Electromagnetic transient simulation models for large-scale system impact studies in power systems having a high-penetration of inverter connected generation

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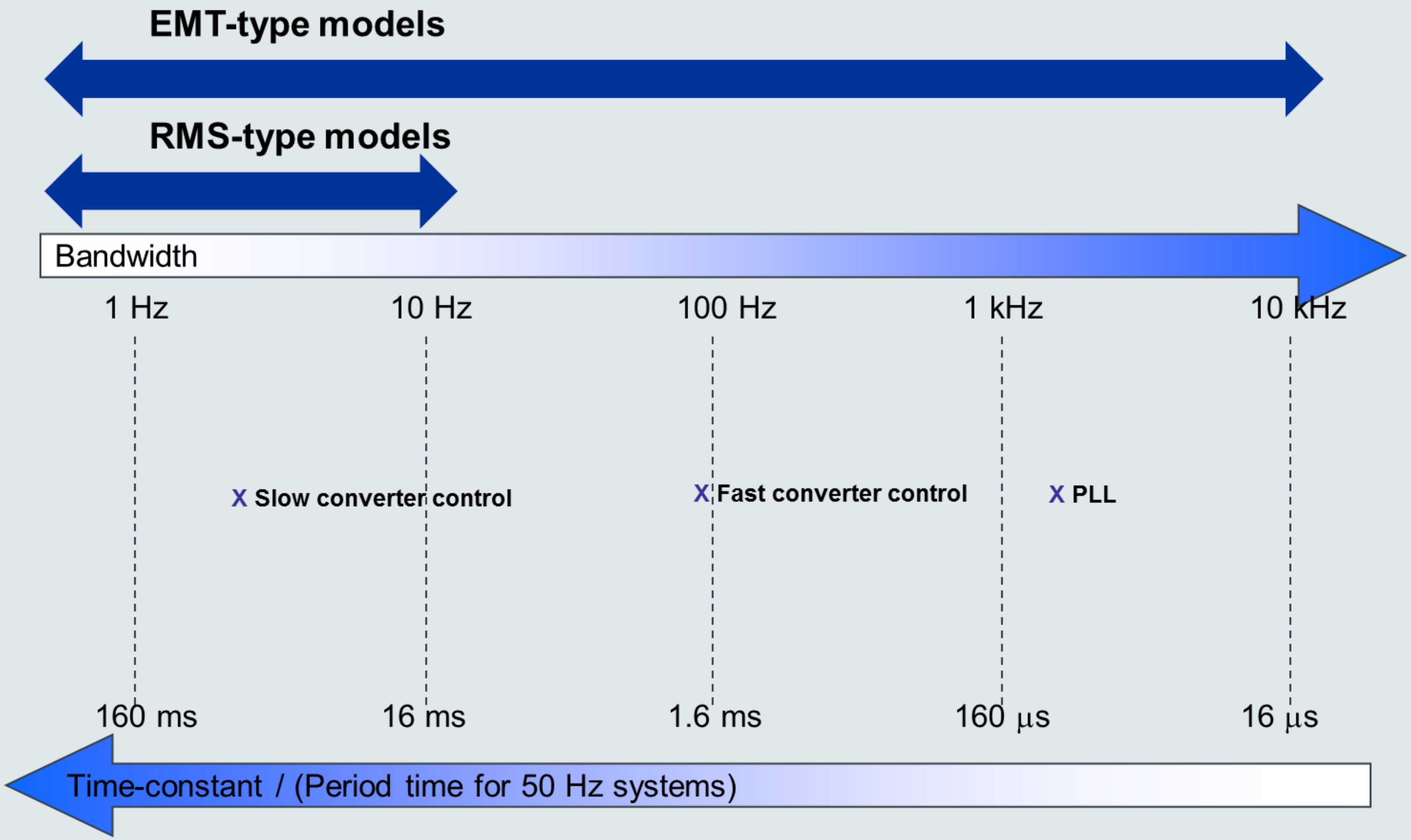
Agenda

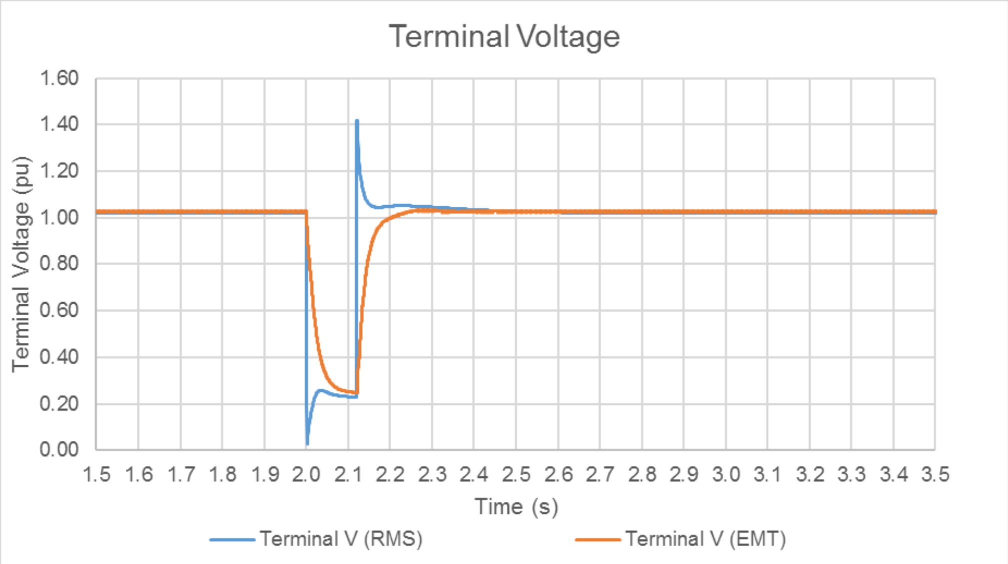
- Comparison of RMS and EMT modelling approaches and impact on results
- Large-scale EMT model development in AEMO
- Considerations when conducting large-scale EMT studies

