AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

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.

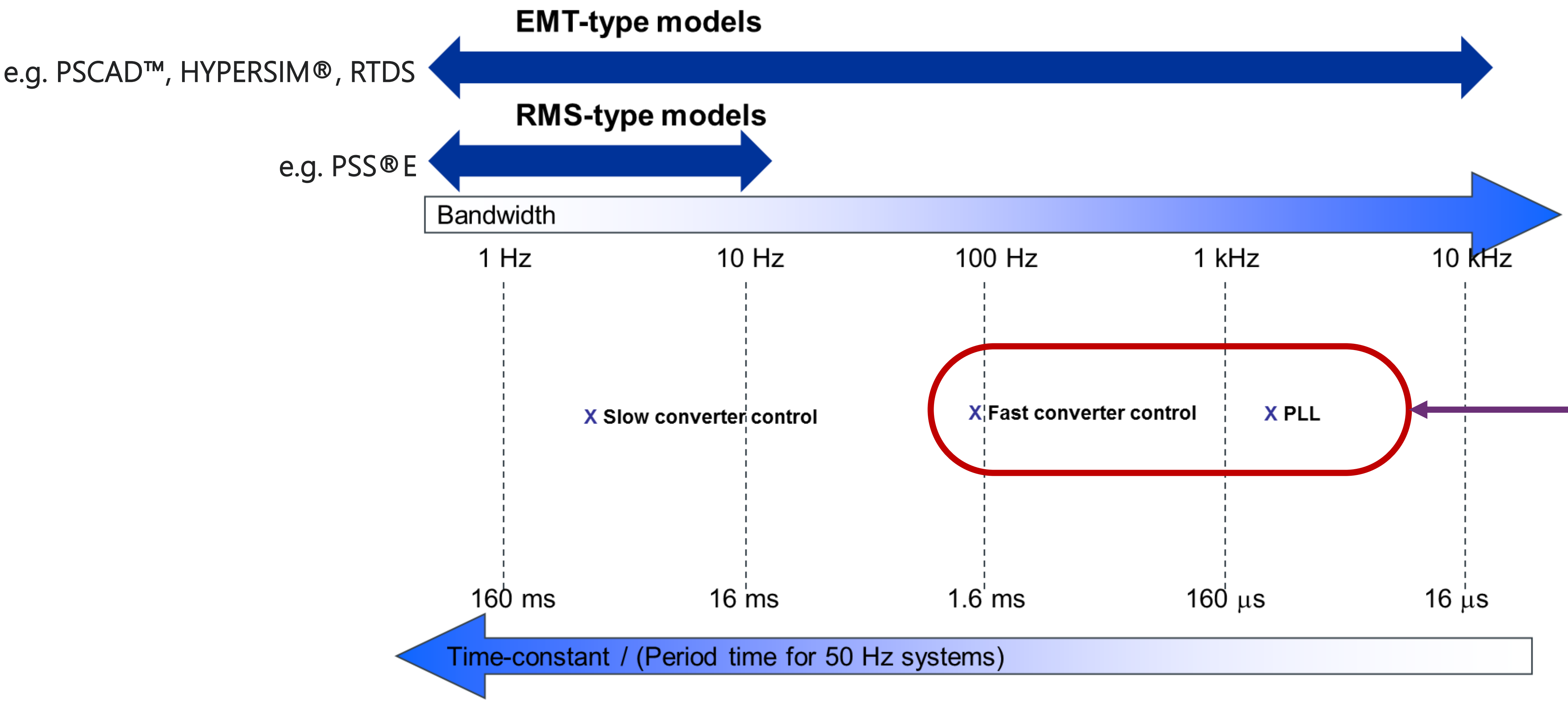
We pay respect to their Elders past, present and emerging.

Agenda

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

AEMO’s EMT Journey

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



Critical to represent in systems dominated by inverter-based resources

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

AEMO EMT Journey

- **2015**: Basslink commutation failure investigation
- **2016**: South Australia blacks out. EMT model of SA developed for root cause analysis
- **2016–2017**: South Australia system strength gap identified and confirmed using the SA model
- **2017**: Minimum synchronous generator combinations developed for SA
- **2018**: EMT models of Queensland and New South Wales developed
- **2018**: EMT model of Victoria developed to manage system strength during outages in the West Murray area
- **2019**: EMT model of Victoria used to re-tune IBR in West Murray, lifting all system strength constraints
- **2020**: First mainland interconnected PSCAD model released, requires 3 servers to run
- **2022**: 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

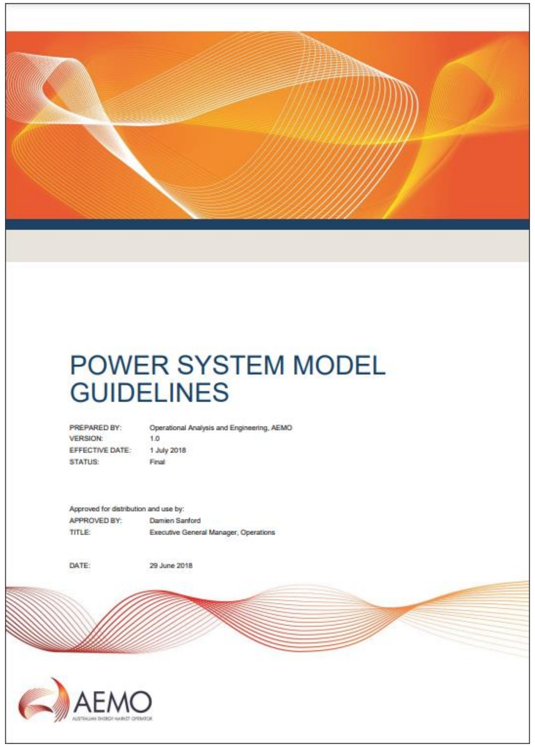
Model Development Process

1. Test generator models in a Single Machine Infinite Bus (SMIB) using the Dynamic Model Acceptance Tests (DMAT)
2. Draw transmission system in PRSIM and test steady-state matches PSS/E loadflow
3. Integrate synchronous generators into the network cases
4. Connect IBR models to the network cases
5. Test each region individually with network equivalents at boundary buses
6. Link network cases together and do full model testing

