

Power System Modelling to Facilitate Uptake of IBR

AEMO's Experience

James Guest

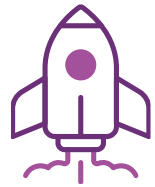


We acknowledge the Traditional Owners of country throughout Australia and recognise their continuing connection to land, waters and culture.

We pay respect to their Elders past, present and emerging.

Agenda

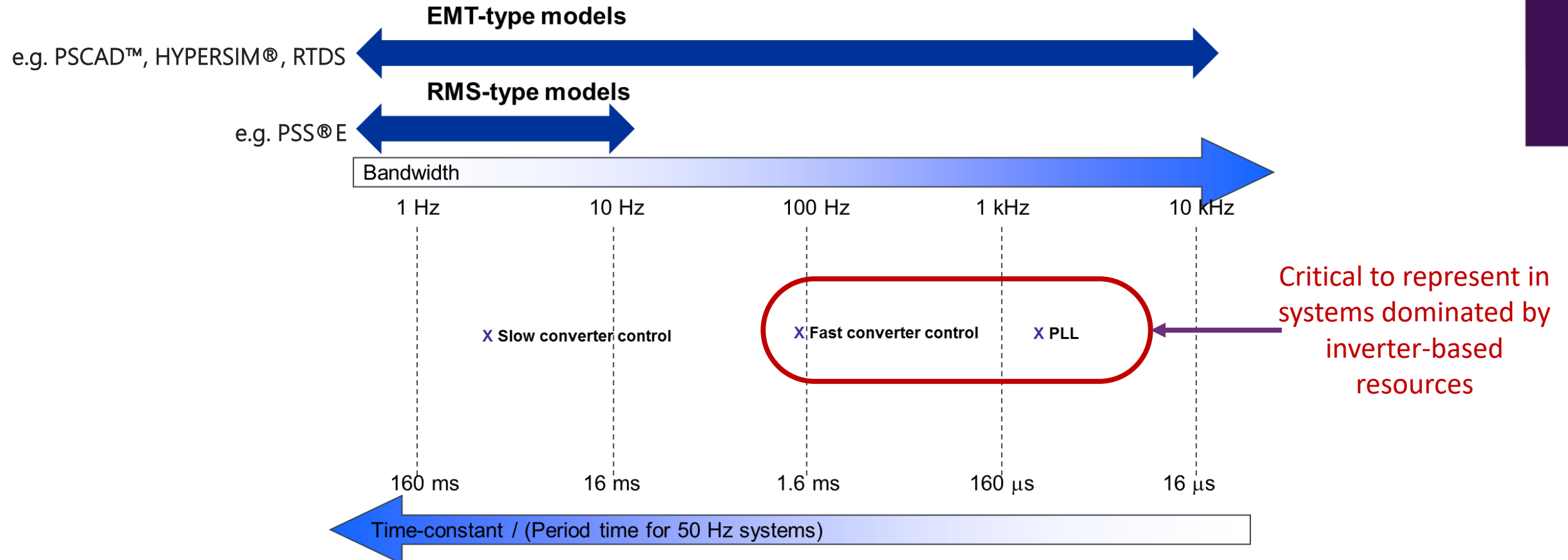
- AEMO's Journey with EMT Modelling
- Model Development
- Applications



AEMO's EMT Journey



Root-mean-Square (RMS) vs Electromagnetic Transient (EMT)



Due to inherent simplifications, RMS models cannot represent components of asynchronous plant that are critical to stability in weak systems

AEMO EMT Journey



Basslink
commutation
failure
investigation

South Australia blacks out.
EMT model of SA
developed for root cause
analysis

Minimum synchronous
generator combinations
developed for SA

EMT model of Victoria used
to re-tune IBR in West
Murray, lifting all system
strength constraints

2015

2016

2017

2018

2019

2020

2021

2022

South Australia system
strength gap identified
and confirmed using
the SA model

EMT models of
Queensland and New
South Wales developed

EMT model of Victoria
developed to manage
system strength during
outages in the West
Murray area

First mainland
interconnected PSCAD
model released, requires
3 servers to run

PSCAD Version 5 case
released with over 135
IBR models, runs on a
single computer

Extensive discussion and collaboration with OEMs, Generators, Participants, Government organisations, rule makers,
number of stakeholders within and outside AEMO

Our PSCAD Version 5 model



The largest EMT model ever developed



150 cases running in parallel



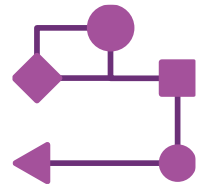
All of the mainland NEM including Basslink



