Operation of the South Australian Power System

Challenges and Solitons

QUT Power Energy and Clean Technology Seminar

We acknowledge the Traditional Owners of country throughout Australia and recognise their continuing connection to land, waters and culture.

We pay respect to Elders past and present.

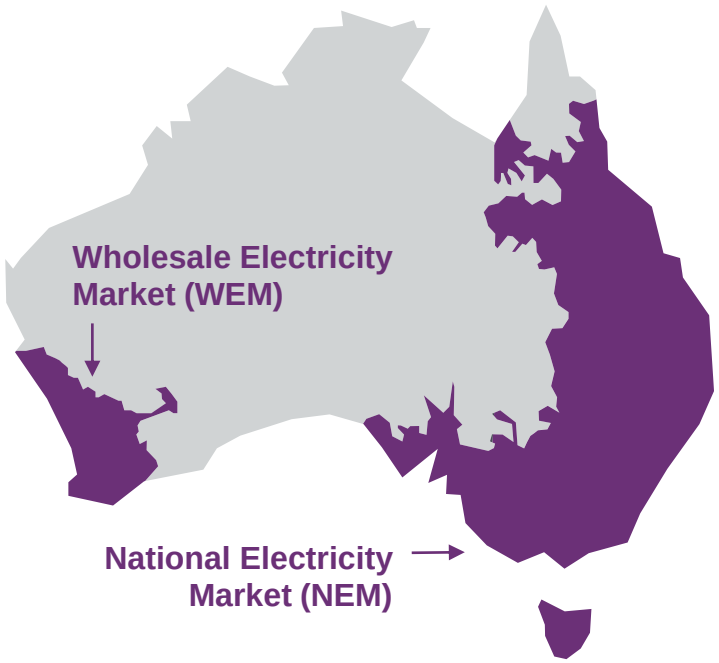
About AEMO

- AEMO is a member-based, not-for-profit organisation.
- We are the independent energy market and system operator for the National Electricity Market (NEM) and the WA Wholesale Electricity Market (WEM), and system planner for the NEM.
- We also operate retail and wholesale gas markets across south-eastern Australia and Victoria's gas pipeline grid.

AEMO SERVICES

AEMO Services is an independent subsidiary of AEMO, established in 2021 to enable the transparent provision of advisory and energy services to National Electricity Market jurisdictions.

Electricity



Gas

Declared Wholesale Gas Market (DWGM)

Short Term Trading Market (STTM)

and

Gas Supply Hub (GSH)

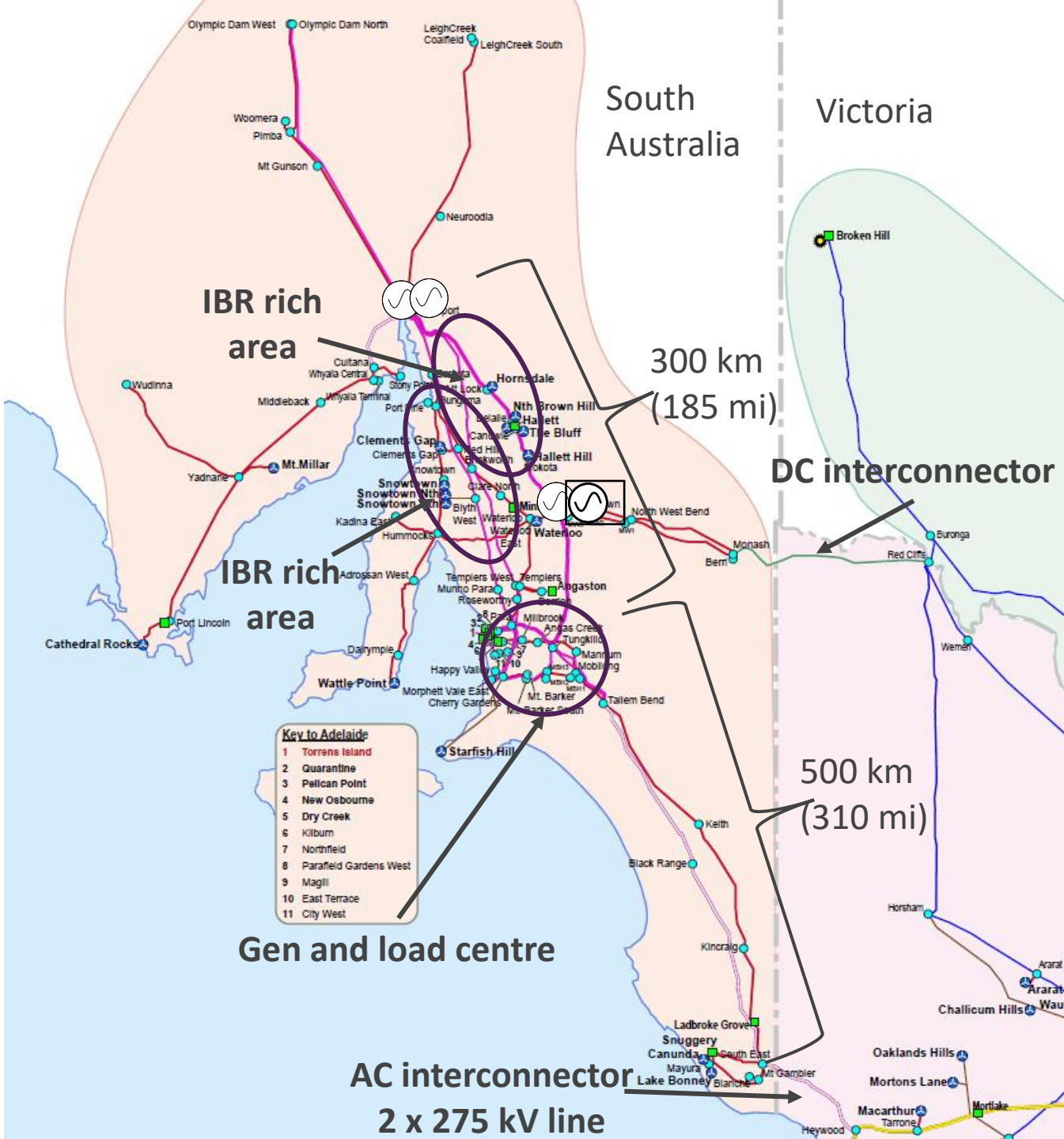
Agenda

1. The South Australia Power System
2. Inertia, Frequency Control and System Strength
3. Managing High Levels of Distributed Energy Resources