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



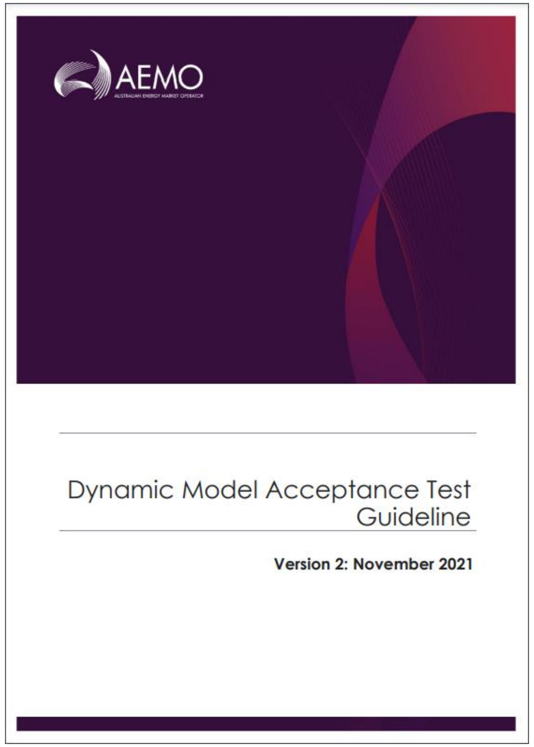
POWER SYSTEM MODEL GUIDELINES

PREPARED BY: Operational Analysis and Engineering, AEMO
VERSION: 1.0
EFFECTIVE DATE: 1 July 2018
STATUS: Final

Approved for distribution and use by:
APPROVED BY: Damien Sanford
TITLE: Executive General Manager, Operations

DATE: 29 June 2018

AEMO



AEMO

Dynamic Model Acceptance Test Guideline

Version 2: November 2021

Model Validation

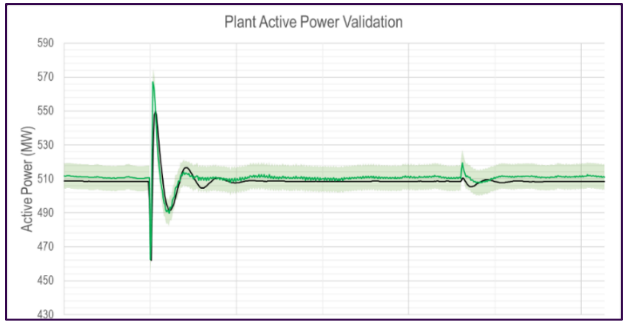
High speed fault recorder data from system events and network testing used for model validation

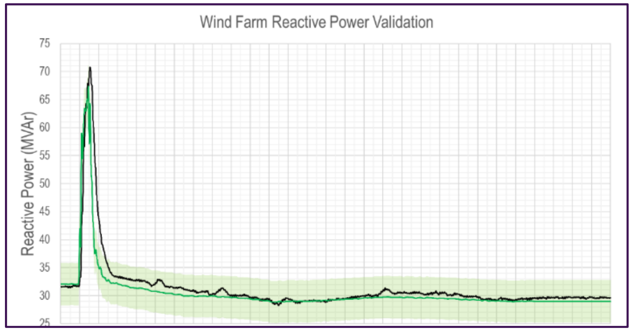
Individual plant validation

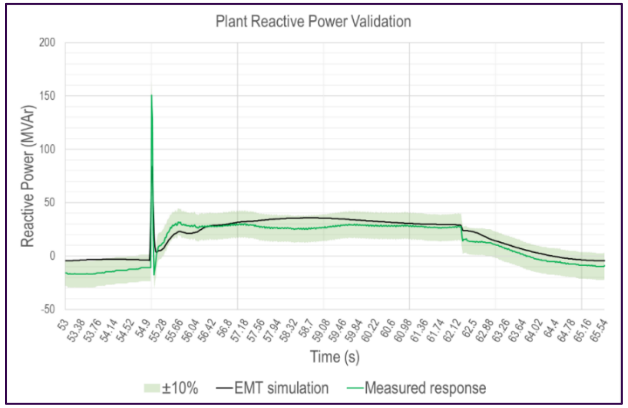
- Single machine, infinite bus setup with playback voltage and phase angle