135 *highly detailed* Inverter Based Resource models



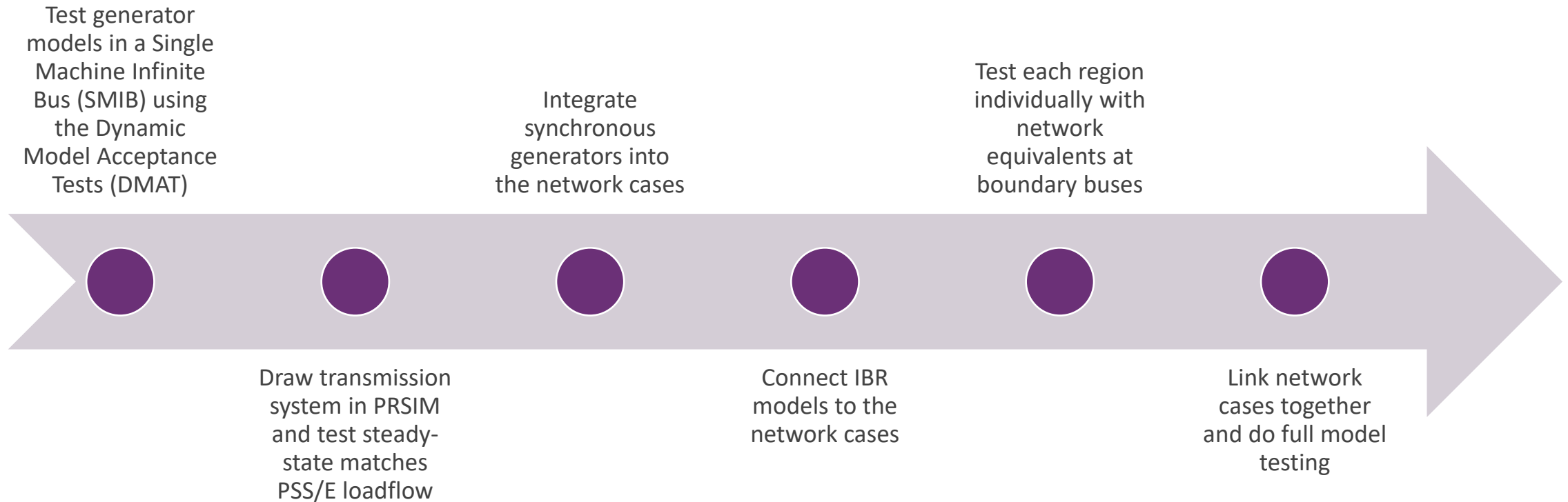
Runs on current hardware in under *2 hours*



Model Development



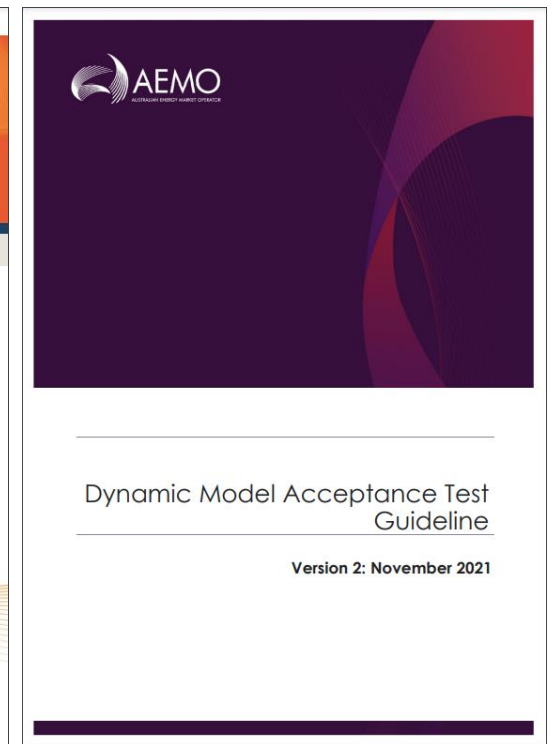
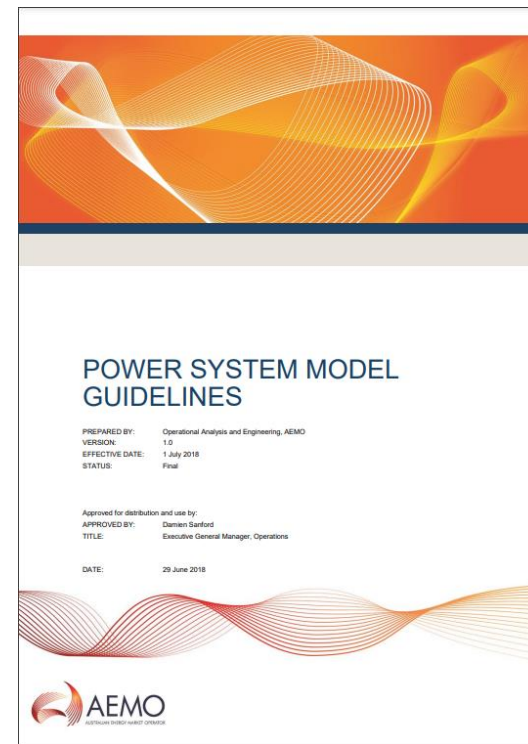
Model Development Process



Model Acceptance and Testing

Power System Model Guidelines is a *legally enforceable* document to ensure model adequacy for new connections, including loadflow and *site specific* RMS and EMT models

Dynamic Model Acceptance Test Guidelines ensure model is robust, accurate and meets AEMO's needs



Model Validation

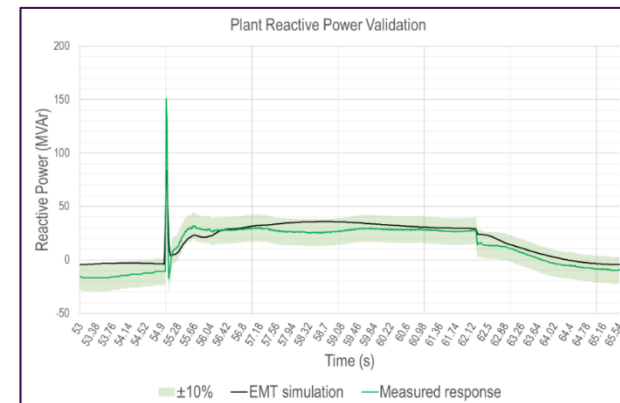
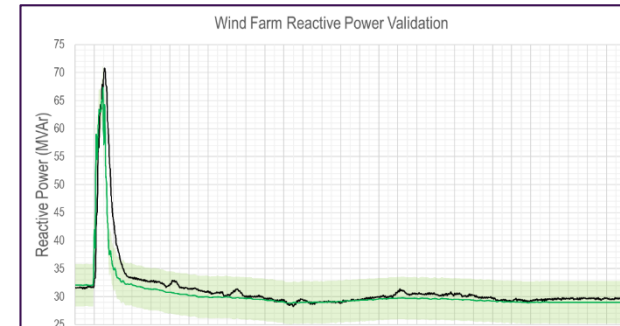
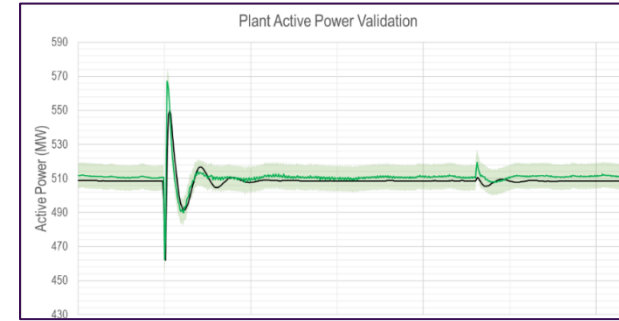
High speed fault recorder data from system events and network testing used for model validation

