Power system operation with high share of inverter-based resources – selected Australian examples

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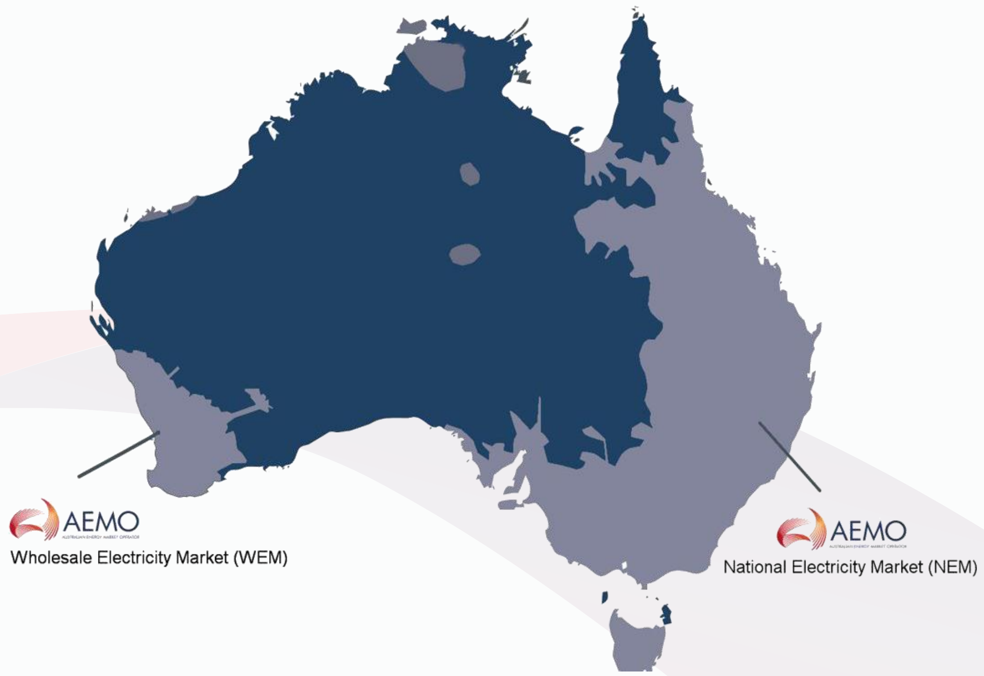
Australia's electricity markets and AEMO role



Almost 50,000 km of transmission lines and cables (both the National Electricity Market (NEM) and the Southwest Interconnected System (SWIS))

AEMO is the independent system and market operator for the NEM and SWIS, operates gas markets in four south-eastern states, and undertakes electricity and gas planning functions.

The NEM has an installed generation capacity of 64 GW (including distributed photovoltaic) and a peak demand of 36 GW

