System strength and inertia challenges associated with increased penetration of inverter-based resources in Australian National Electricity Market

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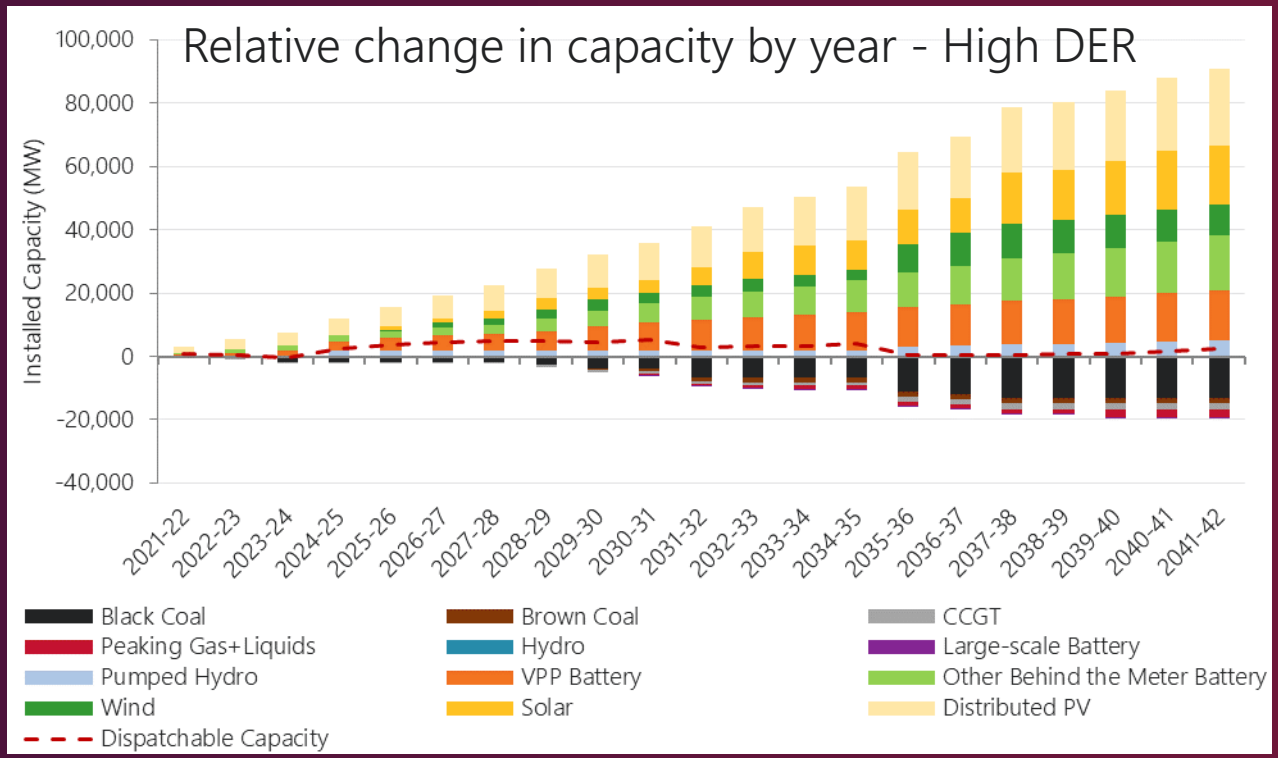