Individual plant validation

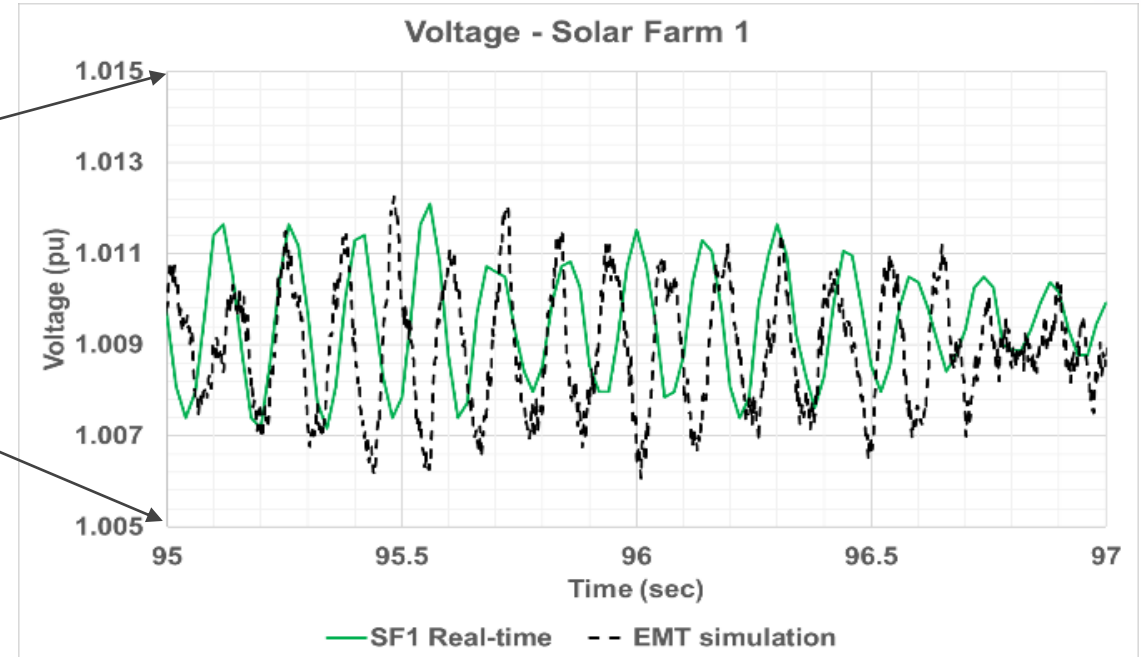
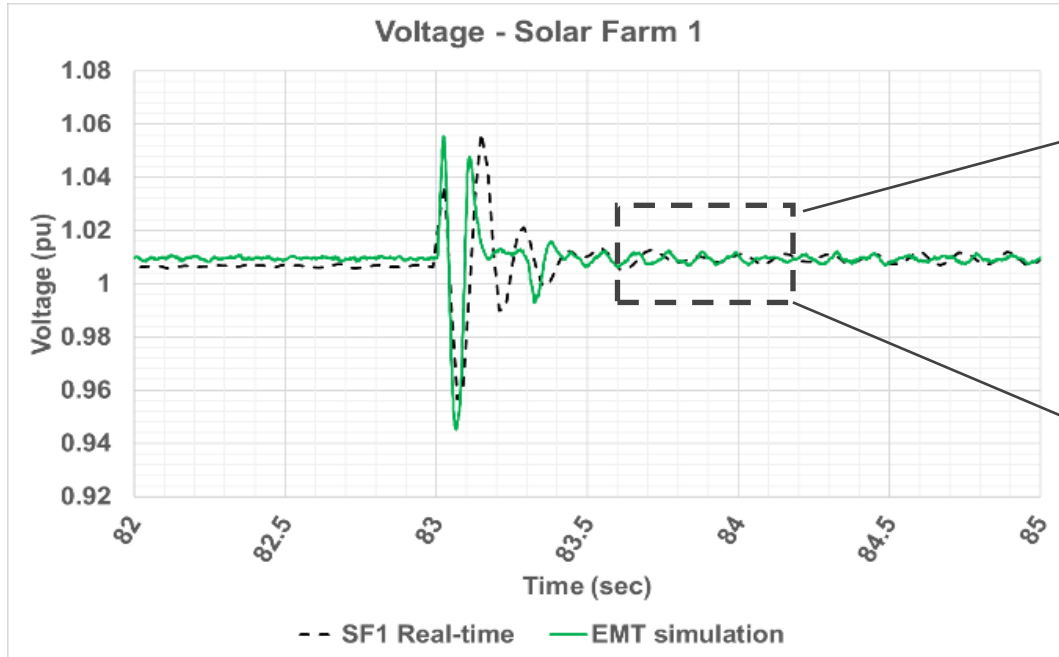
- Single machine, infinite bus setup with playback voltage and phase angle

System wide validation

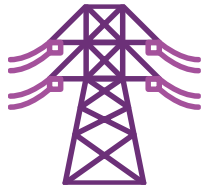
- Replicate a disturbance in PSCAD
- Compare plant responses in PSCAD and system measurements



Validation with Real System Test



Validation using measured data where sub-synchronous voltage oscillations were observed in both simulation and measurement.