AEMO does not own any assets nor make power system or market rules

Topic 1: Inverter-based resource stability under low system strength conditions

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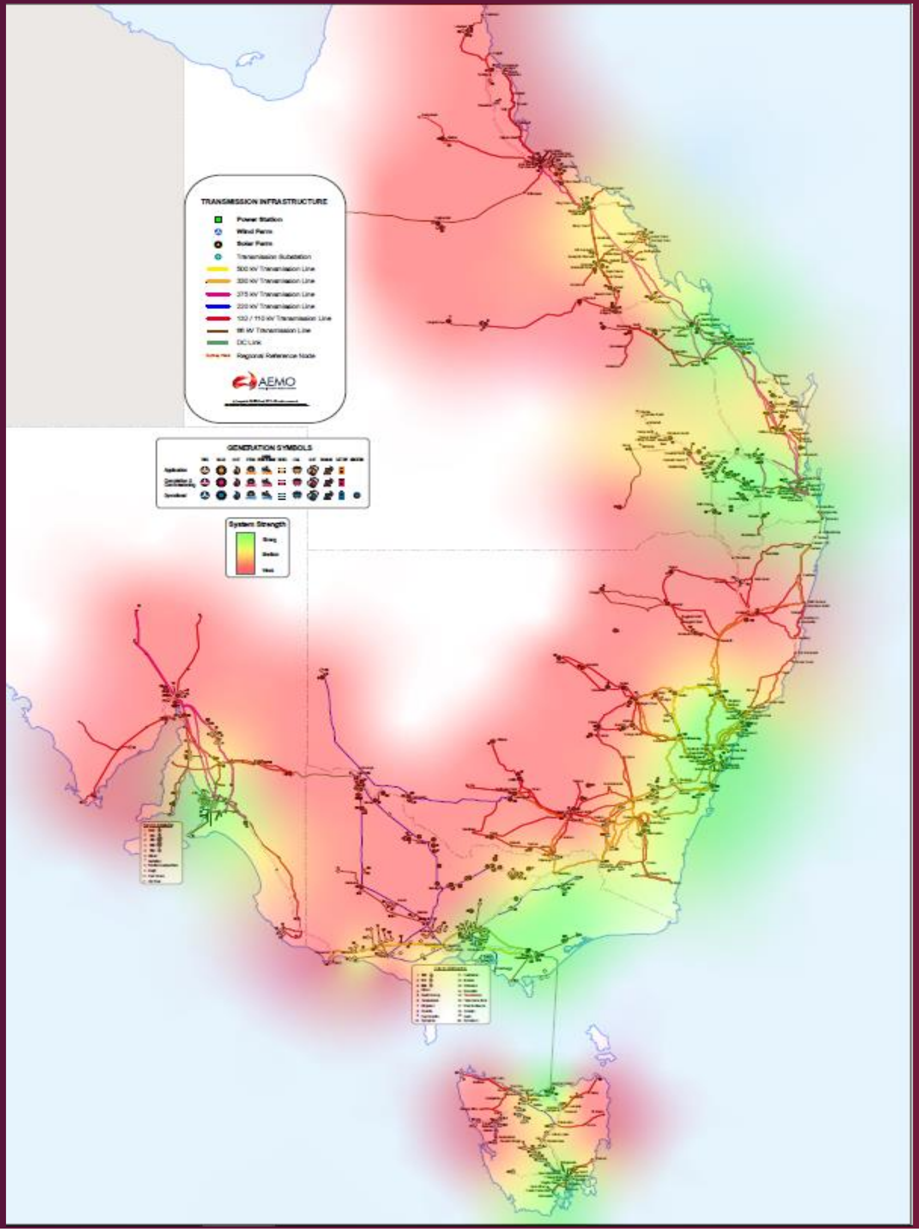
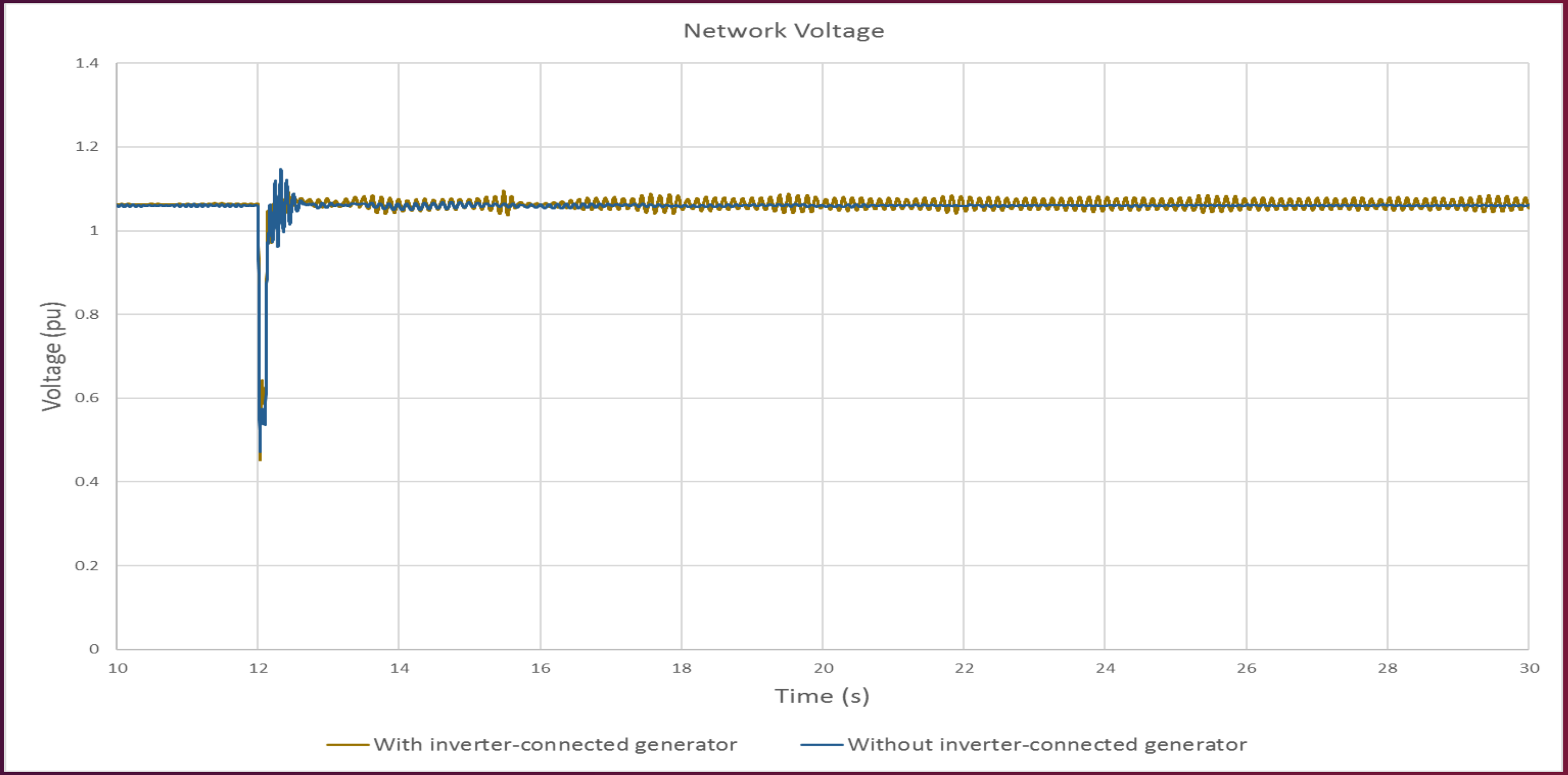
Inverter-based generator connection locations

