Australian Experience with Synchronous Condenser Applications

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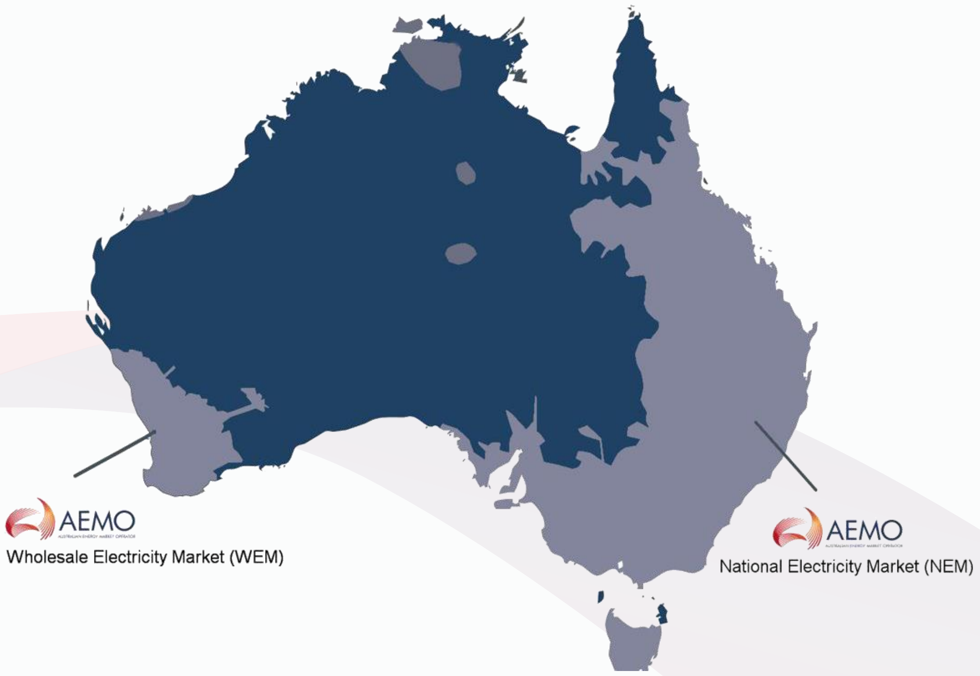
Australian Energy Market Operator

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 61 GW and a peak demand of 36 GW

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

Operating principles

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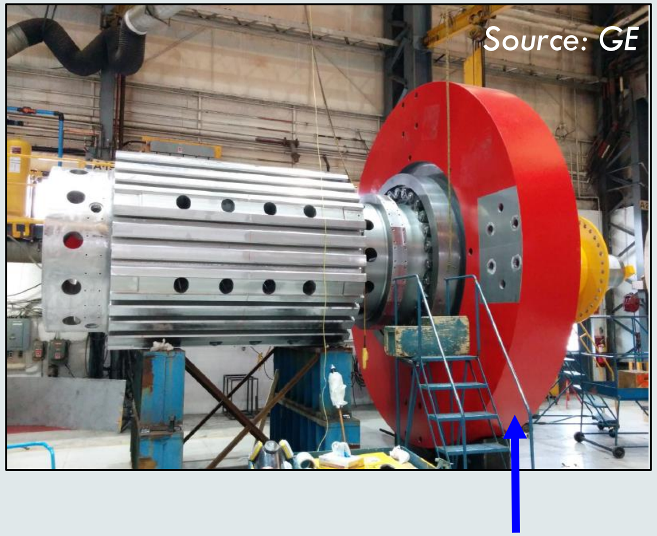
Synchronous condensers

- Established technology (1900–), 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

Synchronous generators vs. synchronous condensers

Attribute	Synchronous generator	Synchronous condenser
System strength	✓	✓
Inertia	✓	✓ (could vary substantially)
Voltage control	✓	✓ (trends in reduced losses and voltage control capability)
Frequency control	✓	✗
Continuous energy	✓	✗