Applications

Applications

Operations

- Determine operating envelope of IBR rich areas
- Investigate sub-synchronous oscillations and propose remediation measures
- Support real-time control room during emergency conditions (e.g. SA extended island operation, Queensland load shedding event)

Connections

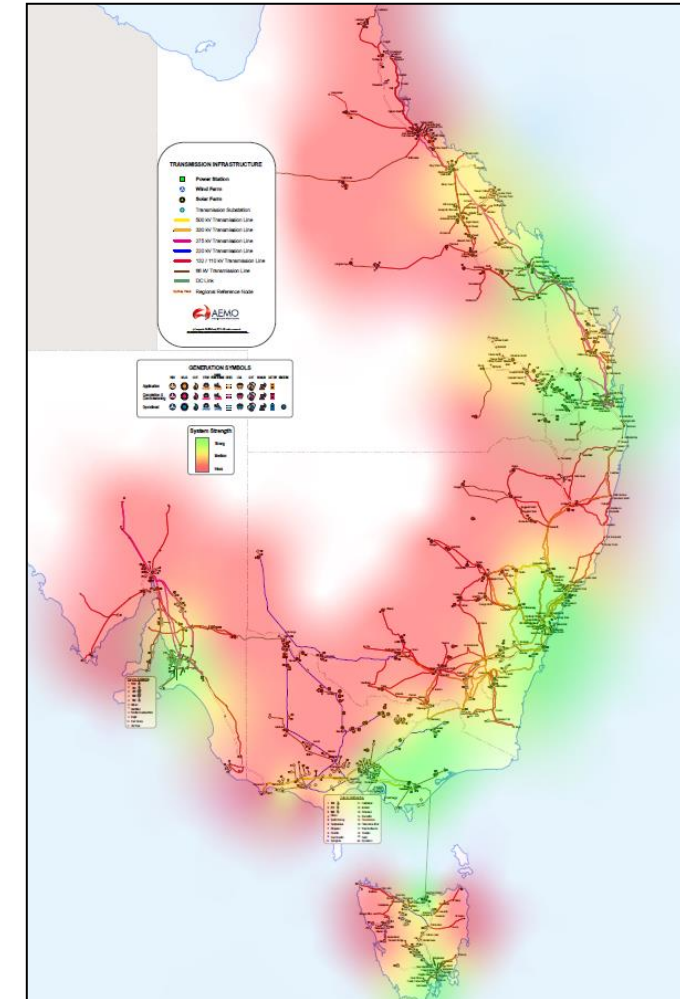
- System strength impact interconnection assessment
- Investigating remedial measures (e.g. run-back schemes, control system tuning)

Planning

- Forward looking system strength requirements
- Assessment of remediation measures (e.g. sizing syncons, control tuning, role of grid-forming inverters etc)
- Inertia requirements

Others

- Design of special protection scheme (SPS/ RAS) for SA



Use Case: West Murray Area

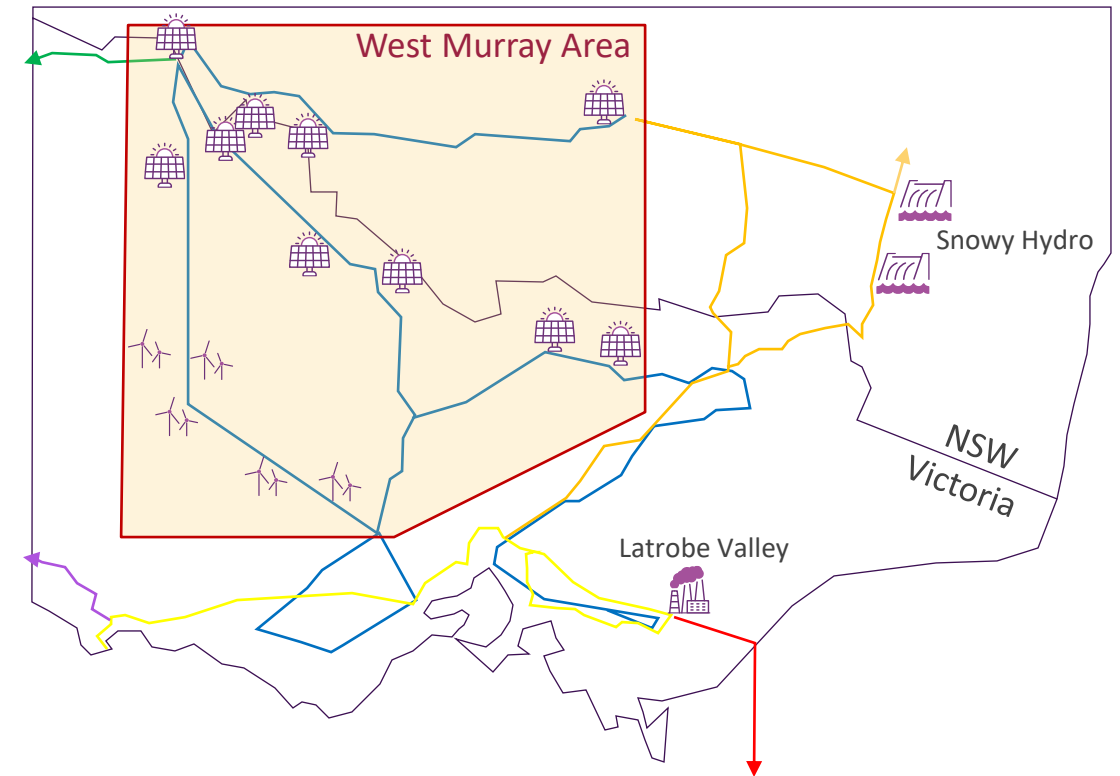
The West Murray area is one of the weakest parts of the NEM