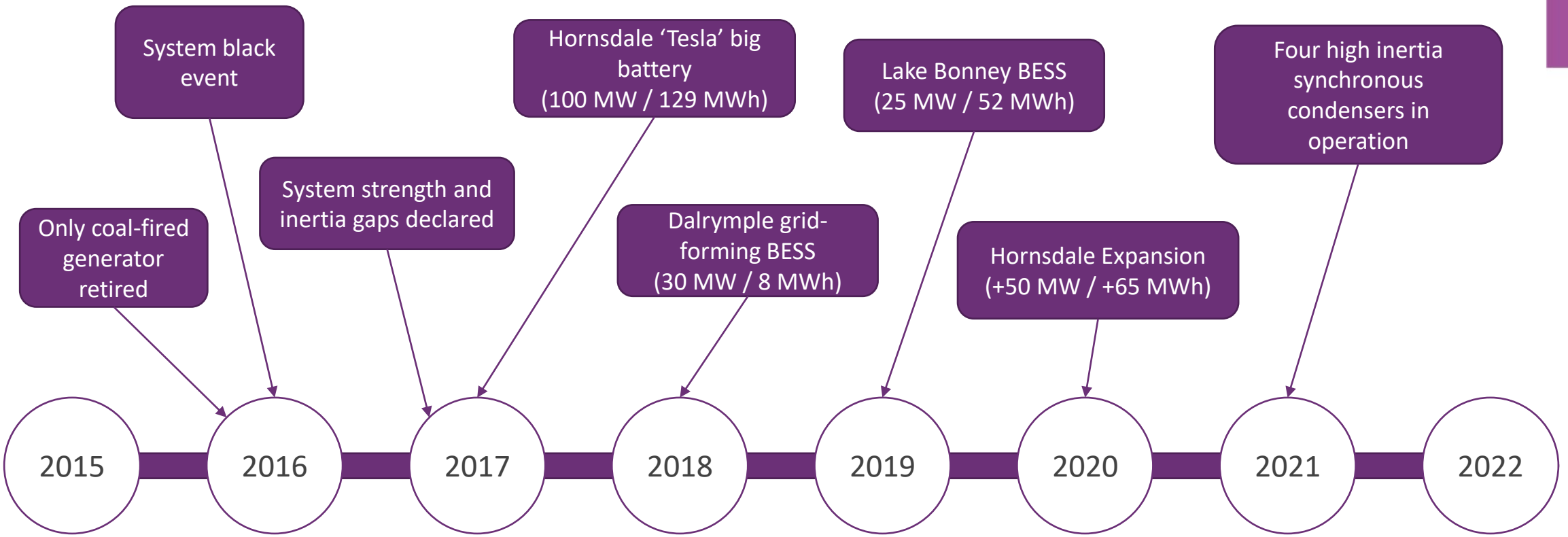
The South Australia Power System

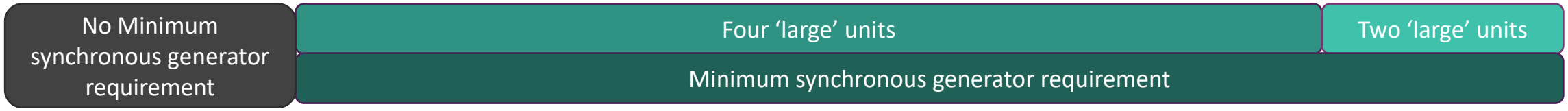
South Australian Power System

- Demand:
  - Peak: ~3,000 MW
  - Average: ~1,500 MW
  - Minimum: ~100 MW
- Capacity:
  - 2,700 MW gas-powered generation
  - 2,400 MW wind
  - 2,300 MW of distributed solar PV (DPV)
  - 600 MW of utility solar PV
  - 260 MW of utility BESS
- Interconnection:
  - 1 x 650 MW AC (dual circuit)
  - 1 x 220 MW DC



SA power system transition



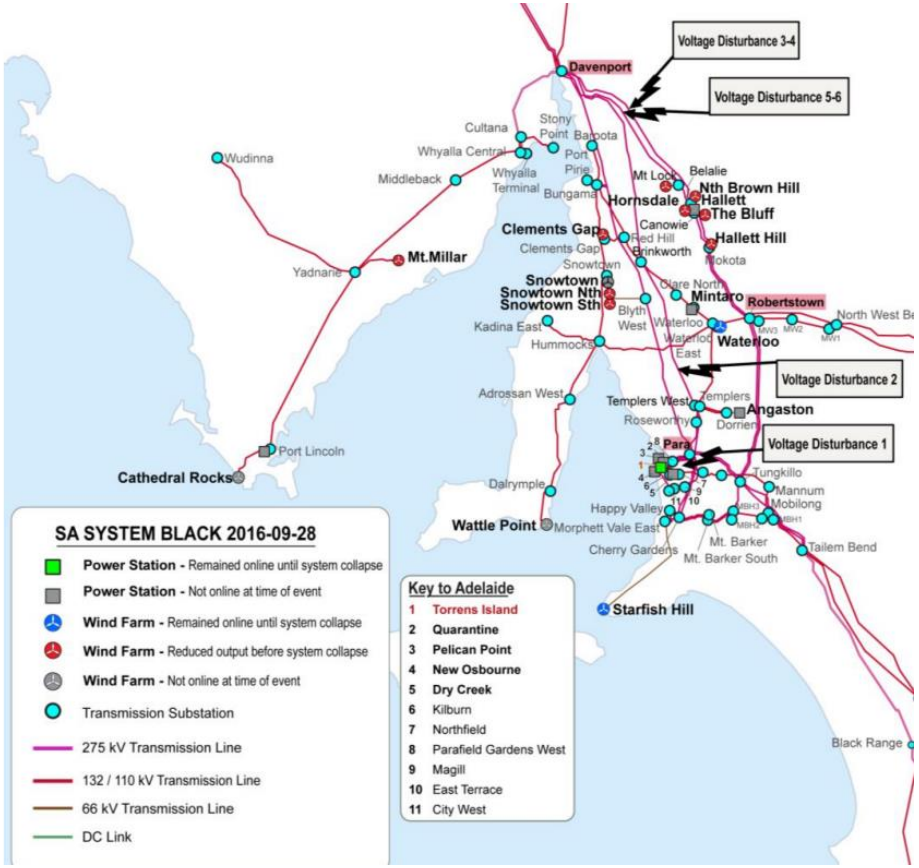


Unprecedented growth of distributed PV installation

Inertia, Frequency Control and System Strength

28 September 2016

Source: ABC News, https://www.abc.net.au/news/2021-09-28/sa-statewide-blackout-anniversary-energy-impacts/100496564



