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Australian Experience with EMT Applications to Power System Modelling

Australian Energy Market Operator (AEMO's experience)

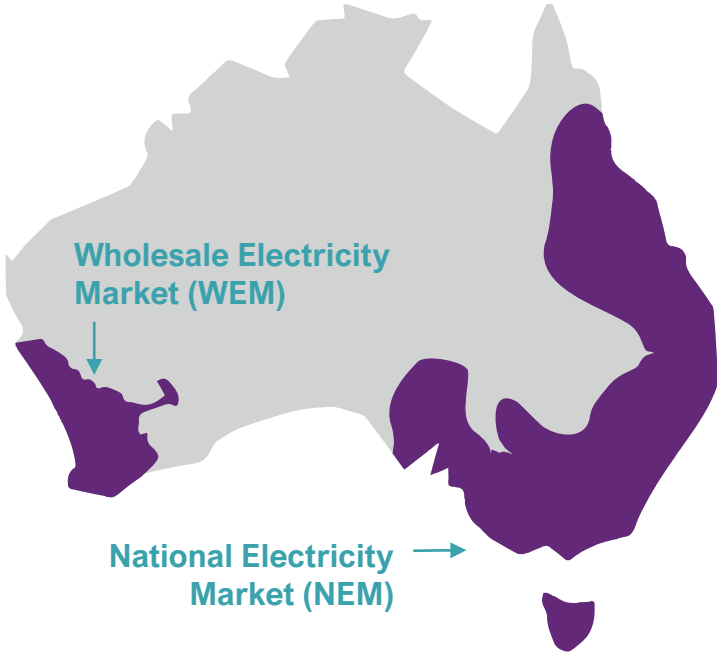
ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

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.

Electricity



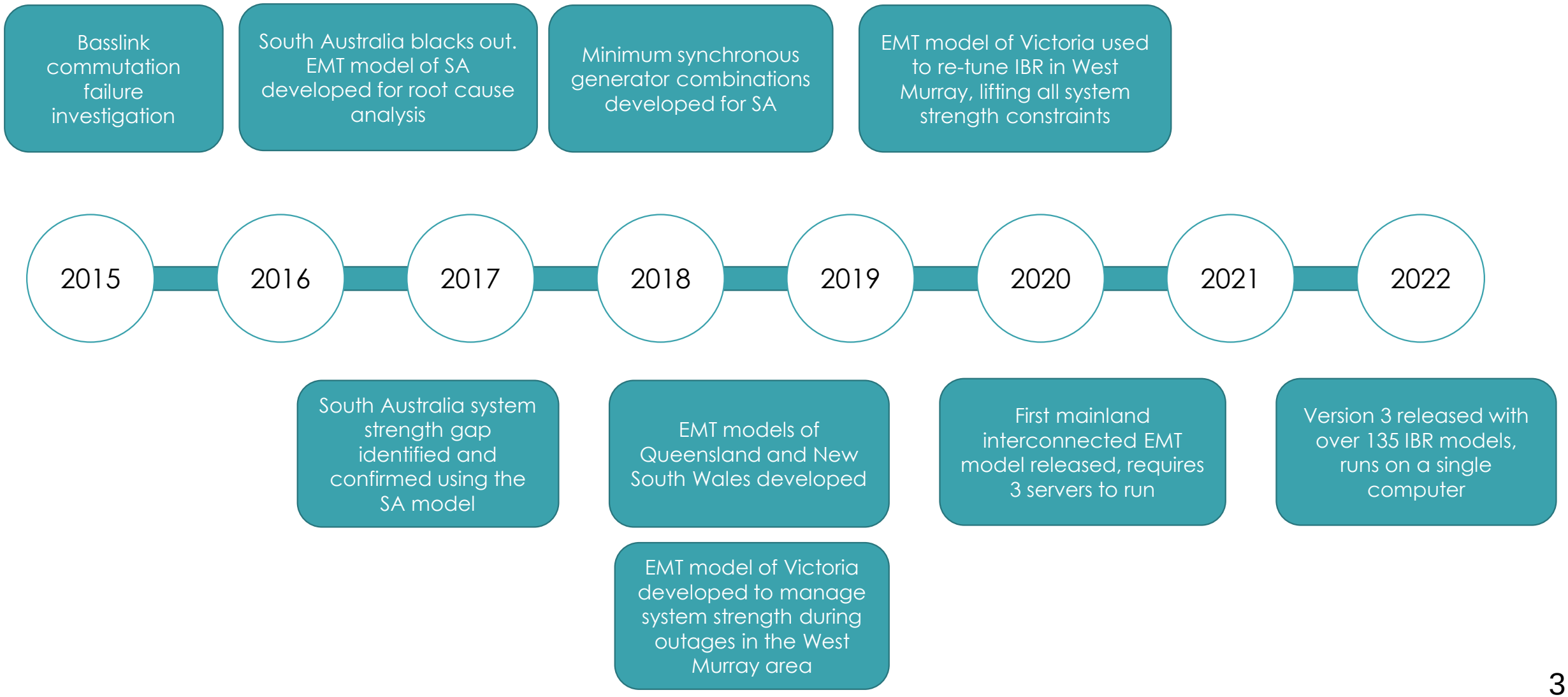
Declared Wholesale Gas Market (DWGM)

Short Term Trading Market (STTM)

and

Gas Supply Hub (GSH)

AEMO EMT Journey



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

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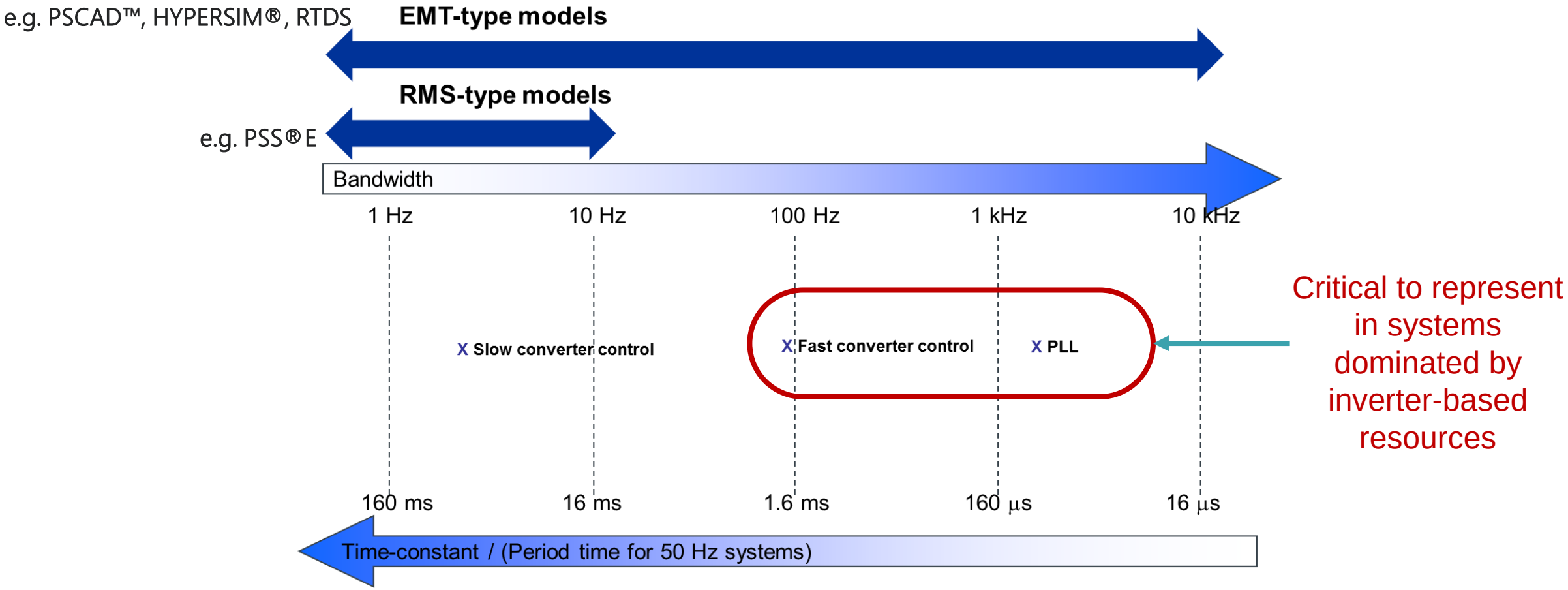
Root-mean-Square (RMS) vs Electromagnetic Transient (EMT)



