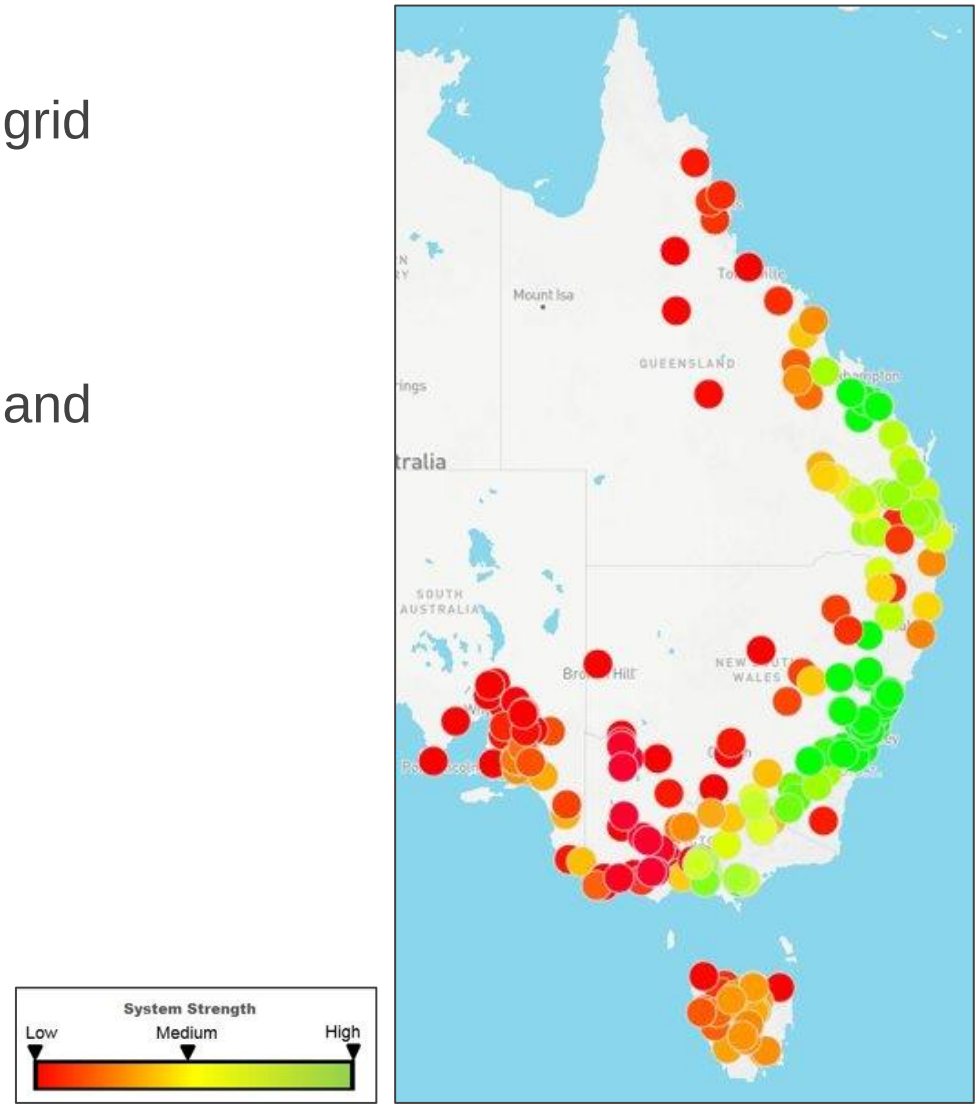
Oscillatory Stability



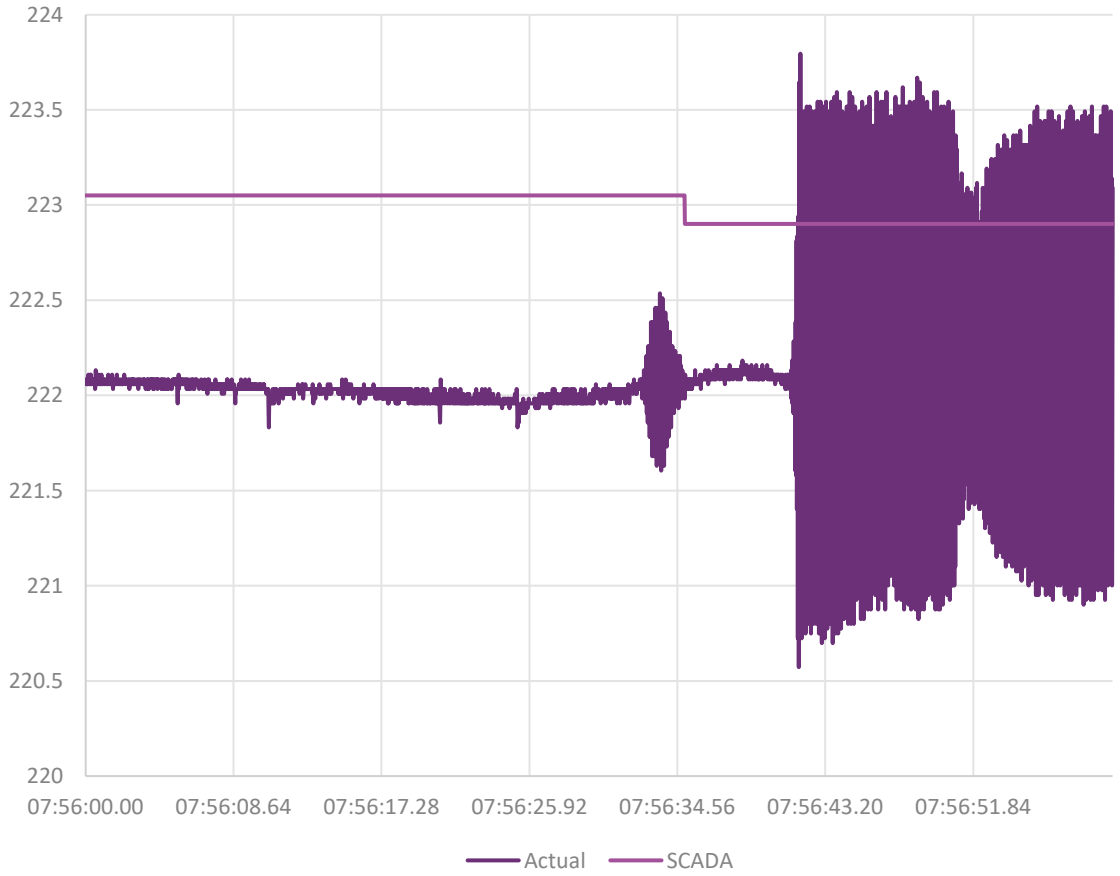
- We can monitor inter-area oscillations by measuring the voltage *angle* of two regions relative to each other
- To get an accurate result, we need measurements of angles at the exact same point in time
- SCADA data is not time-stamped so cannot be used

System Strength

- System strength is how susceptible an area of the grid is to fluctuations in voltage
- An area of low system strength will have large fluctuations for even small disturbances
- Synchronous generators provide system strength, and the system is weaker the further away from any synchronous generators
- Inverter Based Resources do not provide system strength, and their control systems can become unstable in weak areas of the grid
- Areas such as Western Victoria and Northern Queensland have large amounts of IBR, but low system strength



System Strength



- IBR controllers becoming unstable will result in voltage oscillations.
- These oscillations are typically between 5-25 Hz, and cannot be seen by SCADA – we are blind!
- They have been proven to exist through modelling and field tests
- With no visibility AEMO can only pre-emptively constrain or direct

Next Generation: Introducing WAMS

WAMS

- WAMS – Wide Area Monitoring System
- A new ‘Smart Grid’ technology
- First proposed by IEEE in 1995
- Updated as IEEE std c37.118 in 2005
- Devices that stream phasors in real time and comply with c37.118 are commonly referred to as PMUs (phasor measurement units)