System black event

Source: ABC News, https://www.abc.net.au/news/2021-09-28/sa-statewide-blackout-anniversary-energy-impacts/100496564

Shortfall of system strength

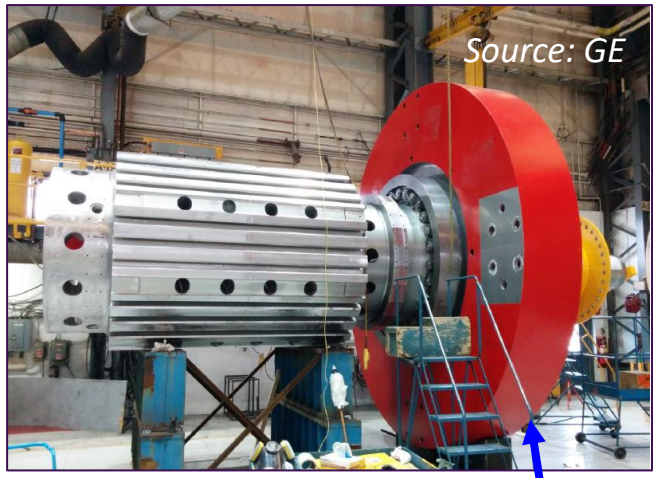
Shortfall of inertia

Sync cons + BESS commissioned

Source: ABC News, https://www.abc.net.au/news/2021-10-26/electricity-grid-security-bolstered-by-synchronous-condensers/100567580

Synchronous Condensers

- Established technology (1900s), used to control voltage before power electronics developed
- Essentially a very large, low output synchronous motor
  - In steady-state, draws a small amount of active power
  - Needs no fuel supply
- Mechanically coupled to the grid
  - Inherent response to disturbances the same as synchronous generators
  - Low inertia compared to traditional generators (no heavy turbine shaft)
    - This can be compensated by the addition of flywheels
- Similar cooling requirements and voltage control capability as synchronous generators
  - Purpose built synchronous condensers are being developed with reduced losses and voltage control capability



Optional flywheel to increase inertia

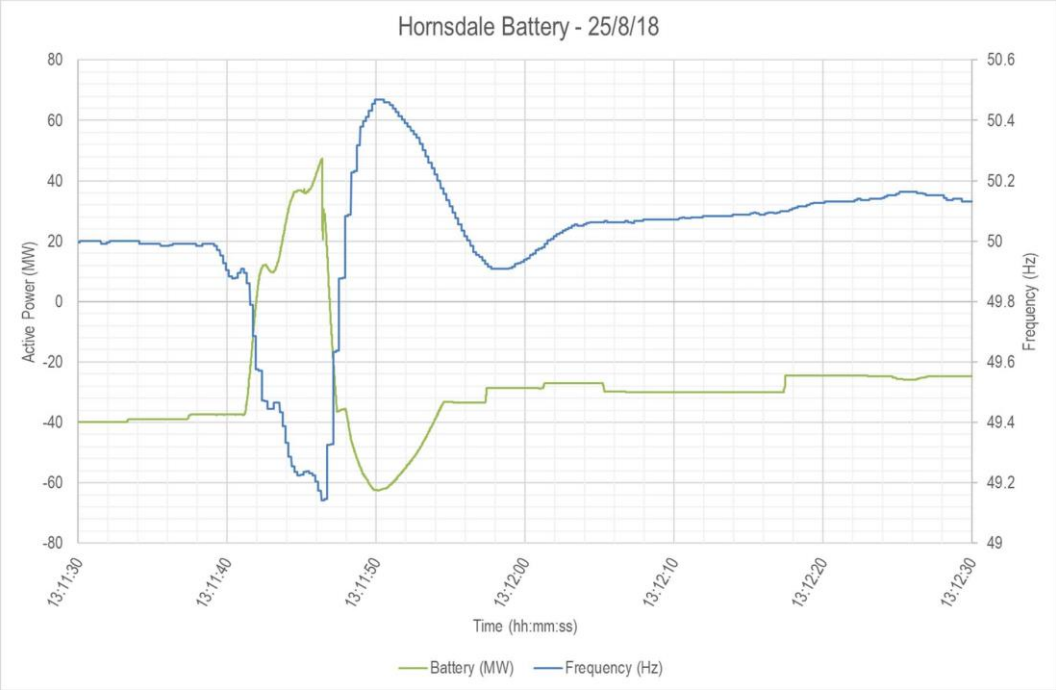
Hornsdale Power Reserve (Tesla Battery)

