Assessment of GFL and GFM Inverter and Synchronous Condenser Connection in Australia: Lessons Learned

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Reactive current injection by grid following inverters during faults

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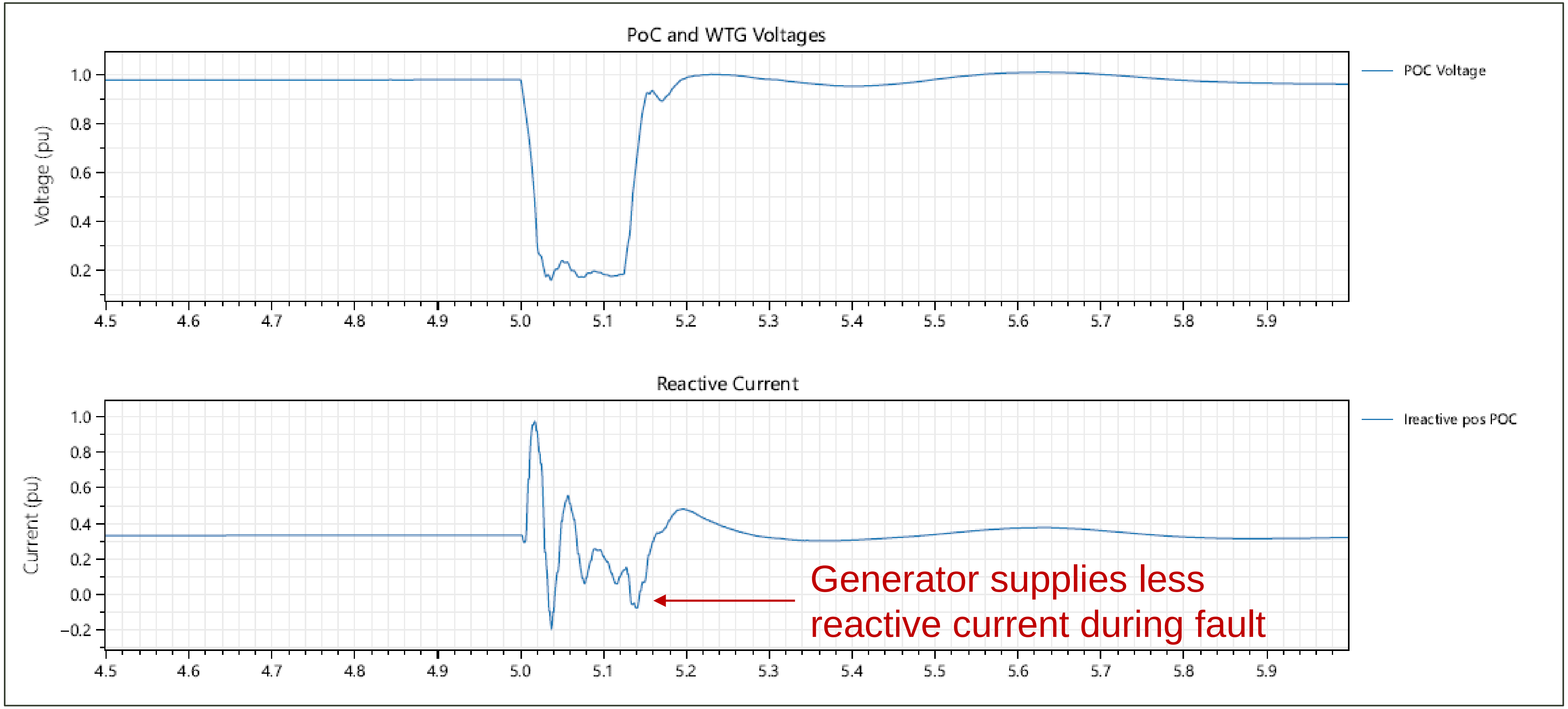
The potential for below zero reactive current injection

- The concept of k-factor is used in many countries to assess the reactive current response during the faults.
- Recent experience shows that even 0% reactive current injection (for every 1% reduction in voltage during fault) cannot be achieved in some scenarios, e.g. when operating at steady-state Qmax.