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

Our Wide-Area EMT model

One of the largest EMT models ever developed

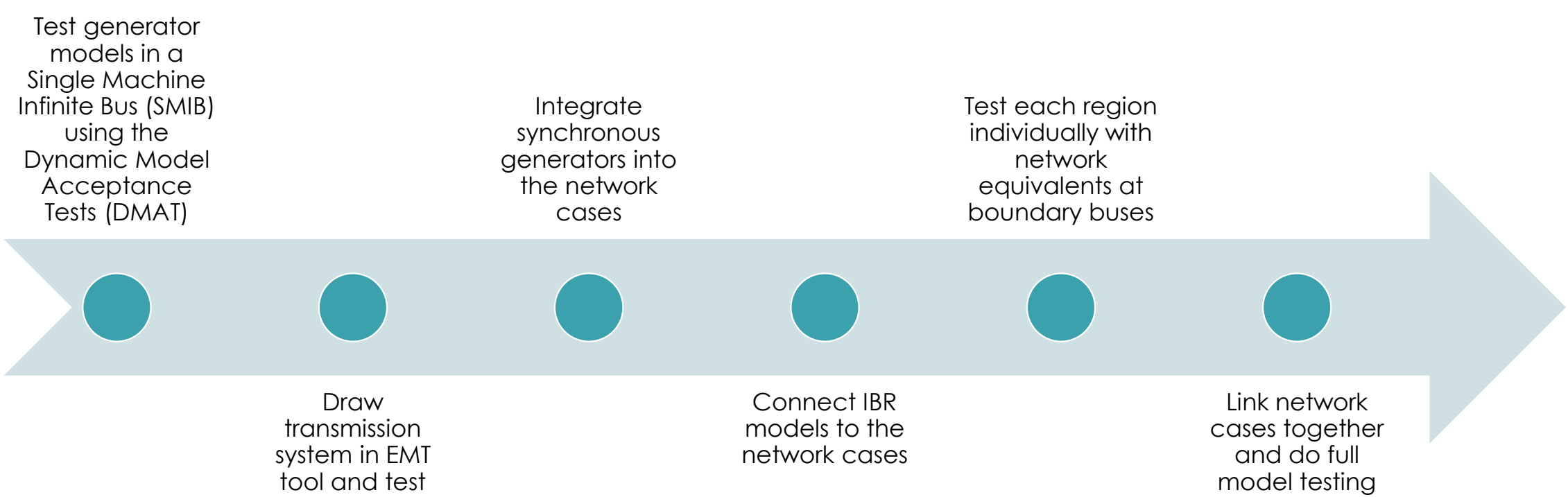
150 cases running in parallel

All of the mainland NEM including Basslink

135 *highly detailed* Inverter Based Resource models

Runs on current hardware in under *1 hour (30 second simulation)*

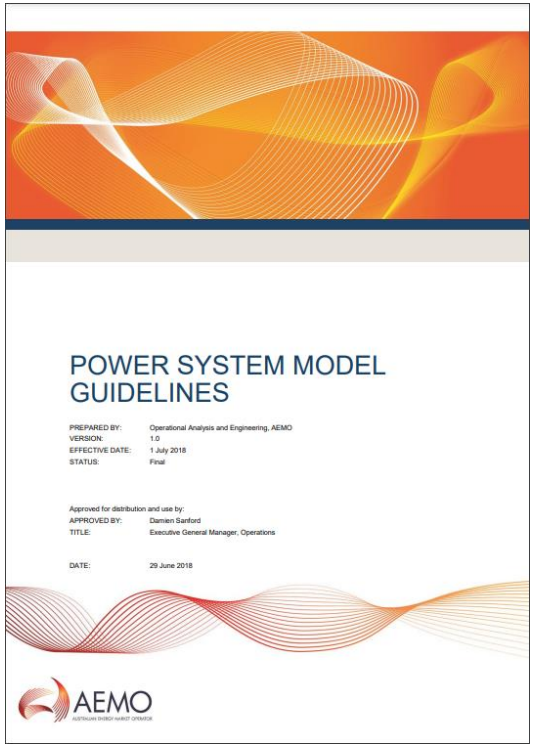
Model Development Process

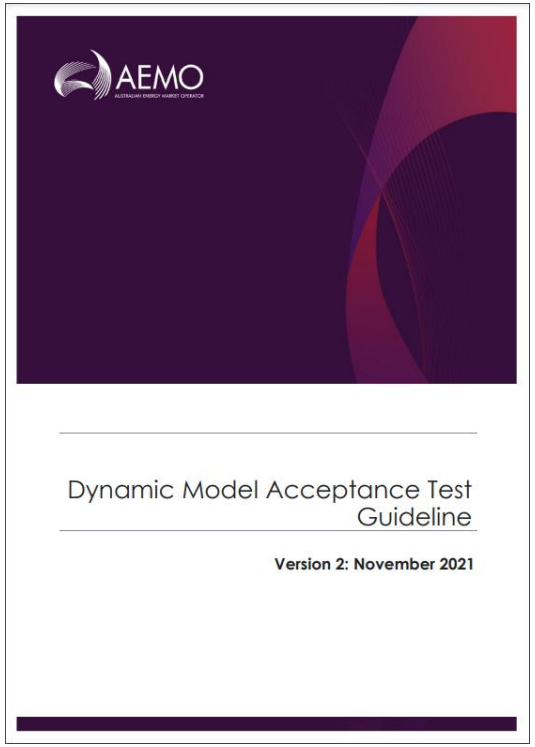


Model Acceptance and Testing

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

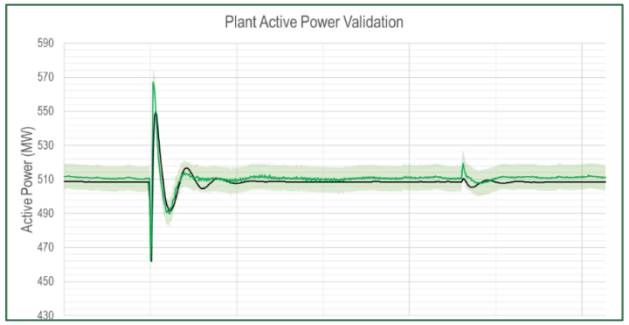
High speed fault recorder data from system events and network testing used for model validation

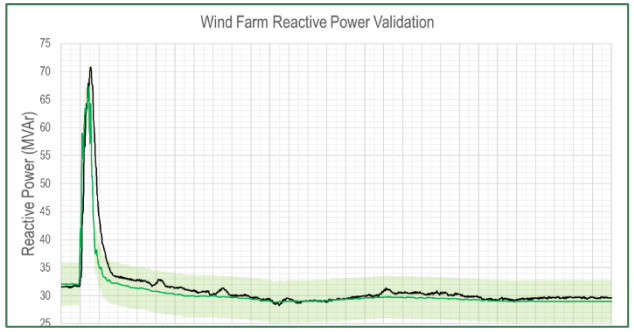
Individual plant validation

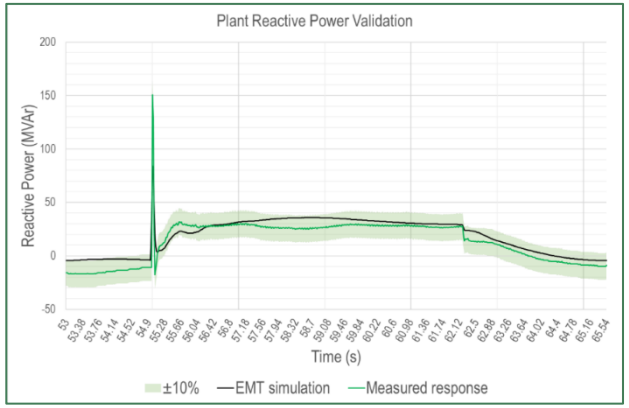
- Single machine, infinite bus setup with playback voltage and phase angle

System wide validation

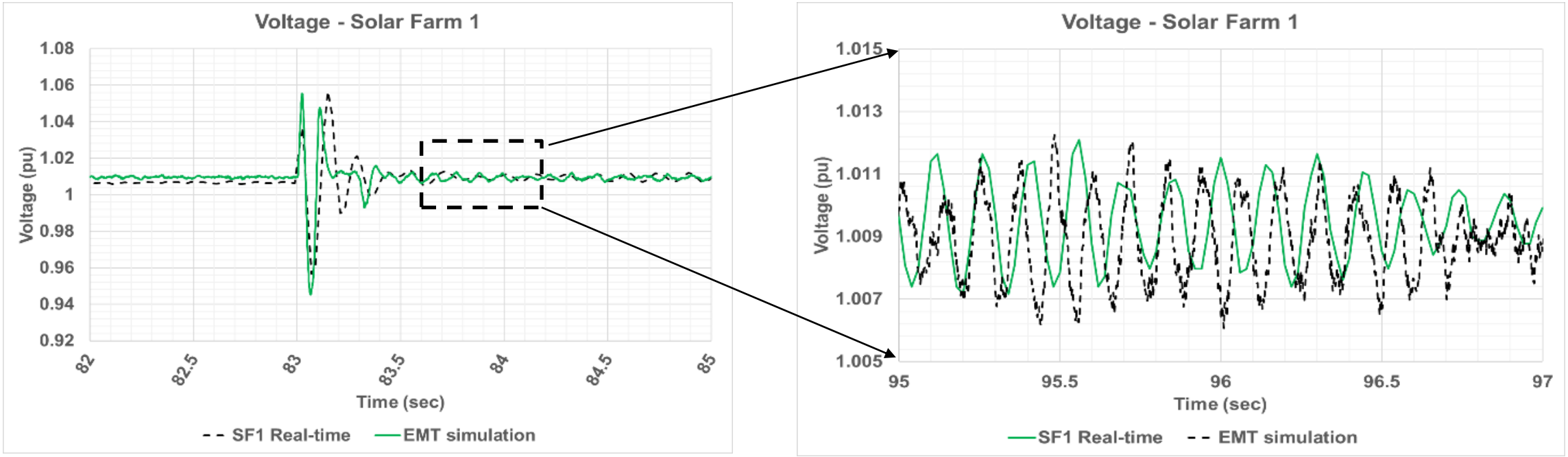
- Replicate a disturbance in EMT
- Compare plant responses in EMT and system measurements







Validation with Real System Test



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

Applications

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

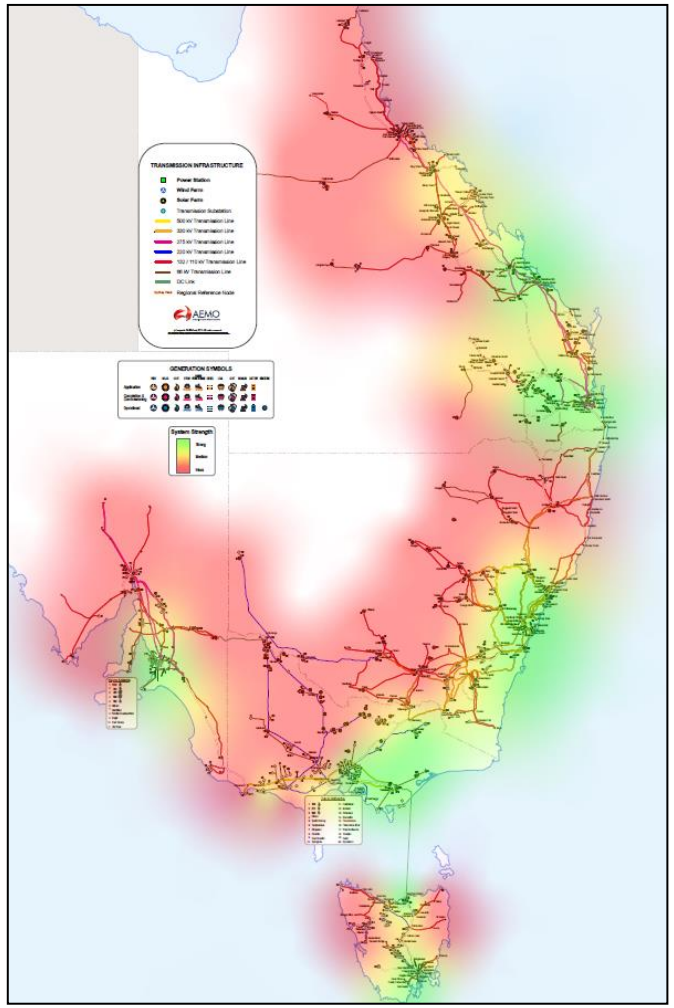
- System strength impact interconnection assessment
- Investigating remedial measures (e.g. run-back schemes, control system tuning)