System wide validation

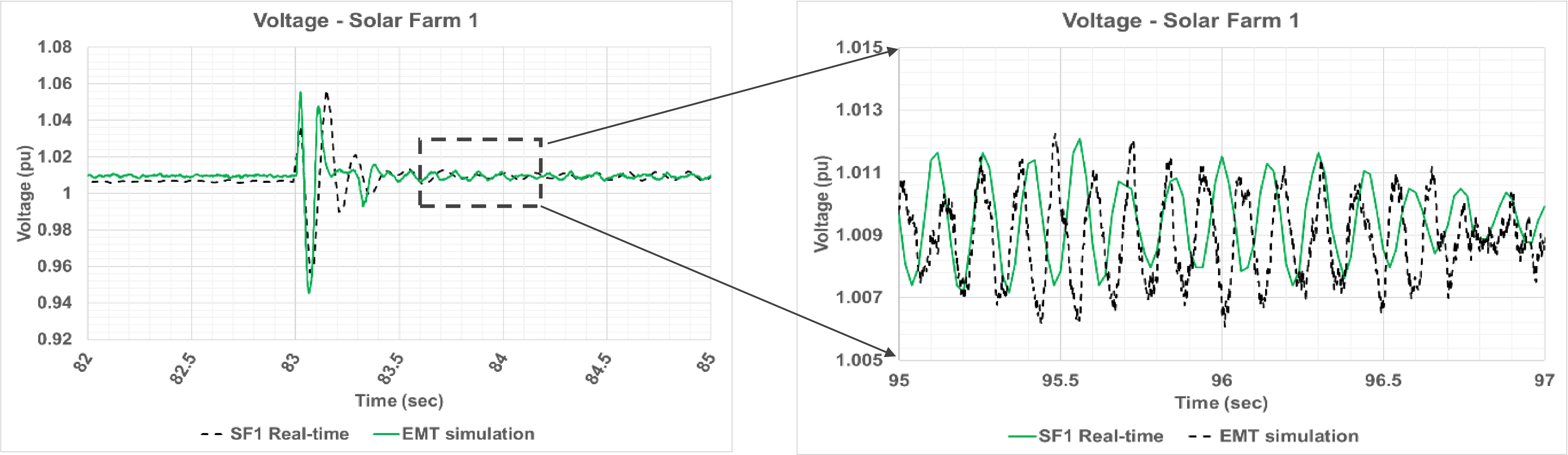
- Replicate a disturbance in PSCAD
- Compare plant responses in PSCAD and system measurements







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

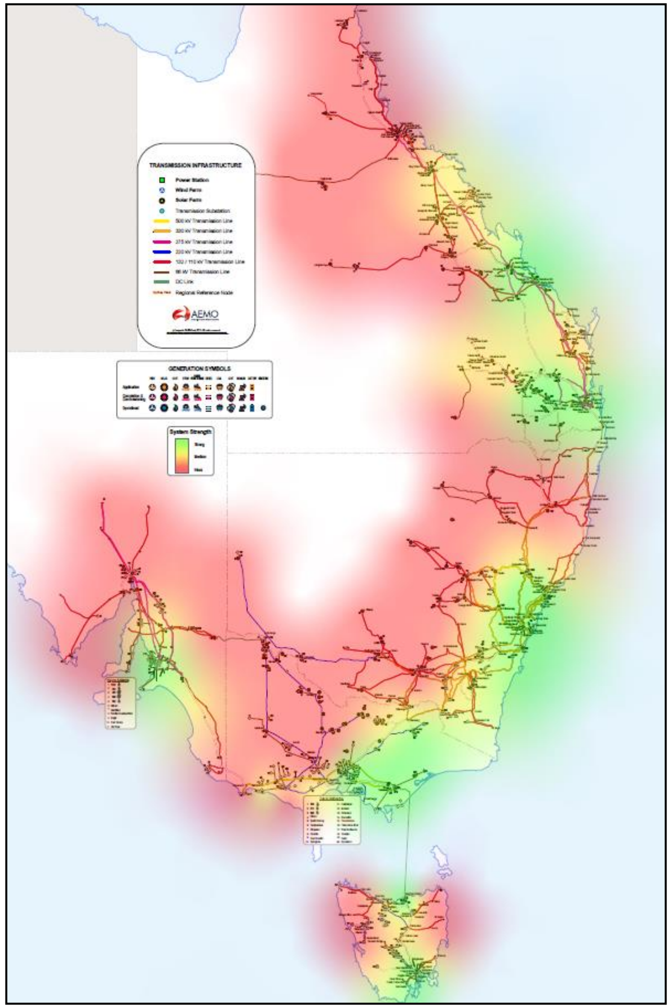
- System strength impact interconnection assessment
- Investigating remedial measures (e.g. run-back schemes, control system tuning)