Large variations in reactive current during faults

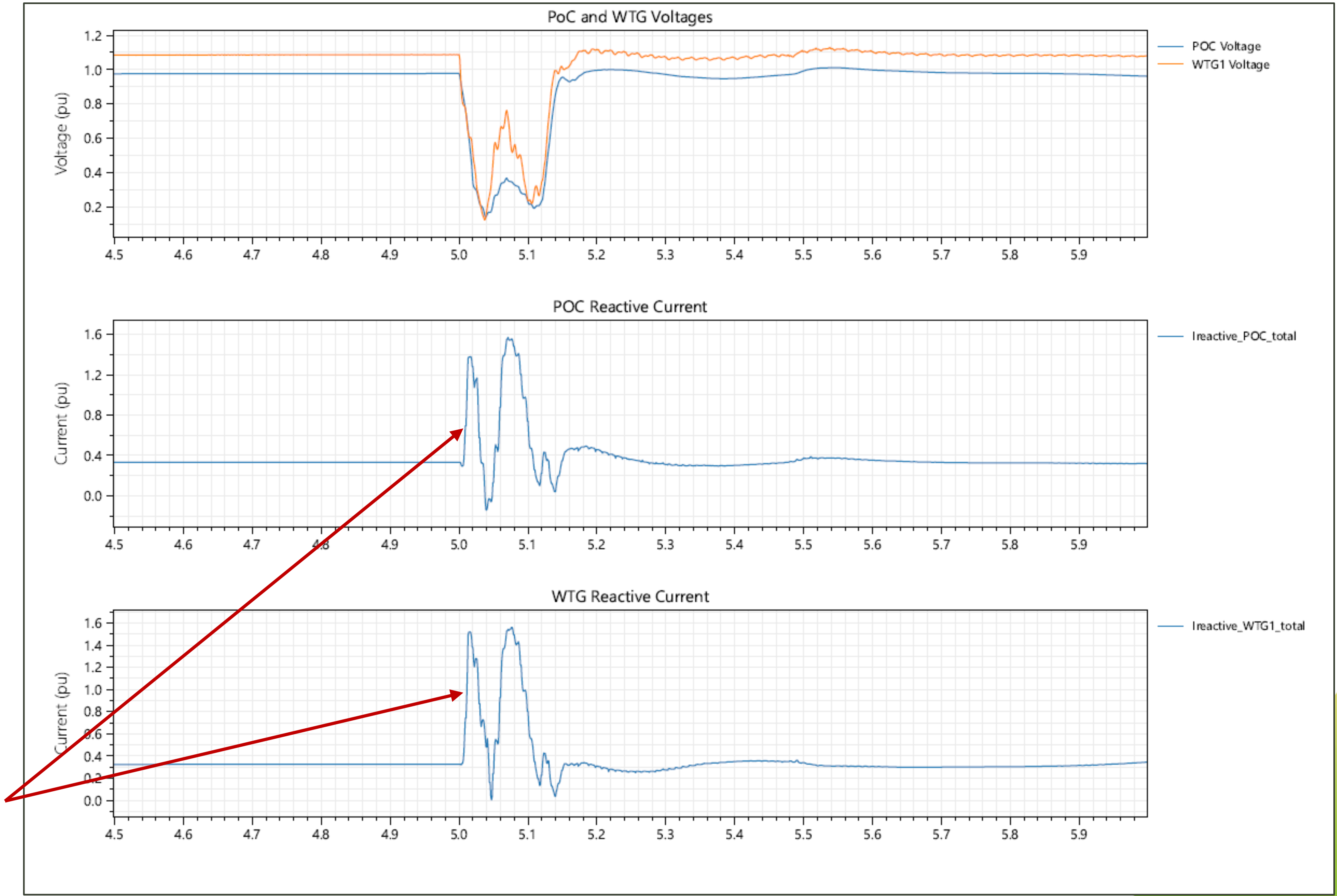
Scenarios of most concern:

Deep unbalanced faults, pre-disturbance reactive current injection

Key Messages:

- Reactive current response varies noticeably especially during unbalanced faults, and as such it may not be the most reliable metric.
- This was observed at both the connection point and unit terminals.