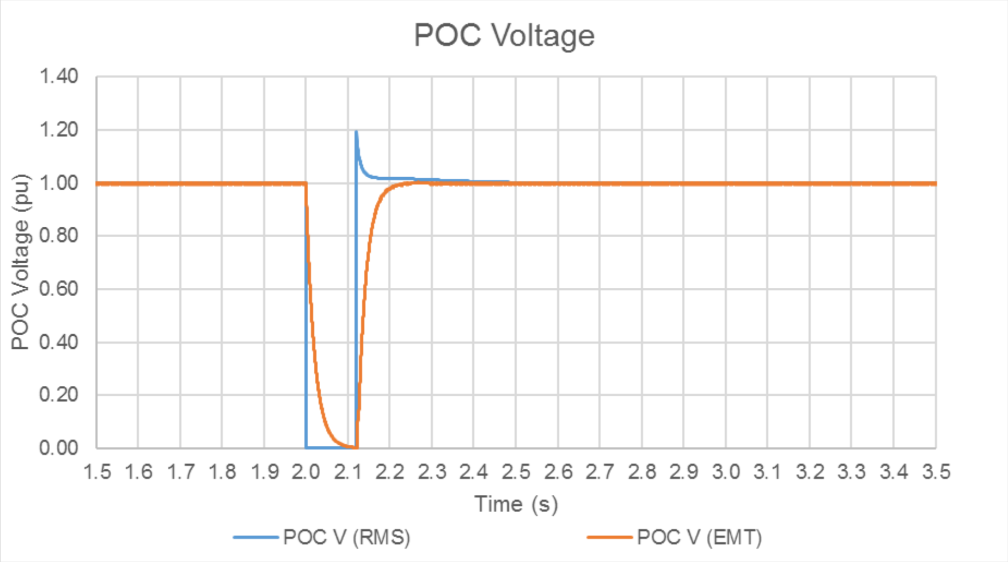
Comparison of RMS and EMT modelling approaches and impact on results

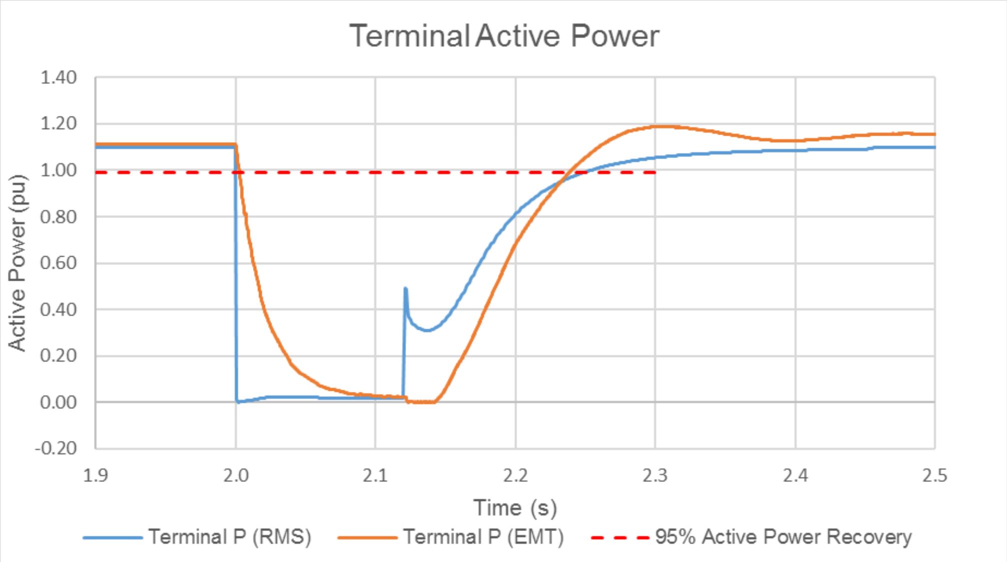
Applicability range of RMS- and EMT-type tools