SEL 451 relay with PMU

WAMS vs SCADA

WAMS

SCADA

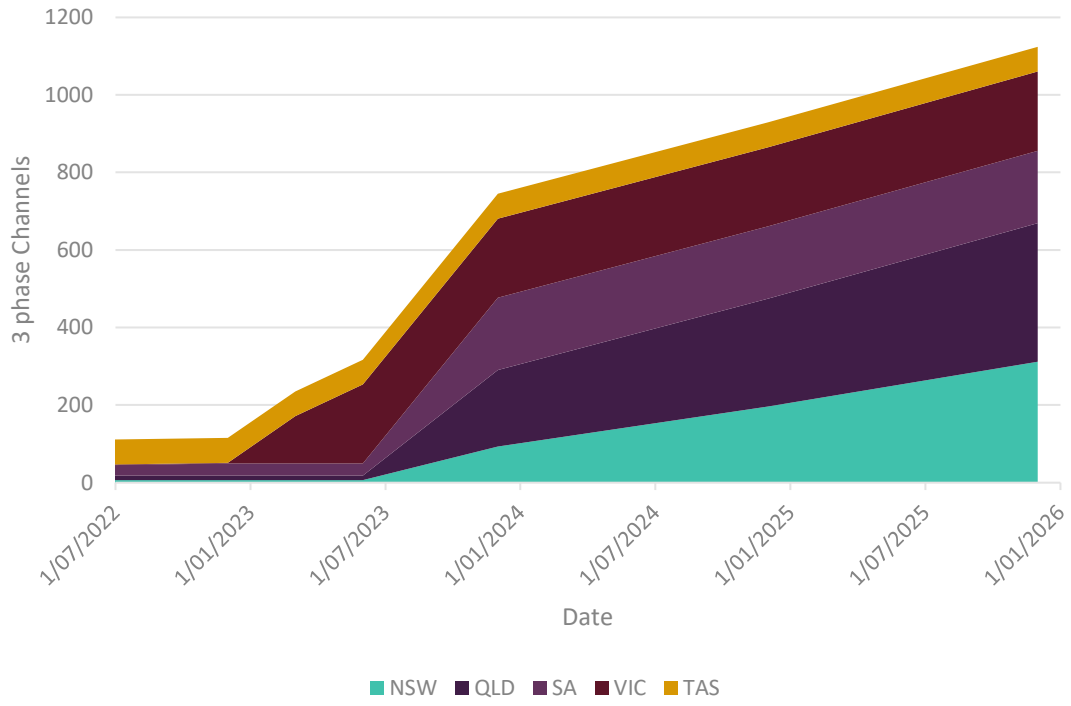
- High resolution data (50 samples per second) is streamed in real-time
- Every sample is time-stamped with a high accuracy GPS clock, meaning measurements from different sites can be accurately compared
- Data can be viewed in real time, or used in on-line analysis
- Data can be stored and easily accessed by AEMO staff

NER Clause 4.11.1(d) and (e)

- (d) Where reasonably necessary to allow AEMO to discharge its market and power system security functions AEMO may, by notice in writing, require a Network Service Provider, a Generator or a Market Network Service Provider to:
  - (1) install remote monitoring equipment which, in AEMO's reasonable opinion, is adequate to enable AEMO to remotely monitor the performance of a transmission system or distribution system, generating unit (including its dynamic performance) or a market network service facility as appropriate; and
  - (2) upgrade, modify or replace any remote monitoring equipment already installed in a facility provided that the existing remote monitoring equipment is, in the reasonable opinion of AEMO, no longer fit for the intended purpose.
- (e) A Network Service Provider, Generator or Market Network Service Provider who receives a notice in accordance with clause 4.11.1(d), must comply with the notice within 120 business days or such further period that AEMO requires.
- Note
  - This paragraph is classified as a tier 3 civil penalty provision under the National Electricity (South Australia) Regulations. (See clause 6(1) and Schedule 1 of the National Electricity (South Australia) Regulations.)