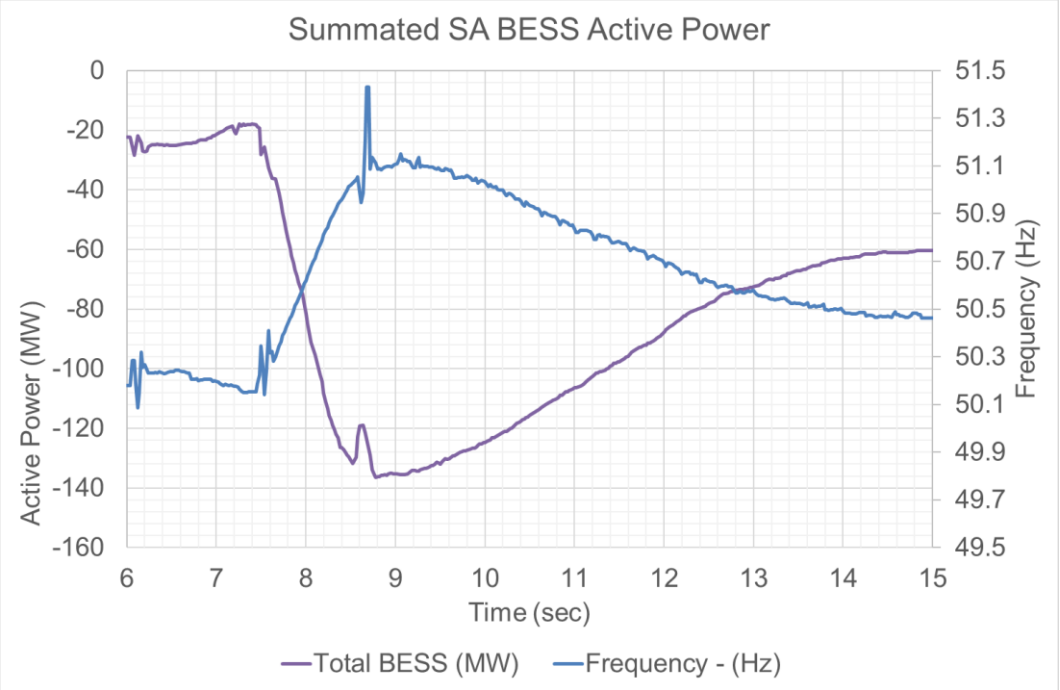
March 2017

Nov 2017

Frequency control - Contingency

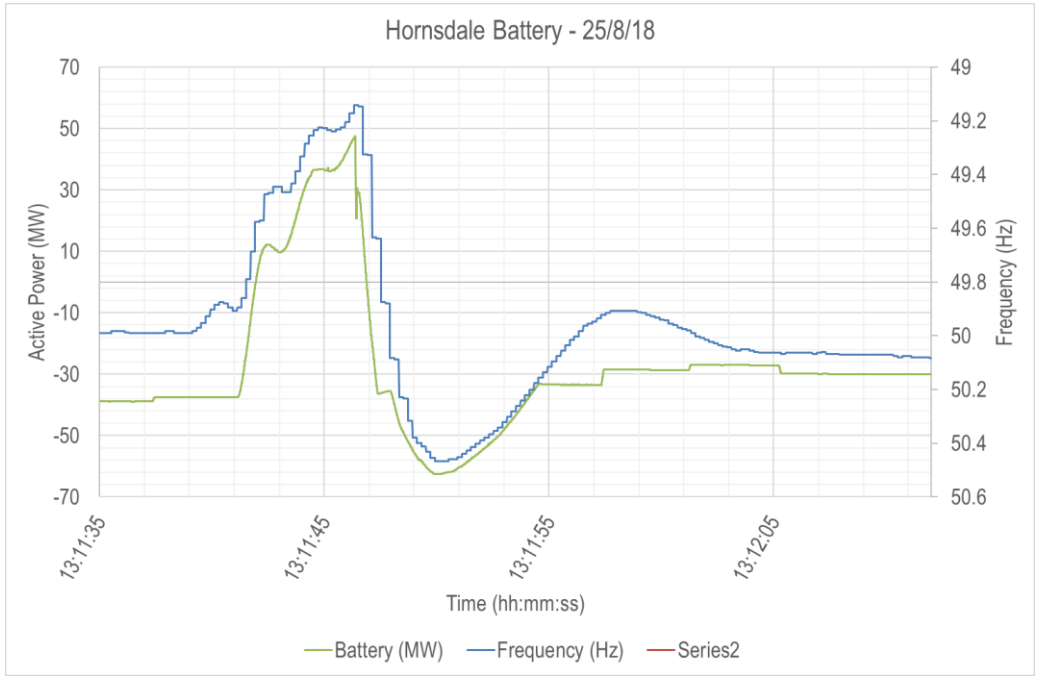
- Faster sustained responses are generally achieved with inverter-connected generation, due to avoidance or decoupling of mechanical components
- Change in the direction (generator to load)

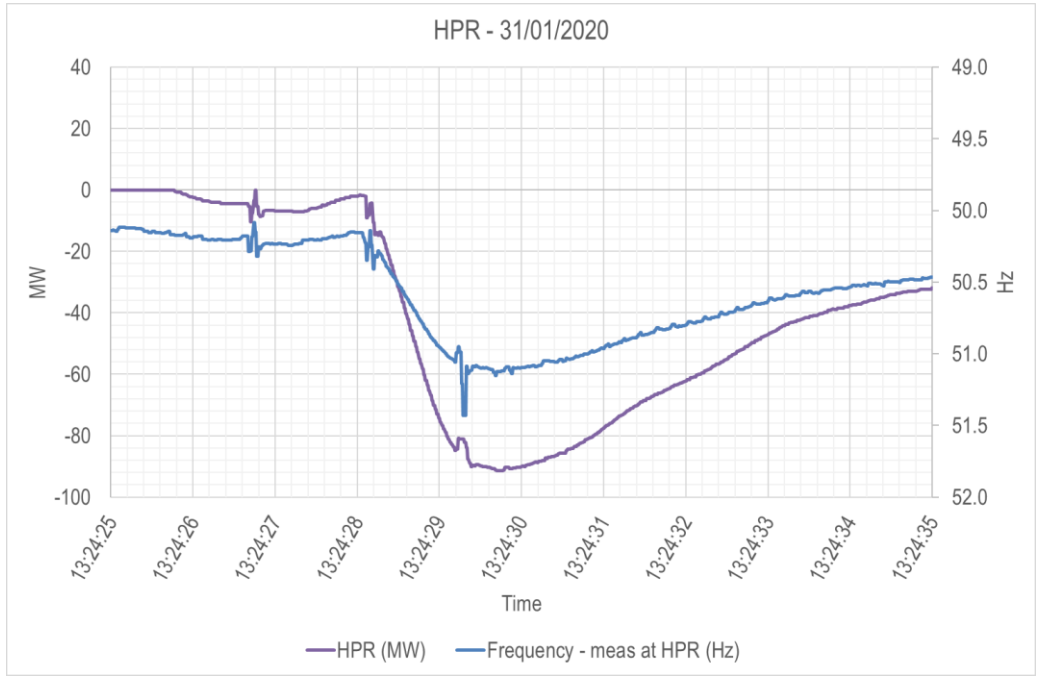




Frequency control – Fast Frequency Control

- <200 ms response time is well within the capability
- Power park control vs inverter control
- Important to maintain security in low inertia environments





Synchronous condensers can mitigate post-disturbance oscillations through injection of fault current