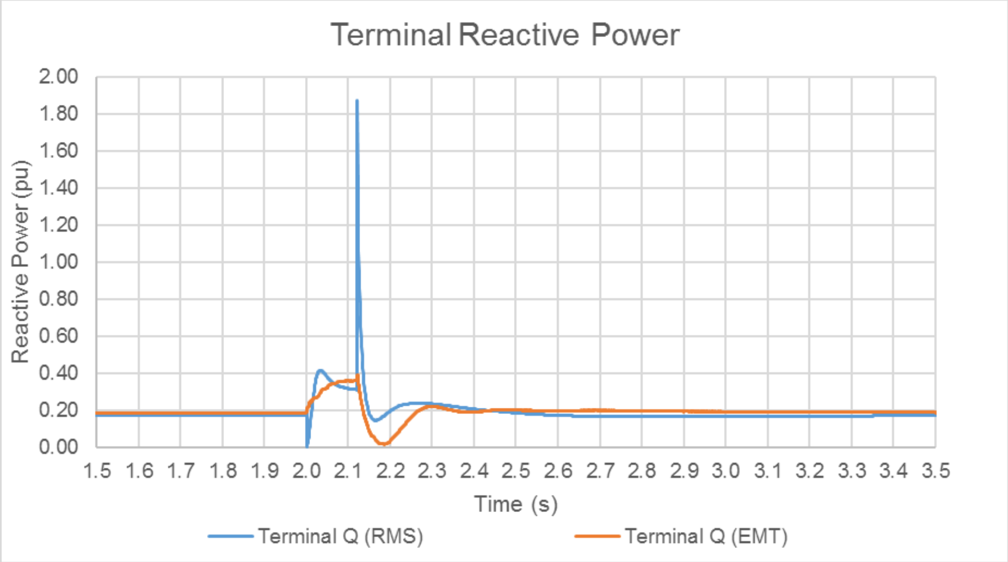


RMS- and EMT-model accuracy: Solar Farm response to fault on a SMIB model

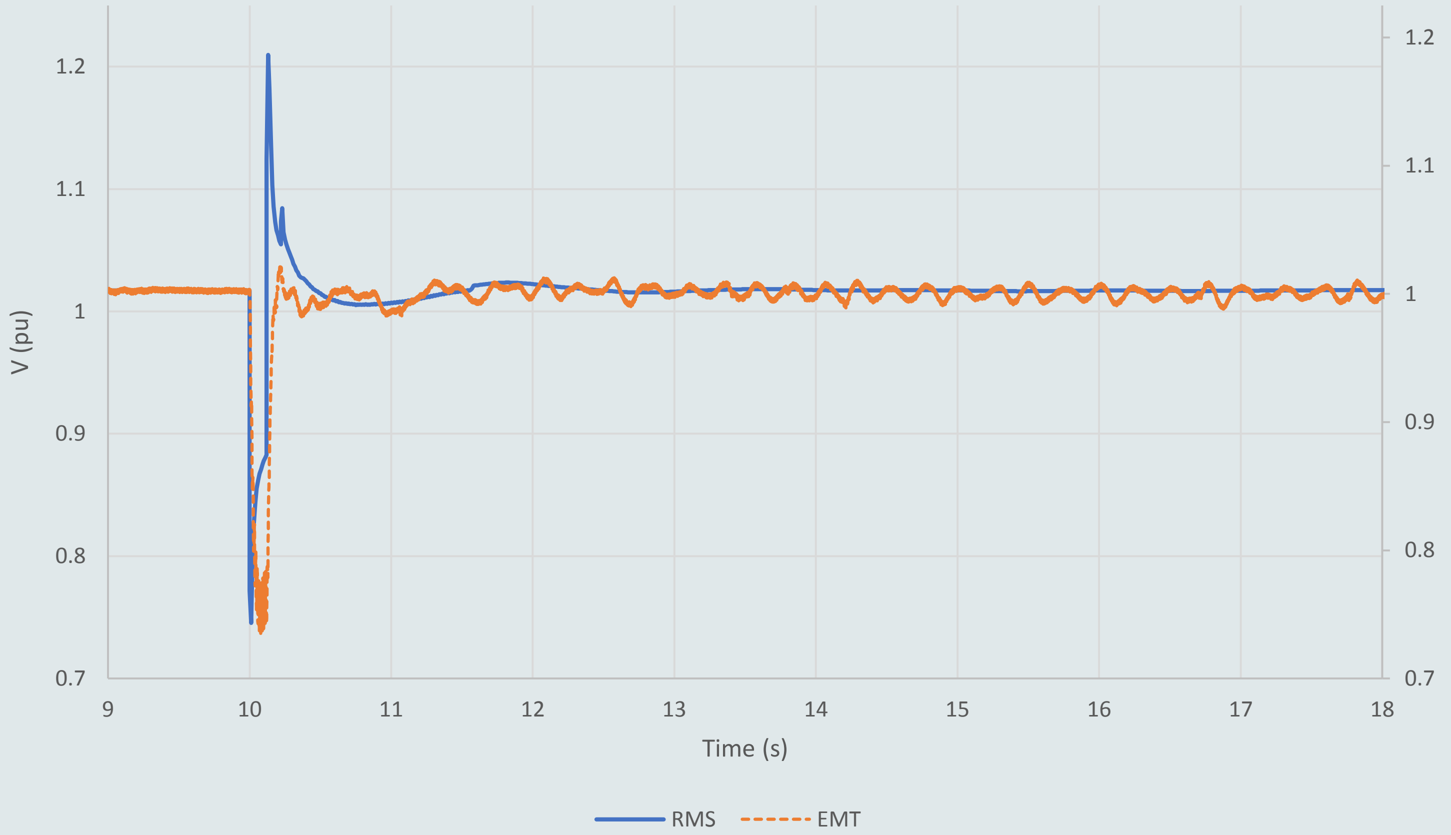






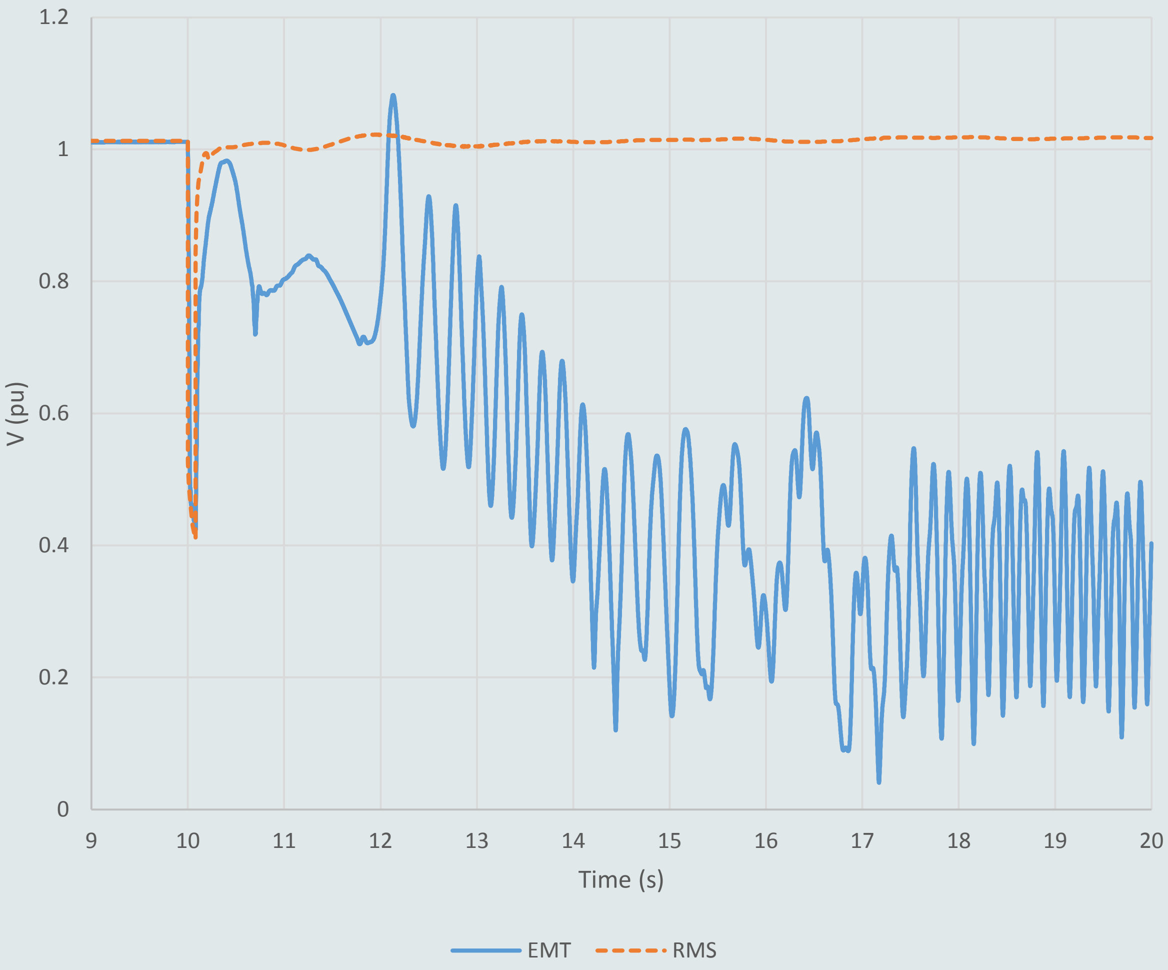


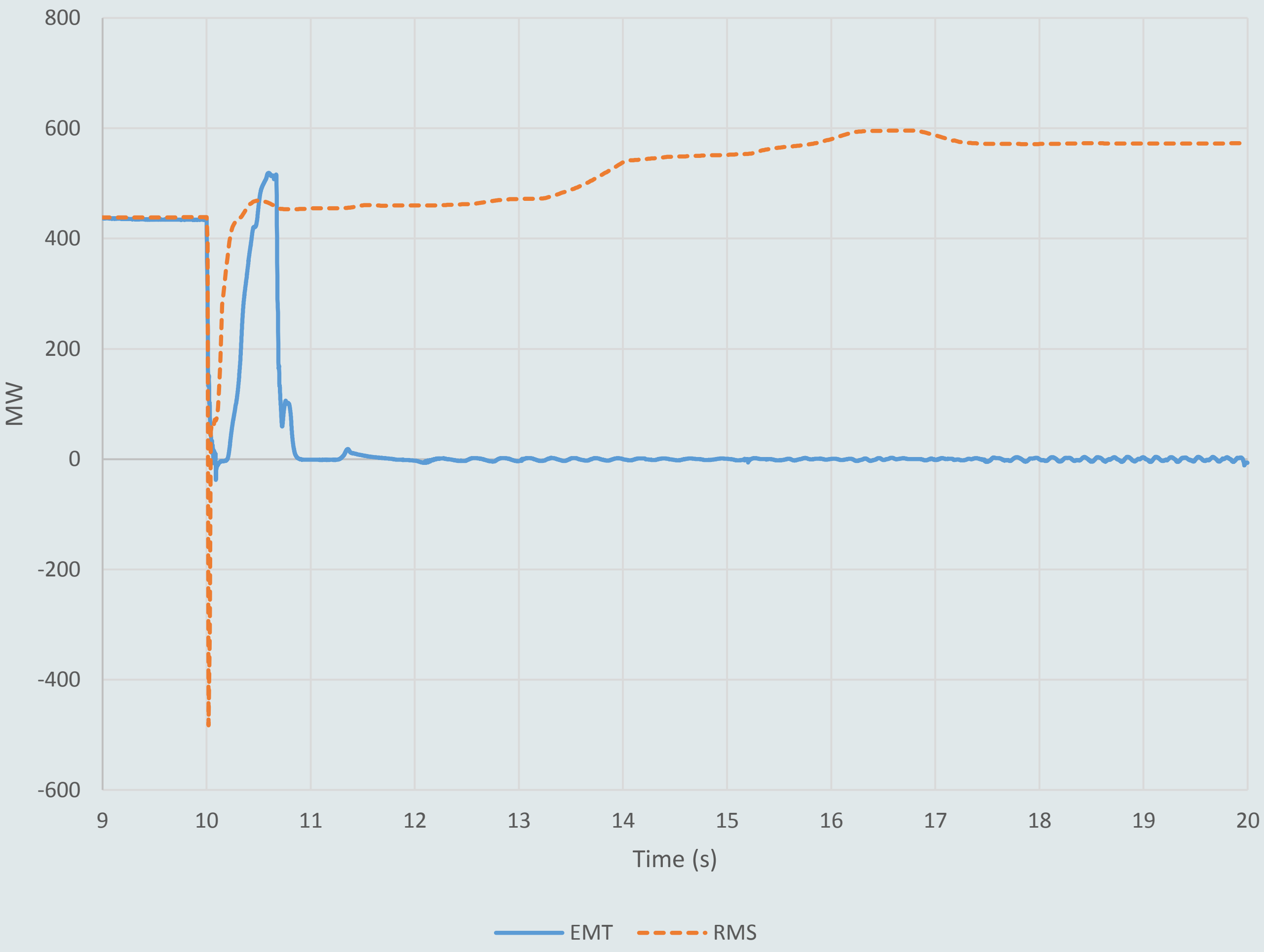
RMS- and EMT-model accuracy: Solar Farm response to fault in a full-scale system model