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

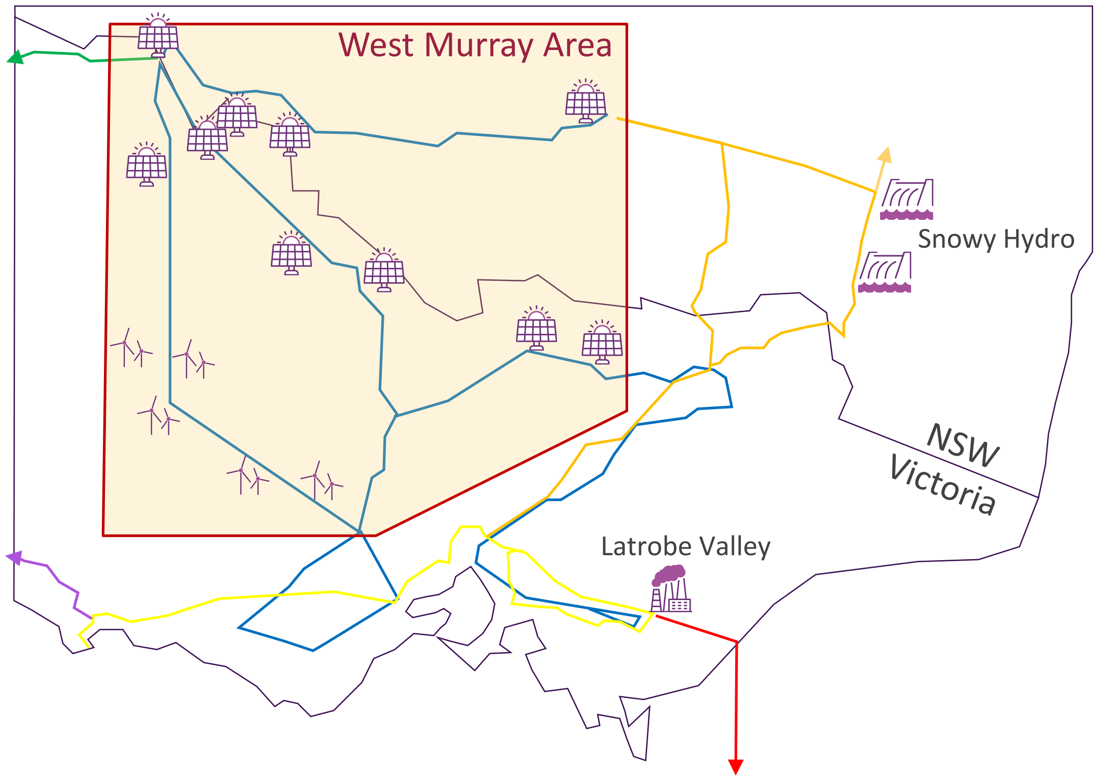
The West Murray area is one of the weakest parts of the NEM

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

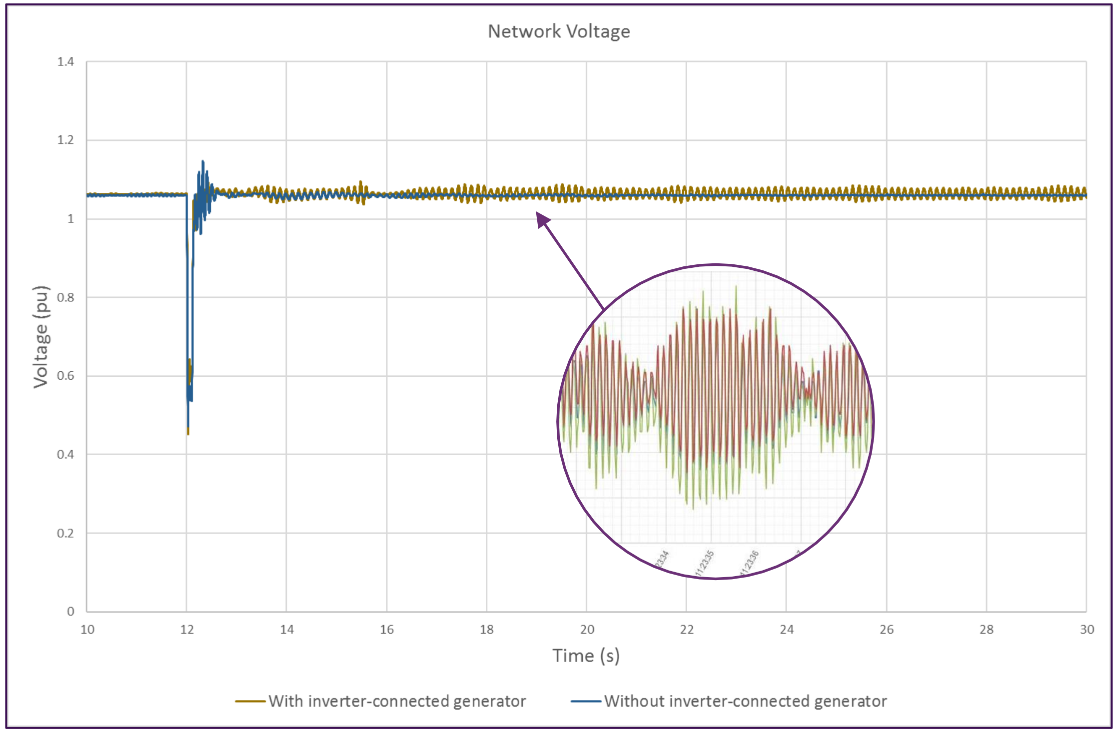


Post Fault Oscillations

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

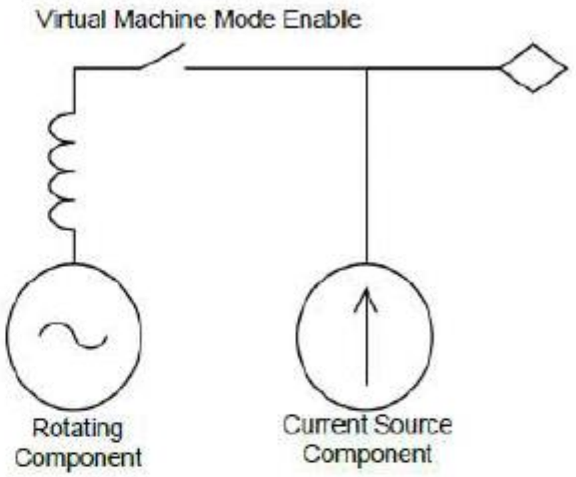
- A wide-area EMT model was used to develop tuned parameters for contributing IBRs in the area and confirm satisfactory performance