Over 500km away from major synchronous generation

Substations are separated by large distances and very long 220 kV transmission lines

Over 2,000 MW of inverter based resources (IBR) including solar, wind and batteries

AEMO has set a goal to engineer the power system to operate at 100% instantaneous penetration of renewables by 2025

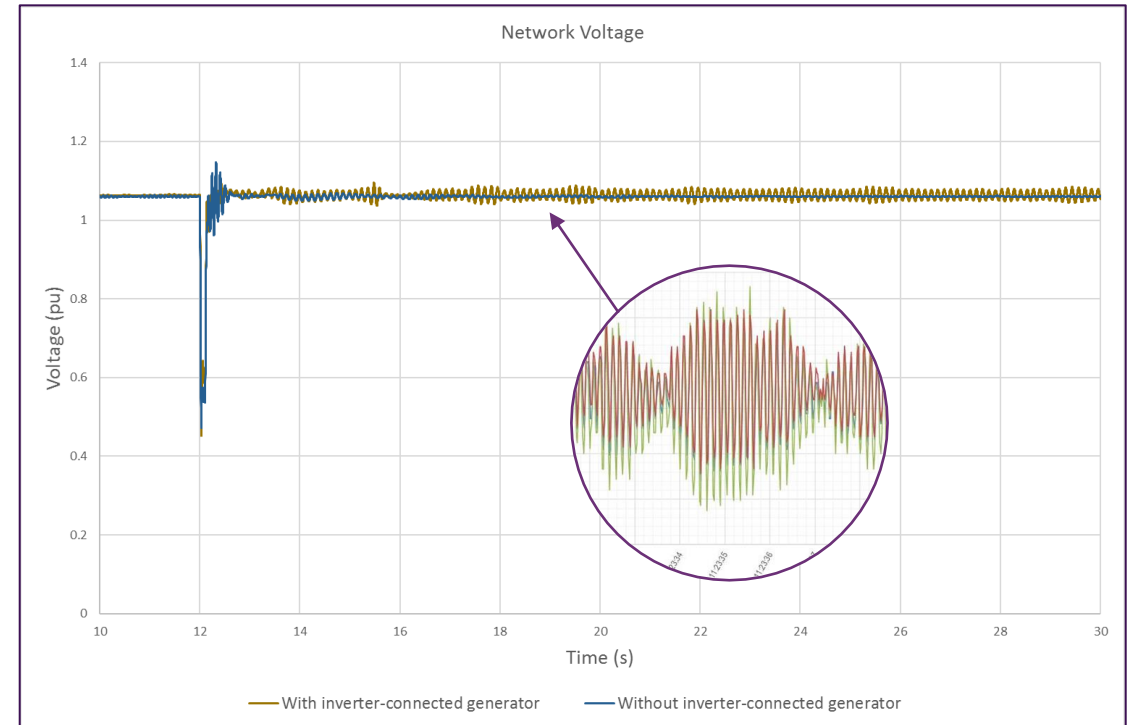


Post Fault Oscillations

Oscillations observed in the West Murray area and confirmed through the wide-area EMT model

Oscillations are unacceptable due to:

- Breach of system security and flicker requirements
- Impact on load/connected equipment



Mitigating Measures

Temporary constraints

- EMT models show constraints on number of inverters or turbines online can mitigate the issue
- Used as a temporary measure, or for planned or unplanned outages

Inverter Control System Tuning

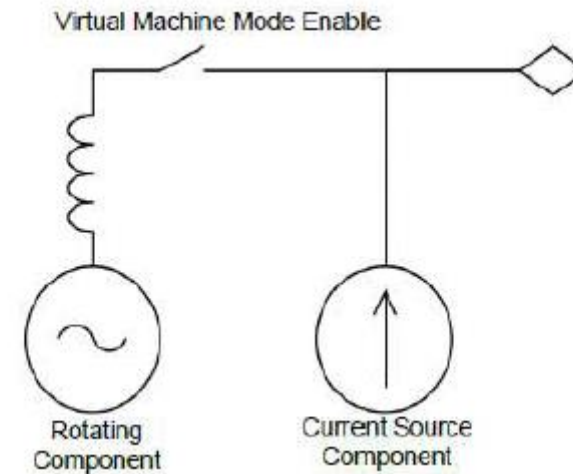
- A wide-area EMT model was used to develop tuned parameters for contributing IBRs in the area and confirm satisfactory performance

Installation of nearby synchronous machines

- The Wide-area EMT model was used to optimally design and locate 4 synchronous condensers in the South Australia network to improve system strength