Rapidly changing generation mix and technology

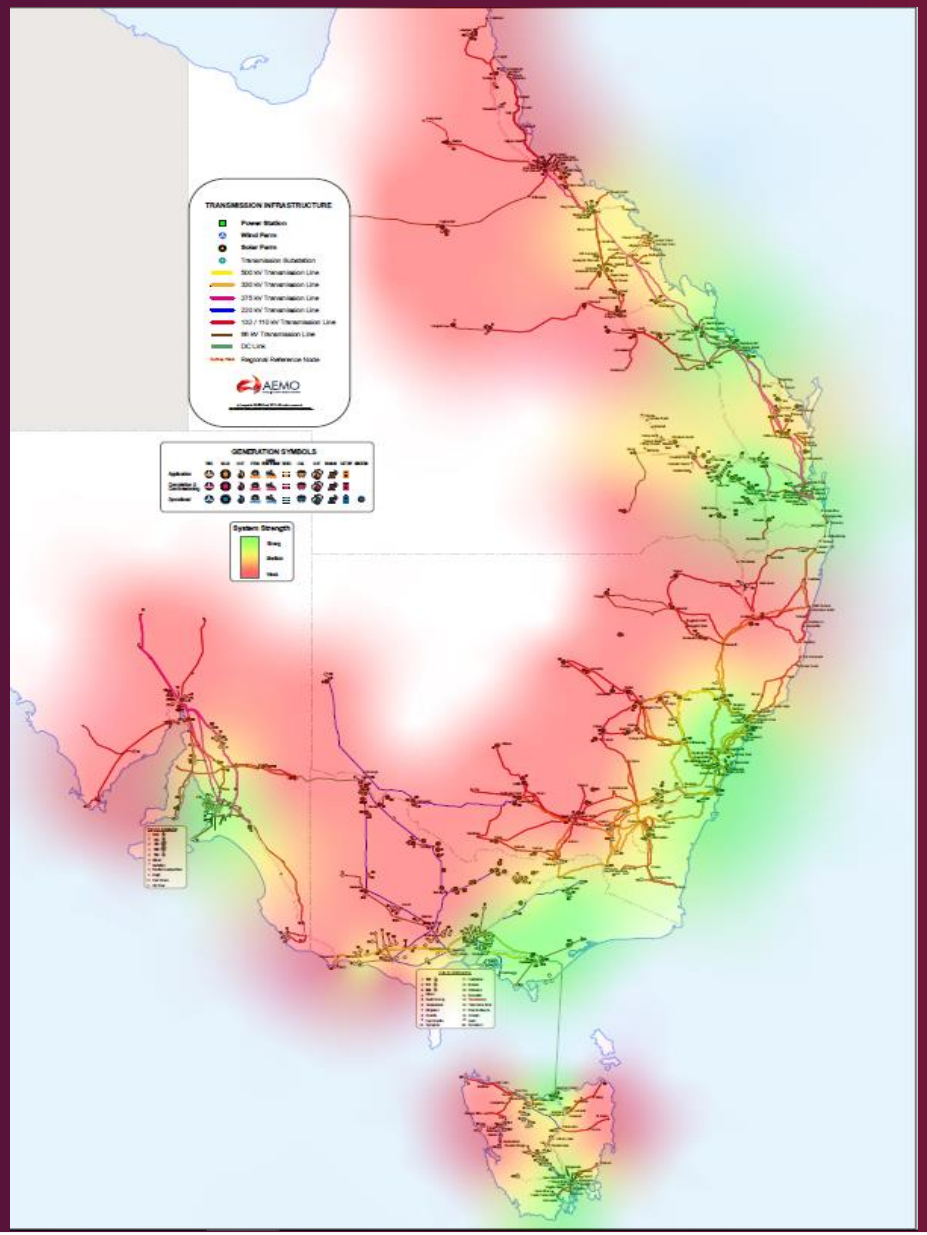
Evolving technology/applications

- Application of batteries for system security enhancement (100 MW BESS in South Australia first of its kind)
- Grid forming inverters for grid-connected applications
- Increasing installation of hybrid wind/solar with batteries
- Increasing application of synchronous condensers