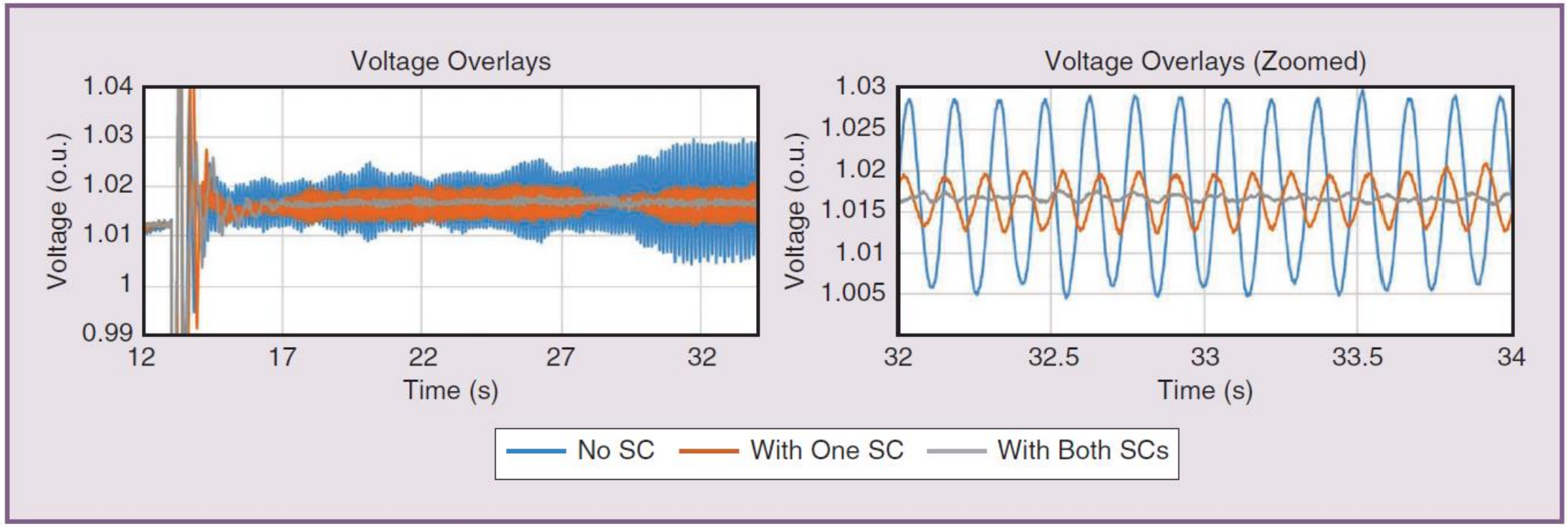
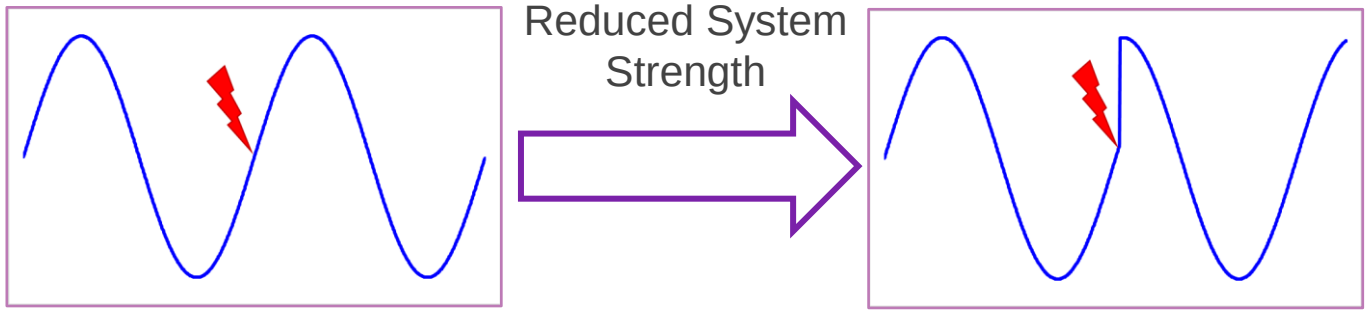


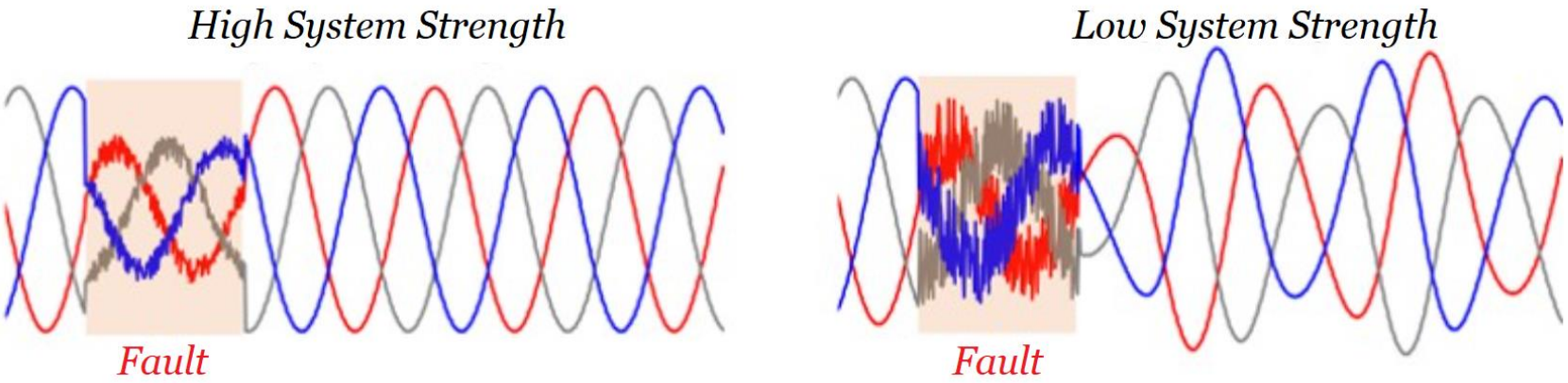
figure 6. The contribution of synchronous condensers on mitigating sustained postdisturbance oscillations.

IEEE, Power system operation with a high share of inverter-based resources: The Australian experience

EMT modelling

Impact of system strength reduction:





- Many of the existing IBRs cannot remain connected under such condition.
- Due to inherent simplifications, RMS models cannot represent components of IBRs critical to stability in weak systems

Reference: https://aemo.com.au/en/learn/energy-explained/energy-101/energy-explained-system-strength