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

Lack of system strength is one of the key challenges



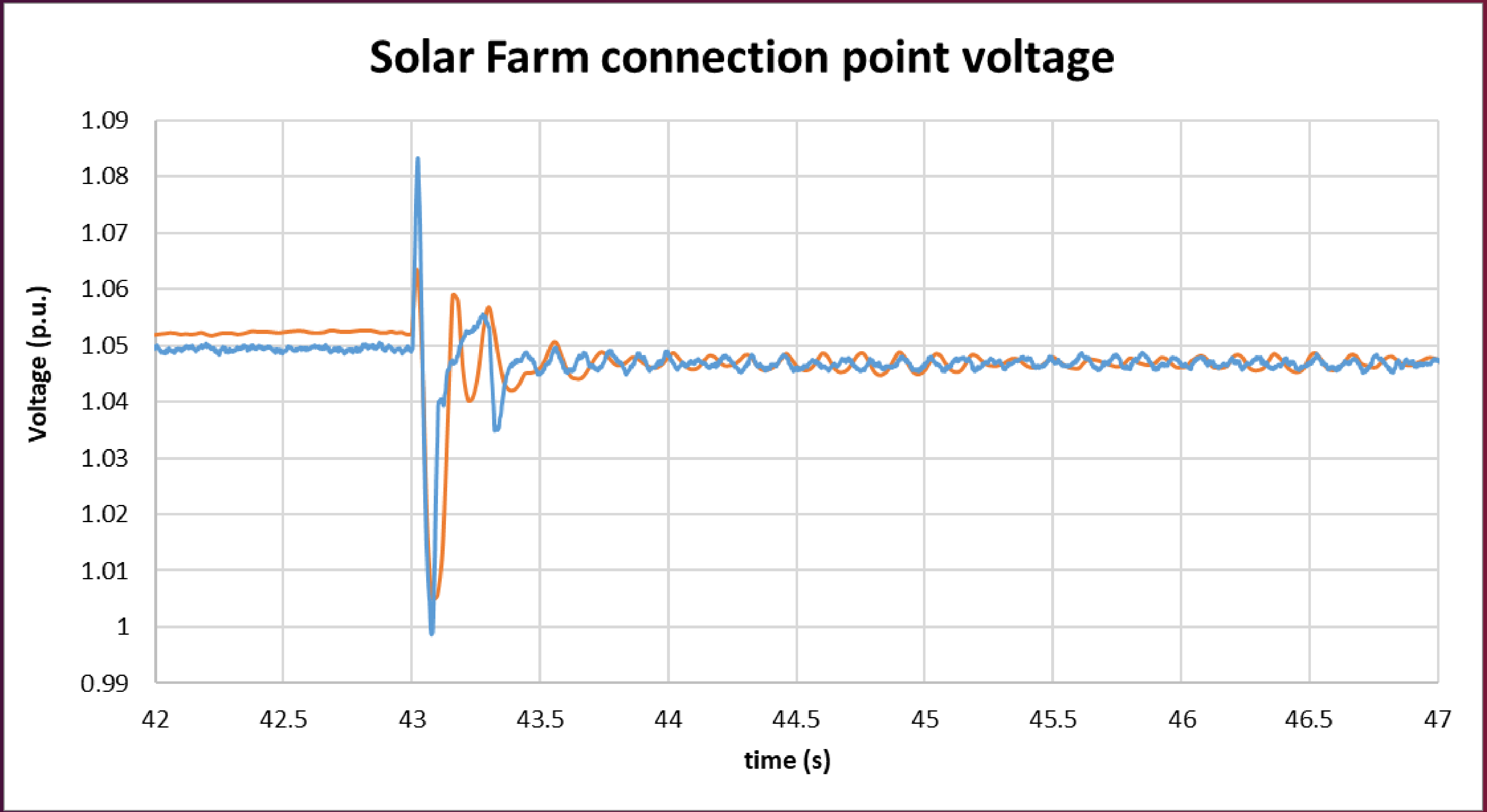
The need to design generating plant capable of operating in such networks



Sustained post-disturbance sub-synchronous oscillations

- These oscillations are in the range of 7-10 Hz, and can be predicted by wide-area electromagnetic transient (EMT) model of the system developed by AEMO in 2019.
- Oscillations unacceptable due to:
  - Breach of system security and flicker requirements
  - Impact on load/connected equipment

Model validation against staged system tests



- EMT simulation results correlate well with the measured responses when subject to a line opening and auto-reclosure event.
- This gives confidence in the use of EMT modelling for analysing any given what-if scenario involving these oscillations.