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

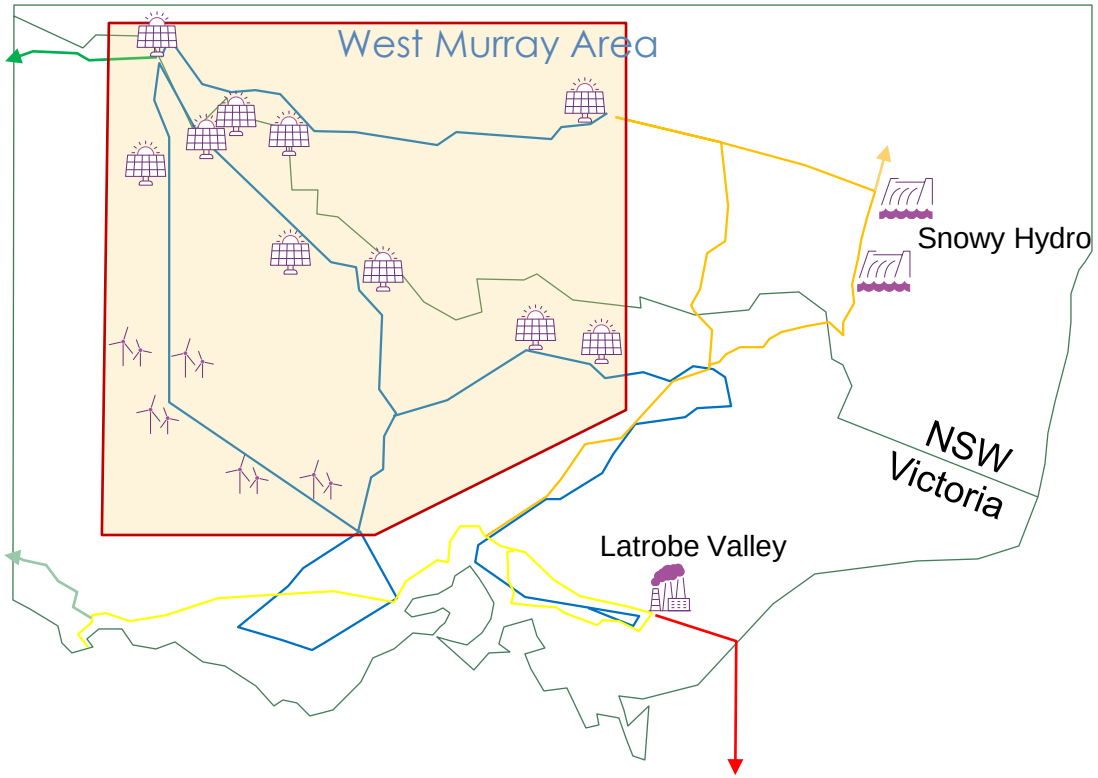
The West Murray area is one of the weakest parts of the NEM

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

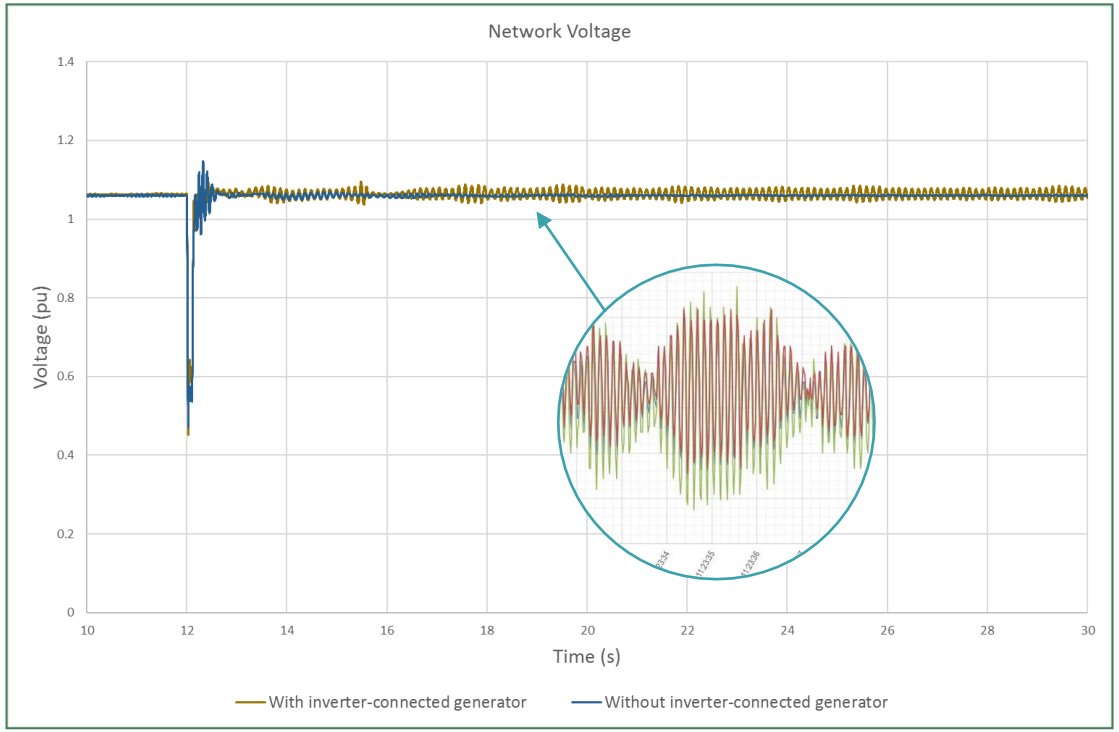


Post Fault Oscillations

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



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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

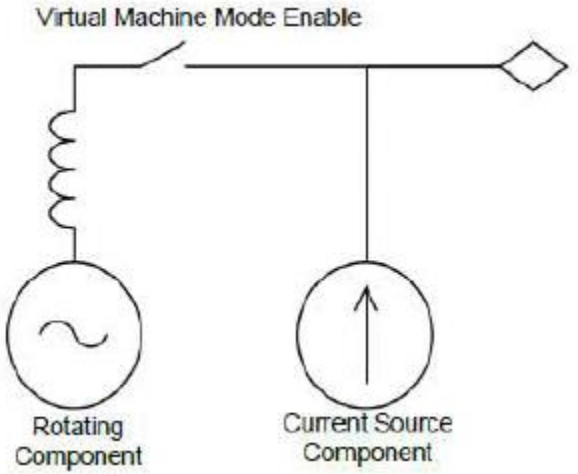
- A wide-area EMT model was used to develop tuned parameters for contributing IBRs in the area and confirm satisfactory performance

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

- BESS in South Australia
- 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



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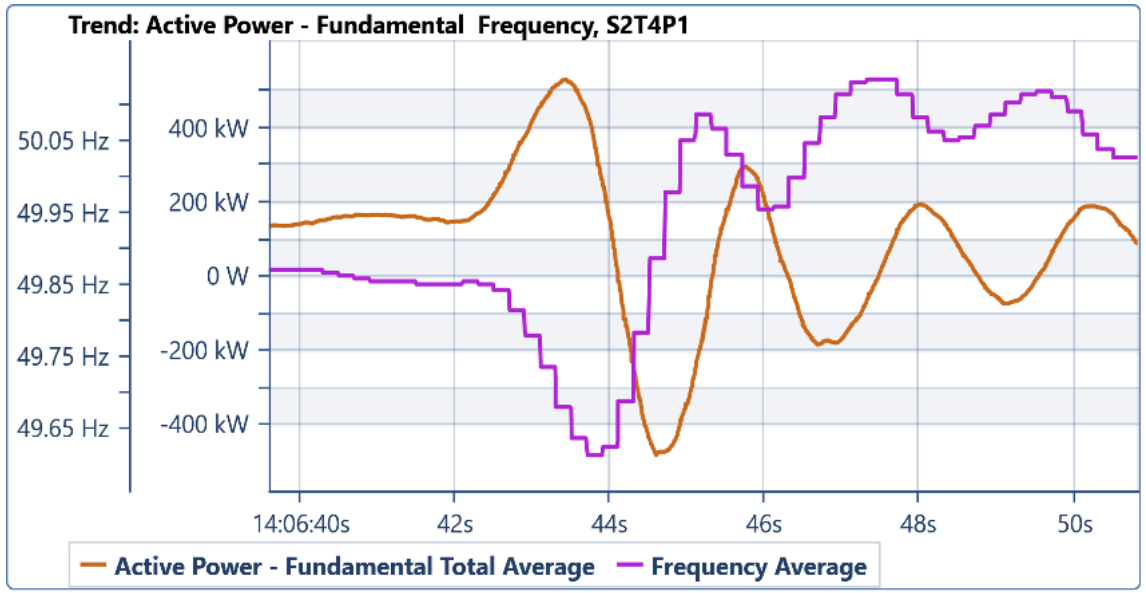
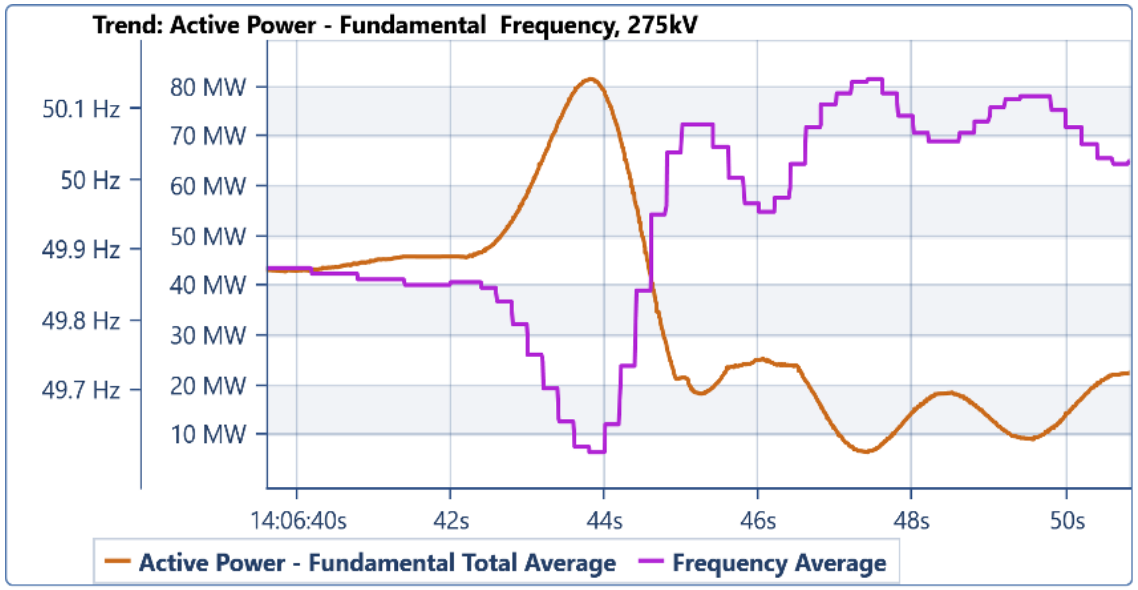
Response to an Event