No reliable reference for reactive current injection during some unbalanced faults



Under-estimation of the total response with positive-sequence only calculations

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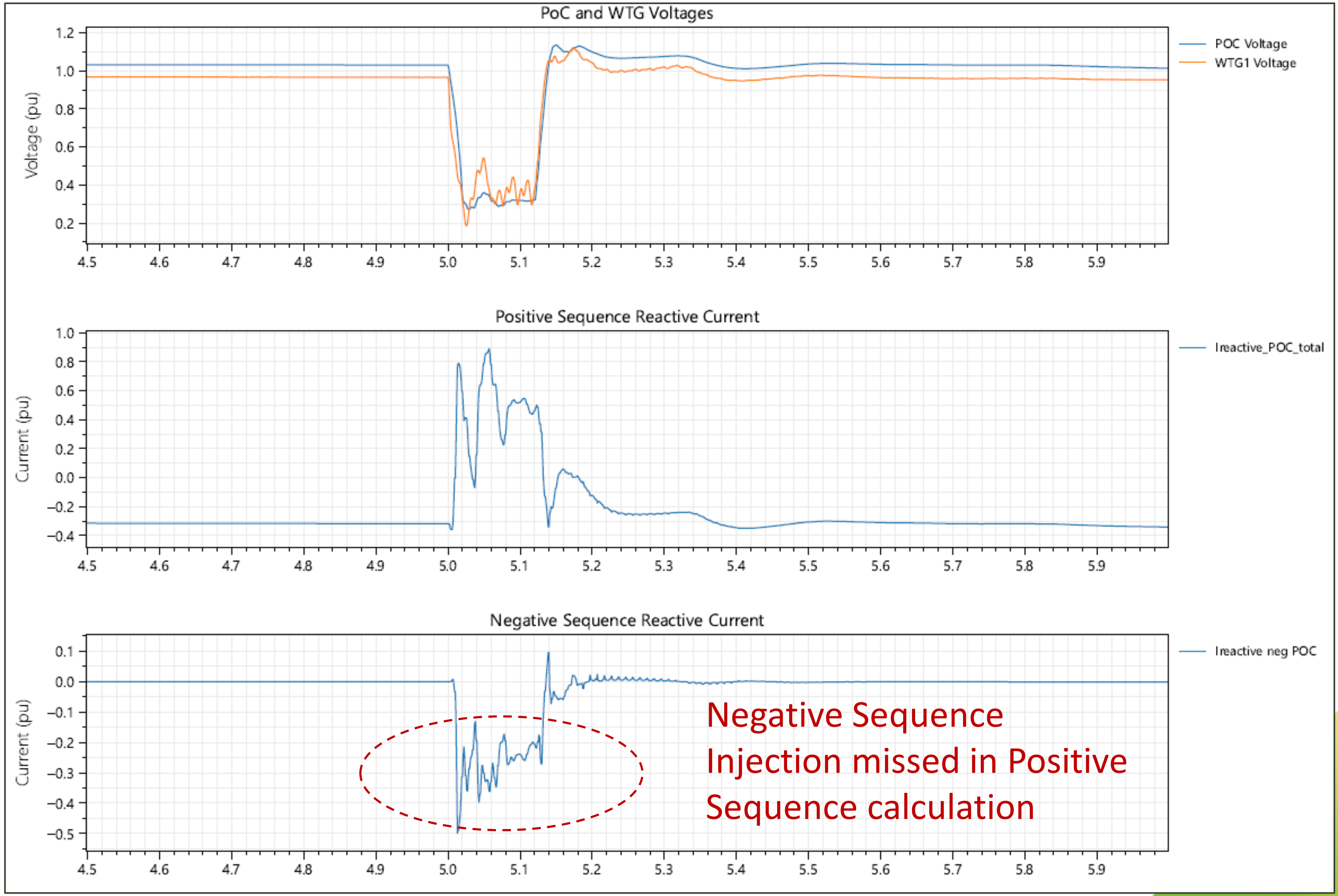
Scenarios of most concern: Unbalanced faults, all pre-disturbance operating conditions