Mitigation measures

Constraints

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

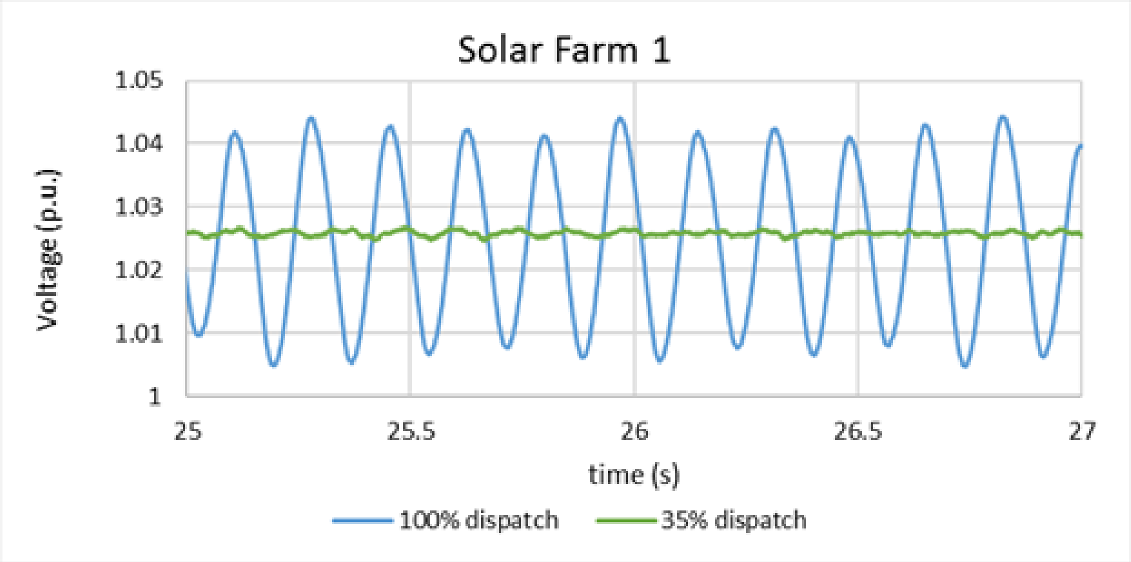
Installation of nearby synchronous machines

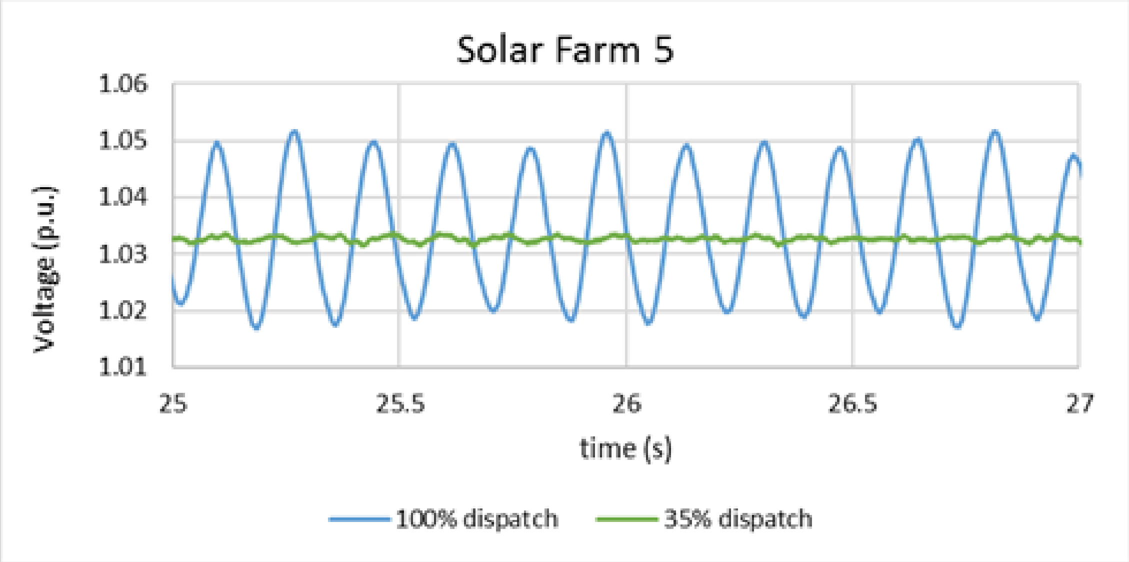
- Installation of nearby synchronous machines increases the system strength available to the inverters in a remote and sparse part of the network

Inverter control system/parameter tuning

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

Option 1: Constraints





- A reduction in the number of online inverters will reduce the oscillations to acceptable levels.
- This was applied while other solutions were being developed.
- A reduction in the total output power (even to 0 MW) while maintaining all inverters online will have a negligible impact.