- Sustained post fault voltage oscillations with a frequency of less than 10 Hz.
- Unacceptable oscillations due to:
  - breach of flicker requirements
  - not being *adequately damped*

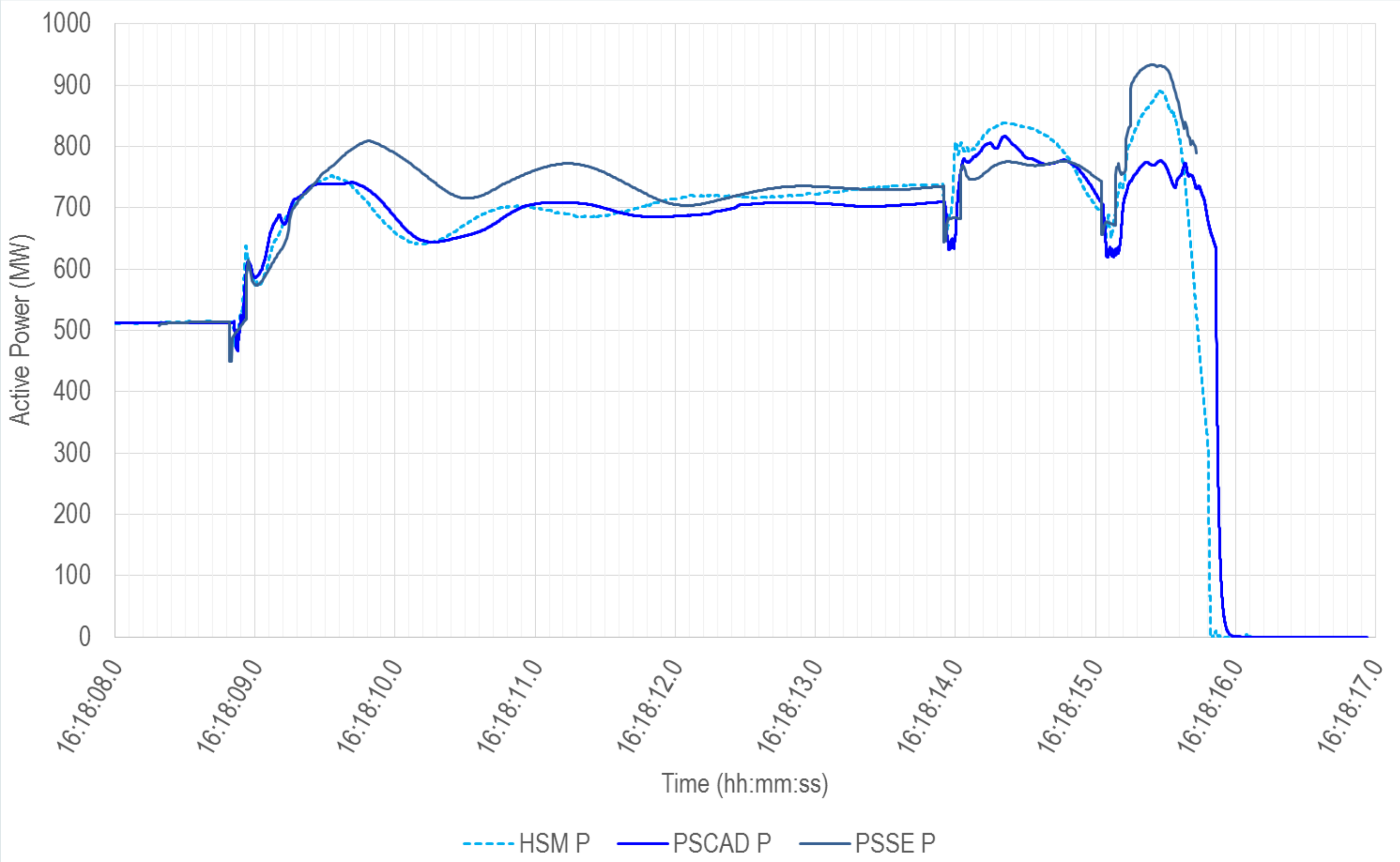
RMS- and EMT-model accuracy: HVDC link response to fault in a full-scale system model