Inverter-based generator connection sparsity

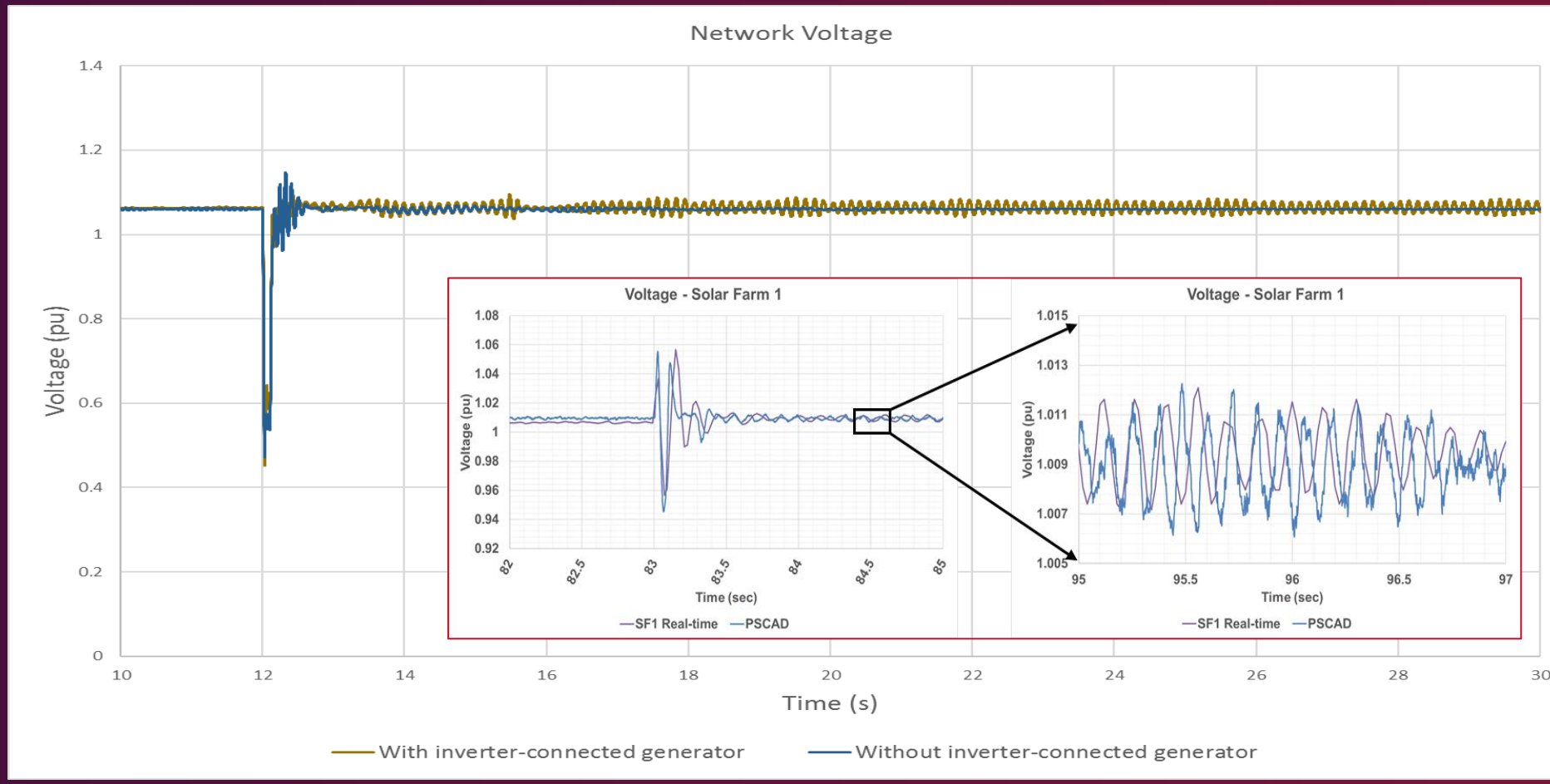
- Far from capable synchronous generators
- Close to other inverter-based generation

Lack of system strength is one of the key challenges



The need to design generating plant capable of operating in such networks

Sustained post-disturbance sub-synchronous oscillations



- Oscillations unacceptable due to:
  - Breach of system security and flicker requirements
  - Impact on load/connected equipment

Mitigation measures

Temporary constraints

- A reduced number of inverters limits the oscillations within acceptable levels

Inverter control system/parameter changes

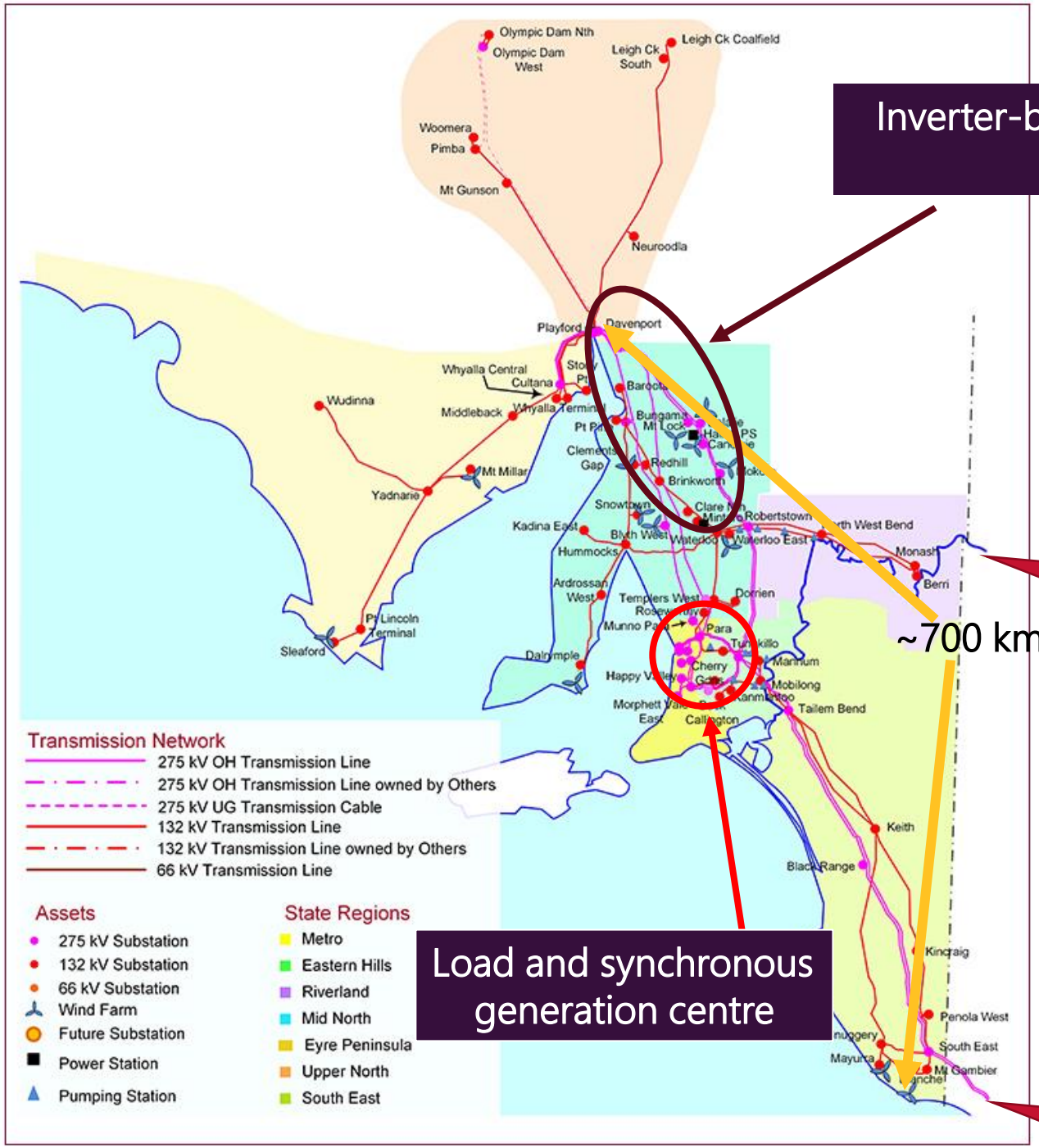
- Retuning the control parameters or refining the control strategy of the impacted inverters limits the oscillations within acceptable levels or removes the oscillations altogether