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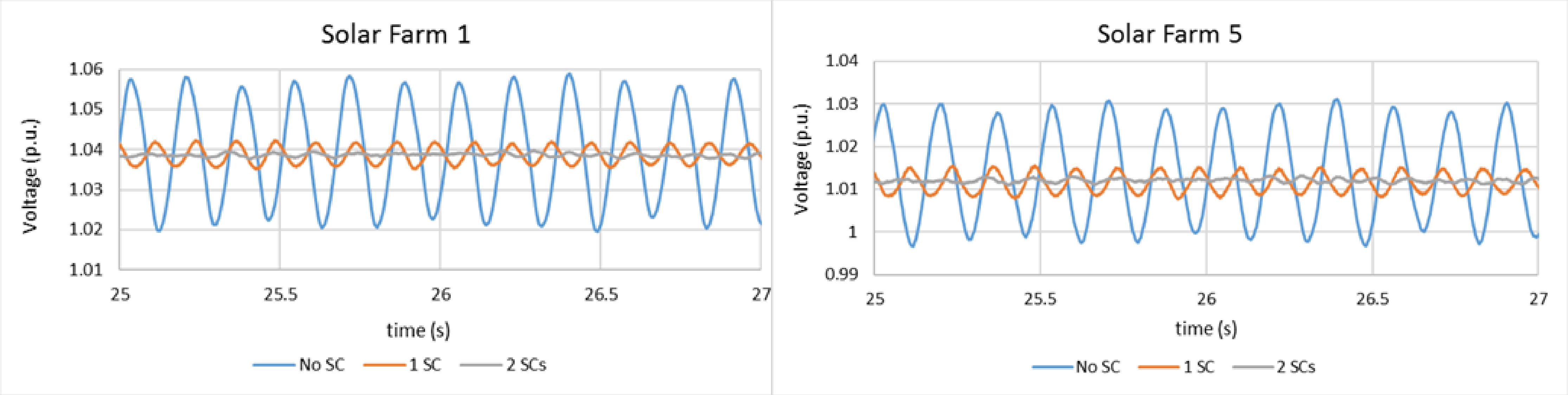
Option 2: Installation of nearby synchronous condensers



- Synchronous condensers will reduce the level of post-fault voltage oscillations caused by the inverter-based resources within the acceptable limits.
- The increase in the available system strength achieved by addition of synchronous condensers would bring back the inverter control within its stable design range.

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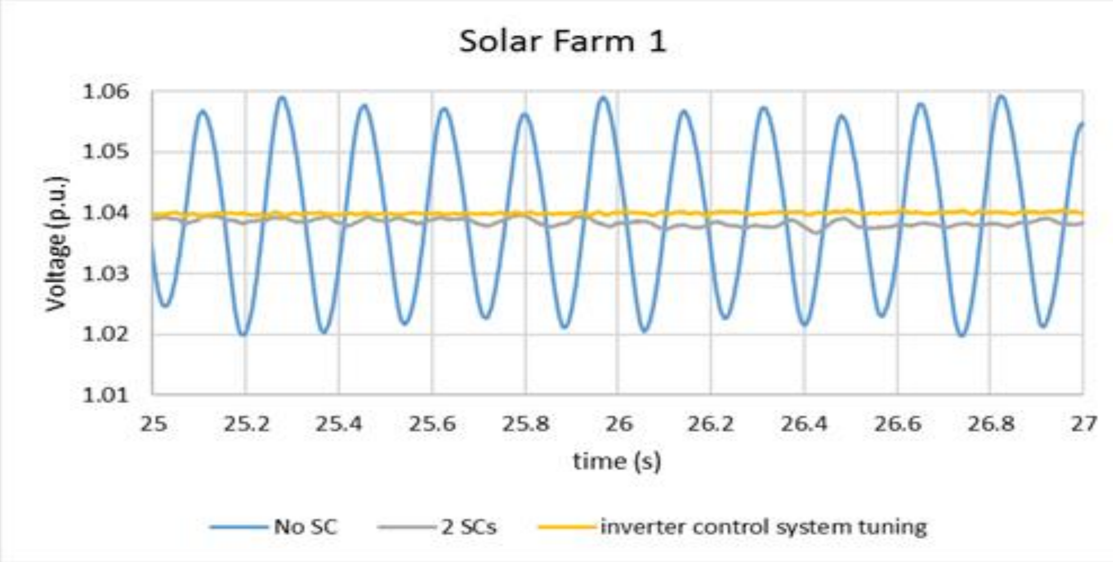
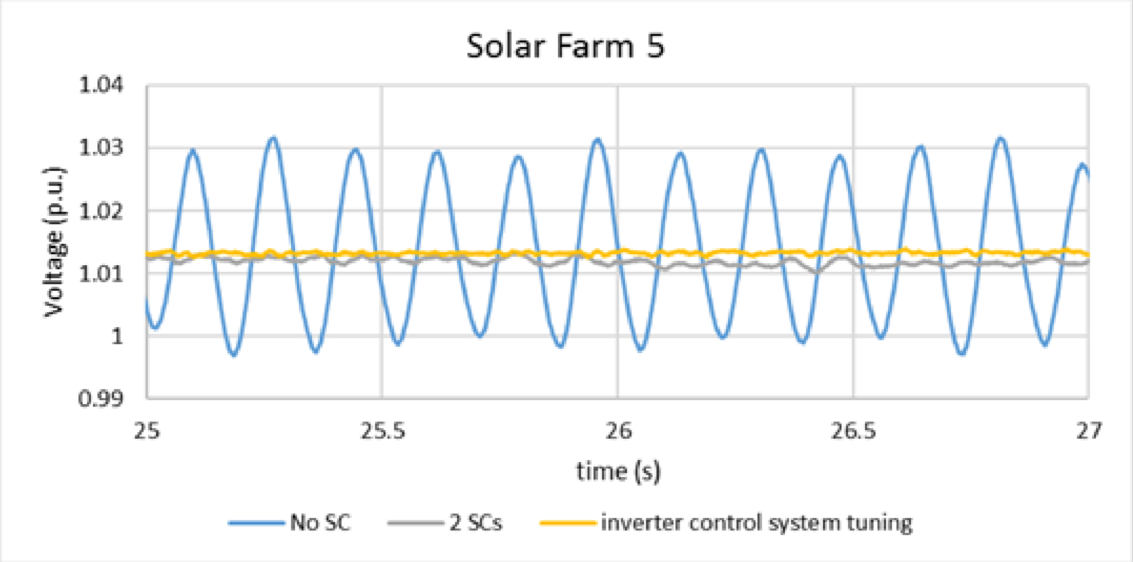
Option 3: Inverter control system/parameter tuning