Important fact:

Type 3 wind turbines exhibit inherent negative-sequence current absorption, which cannot be often fully tackled by the control system

Key Messages:

- The use of positive-sequence only
  - Under-appreciates the total generator's response
  - Could be inconsistent and largely variable in particular for technologies where there is an inherent negative-sequence current contribution



Accounting for negative-sequence current contribution

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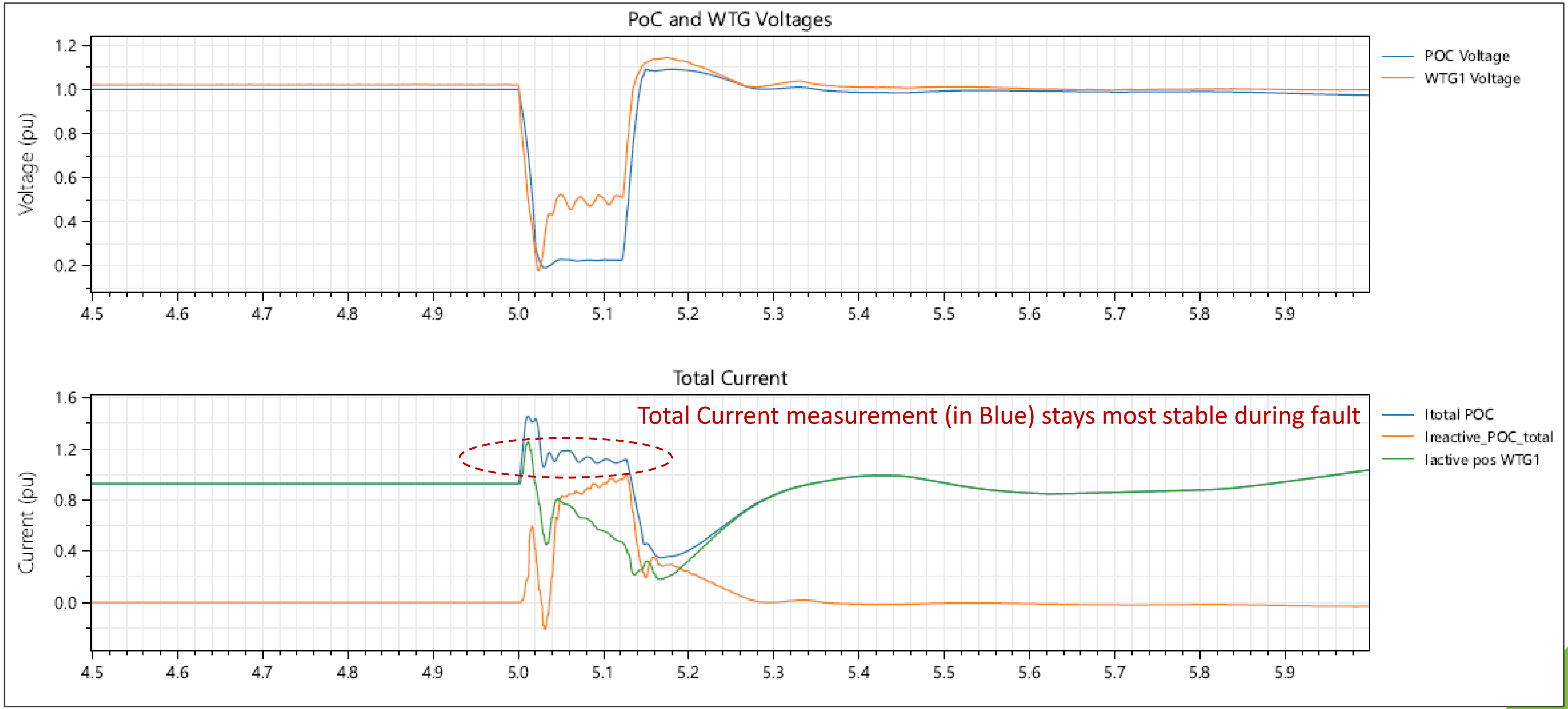
Key Observations:

- Measurement of total current captures Positive and Negative sequence contribution during the fault, as well as the active and reactive currents.
- Observed to be a consistently less volatile signal during the fault event across sensitivities investigated.