Installation of nearby synchronous machines

- Installation of nearby synchronous machines increases the system strength available to the inverters in a remote and sparse part of the network

South Australia power system

- Demand: ~600-3,100 MW with a 1,400 MW median
- Installed inverter-based generation: ~2,600 MW
- Rooftop PV in addition: ~1,100 MW
- Synchronous generators are primarily gas-fired (no hydro or coal), hence have the highest marginal cost
- These synchronous generators are sources of system strength for inverter-based generation



Inverter-based generation centre

DC Interconnector

~700 km

Load and synchronous generation centre

AC Interconnector

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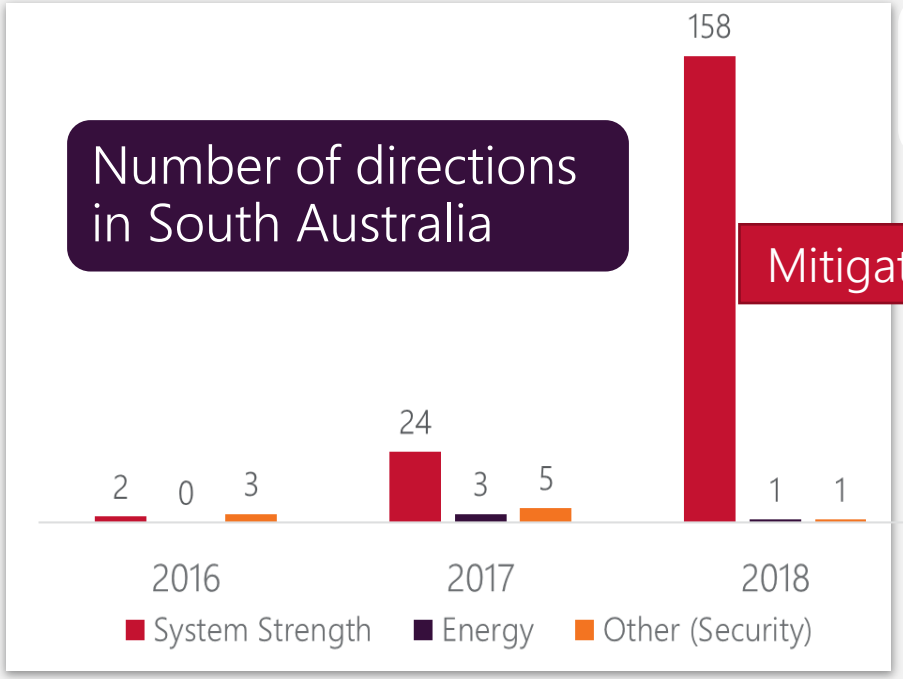
Synchronous generator scarcity

