

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

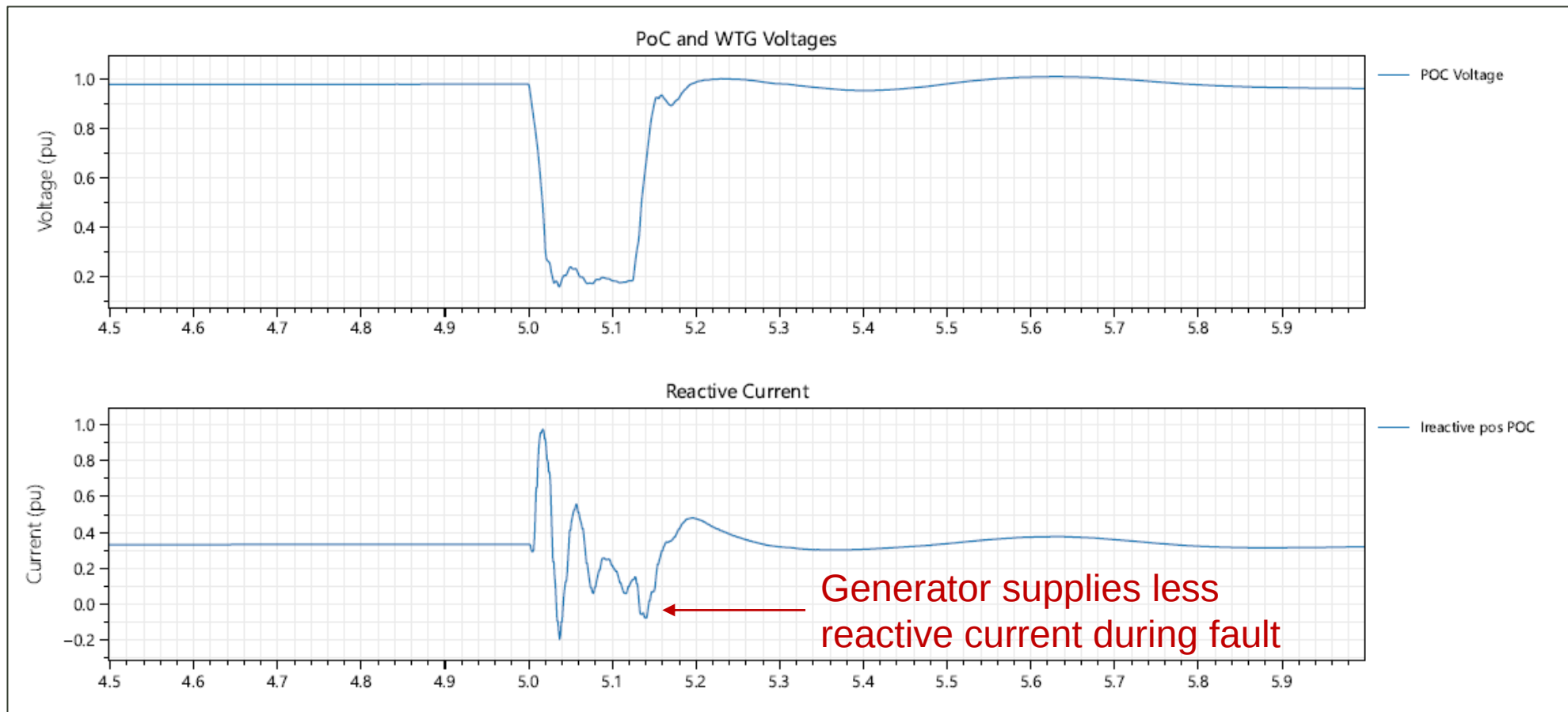
Babak Badrzadeh

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Reactive current injection by grid following inverters during faults

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 Q_{max} .