- Two inverter 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

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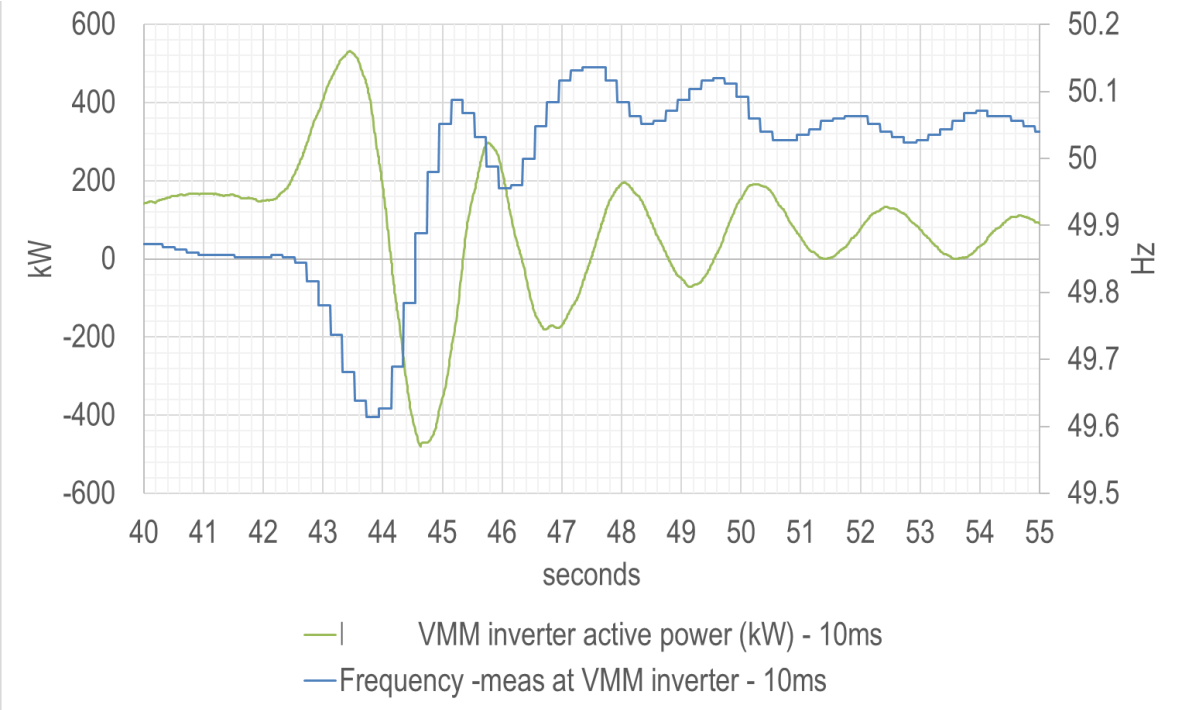
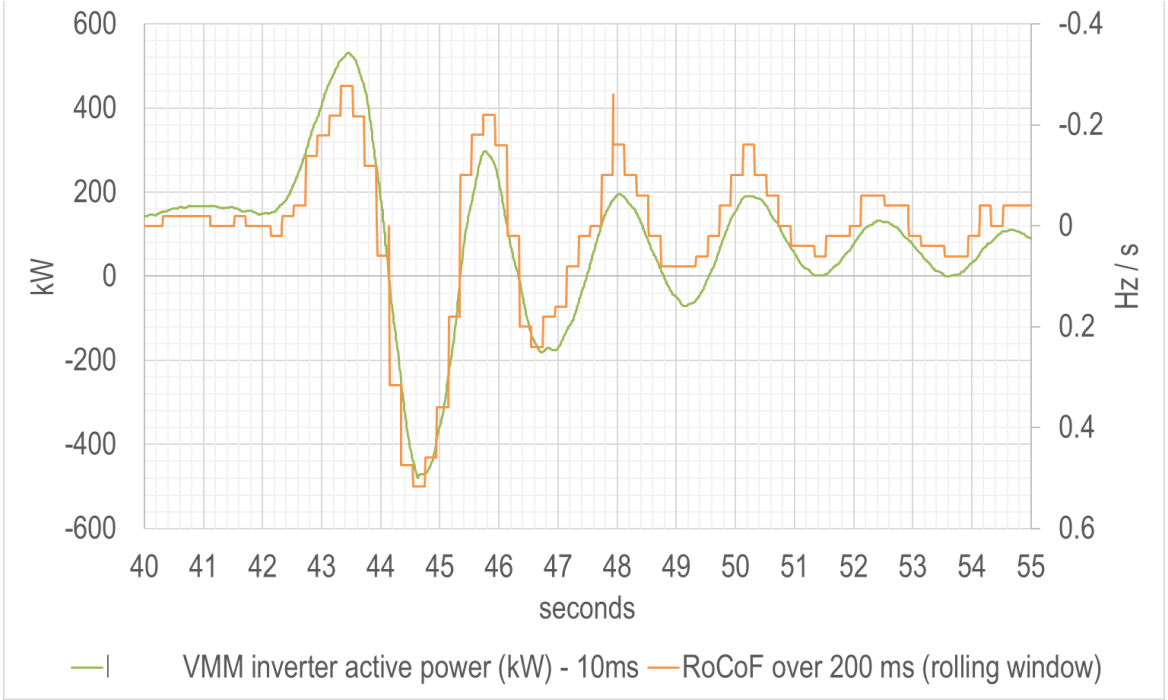
Response to an Event