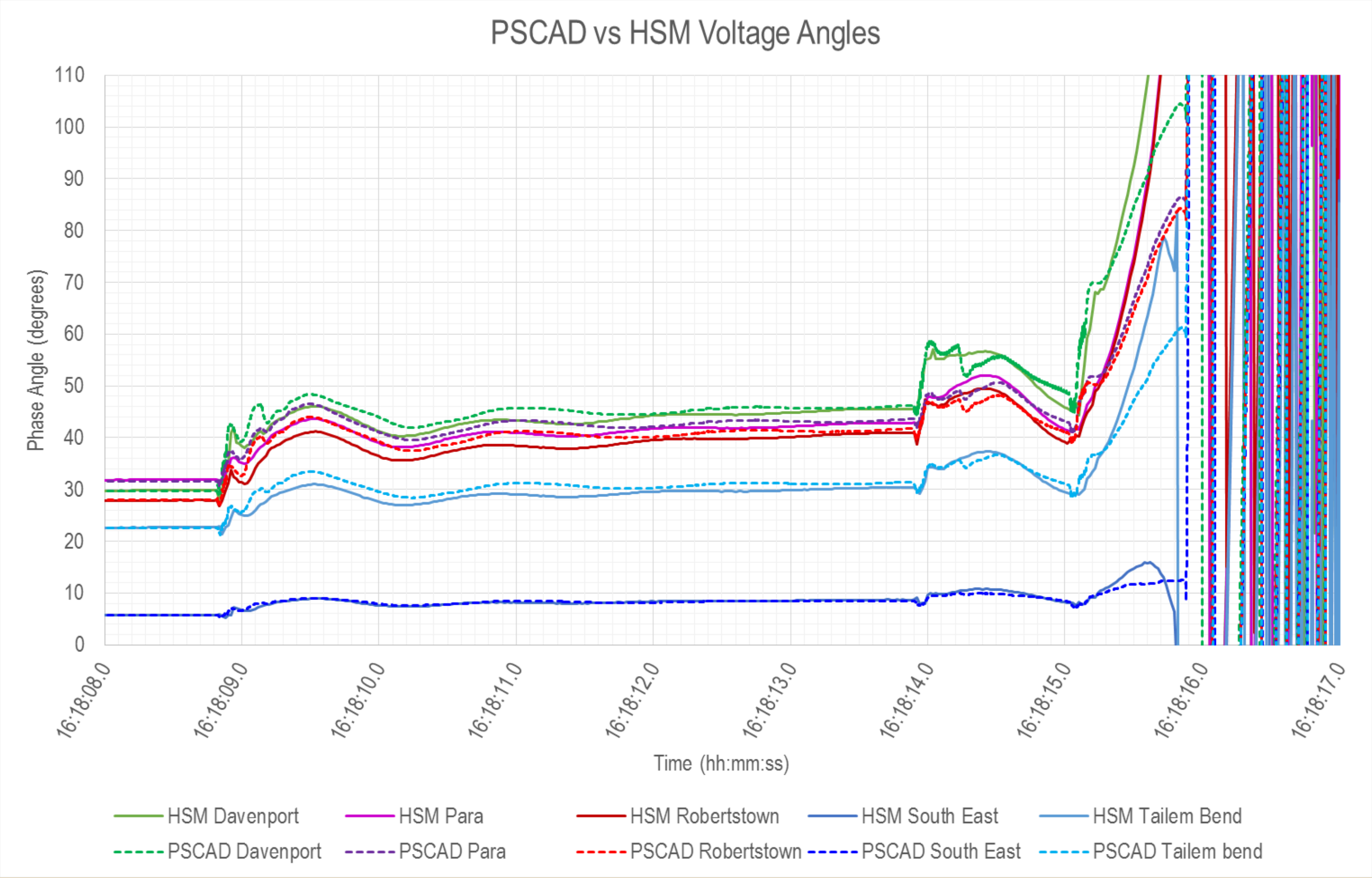
RMS model does not predict sustained commutation failure and subsequent disconnection of LCC HVDC link

RMS- and EMT-model appropriateness: South Australia black system event (1)



RMS model stops working as soon as SA system becomes islanded

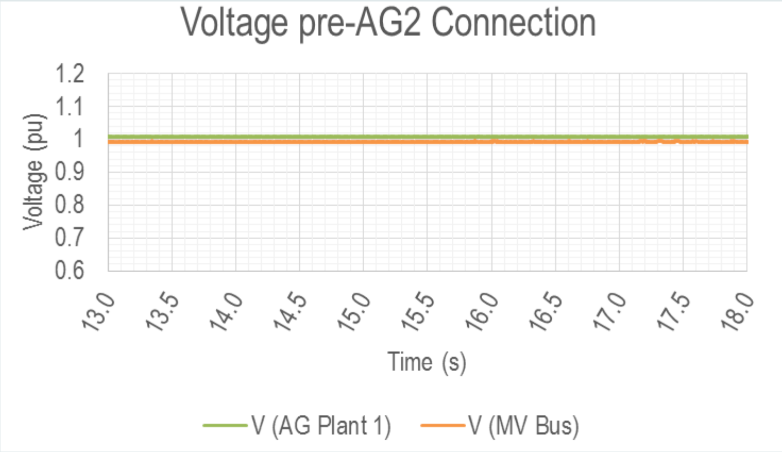
RMS- and EMT-model appropriateness: South Australia black system event (2)