Large variations in reactive current during faults

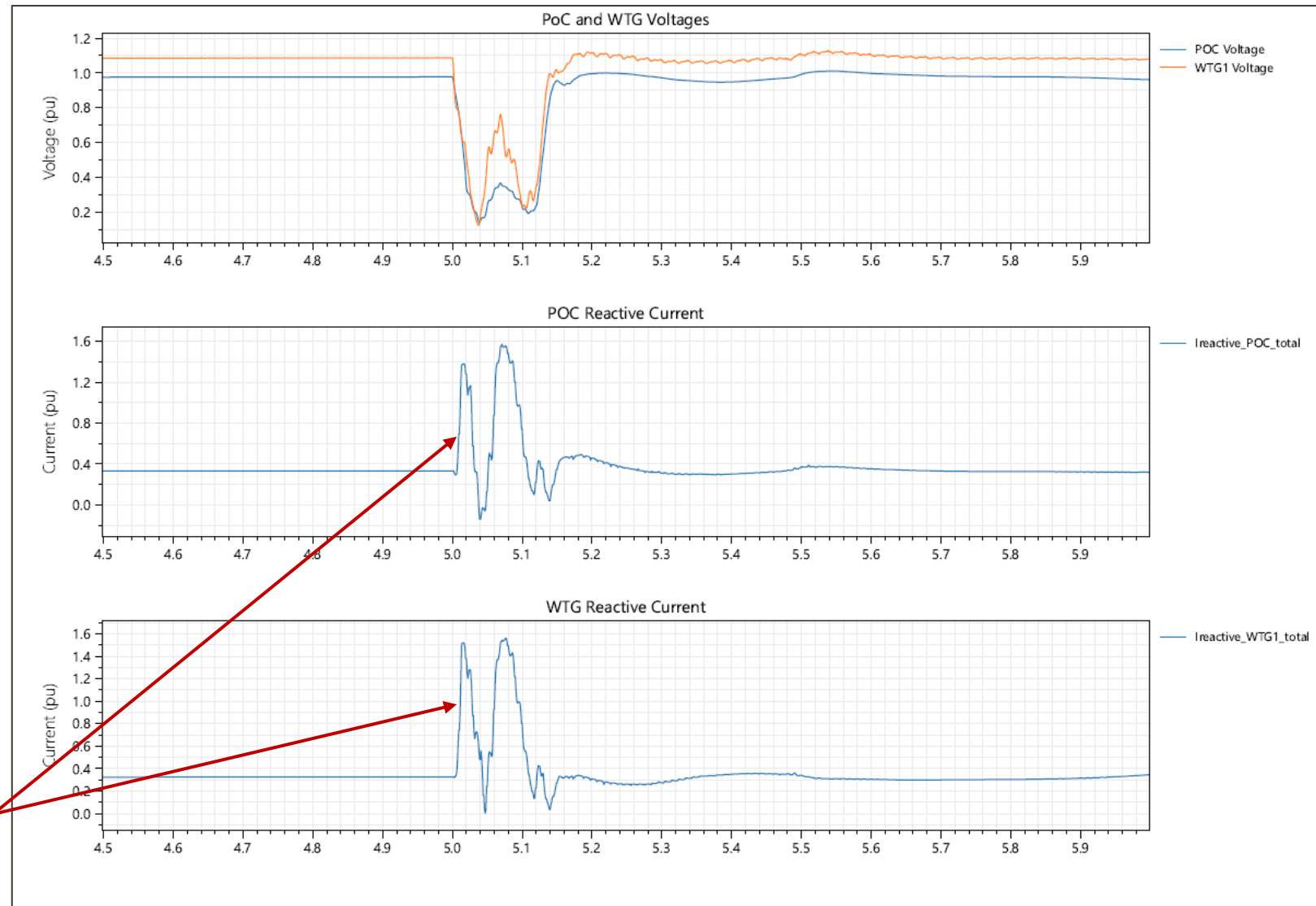
Scenarios of most concern:

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

*Bringing ideas
to life*

Scenarios of most concern:

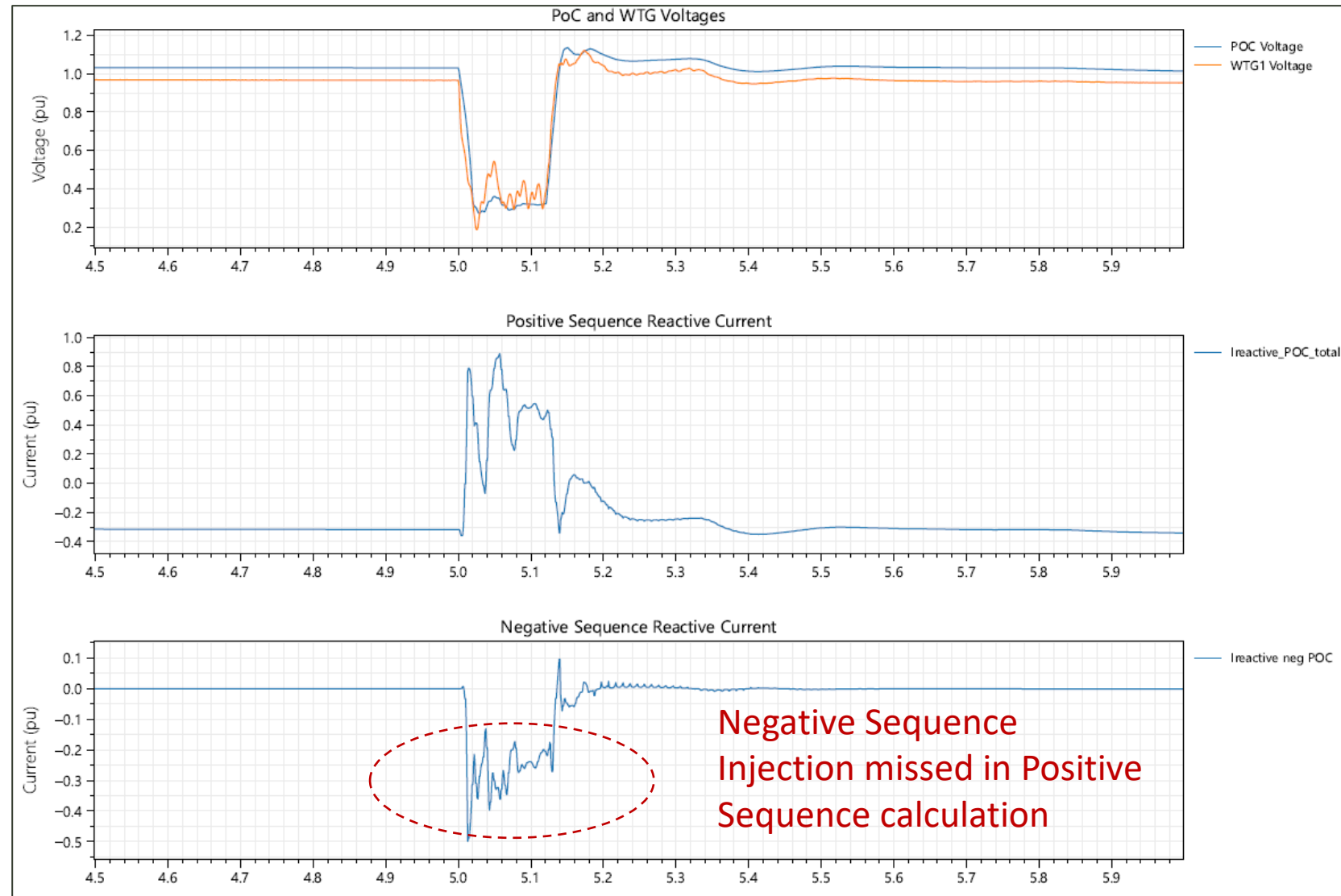
Unbalanced faults, all pre-disturbance operating conditions