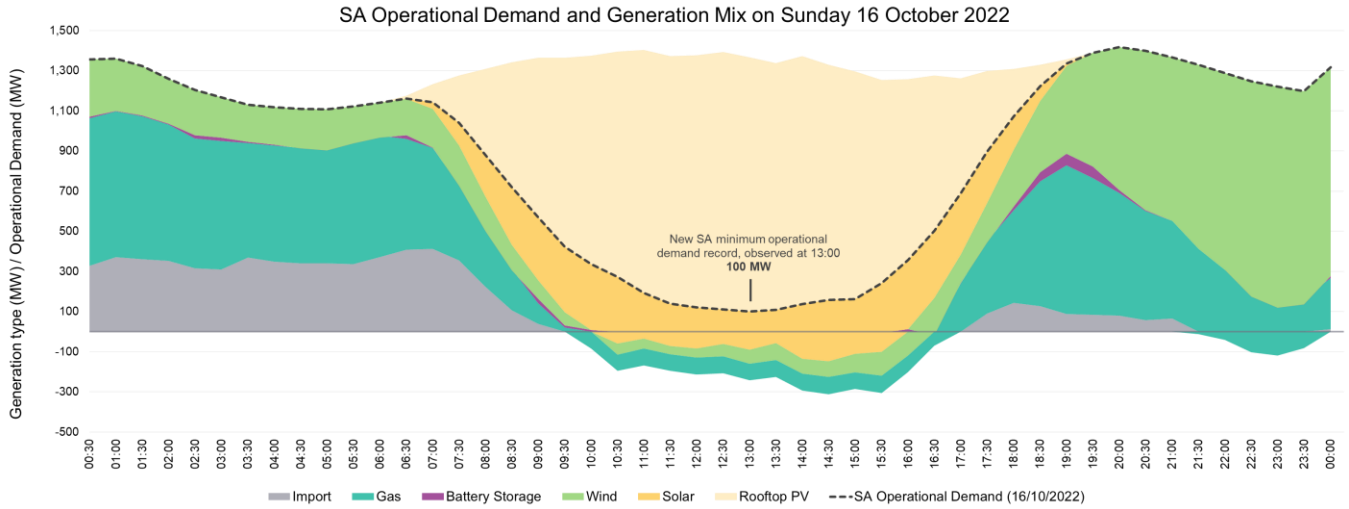
Managing High Levels of Distributed Energy Resources

November 2022 Event

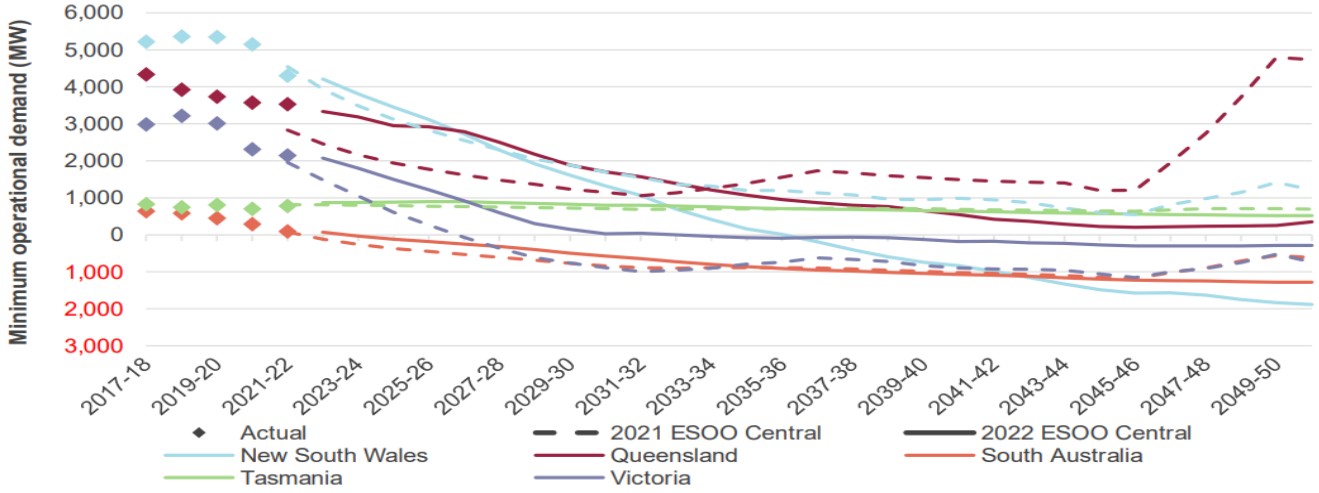
- Severe weather disconnects multiple transmission lines
- Synchronous separation of South Australia occurs Saturday 12 November 2022 @ 1639 hrs
- Operated as an island until Saturday 19 November

Minimum Demand

South Australian Operational Demand and Generation Mix – Sunday 16 October



Regional annual actual and forecast 50% POE minimum operational demand (sent-out), 2022 ESOO Central and 2021 ESOO Central scenarios, 2017-18 to 2050-51



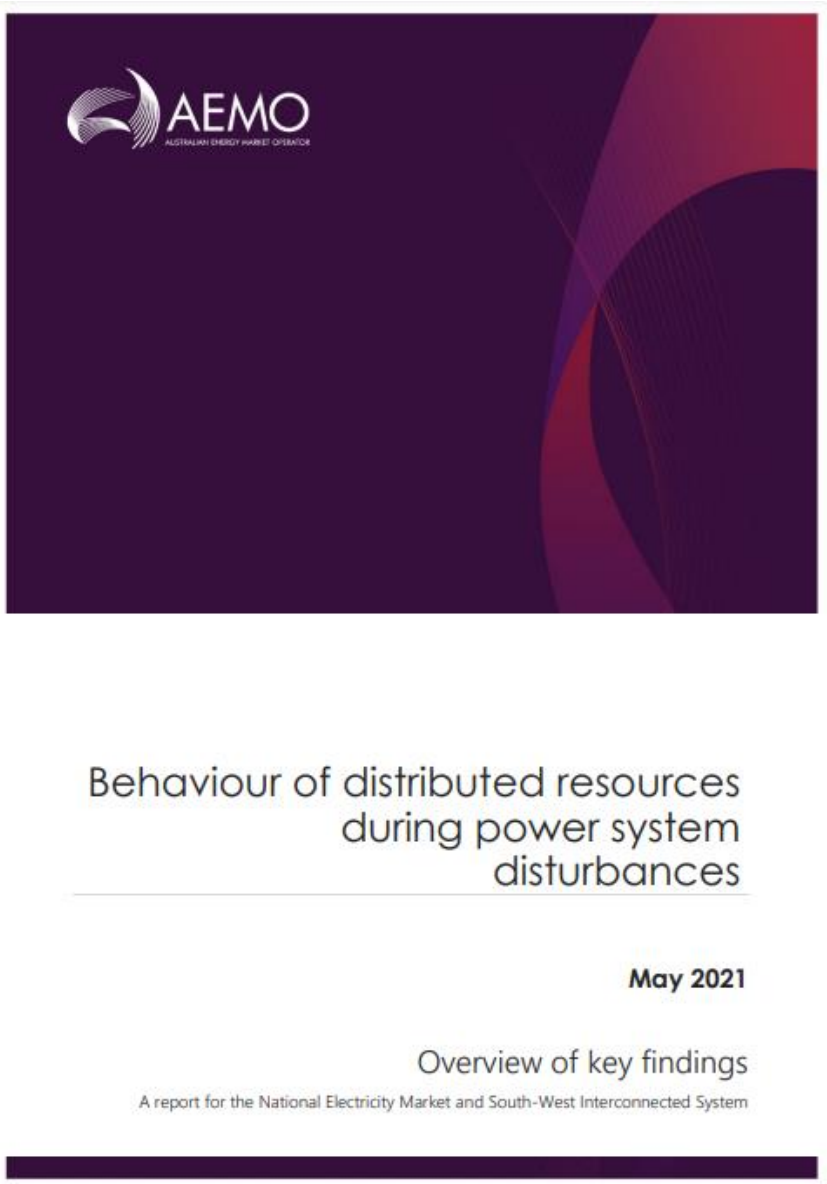
Operational risks

- Demand falls below Minimum System Load (MSL) required for essential units to remain online