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

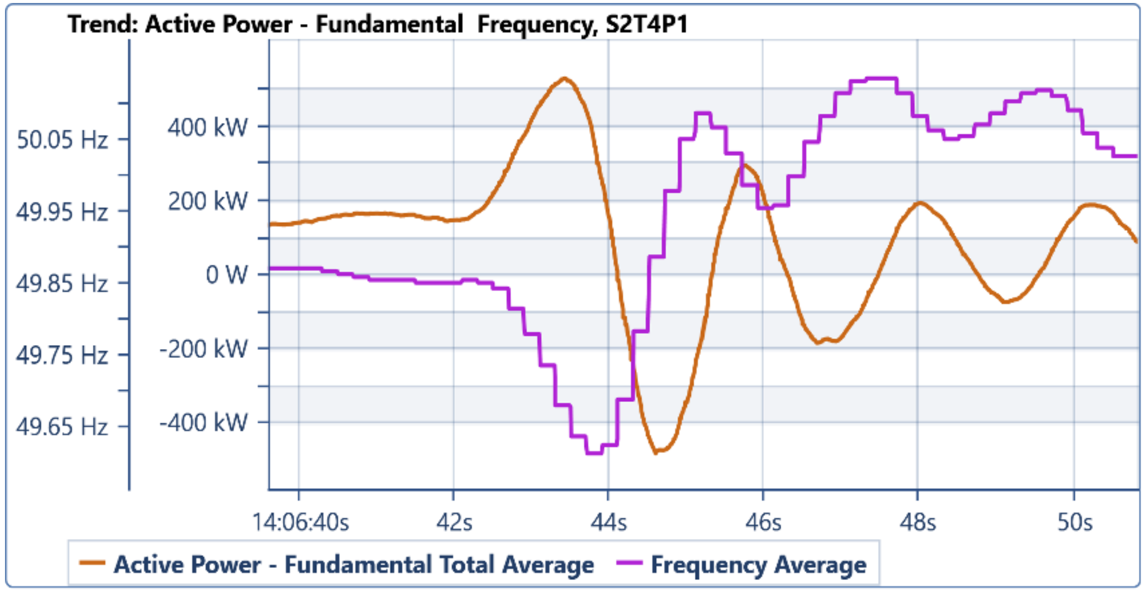
Use Case: Grid Forming Model Validation

- 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

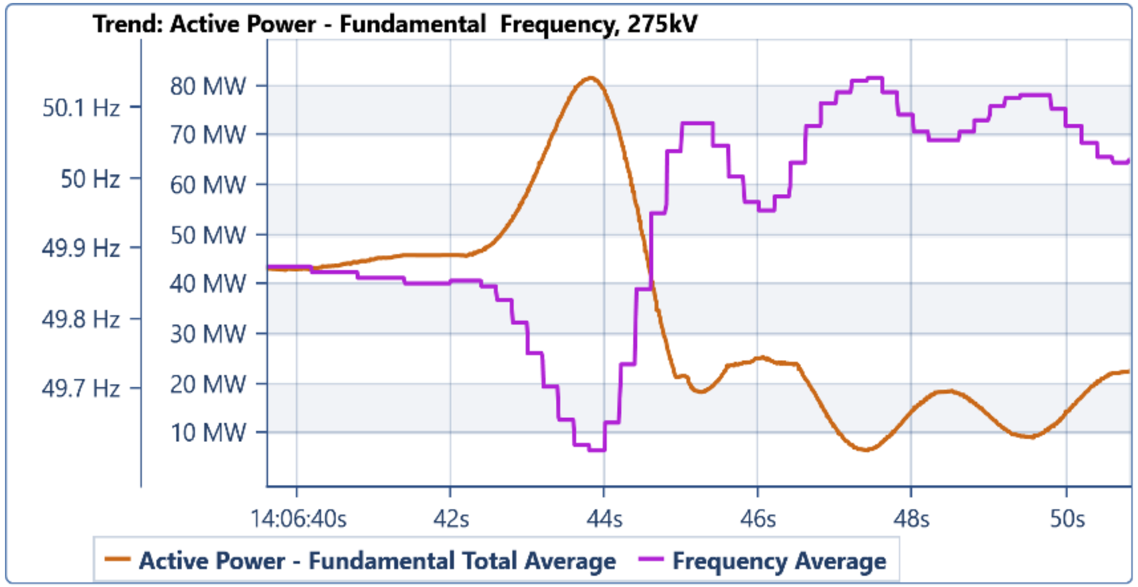


Response to an Event

- 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)