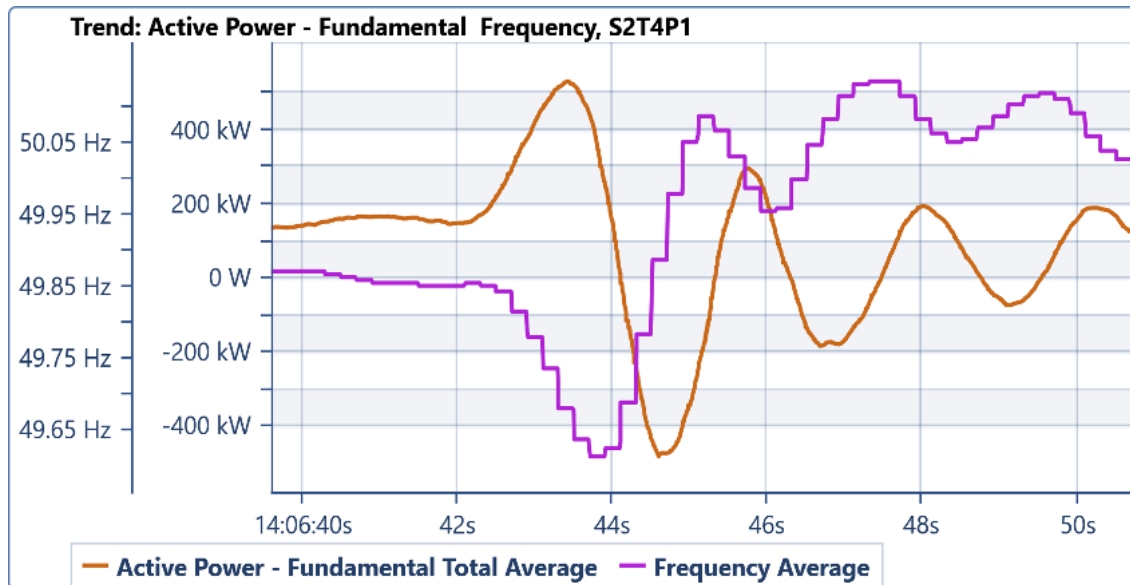
Use Case: Grid Forming Model Validation

- Hornsdale Power Reserve in South Australia
- 150 MW / 193.5 MWh
- Virtual Machine Mode (VMM) - Mimicking synchronous machine
- During steady state
 - Response dominated by current source component
- During disturbance
 - MW response proportion to the rate of change of frequency (RoCoF)
 - MVAr response in response to change in voltage

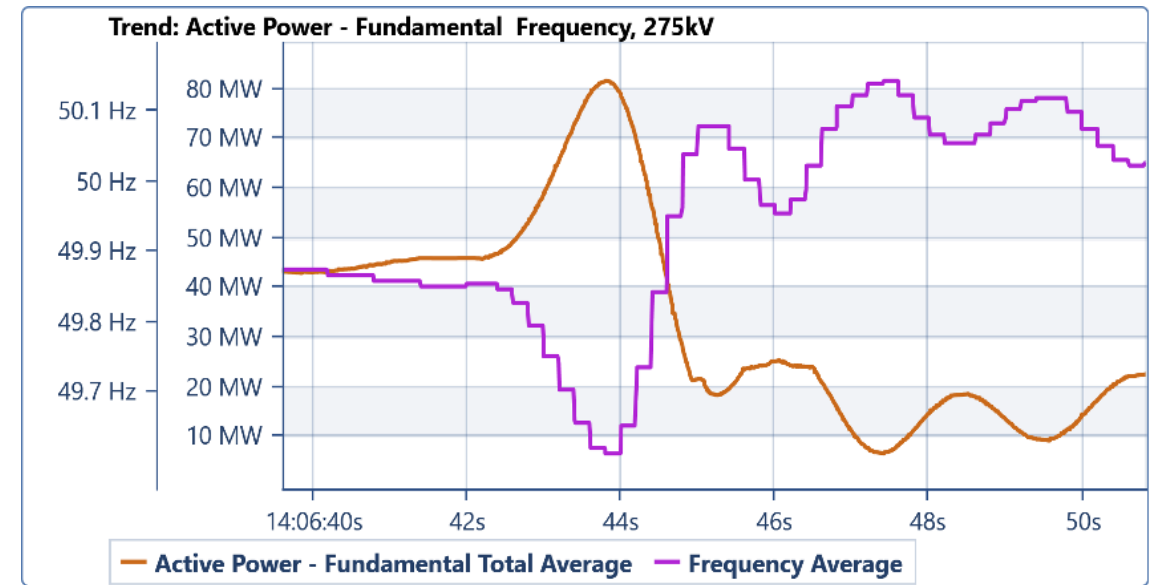


Response to an Event

- Two inverter trial at Hornsdale Power Reserve
 - H = 5s and 50s trial
- Response is largely driven by the rate of change of frequency
- Maximum MW at max/min frequency vs max RoCoF



Inverter Response (in VMM)