- VMM inverter response during a real-time event





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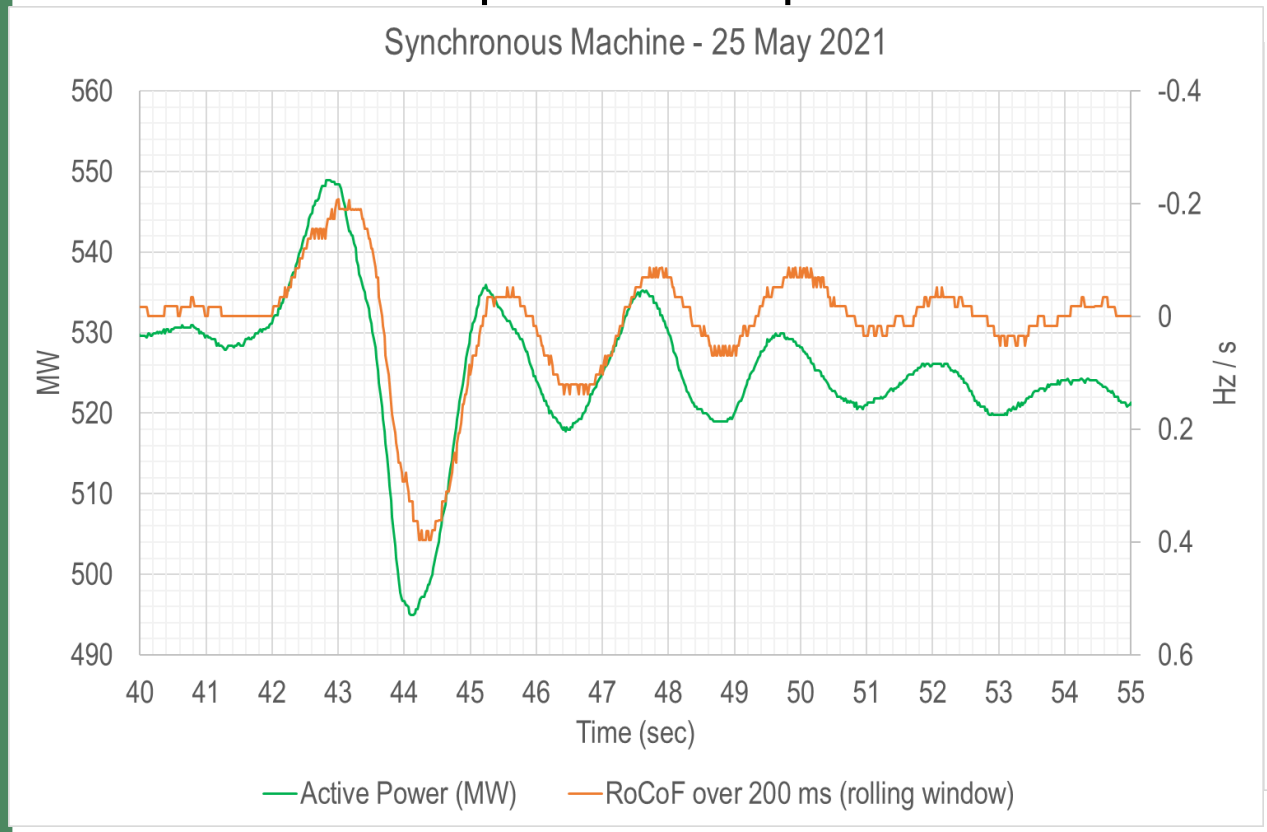
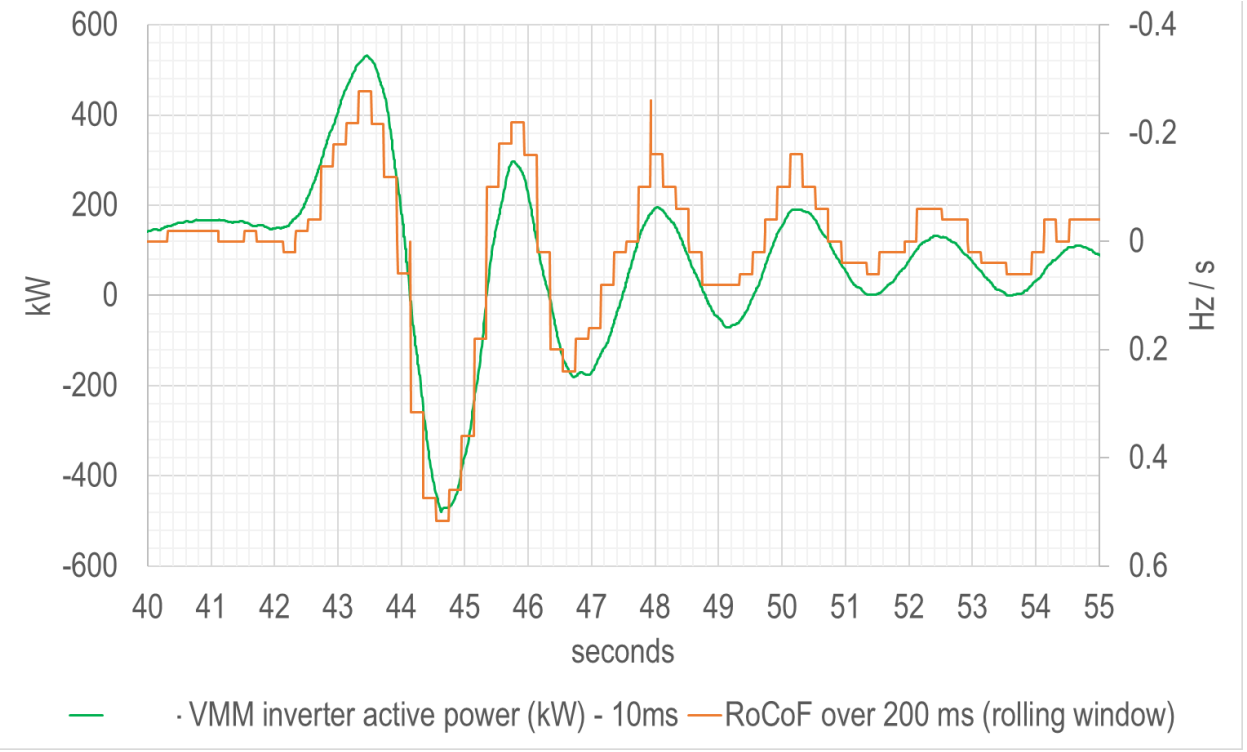
Synchronous machine vs Virtual Machine Mode

- An example comparison





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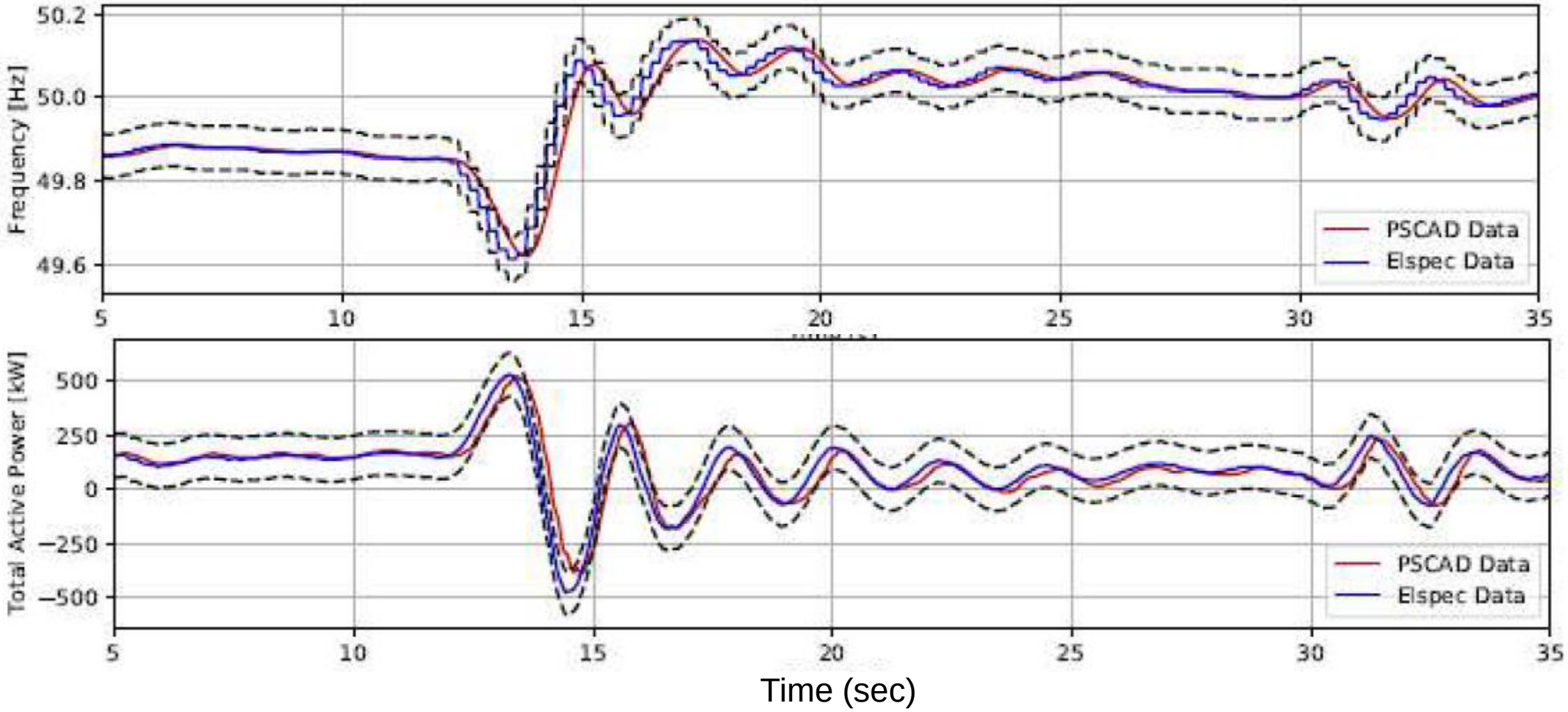
Validation of the Model



Source: Tesla

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AEMO Operations Simulator

Project driver

- The Operations Simulator is part of the Operations Technology Program which seeks to address the challenge of maintaining system security and reliability in an increasingly complex network

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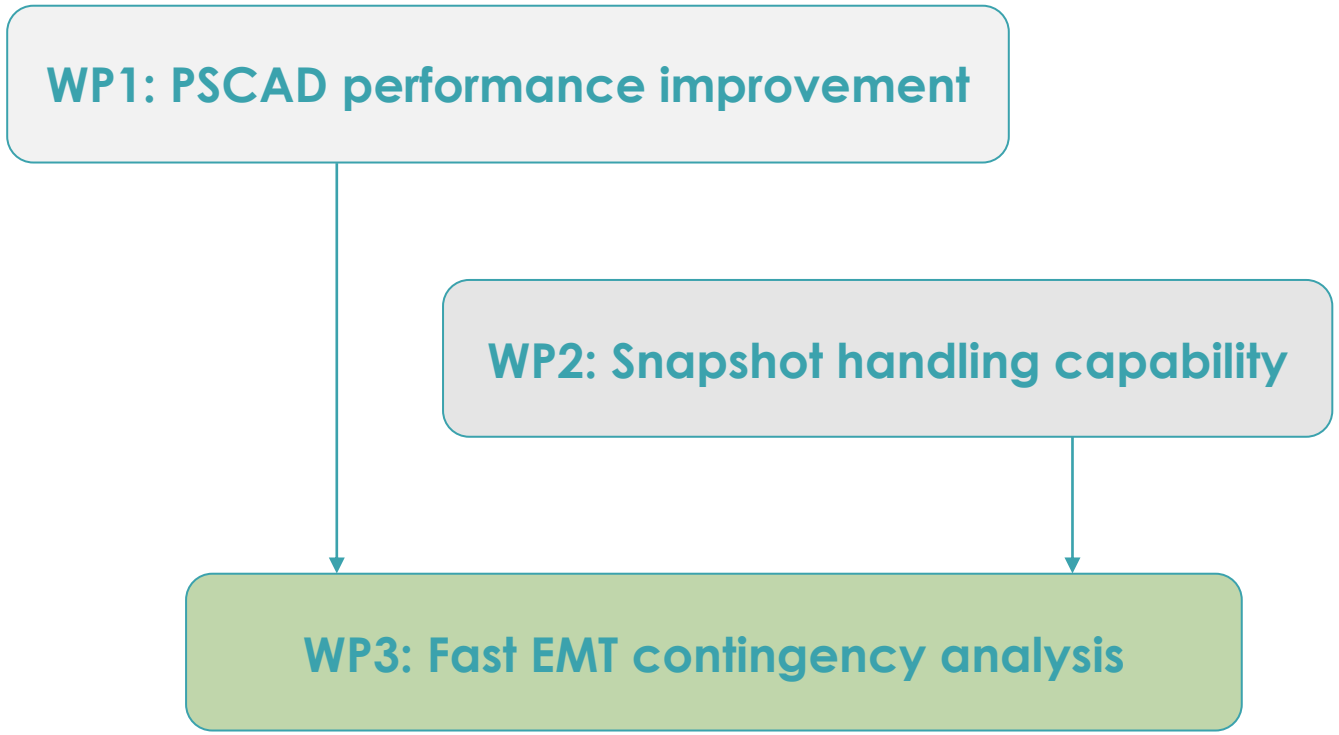
Project goals