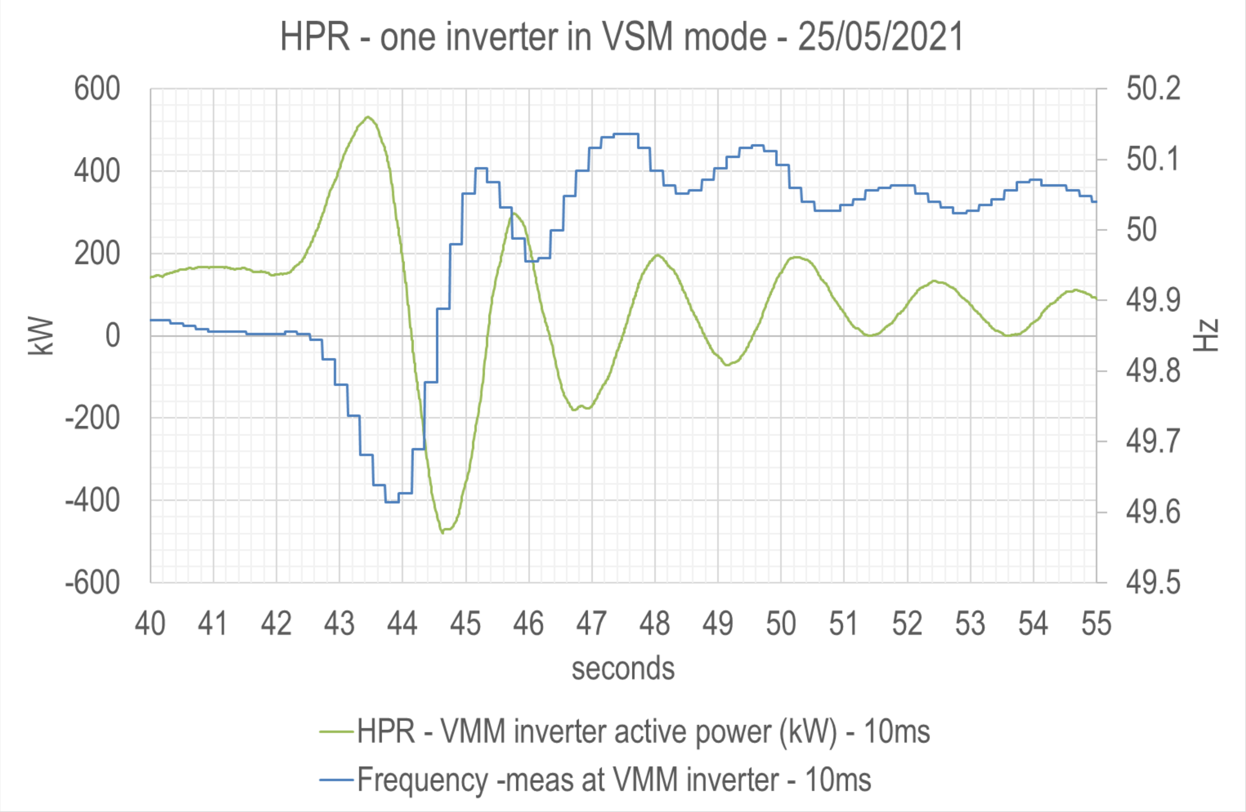


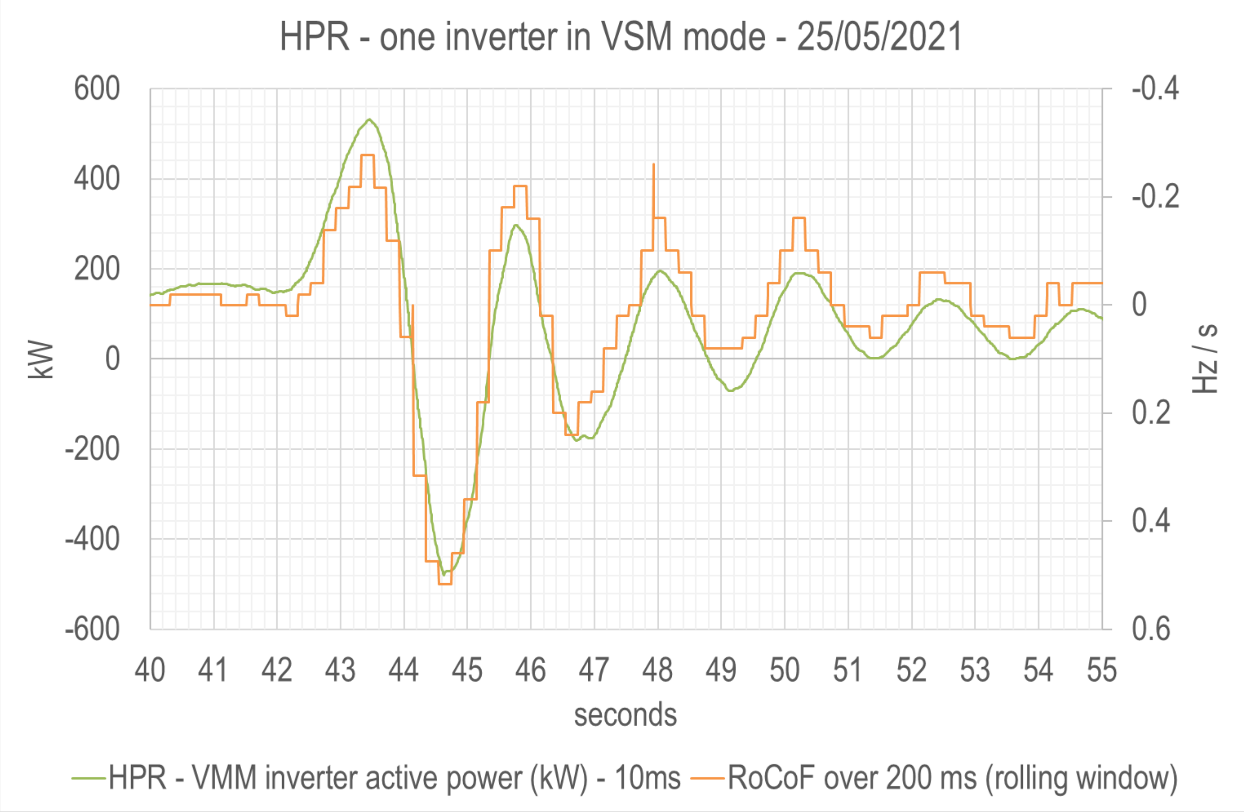
Site Response

Source : Tesla