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Grid-forming inverter challenges

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Summary of challenges

Vendor-specific phasor-domain models

No dedicated technical performance requirements

The need to prioritise capabilities delivered on a case-by-case

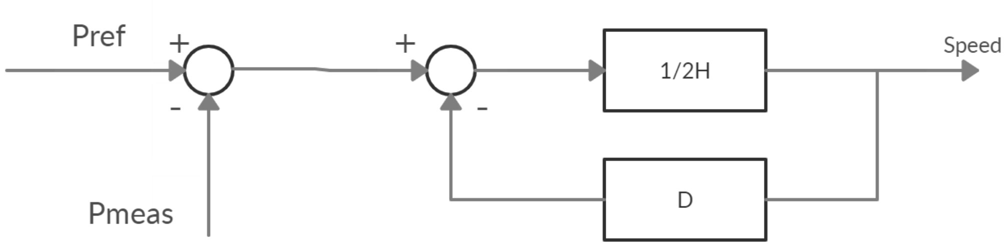
Grid forming vs grid-following inverters

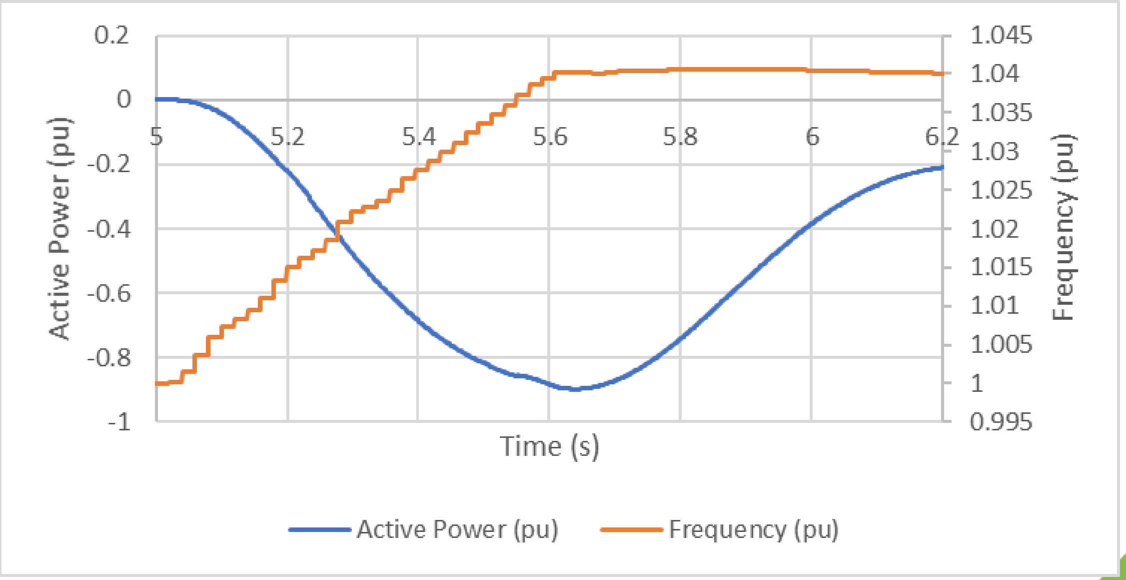
Grid-forming inverter characteristics:

- Have no susceptibility or instability mechanisms
- Resolve all wider system stability and power quality issues
- Substitute completely grid-following inverters in mid-term
- Eliminate the need for synchronous machines