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

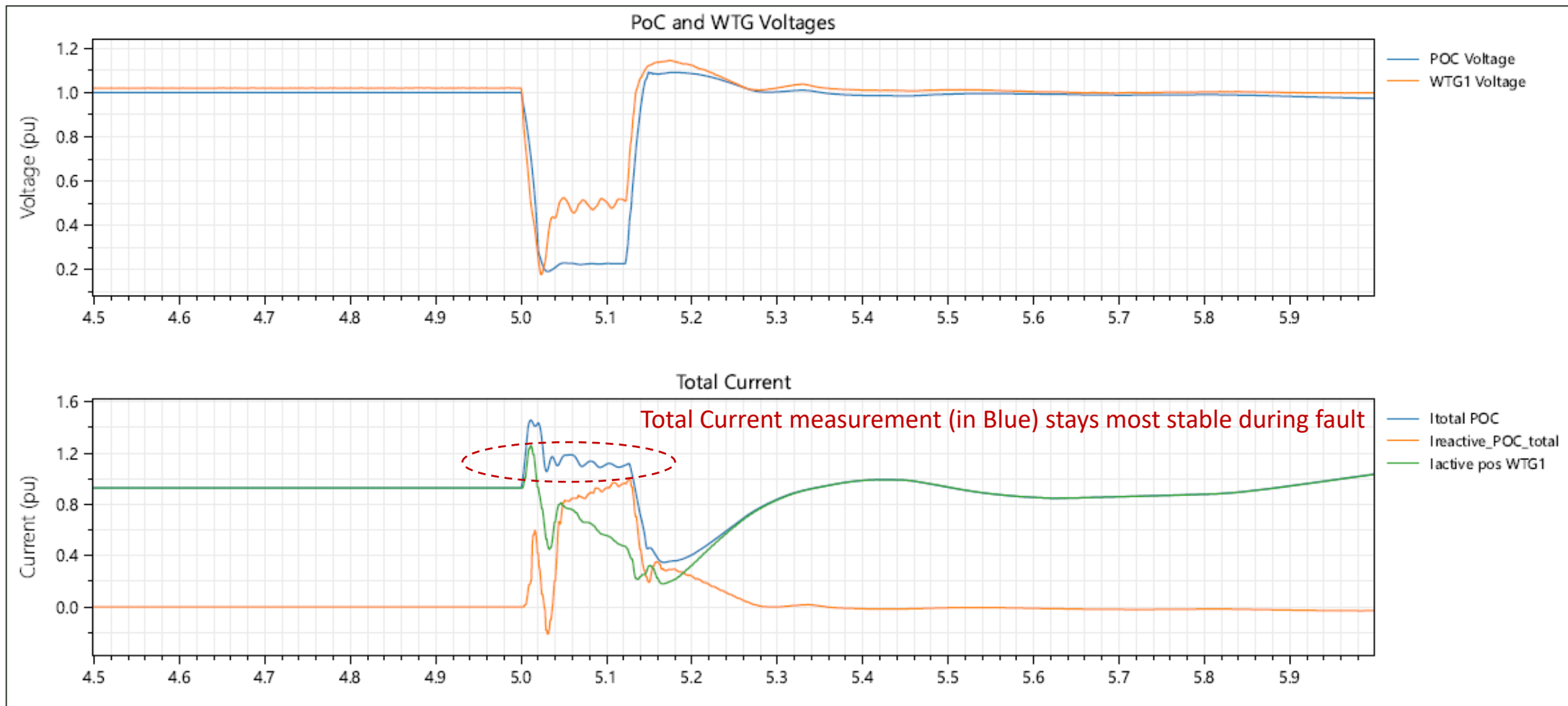


Accounting for negative-sequence current contribution

Bringing ideas
to life

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.



Grid-forming inverter challenges

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

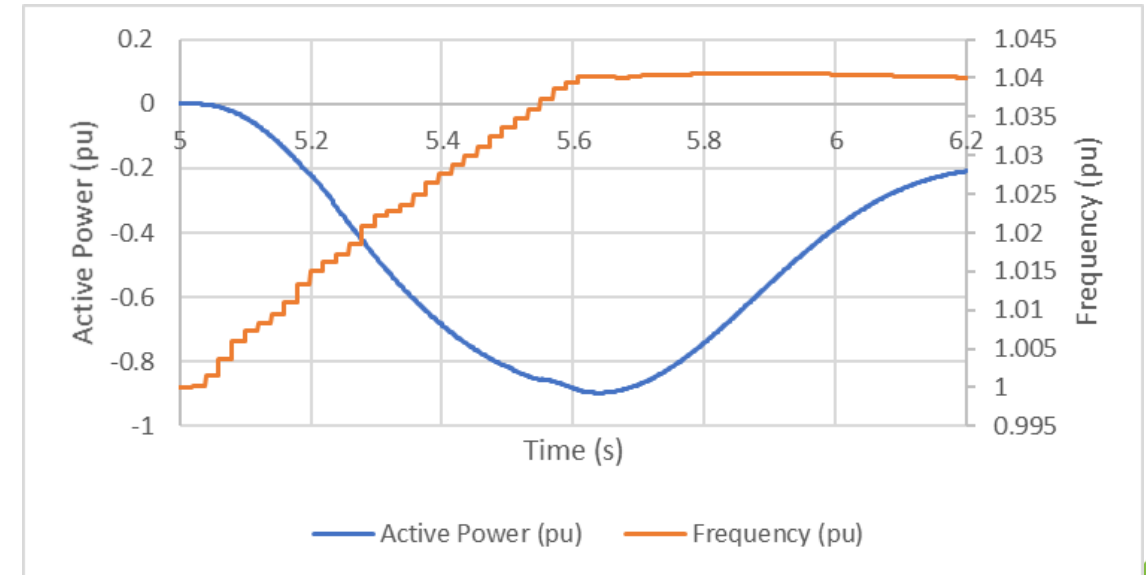
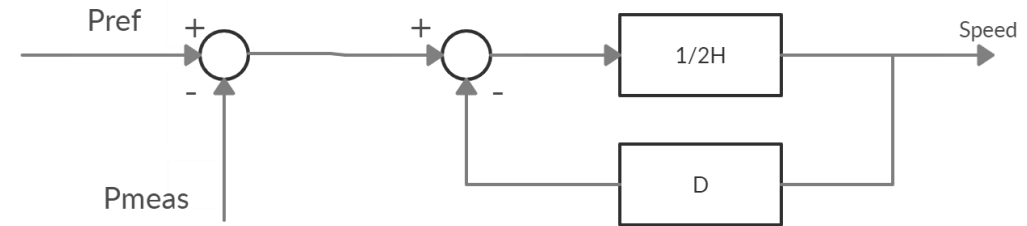