- Change in some of the inverter control loops and parameters can practically eliminate the oscillations.
- This re-tuning will provide stable response under conditions with a lower available system strength relative to that assumed in the original tuning.

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Topic 2: Importance of fast frequency response provided by Inverter-based resources

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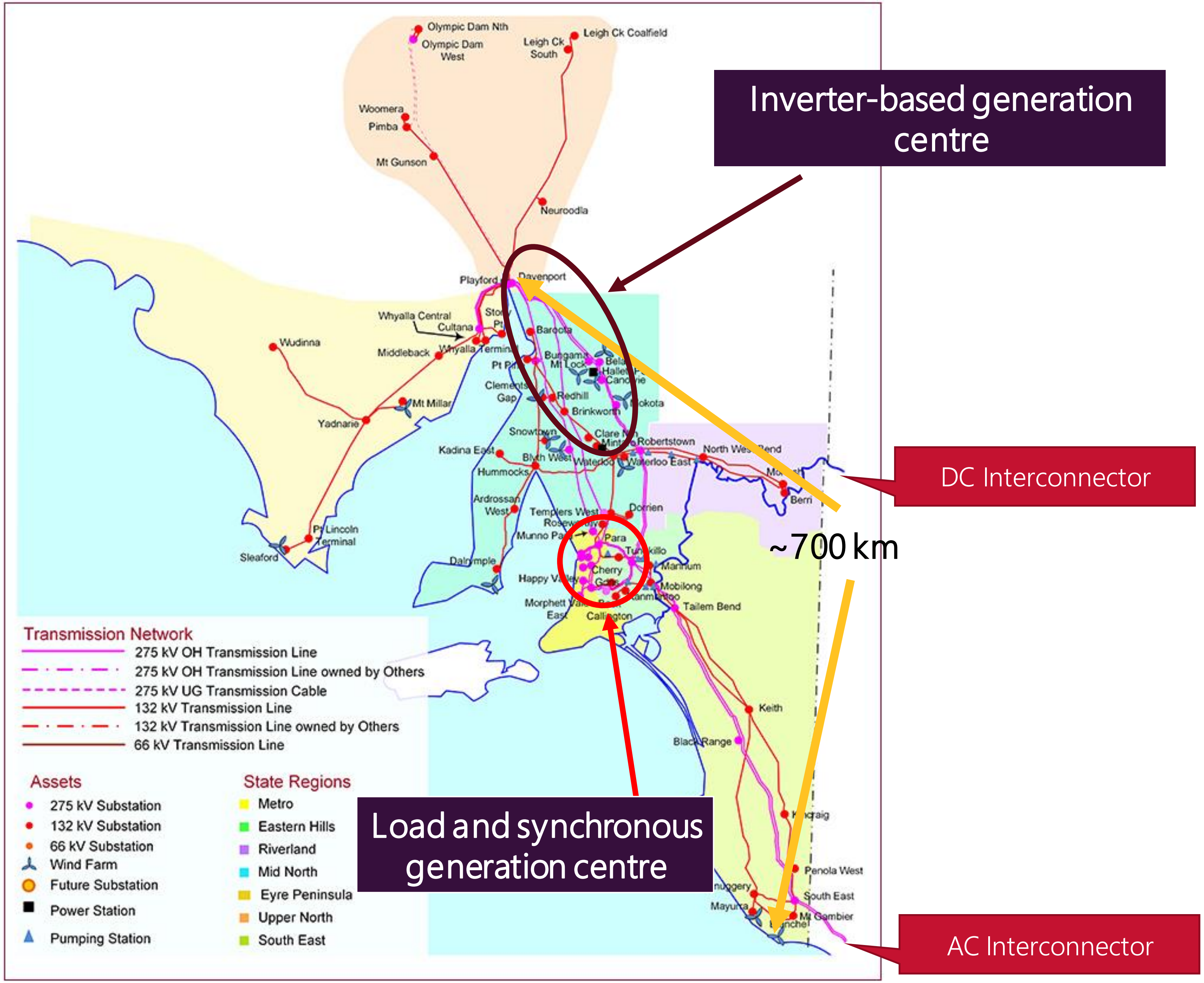
South Australia power system