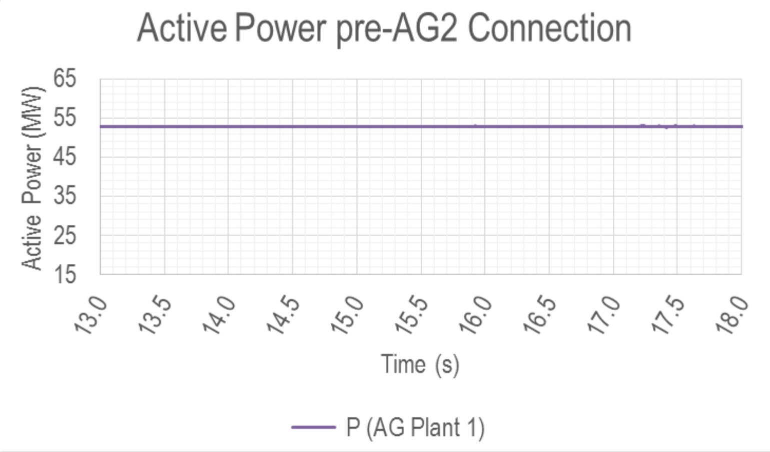


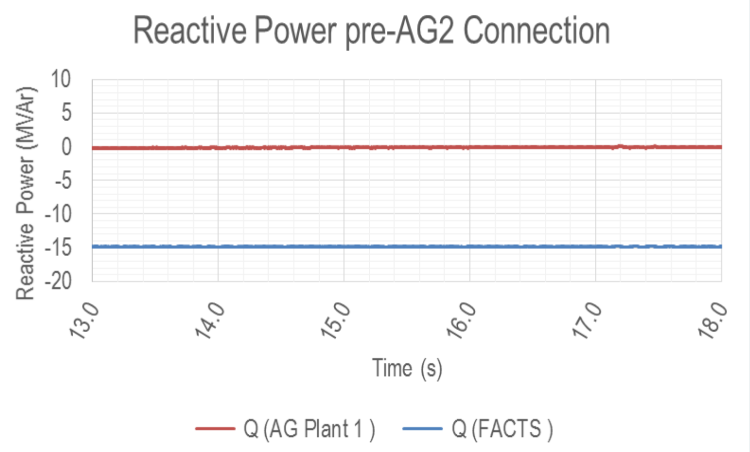
Accurate simulation of voltage phase angles being the key indicator of loss of synchronism conditions

RMS- and EMT-model appropriateness

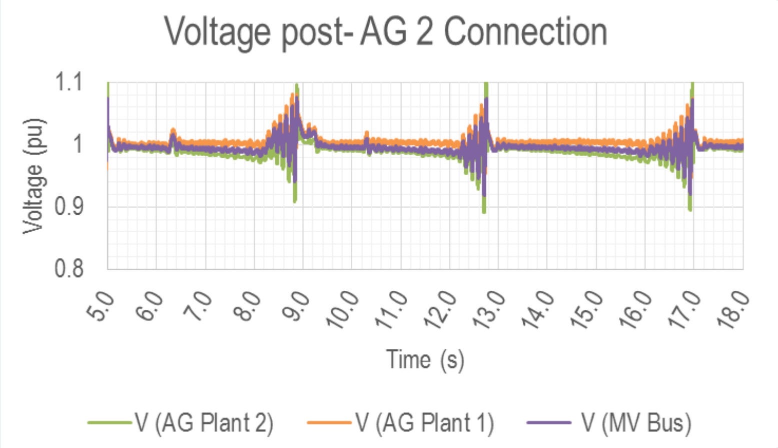
Voltage, active/reactive power before connection of new asynchronous generation

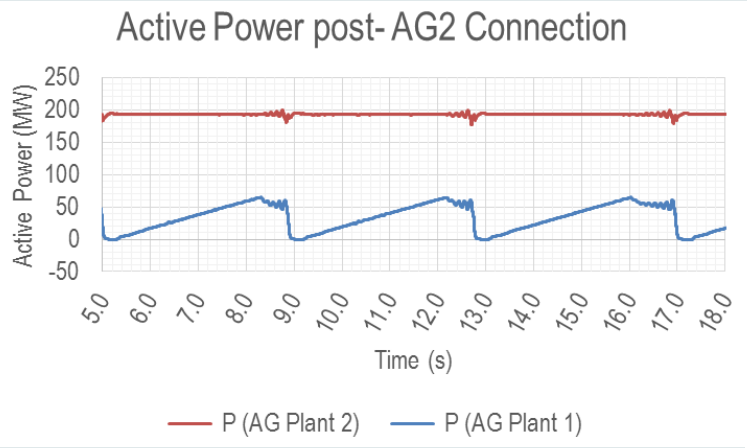


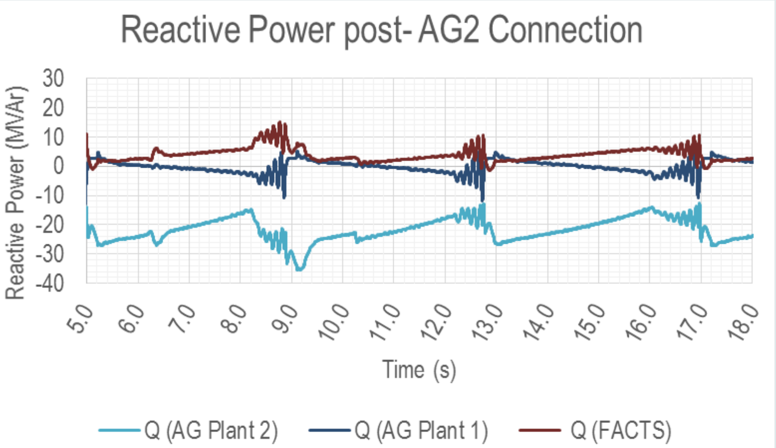




Voltage, active/reactive power after connection of new asynchronous generation







Large-scale EMT model development in AEMO

Summary

- Large-scale EMT models of four of the five regions are currently complete in Australian national electricity markets (NEM)
- This corresponds to an installed generation capacity of more than 30 GW, with several hundreds of busbars and approximately 100 large-scale inverter connected generators.
- These models are used for a variety of applications including:
  - Generator interconnection studies for inverter-connected generation
  - Determining system strength and inertia requirements at the transmission network level
  - Determining minimum must run synchronous generators in each region
  - Designing system-wide special protection schemes

PSCAD load flow model development

- AEMO uses PSCAD/ETMDC and PSS/E for large-scale simulation studies.
  - Other capable tools may exist in the industry.
- PSCAD load flow cases are developed automatically from PSS/E load flow files sourced from actual system snapshots.
- An auxiliary tool is used to draw network single line diagram in PSCAD, and map PSCAD to PSS/E.
- Another auxiliary tool is used to apply element status, correct tap position and machine setpoints in PSCAD.
  - This allows obtaining correct initial conditions without manual intervention.