Control system coordination challenges

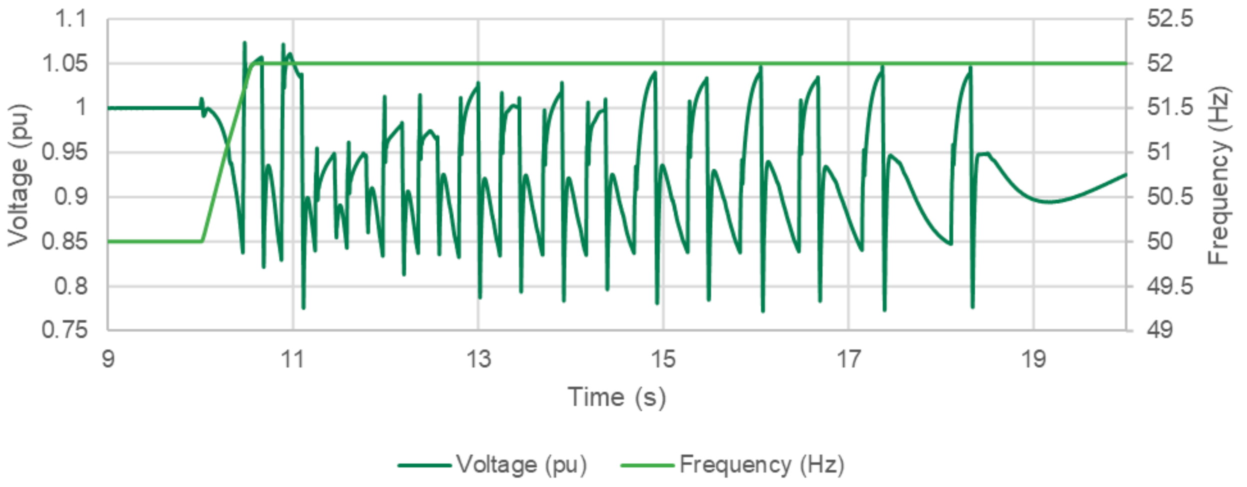
- Connection summary:
  - Remote location
  - Two existing nearby IBRs
  - Short circuit ratio (SCR) ~2.0 on its own
  - Battery equipped with virtual synchronous machine (VSM)
- Challenges:
  - PPC and inverter coordination
  - Inverter control time delays
  - Virtual inertia vs sustained frequency control

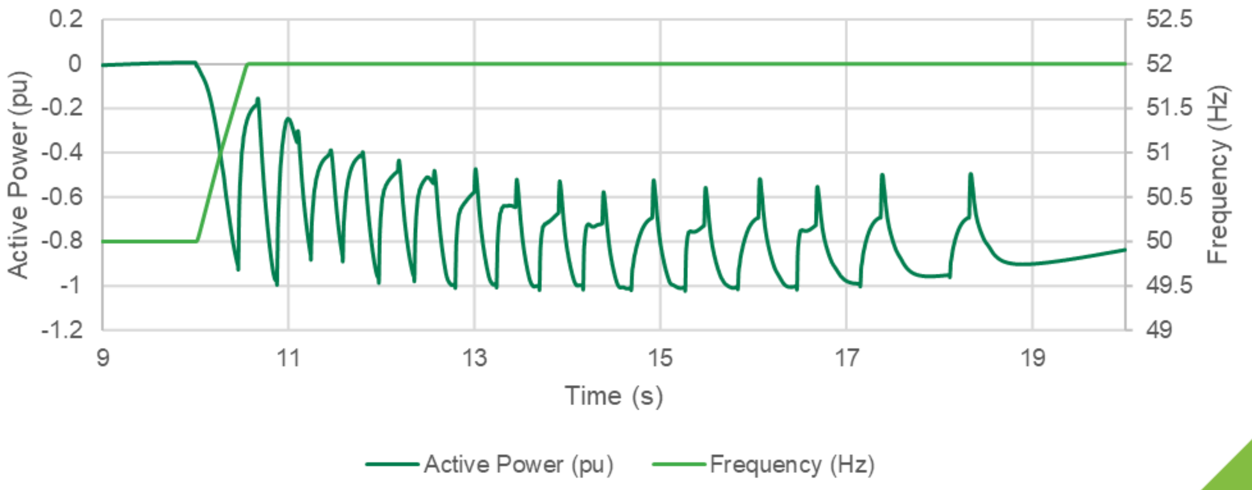




Voltage collapse

- Virtual inertia/frequency response
- Low SCR conditions
- Active power flow change drives change in voltage
- Voltage rise/collapse ensues
- Voltage FRT re-striking occurs