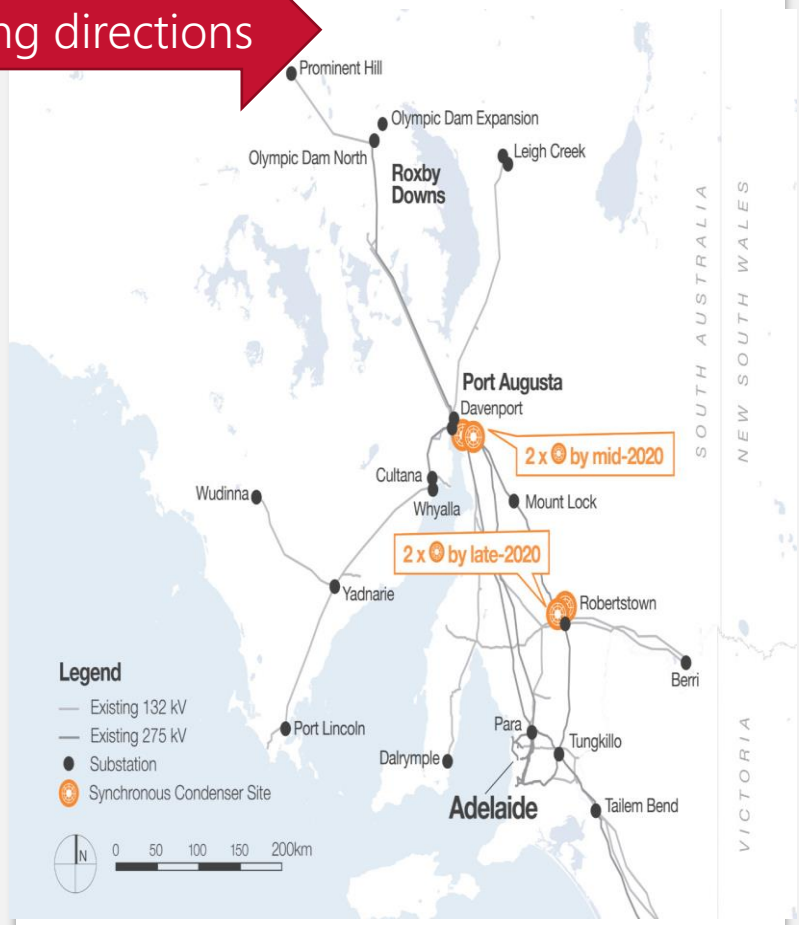
- Synchronous generator retirement/de-commitment
- Aging synchronous plant also contributes to more frequent planned and forced outages



- Minimum synchronous generator requirements apply operationally to maintain sufficient system strength
- Synchronous generators do not tend to run at periods of low demand and low prices
- AEMO directs synchronous generators for system security purposes