- Online EMT contingency analysis capability to aid control room decisions: need identified in AEMO's Operations Technology Roadmap
  - Improved workflow for study engineers
  - Maintenance and use of a single EMT model
  - Speed and accuracy of EMT simulations

Work packages & dependencies

- WP1: PSCAD performance improvement (2022 - 2024) using v3.2 and v3.3 NEM Mainland PSCAD models
- WP2: Snapshot handling capability (2023 - 2024)
- WP3: Fast EMT contingency analysis; offline then automated (2024)



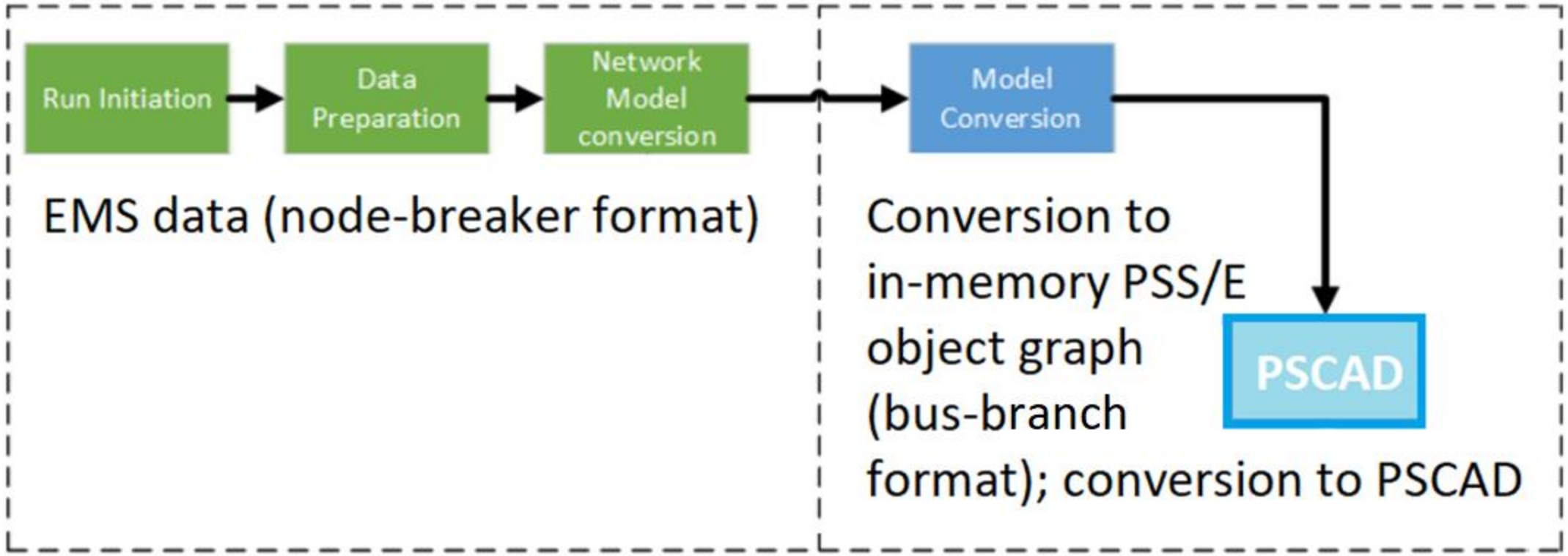
WP1: Scope

- Identify the slowest plant and network models
- Identify opportunities for software performance improvement
- Apply modified subsystem splitting algorithms and improved matrix solution techniques
- Performance logging

WP1: Scope

- Investigate potential options to improve simulation speed without altering the functional aspect of vendor models
- Compare performance using various hardware configurations; i.e. 64-core, 128-core, and shared memory vs. RDMA
- Provide recommendations to improve simulation speed

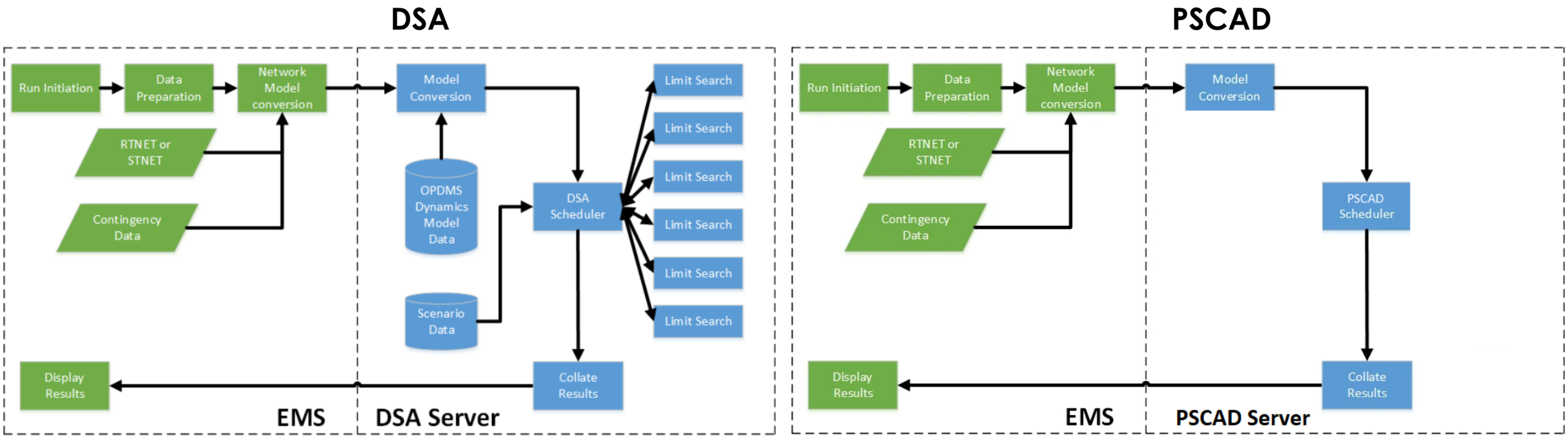
WP2



- Creation of a .pscx file (XML format) for importing to PSCAD

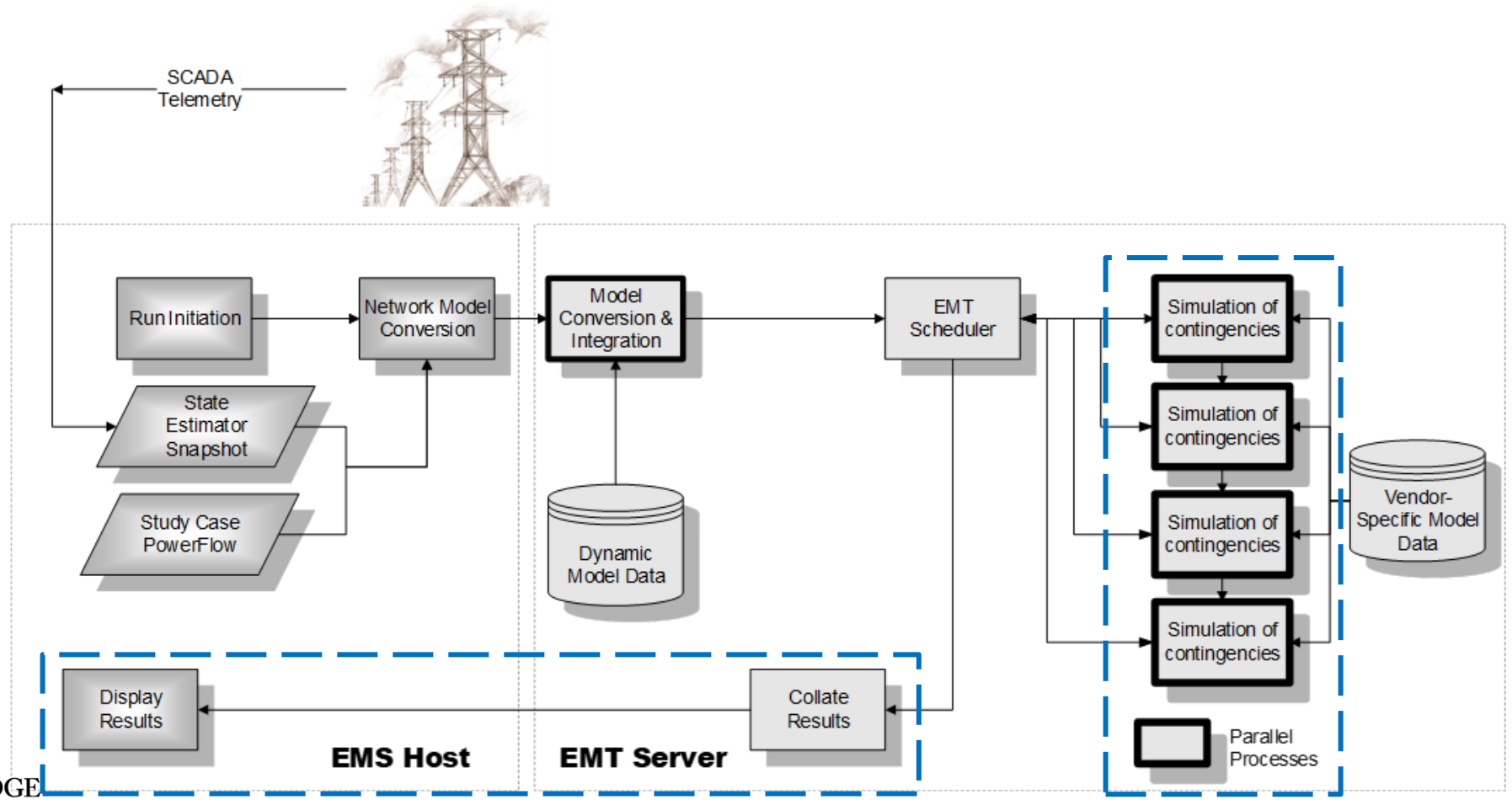
WP3: Fast EMT contingency analysis

- Offline then online EMT contingency analysis; analogous process to DSA
- Due to start in 2024



WP3: Fast EMT contingency analysis

- Offline then automated 'online' EMT contingency analysis; analogous process to DSA



Work in progress

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Key takeaways

- Pioneer R&D project: de-risk where possible (difficult)
- Careful investment of resources until minimal viable product achieved
- Maintain an agile approach
  - Highly dynamic field - stay informed of global developments
  - Be prepared to pivot
- What do we need now and how can we get it?
- What will we need in x years and how can we get it?