Monitor Installation

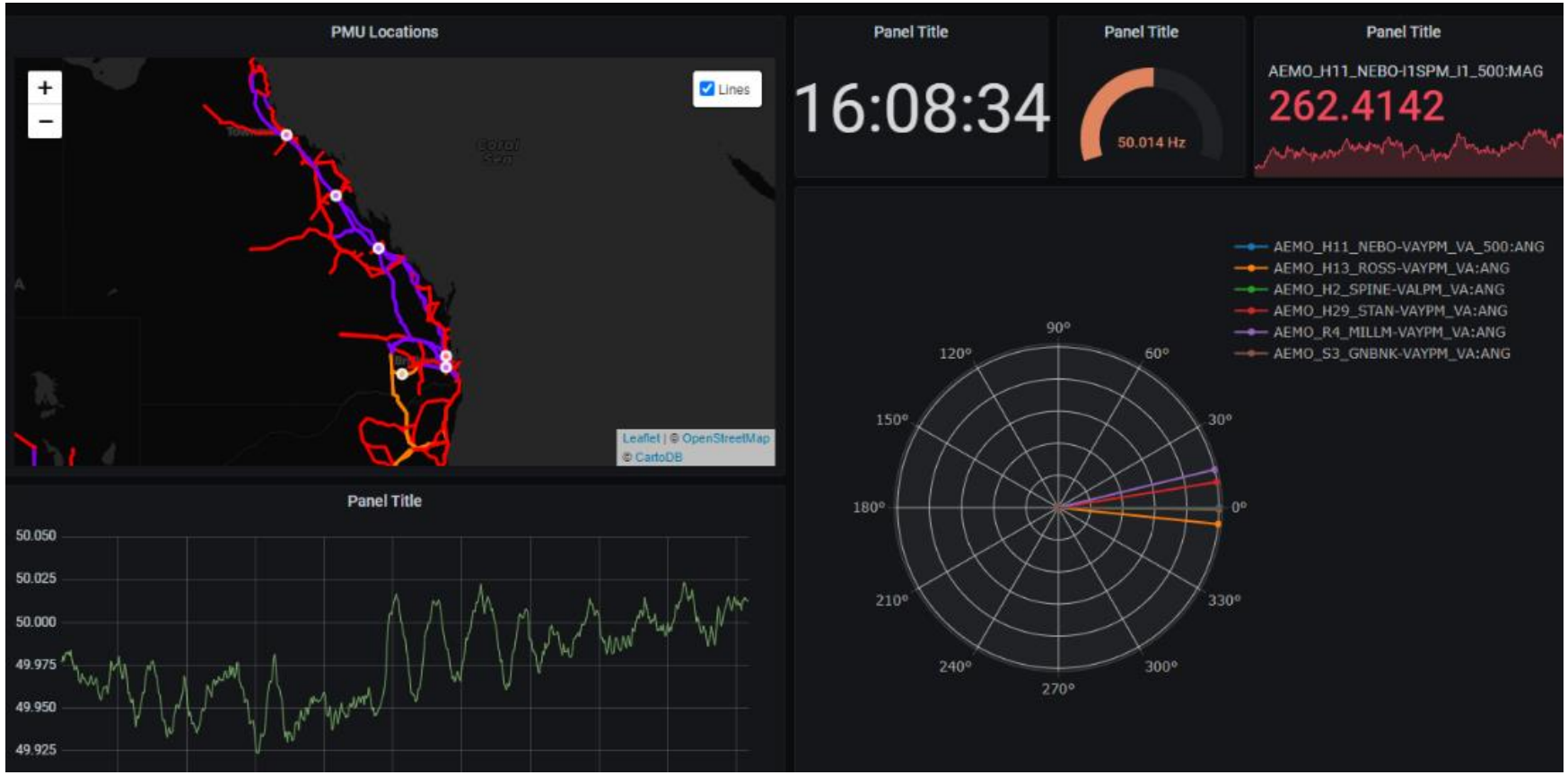
Timeline



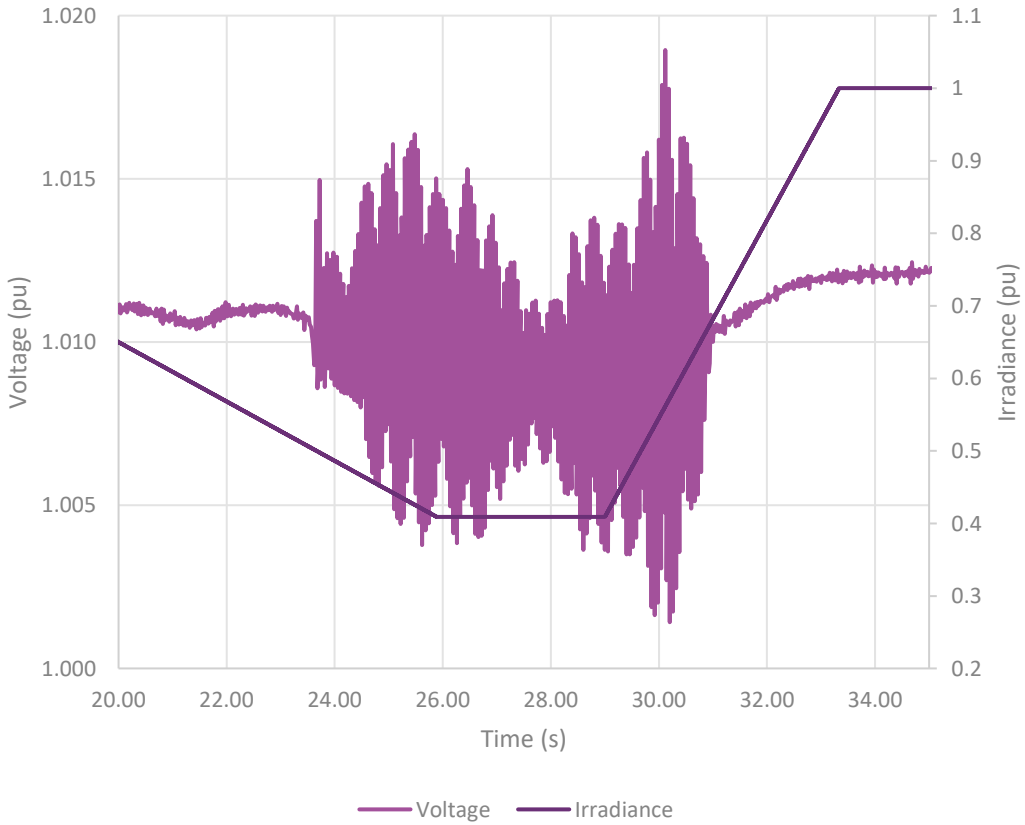
Coverage per region

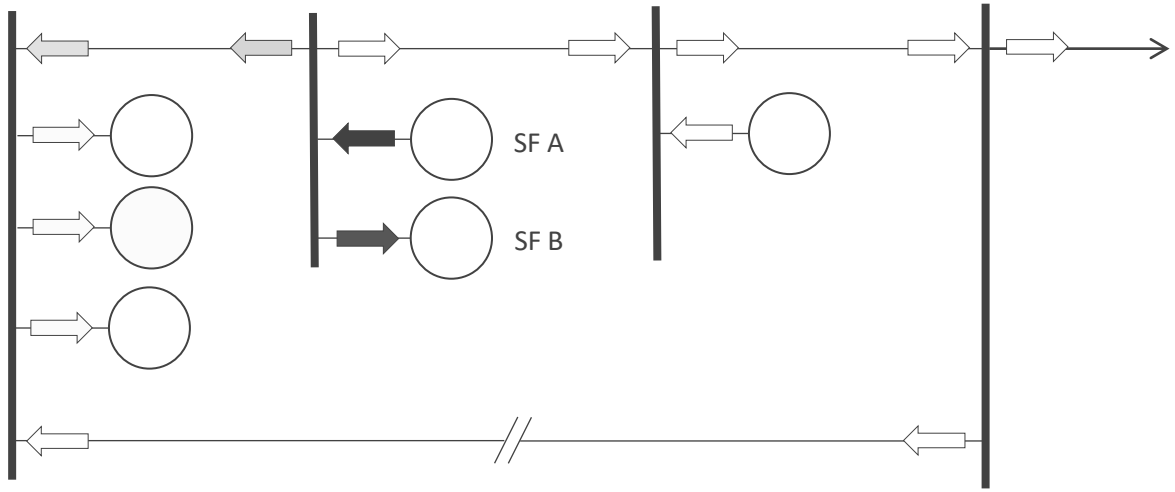
Region	Substations
NSW	45
QLD	57
SA	28
TAS	12
VIC	20
Grand Total	**162**

Next Generation Real-Time Analytics



Future Development: Oscillation Source Location





Challenges

- How do we use the data both offline and online?
- What actions should the control room take?

For more information visit

aemo.com.au