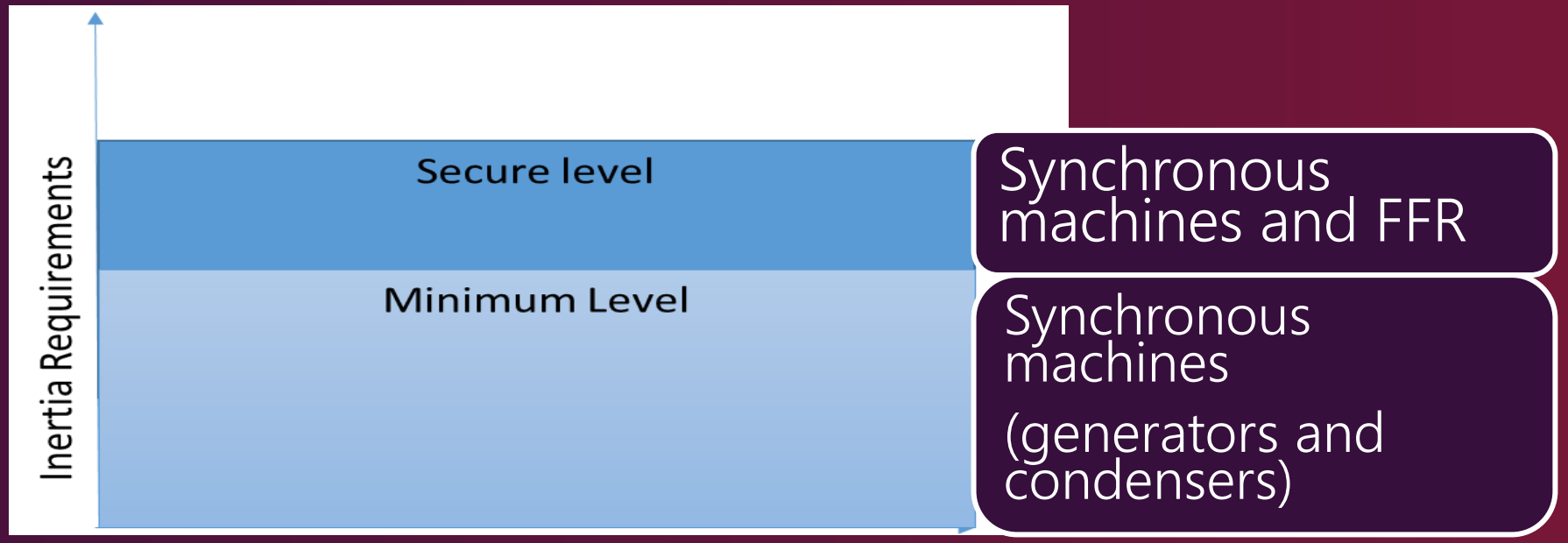
Mitigating directions

Network synchronous condensers



Source: ElectraNet

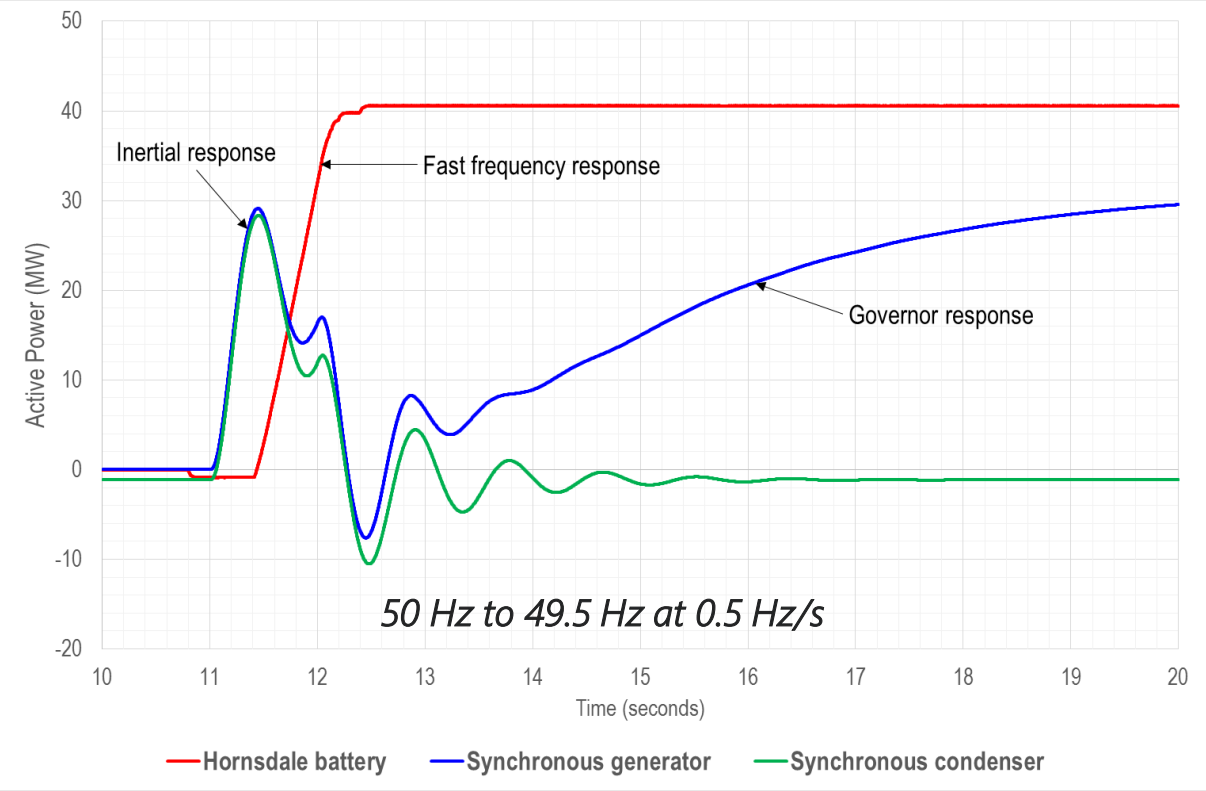
Inertia Requirements

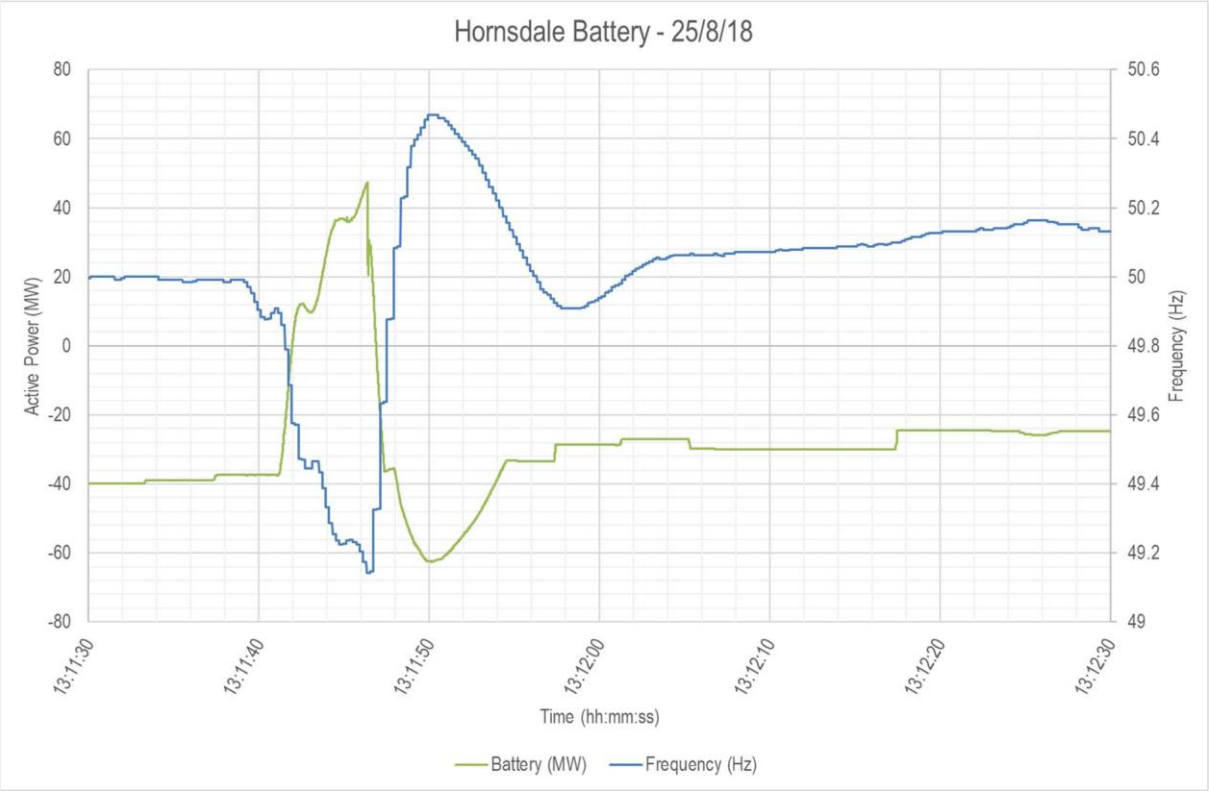


- Two levels of inertia:
  - Minimum threshold level: maintain satisfactory operating state
  - Secure operating level: maintain secure operating state
- Unlike their adverse impact on system strength, inverter-connected generators do not degrade system inertia.