- DPV Contingency (DPVC) risk exceeding frequency control capabilities

DPV Contingency?

- DPV generation has been observed to suddenly disconnect following power system disturbances
- This DPV “shake-off” presents a generation contingency risk, and can occur in addition to the loss of a generating unit

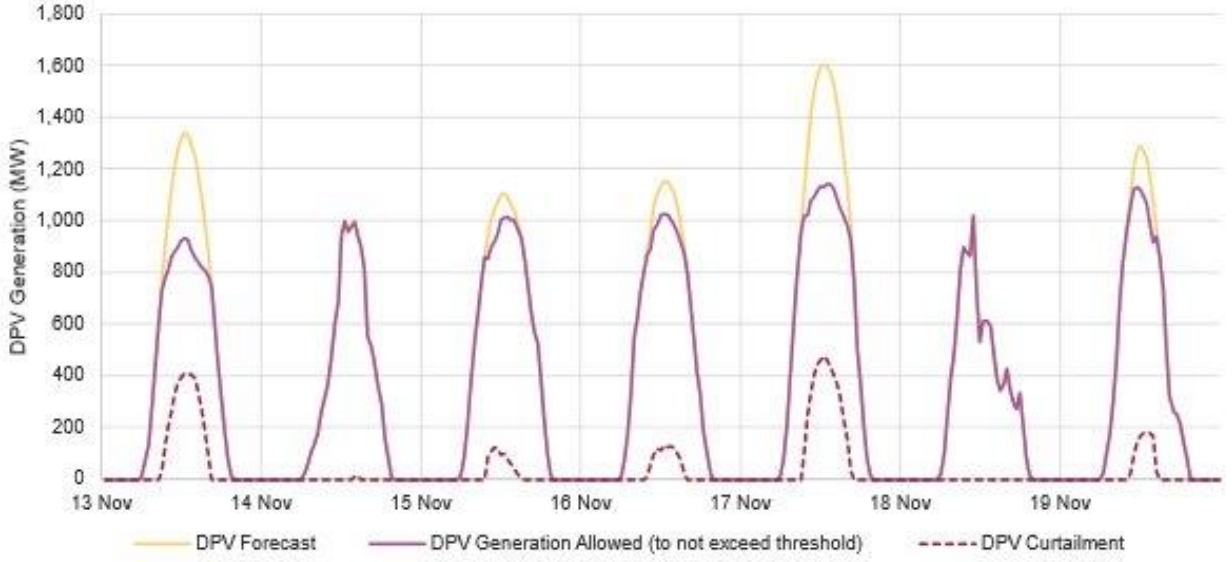


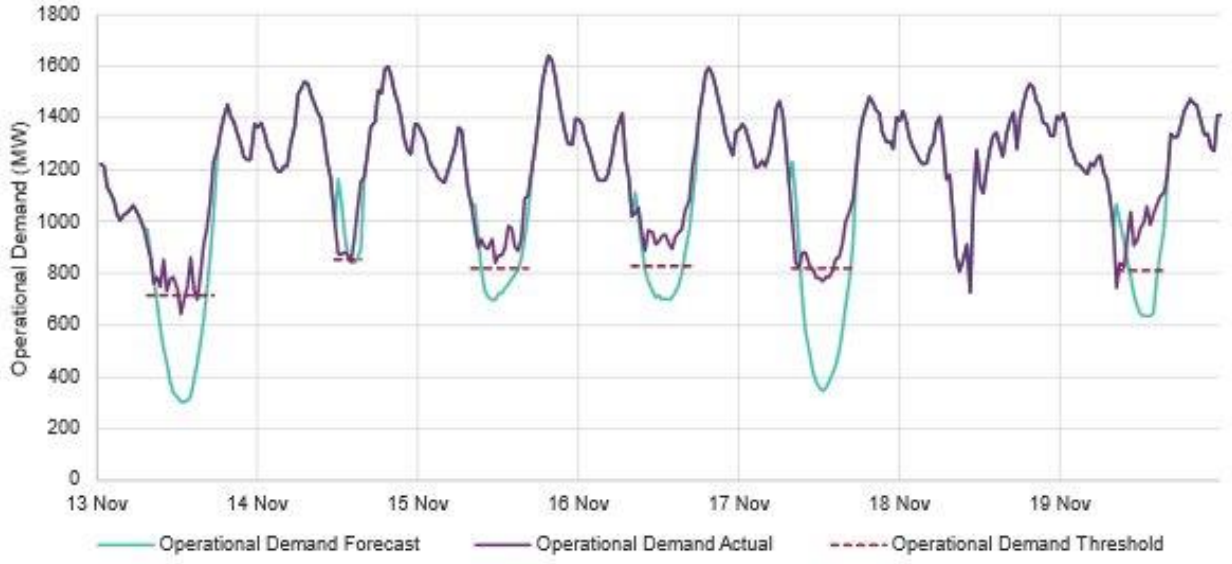
Actions taken

- Constrain down/offline generating units not required for essential services.
- Constrain large batteries output to maximise headroom and footroom for frequency response.
- Curtail DPV generation to maintain contingency size within manageable thresholds.