- Installed inverter-based generation: ~2,700 MW
- This includes 150 MW of large-scale batteries with 50 MW to connect soon
- Rooftop PV in addition: ~1,300 MW
- All large synchronous generators are gas-fired
- Certain combinations of synchronous generators must be online at all times



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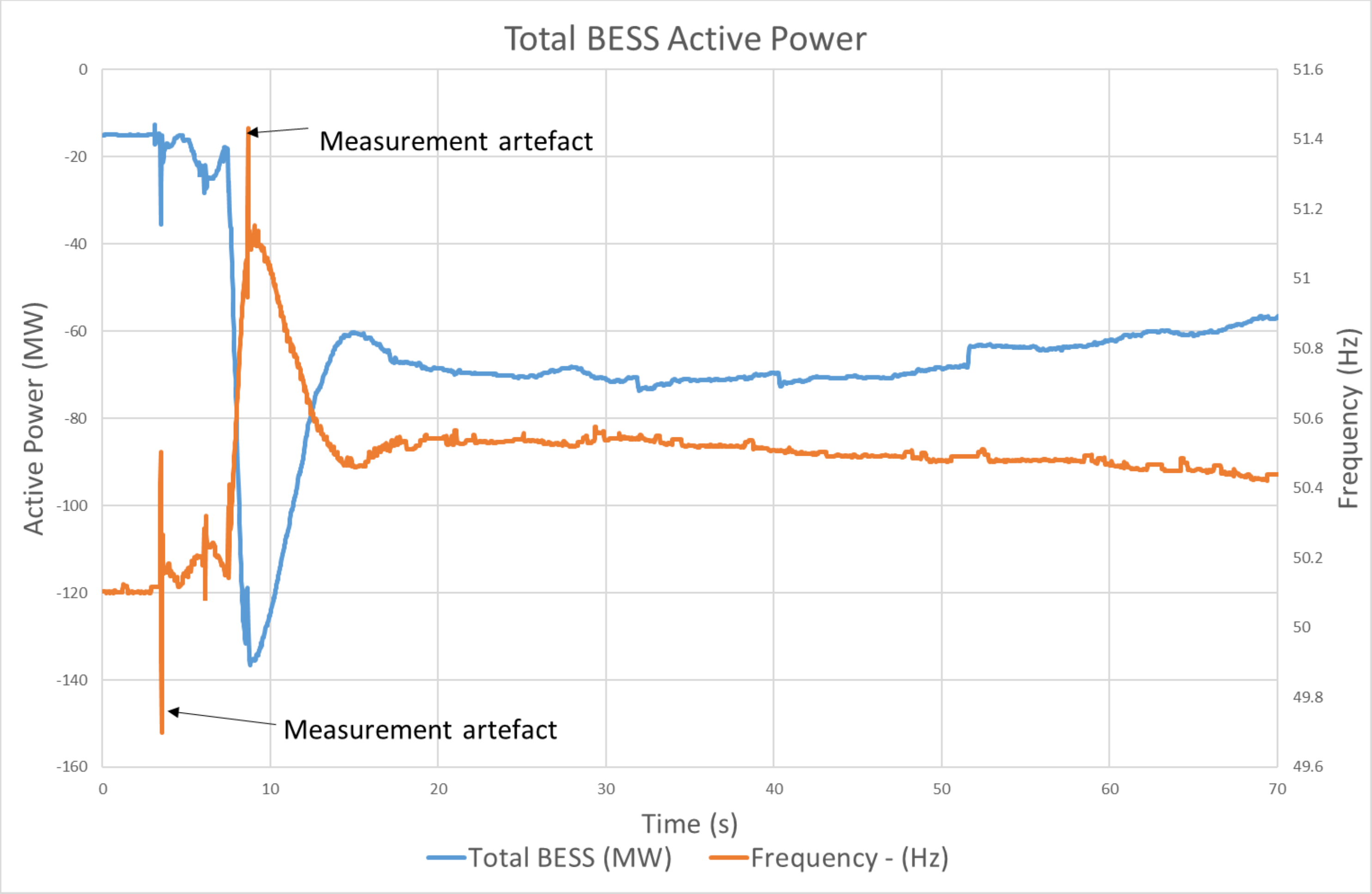
Sustained islanding operation

- On 31 January 2020 a non-credible event resulted in formation of an electrical island with the whole South Australia power system and small part of adjacent state network (Victoria).
- Islanding conditions lasted for 18 days.
- Several combinations of synchronous generators were developed for islanded system based on EMT modelling.
- A key challenge was maintaining frequency in response to the largest credible contingency.