Network and generator Splitting

- Network splitting
  - To increase the simulation speed (see the example).
- Generator splitting
  - Models of inverter connected generators often run at different time-steps, sometimes as low as 1-2 μs.
  - The slowest model(s) will largely determine the overall simulation speed.
  - Each model run at a different case to support their needs for different time steps without slowing down the overall simulation.

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Generator model dynamic model development and integration

Synchronous

- Source codes are available to AEMO
- Often no major differences between respective RMS and EMT models
- Fast to simulate
- Placed in network cases
- Often developed by AEMO internally

Inverter-connected

- Highly confidential and vendor specific
- Appreciable differences between respective RMS and EMT models
- Relatively slow to simulate
- Placed in separate cases
- Obtained from OEMs

Model confirmation

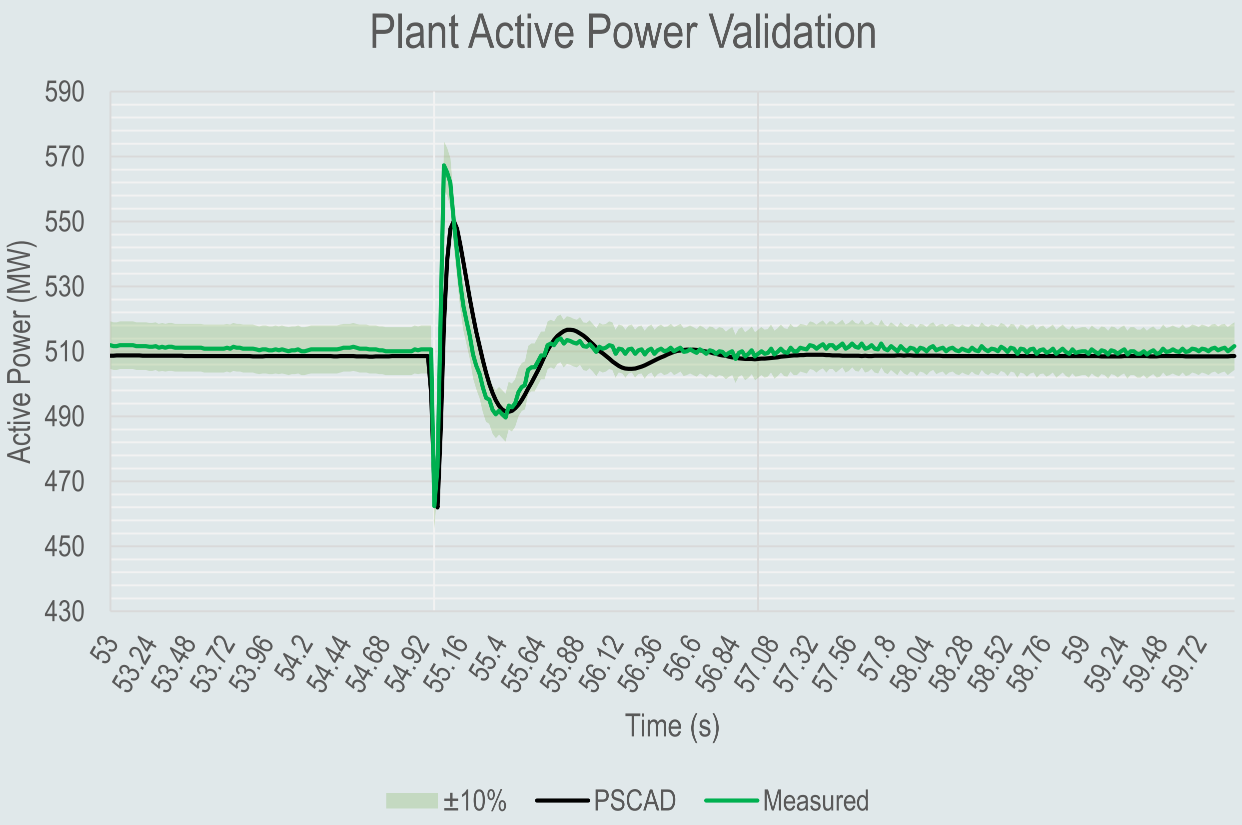
Individual plant

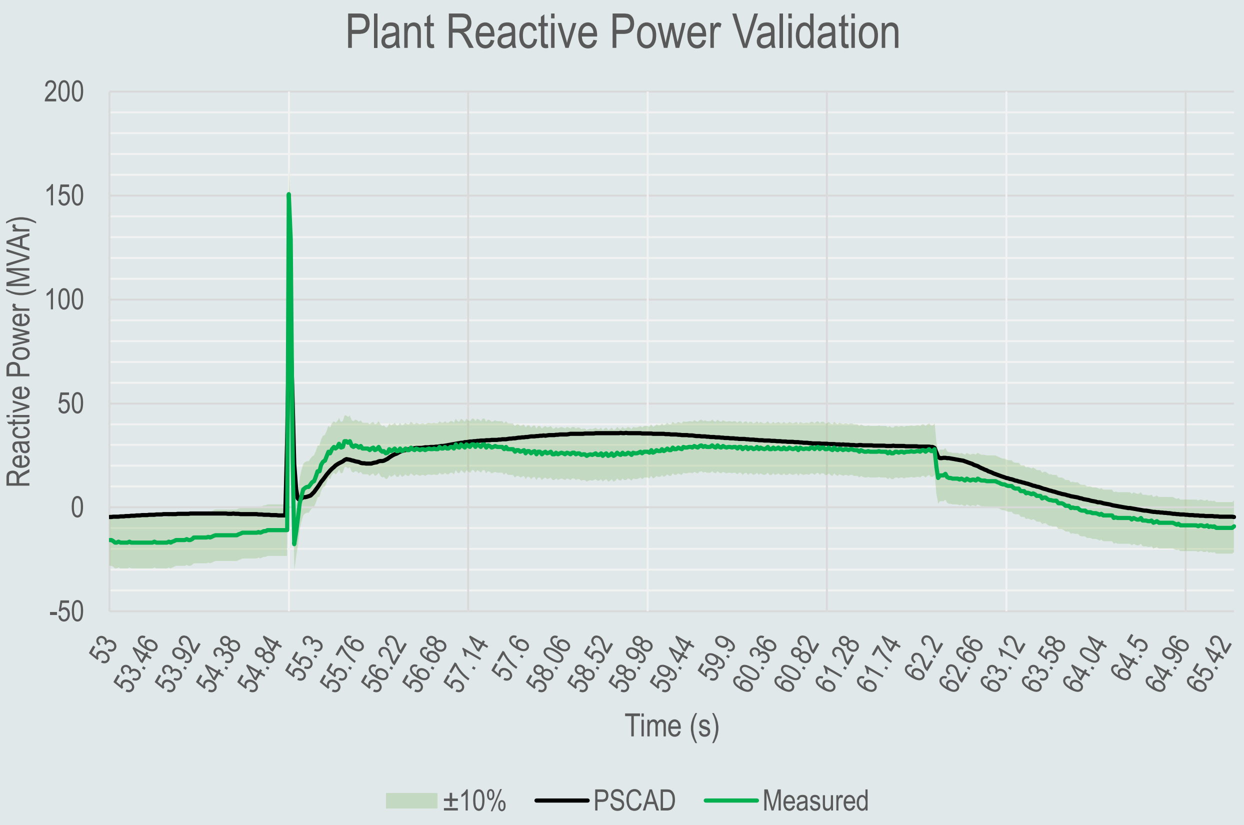
- Playback of real measured disturbances into each individual model in isolation
- Compare measured and simulated responses
- Confirm the accuracy of each model in isolation