Grid-forming inverter characteristics:

- 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

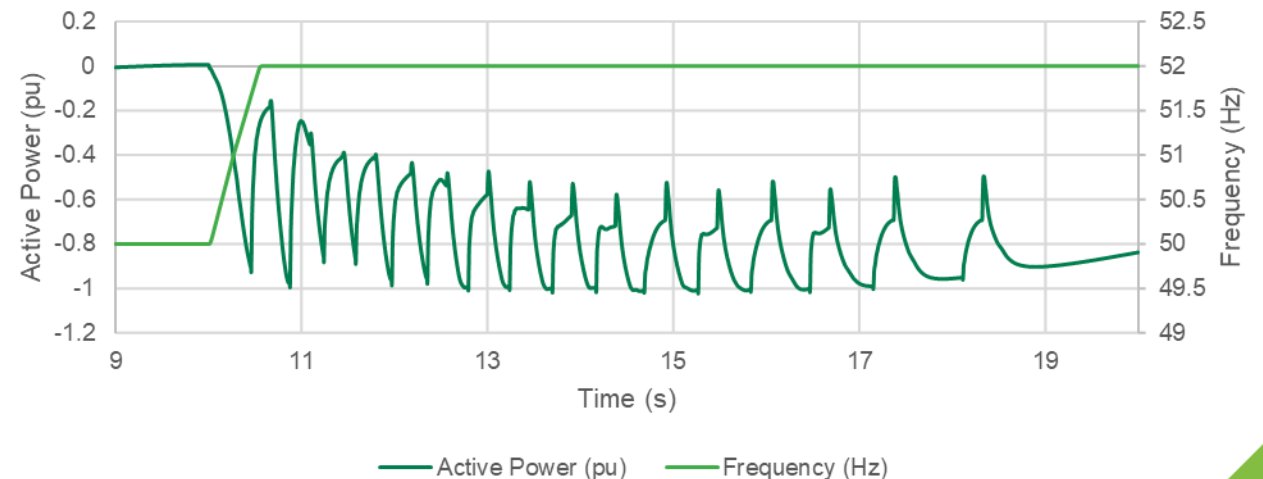
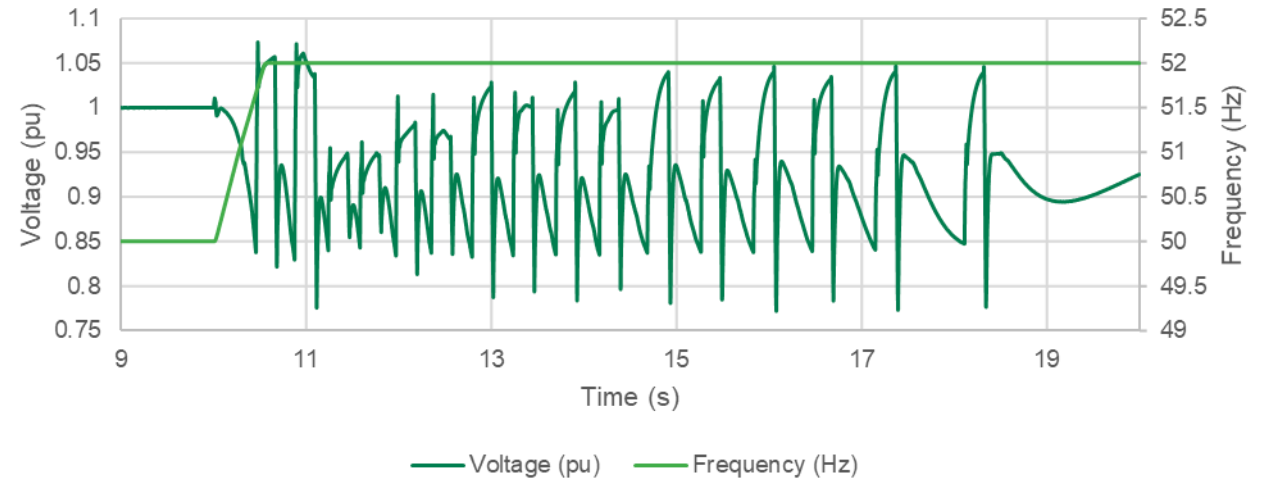
Control system coordination challenges