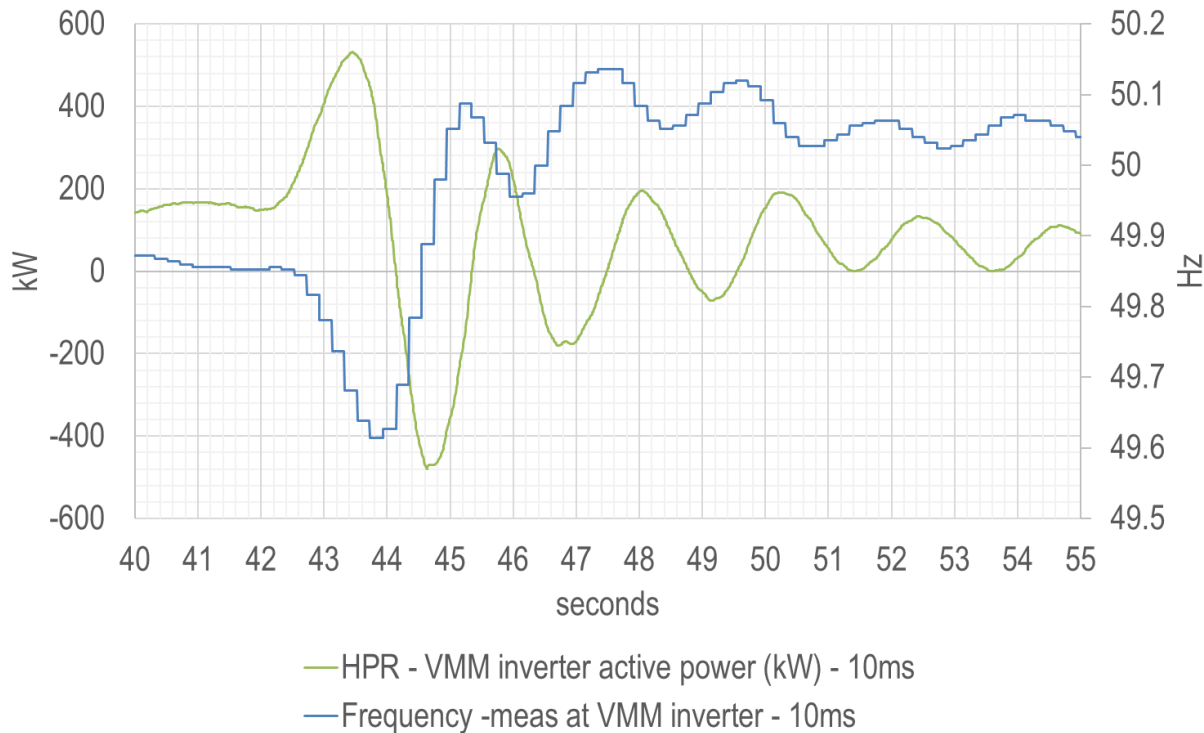
Site Response

Source : Tesla

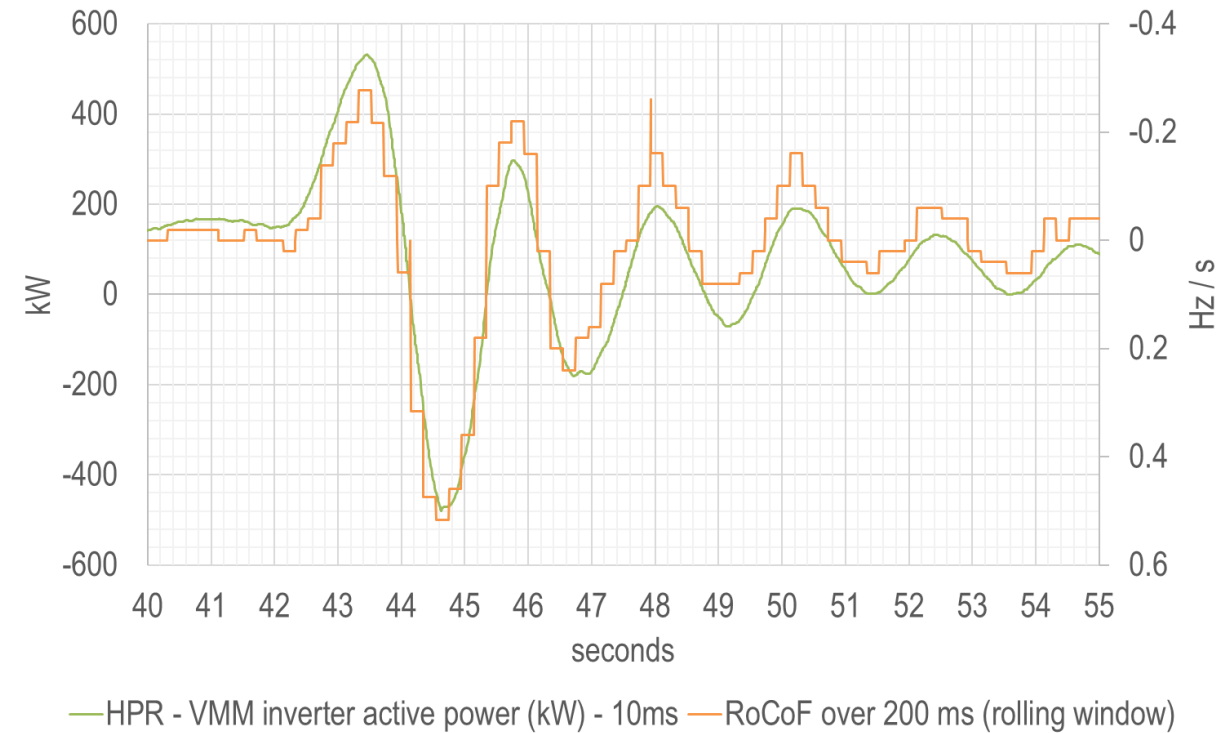
Response to an Event

- VMM inverter response during a real-time event

HPR - one inverter in VSM mode - 25/05/2021



HPR - one inverter in VSM mode - 25/05/2021