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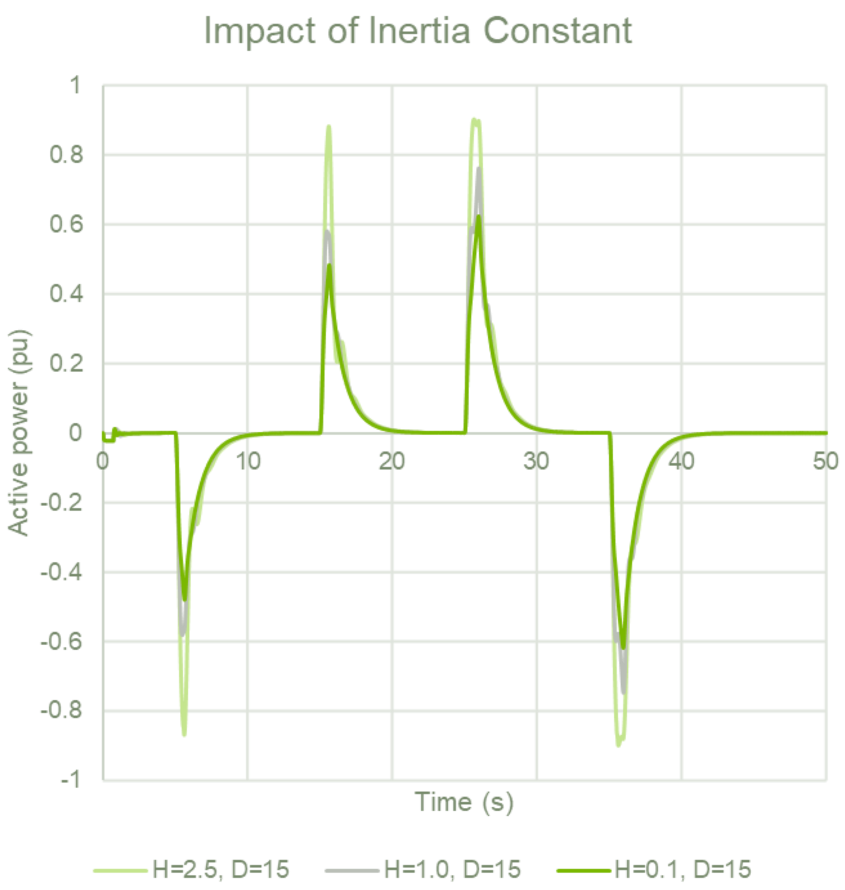
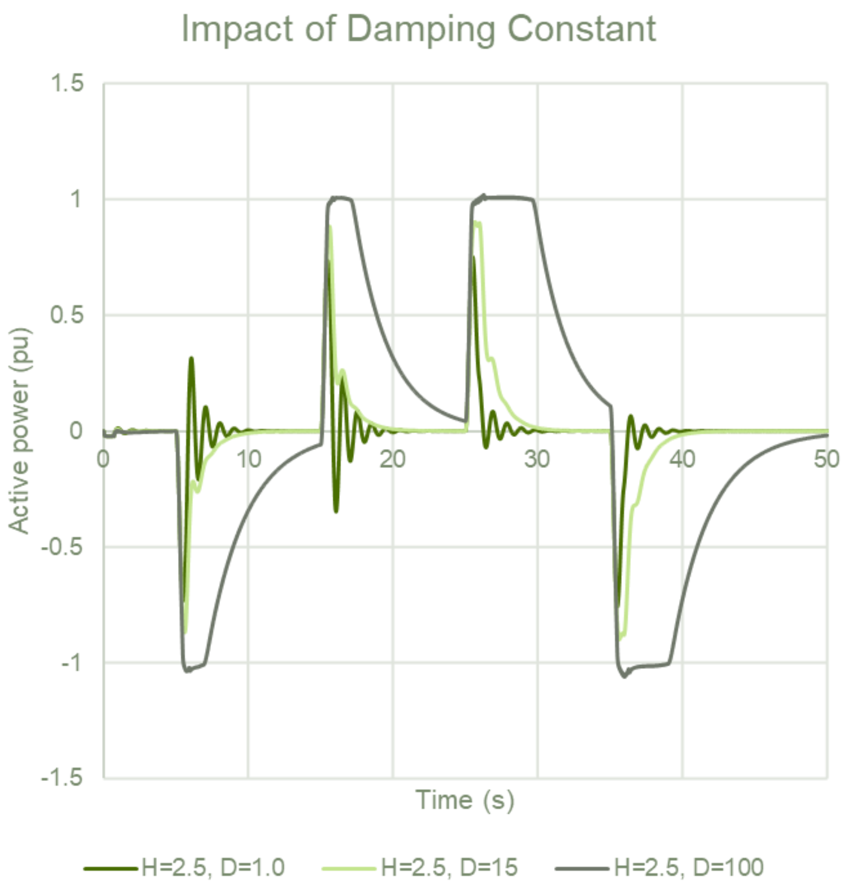
Impact of inertia and damping constants