- 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

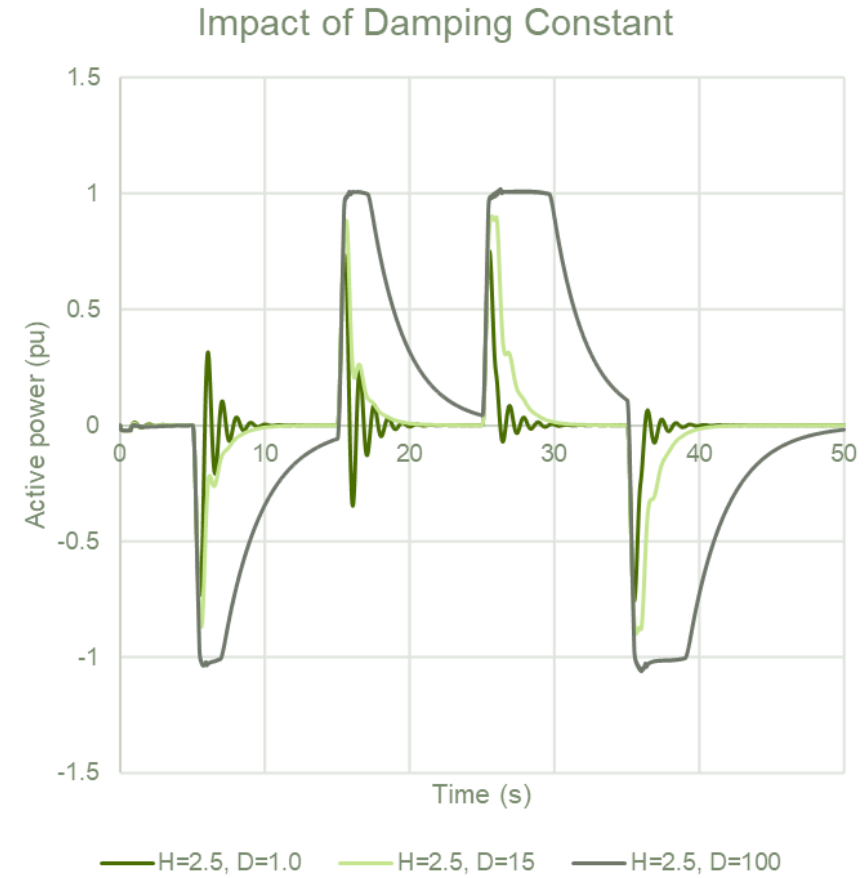
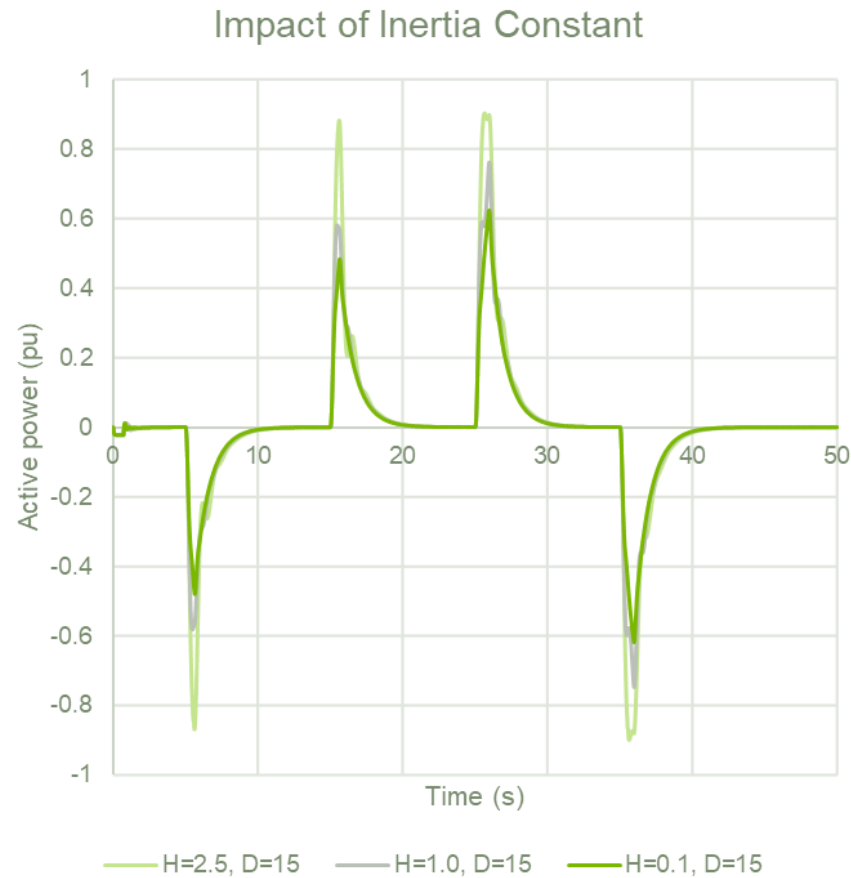