Response of large-scale batteries during system separation

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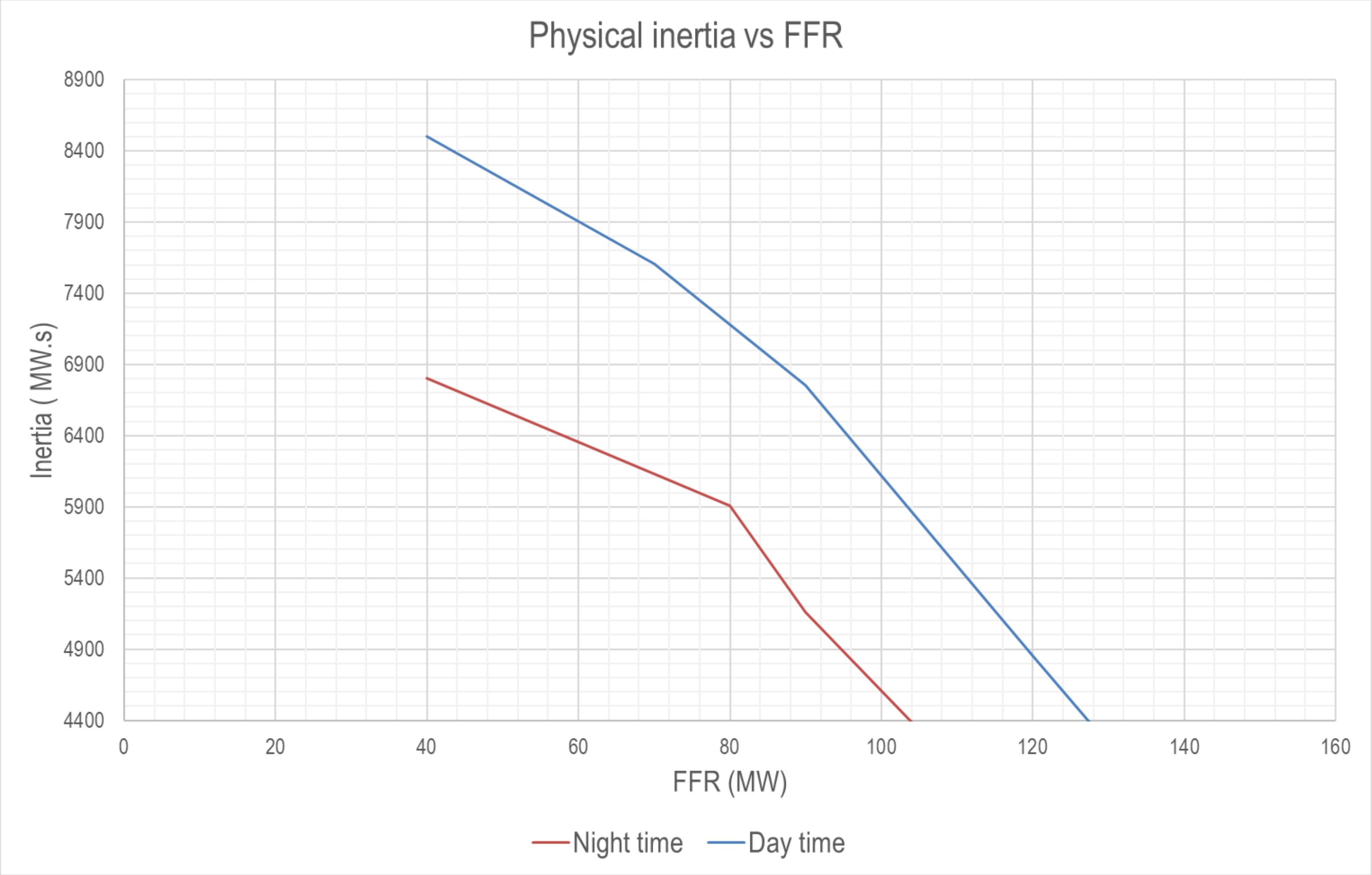
Frequency control under islanding conditions

- Synchronous generators provide both the physical inertia and frequency control.
- Batteries provide frequency control only, but it is typically 5-10 times faster.
- Trade-off is possible between physical inertia and fast frequency response (FFR).
- Speed of response plays a more important role than the level of response.
- Most efficient points are those with higher FFR and lower inertia.



Higher requirements in daytime to cater for sudden loss of distributed PV which creates a larger credible contingency than that could otherwise occur.

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