- Fast frequency response (FFR) provided by inverter-based generators can be procured as a service to complement physical inertia.

Frequency Control - Contingency

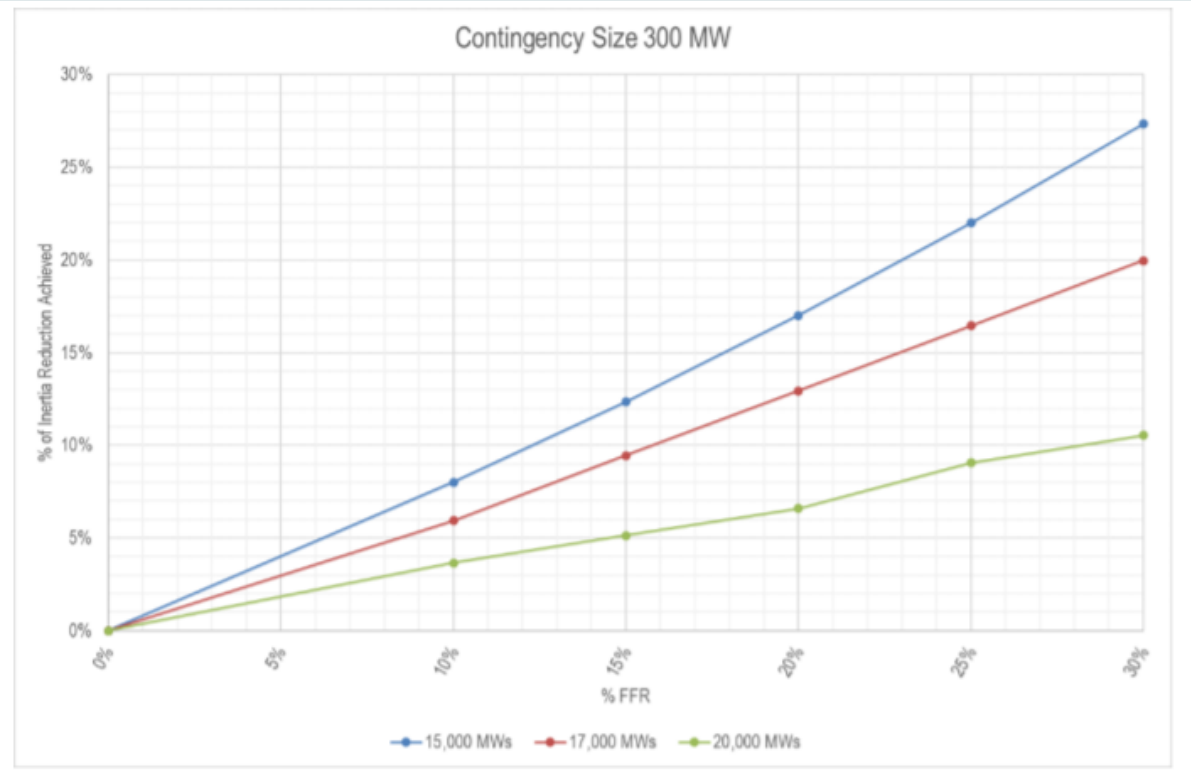
- Faster sustained responses are generally achieved with inverter connected generation, due to avoidance or decoupling of mechanical components
- Change in the direction of flow (generation to load)