May require parallel workstreams with different vendors

Key insights

Challenges	Opportunities
Lack of sophistication in current tools	Engage stakeholders to drive development
Lack of international experience	Participate in global initiatives
Simulation speed	Engage software vendors
Slow OEM models	Engage OEMs and software vendors
Speed vs accuracy	Use equivalents, average models, co-simulation

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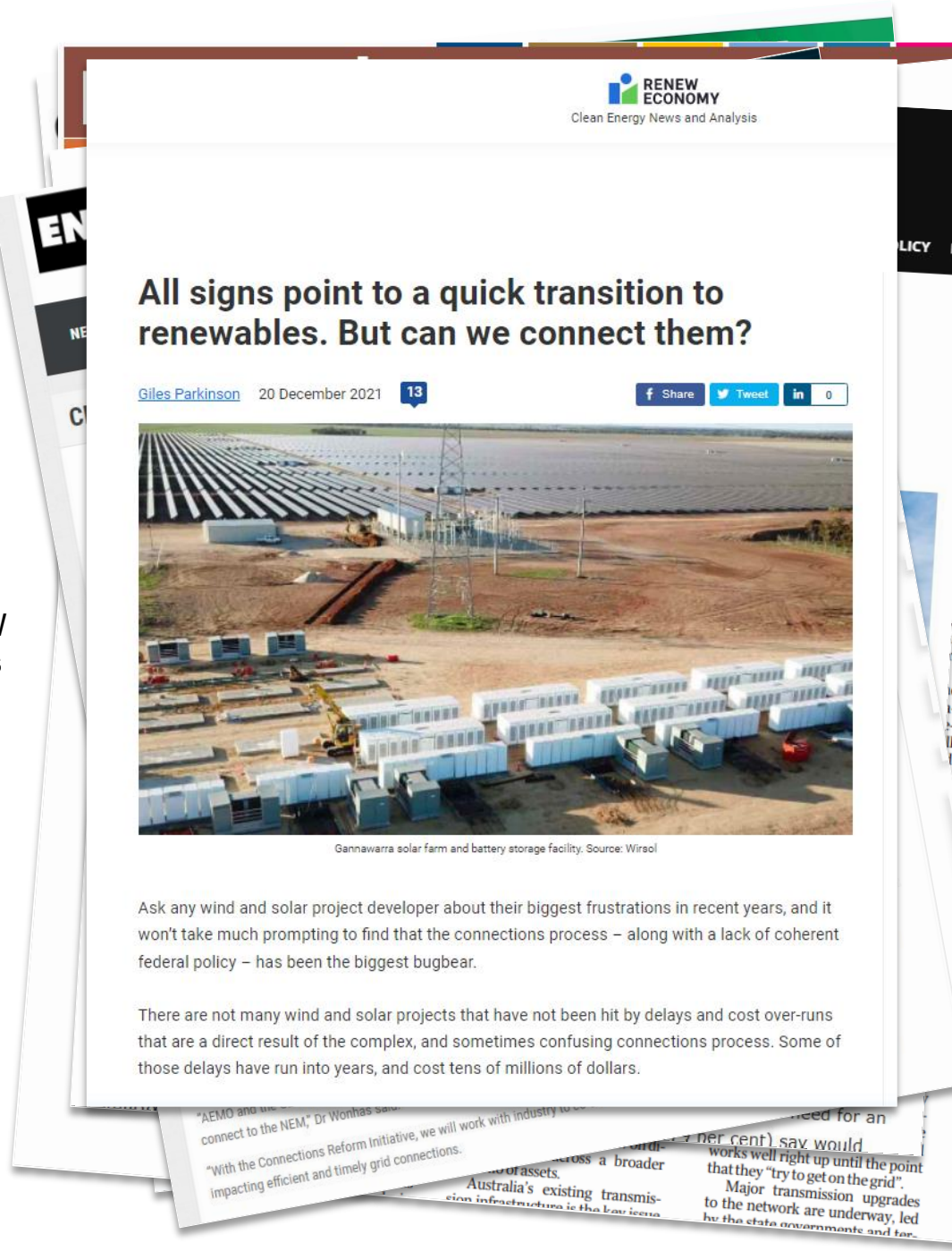
The Connections Landscape

Australia is undergoing the fastest transition of any energy system in the world

- 25 projects and 3.56 GW of new generation has been connected to the NEM during FY22
- AEMO National Connections is currently managing over 193 projects, representing 28.3 GW of generation, through the Connections Application, Registration and Commissioning stages of the NEM connection process

- The magnitude and pace of the transition means it is critical to get connections right. The speed of transition is creating significant challenges in connecting new projects to the grid.
- Large numbers of generators are being connected in close proximity of each other. Generators are being connection where there was previously no generation, commonly in weak parts of the network.
- In the current connection process, proponents, consultants and OEMs are unable to access the NEM Mainland PSCAD model. NSP conducts the FIA and AEMO carries out wide area studies.

The Connections Simulator Tool will change this,
It will provide industry participants access to the NEM Mainland PSCAD model to develop, simulate and tune new generators


RENEW ECONOMY
Clean Energy News and Analysis

All signs point to a quick transition to renewables. But can we connect them?

Giles Parkinson 20 December 2021 13

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Gannawarra solar farm and battery storage facility. Source: Wirsol

Ask any wind and solar project developer about their biggest frustrations in recent years, and it won't take much prompting to find that the connections process – along with a lack of coherent federal policy – has been the biggest bugbear.

There are not many wind and solar projects that have not been hit by delays and cost over-runs that are a direct result of the complex, and sometimes confusing connections process. Some of those delays have run into years, and cost tens of millions of dollars.

The Connection Simulation Tool Industry Benefits

Industry member surveys have demonstrated strong support for the Connections Tool due to the significant benefits

Shared System Model

During the Enquiry and Application stages of the connections process, connections applicants will perform studies which incorporate their new plant model with the **same large-scale power system model that is used internally by AEMO** to assess connections applications.

Greater Confidence in Studies

Connections applicants will be able to **better design** their generating system and then be confident that the study outcomes will meet the acceptance criteria as defined in the rules.

Faster Application Process

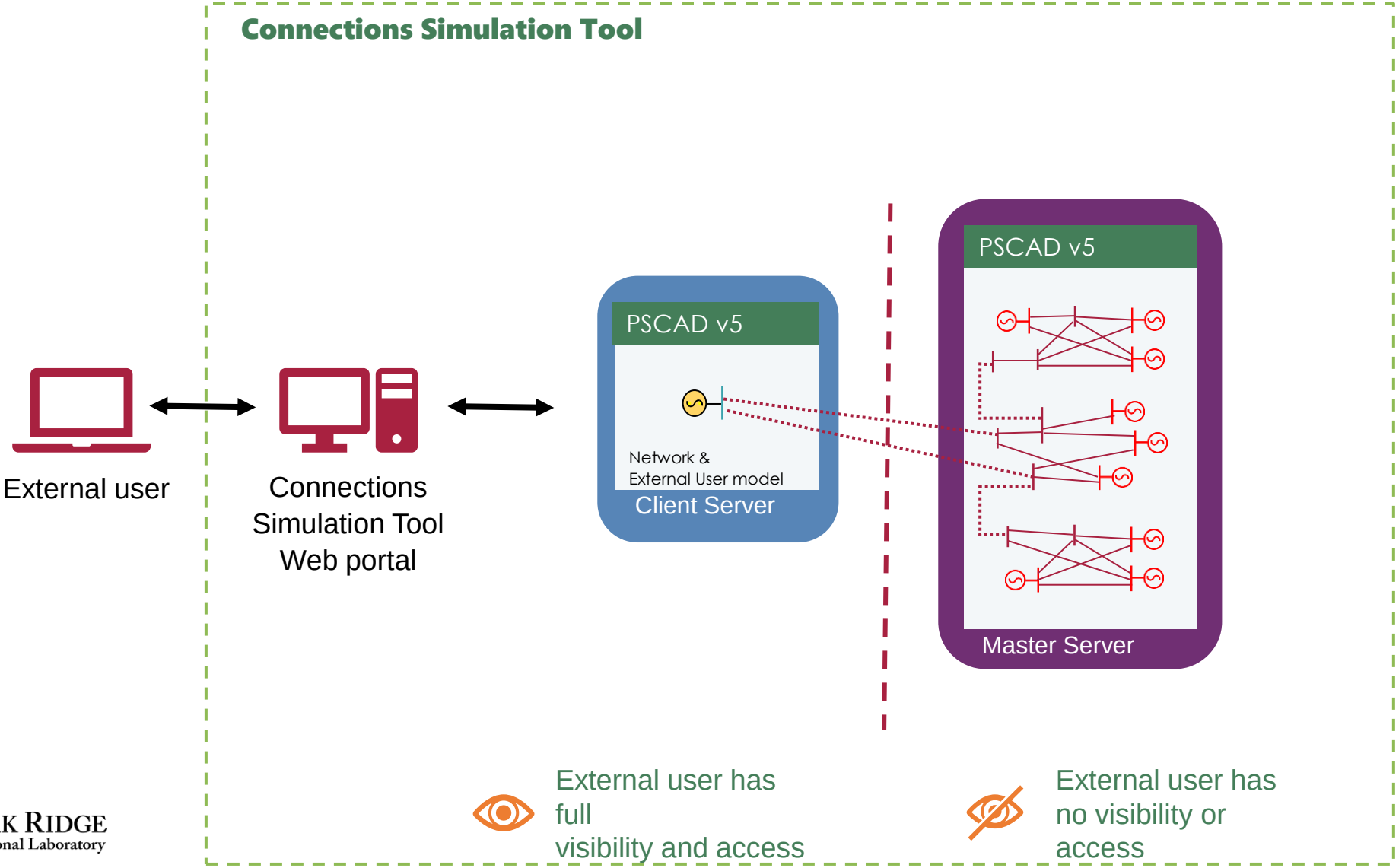
This will significantly streamline the applications process, reducing both **risk and costs and reducing the iterations/time to complete connections approvals** (including AEMO's time to assess and finalise new asynchronous plant connections