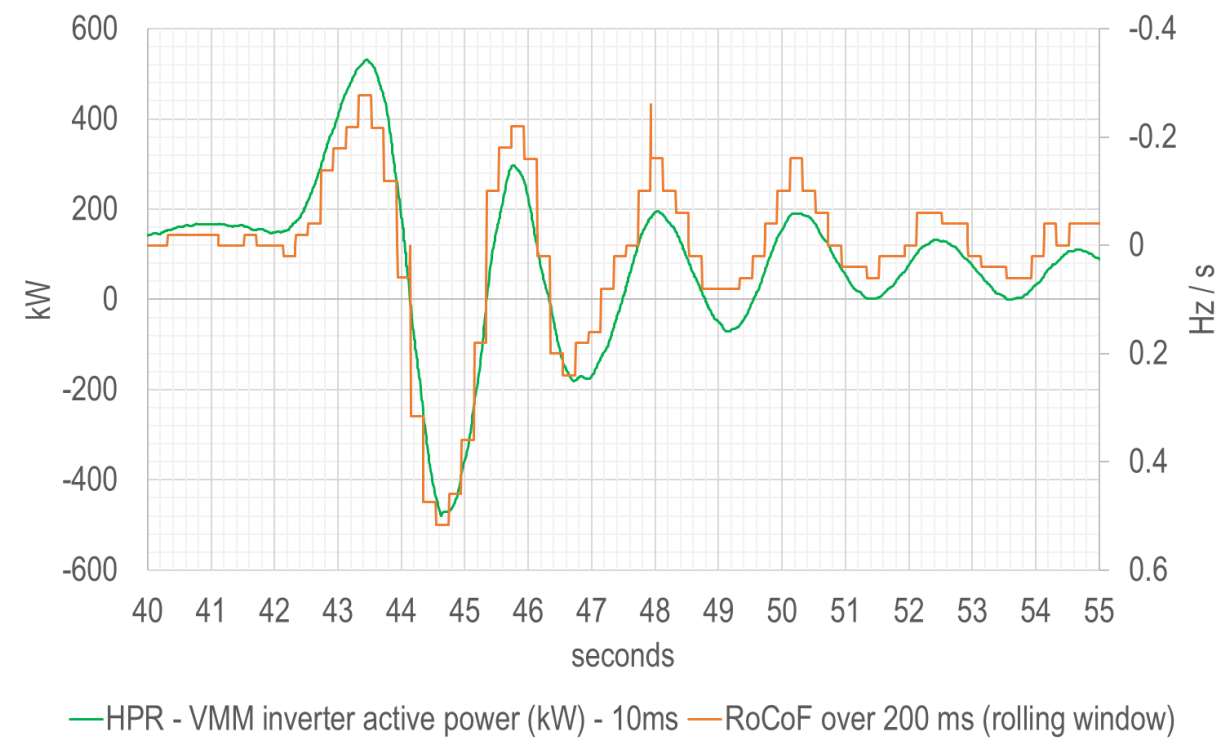
Synchronous machine vs Virtual Machine Mode

- An example comparison

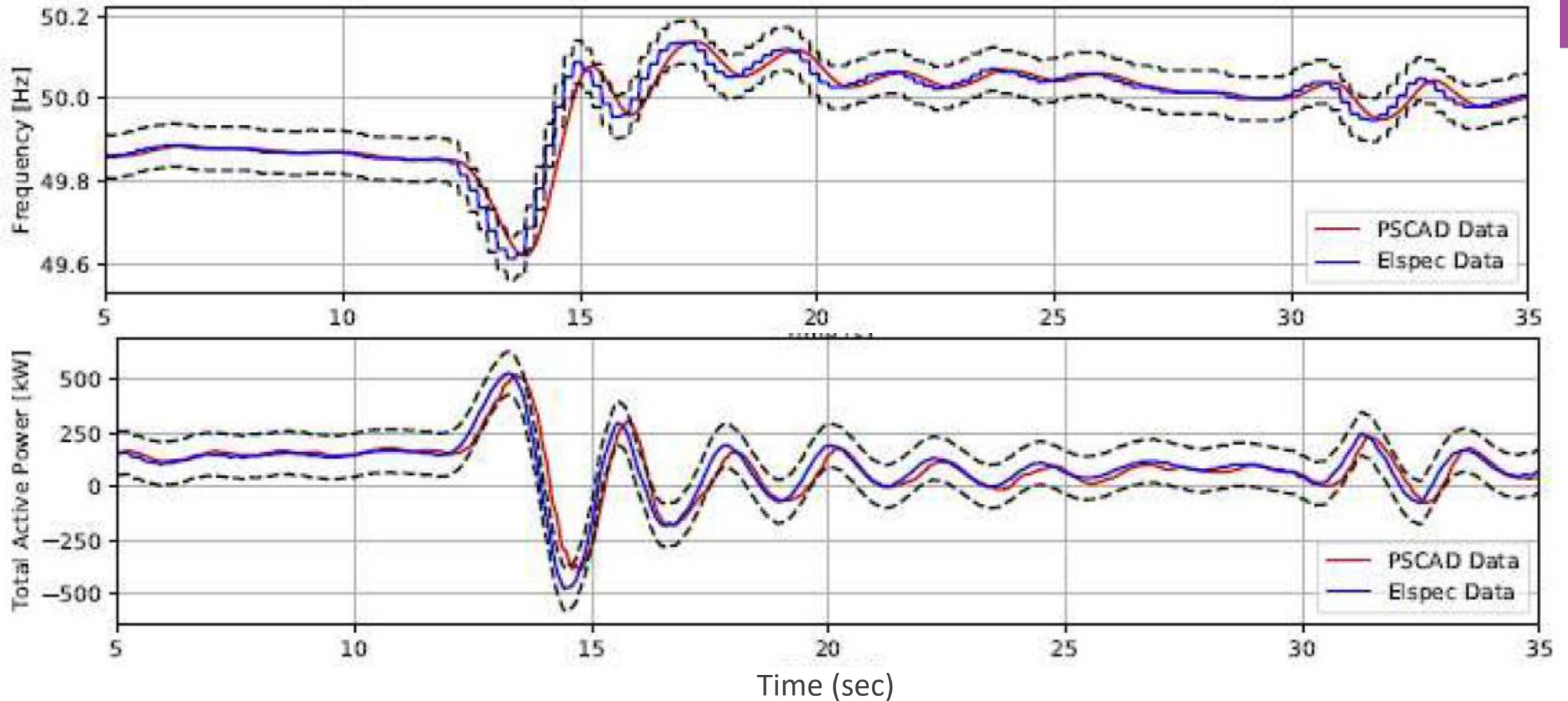
Synchronous Machine - 25 May 2021



HPR - one inverter in VSM mode - 25/05/2021



Validation of the Model





For more information visit

aemo.com.au