Response to an Event

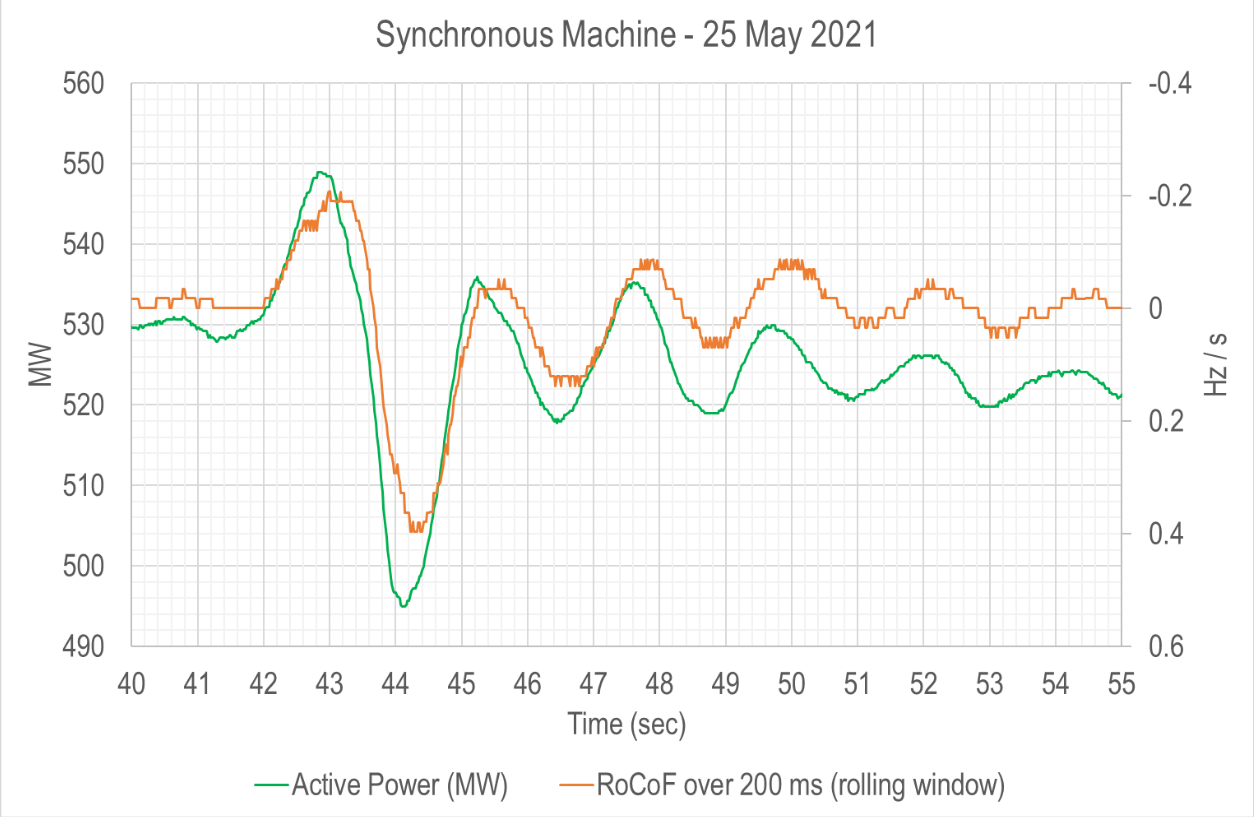
- VMM inverter response during a real-time event