Proposed Industry Users:

- External Developers
- Consultants
- Original Equipment Manufacturers

Development of the Connections Simulation Tool is funded by AEMO and the Australian Renewable Energy Agency (ARENA)

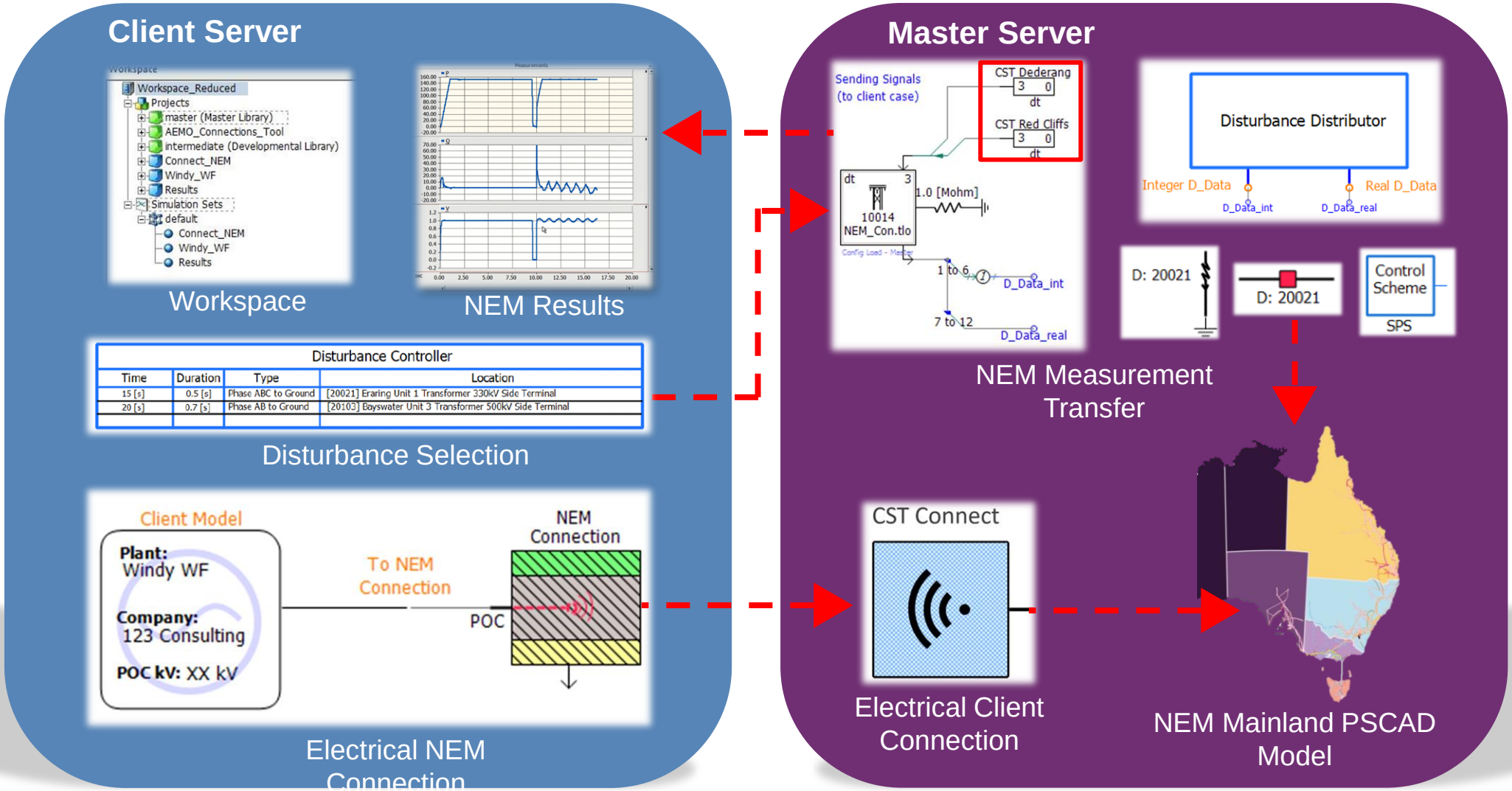
Connections Simulator Tool (CST) Concept



Features:

- Maintaining confidentiality with an electrical connection across two servers (Only Point of Connection visible to user)
- PSCAD Run/Stop scripted automation that's tied to 'Client-side' run
- Client ability to influence the study undertaken
- Measurement transfer between servers
- Automatic deployment and license retrieval of two PSCAD V5 software instances
- AEMOs wide-area PSCAD case used in study
- Ability to automatically generate results request
- And much more!

Simulation within the CST



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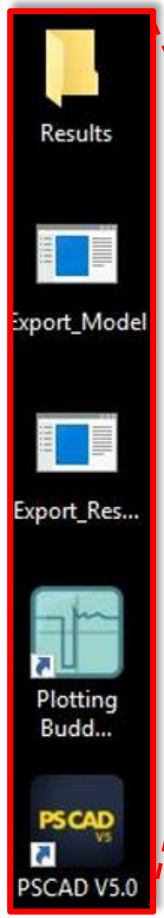
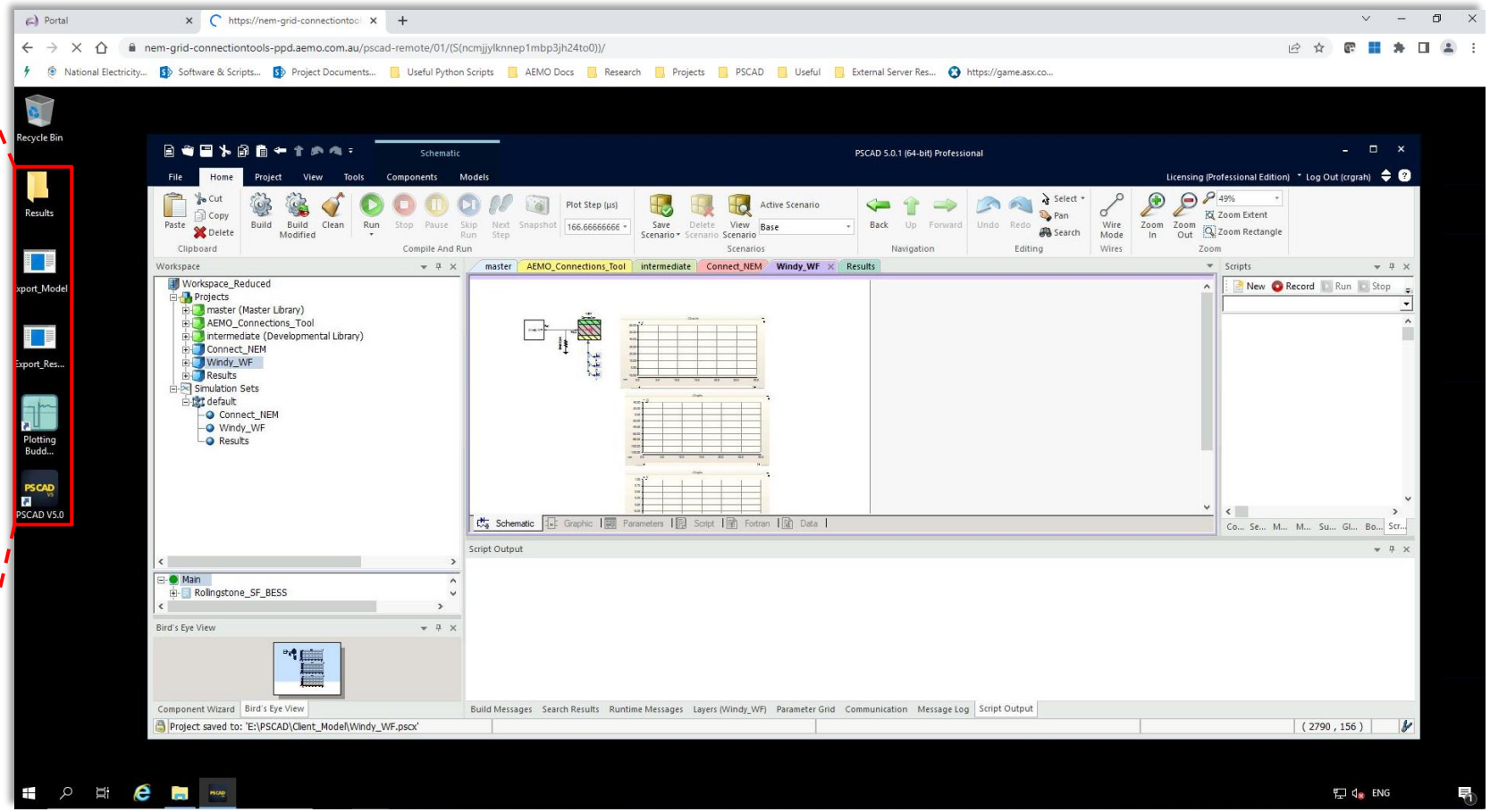
Interface and Tool Outputs

Request export of users PSCAD model or PSCAD results





Generates email and attachment for National Connections to forward to user

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Future initiatives

- Oscillation source location
- Impedance based scanning techniques

Thank You

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