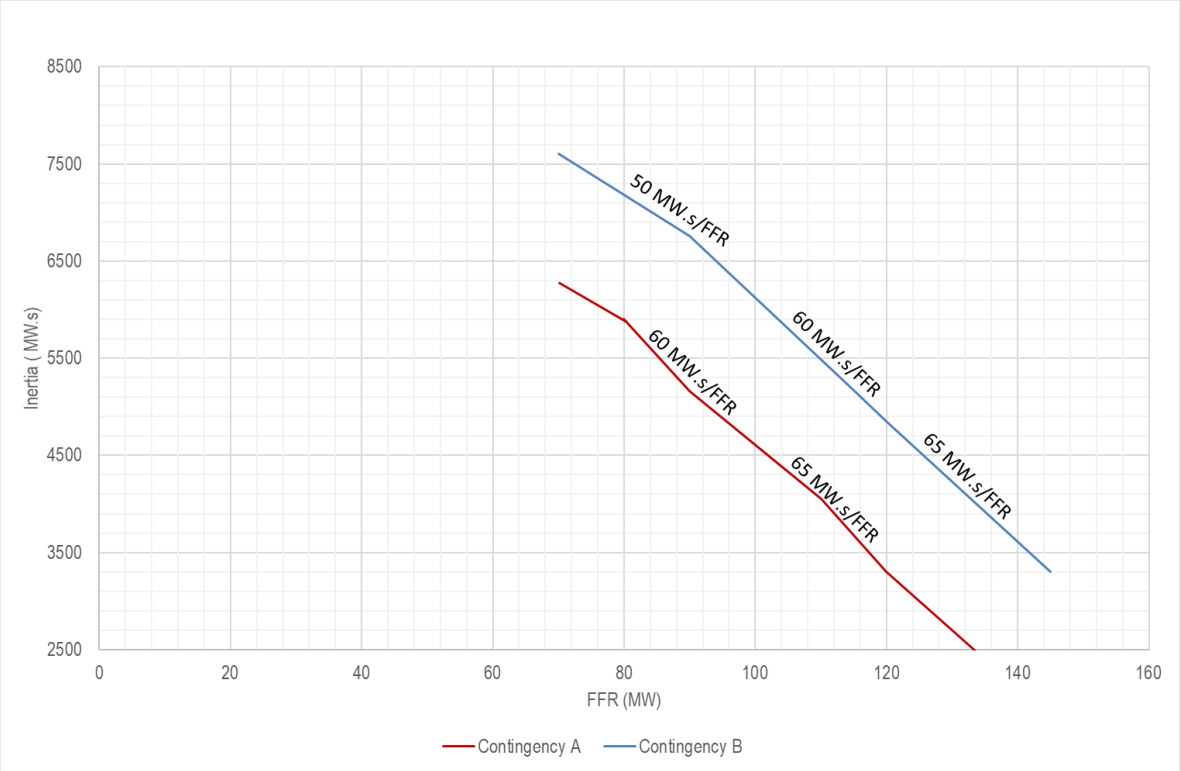




Inertia substitution

- FFR is more effective for low inertia systems compared to high inertia systems





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