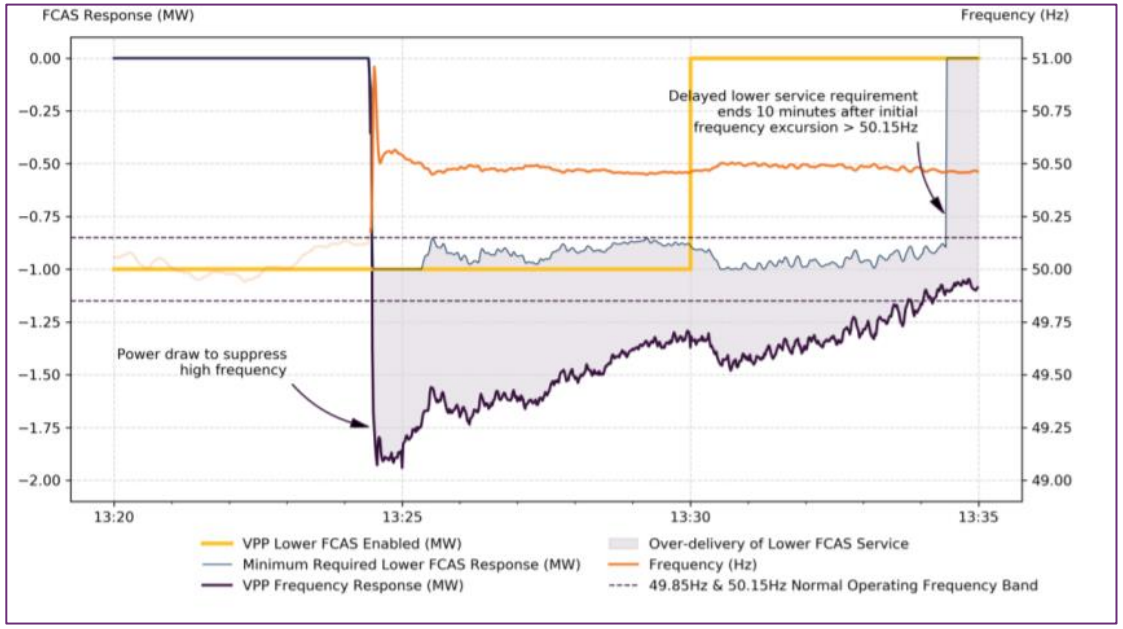
DPV Curtailment

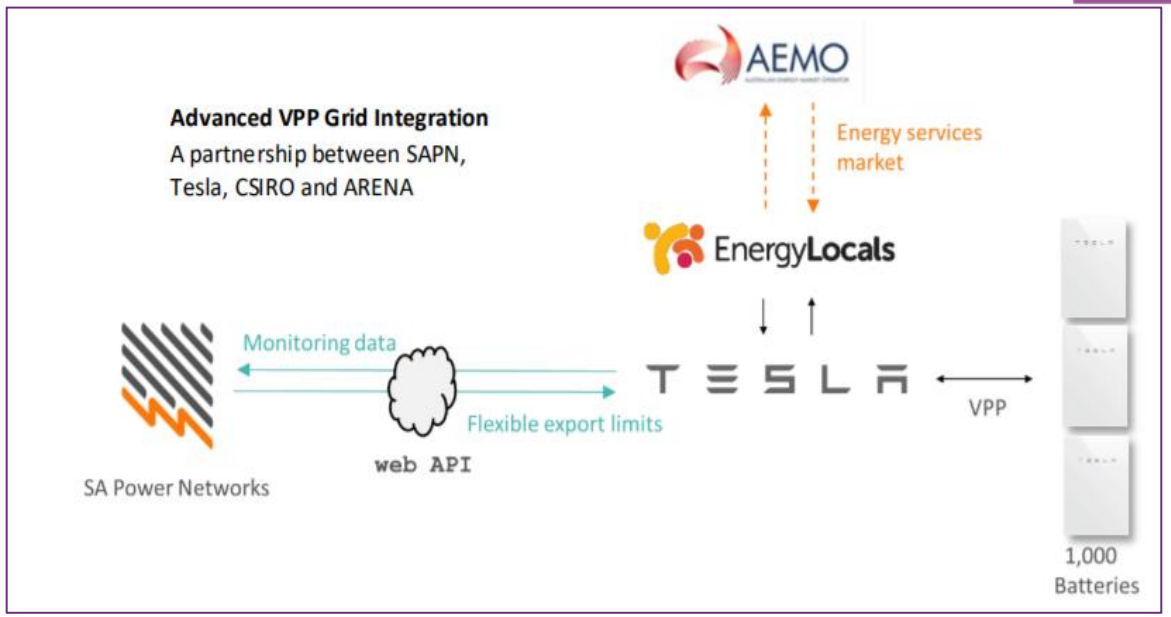
- Emergency DPV curtailment required for six of seven days.
- A maximum of approx. 400 MW of DPV generation curtailed.
- DPV curtailment requirement forecast to exceed capabilities on 17th & 19th Nov. AEMO implemented bespoke procedures.
- DPV curtailment instruction delivered in the form of a demand threshold.





Virtual Power Plants





For more information visit

aemo.com.au

Current projects

- Dalrymple battery (30MW) South Australia
  - Grid connected or island mode operation
  - Smooth transition to and from island state

- Hornsdale Power Reserve (150MW) South Australia
  - Initially 2 x inverters in grid forming mode
  - Full 150MW now grid forming as of mid 2022
  - Provides inertia up to 2100 MWs

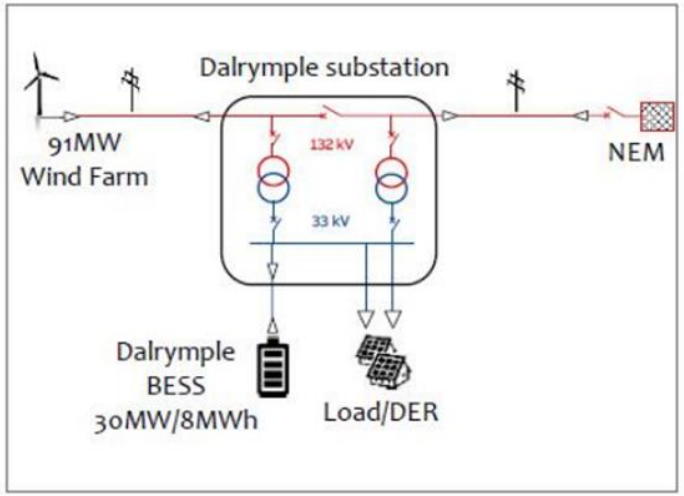


Figure: Operation of Dalrymple BESS in island mode
Source: AEMO grid forming white paper

Performance example – Virtual Machine Mode

- Hornsdale Power Reserve
- Under frequency event on 11/08/2022 (NEM time 1852:35)
- Inertial response is driven by the Rate of Change of Frequency (RoCoF)
- Followed by the primary frequency response