±2Hz and ±3Hz frequency step change applied to produce figures

Synchronous condensers

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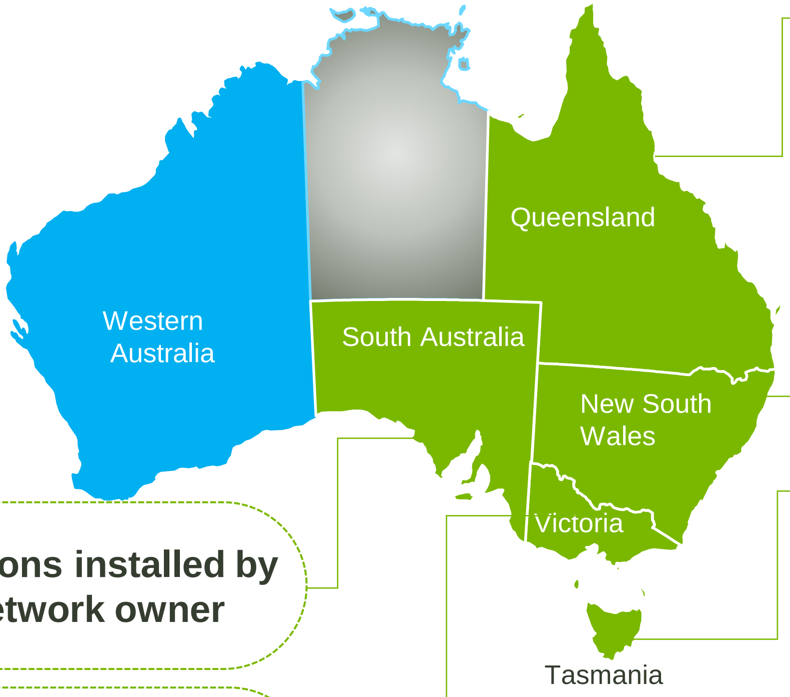
Synchronous condensers in Australia



- A 65 Mvar Syncon installed by the SF owner
- 2x42.5 and a 60 Mvar Syncon installed by SF owners
- None, however, there are many Syncon capable hydro units
- 4x130 Mvar syncons installed by Transmission network owner
- A 190 Mvar syncon installed by SF owner

Synchronous condensers learnings

Courtesy of ElectraNet

- Simpler grid connection modelling and studies
- No syncons has been approved in the recent time
- Different risk appetite in Australia compared to some other countries on syncons vs grid-forming inverters
- Single point of failure in the event of outages, and the time required to address failures
- It is still a good tool in the toolbox noting supply chain issues.
- Future syncons will be installed by networks rather than generators