Voltage collapse

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



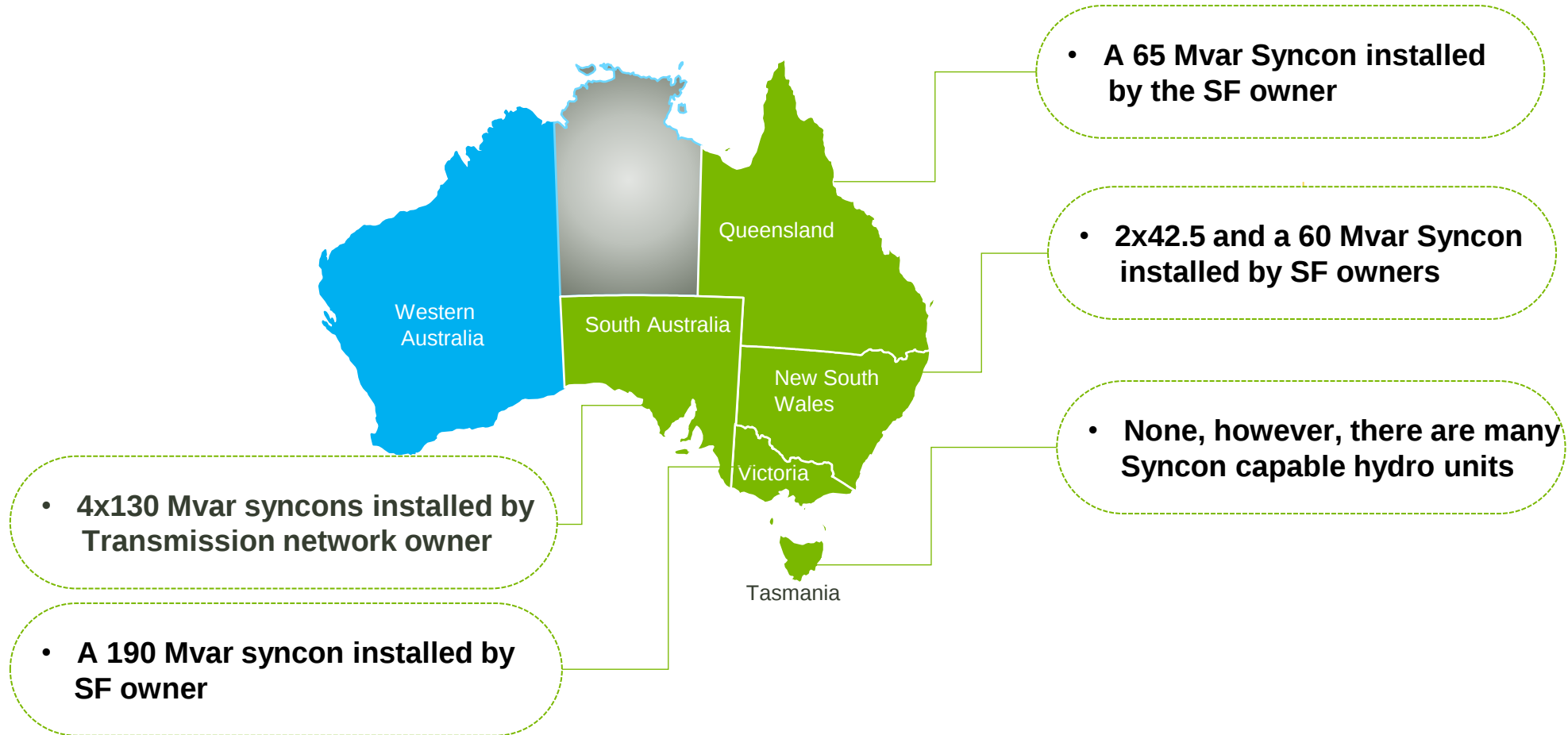
Impact of inertia and damping constants



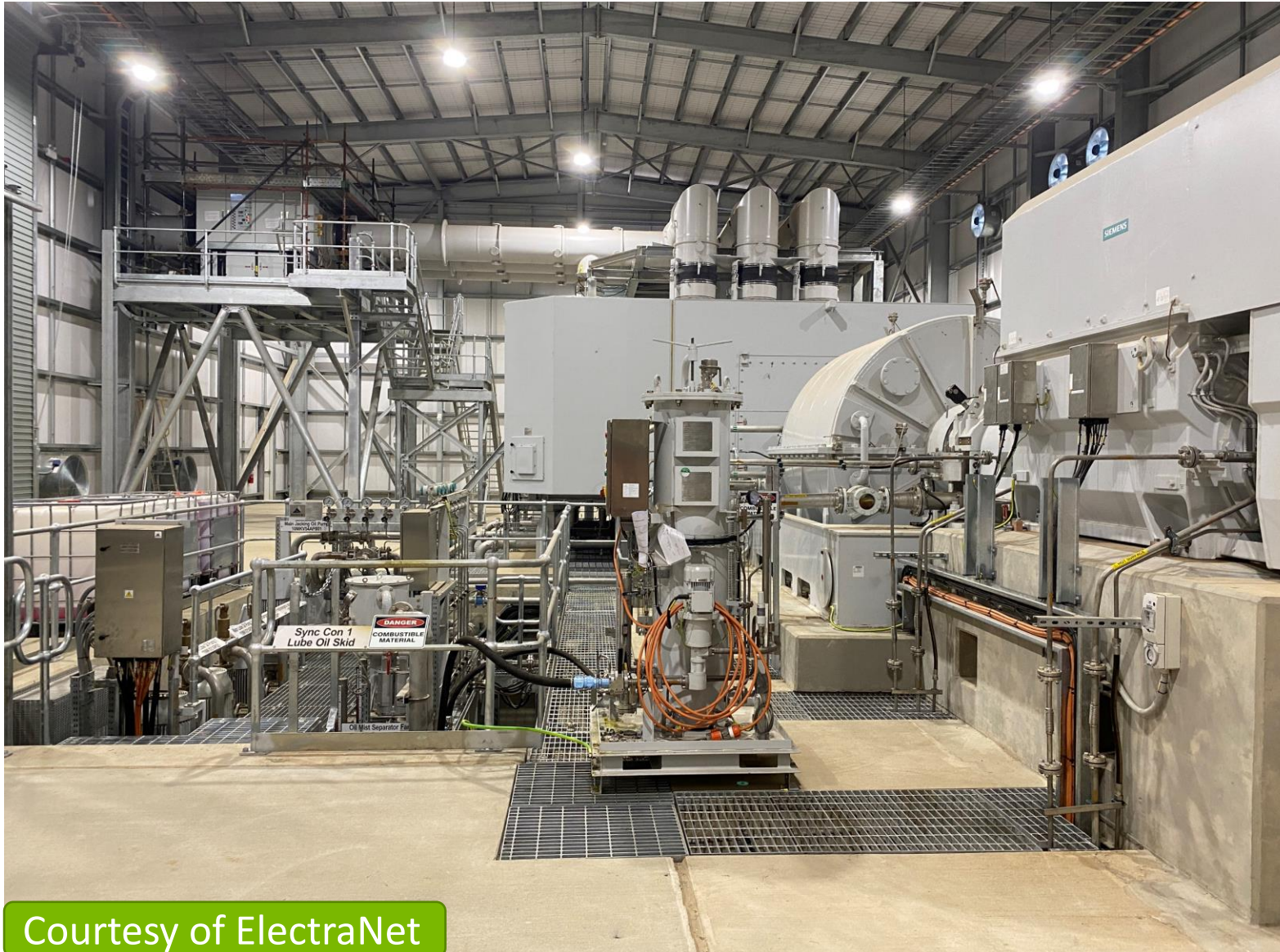
$\pm 2\text{Hz}$ and $\pm 3\text{Hz}$ frequency step change applied to produce figures

Synchronous condensers

Synchronous condensers in Australia



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