System-wide

- Run system-wide studies
- Apply a known fault at a known location that occurred in practice
- Often requires adjusting fault impedance to obtain the same voltage dip as occurred in practice
- Confirm the accuracy of system-wide models including impact of multiple generators and loads

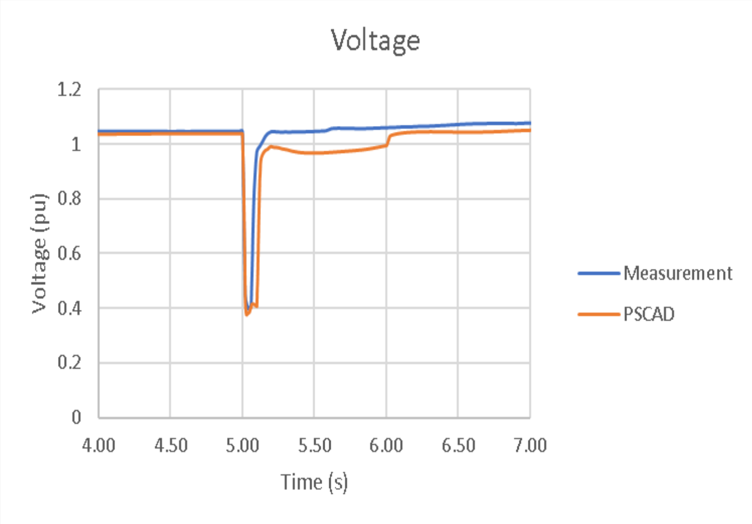
Example of a thermal synchronous generator model confirmation

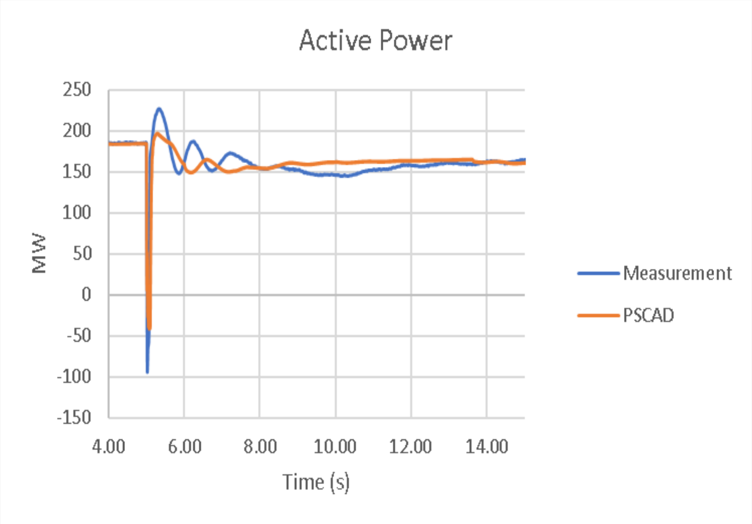


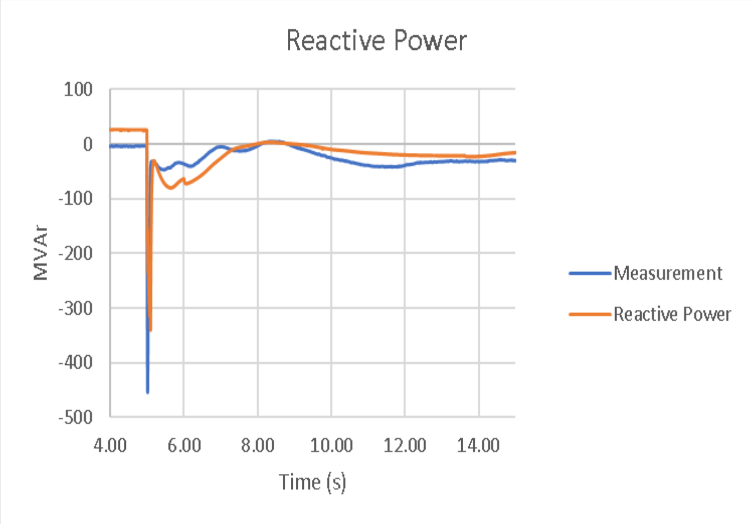


+/-10% bands are statutory model accuracy requirements in Australian NEM

System-wide model confirmation







Voltage, active and reactive power for a substation close to the faulted point

Considerations when conducting large-scale EMT studies

Considerations when conducting large-scale EMT studies

- Simulation speed and hardware implications
- Obtaining vendor-specific EMT models from OEMs
  - Not an issue in Australian NEM due to legally binding requirements set out in AEMO's Power System Model Guidelines
- Are there screening methods for determining when RMS and EMT simulations are required?
- The extent of the system that needs to be modelled in EMT domain
- Hybrid RMS and EMT simulation
- Offline vs real-time EMT simulation

The newly formed CIGRE WG C4.56 looks at some of these aspects in more details

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