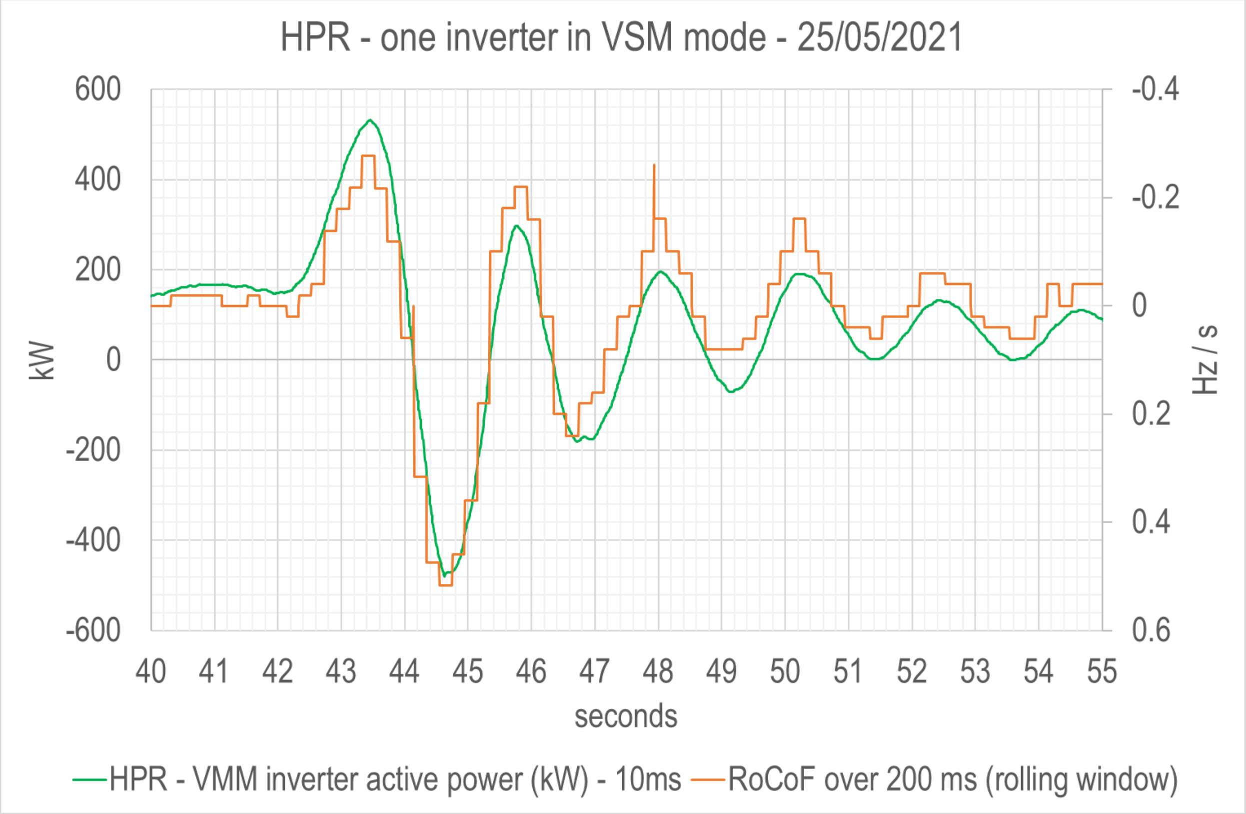




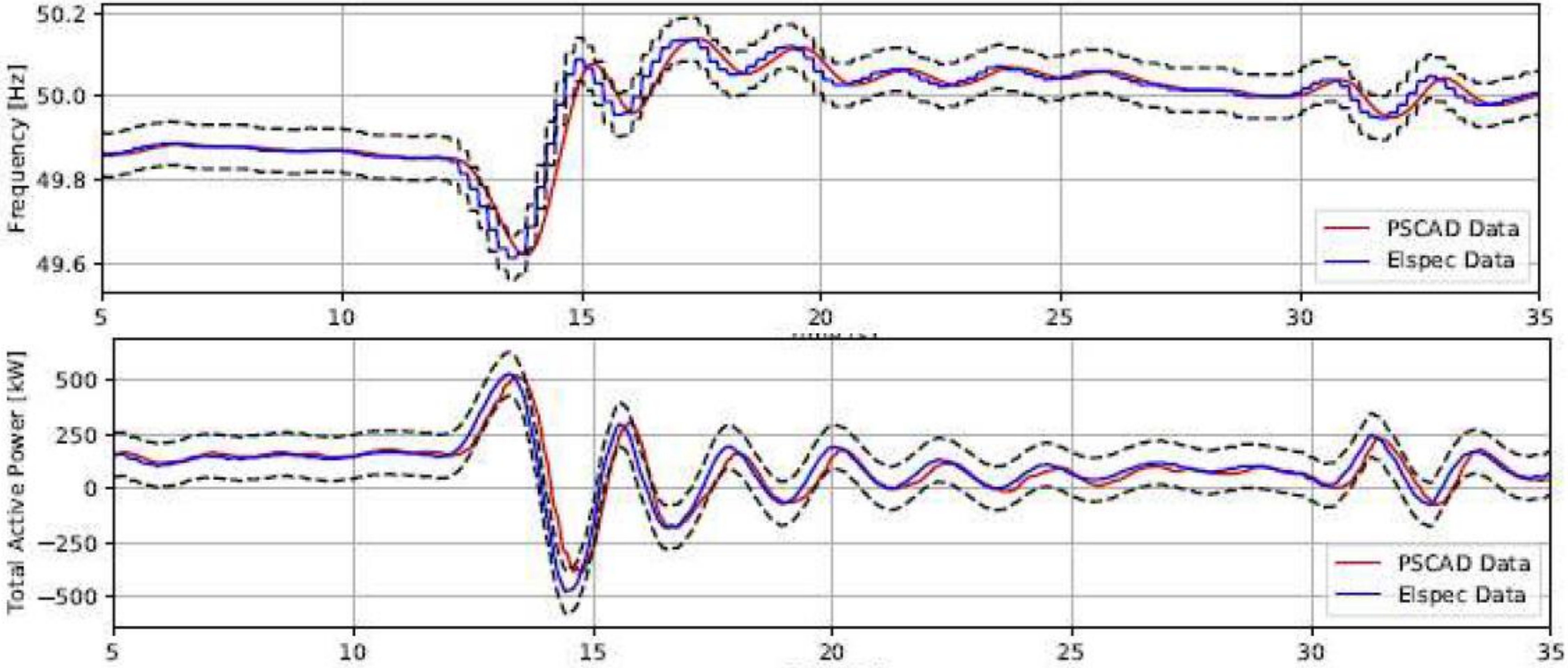
Synchronous machine vs Virtual Machine Mode

- An example comparison





Validation of the Model



Time (sec)

Source: Tesla

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

For more information visit

aemo.com.au