Source: Wikipedia

Drivers for installation of synchronous condensers in the NEM

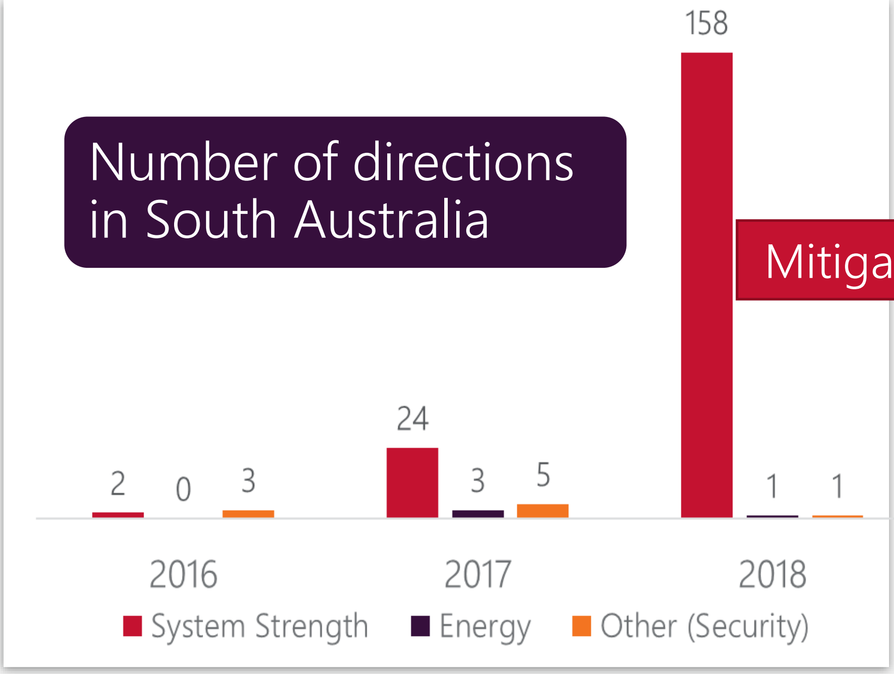
Responsibilities for maintaining system strength

- Fault level rules
  - System Strength Requirements
    - Transmission network owner to maintain
    - System Strength Shortfall?
    - Secure additional synchronous machines
  - System Strength Impact Assessment
    - Network owner to assess the impact
    - Adverse System Strength Impact?
    - Remediations (next slide)

Cater for synchronous unit retirement/de-commitment/outages

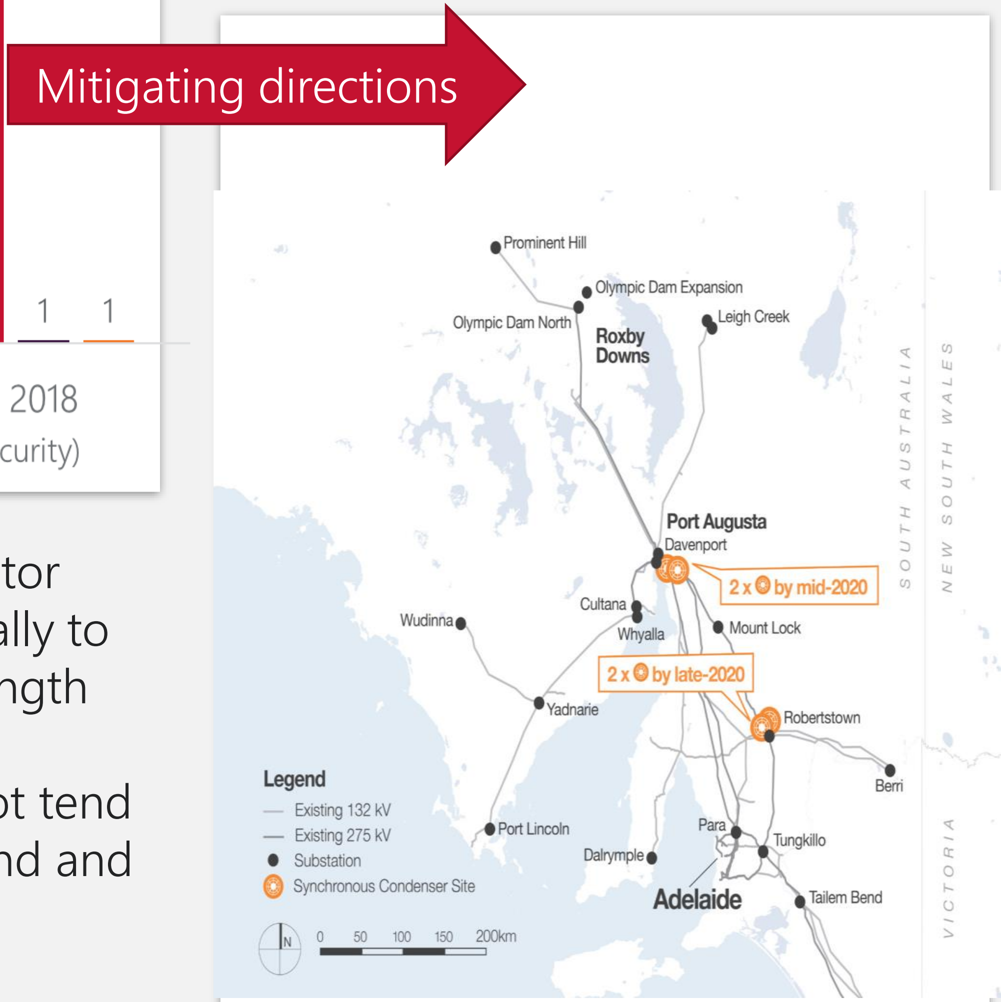
Cater for incremental impact of new or modified connection

Synchronous condenser installation by transmission network owners



- 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

Network synchronous condensers

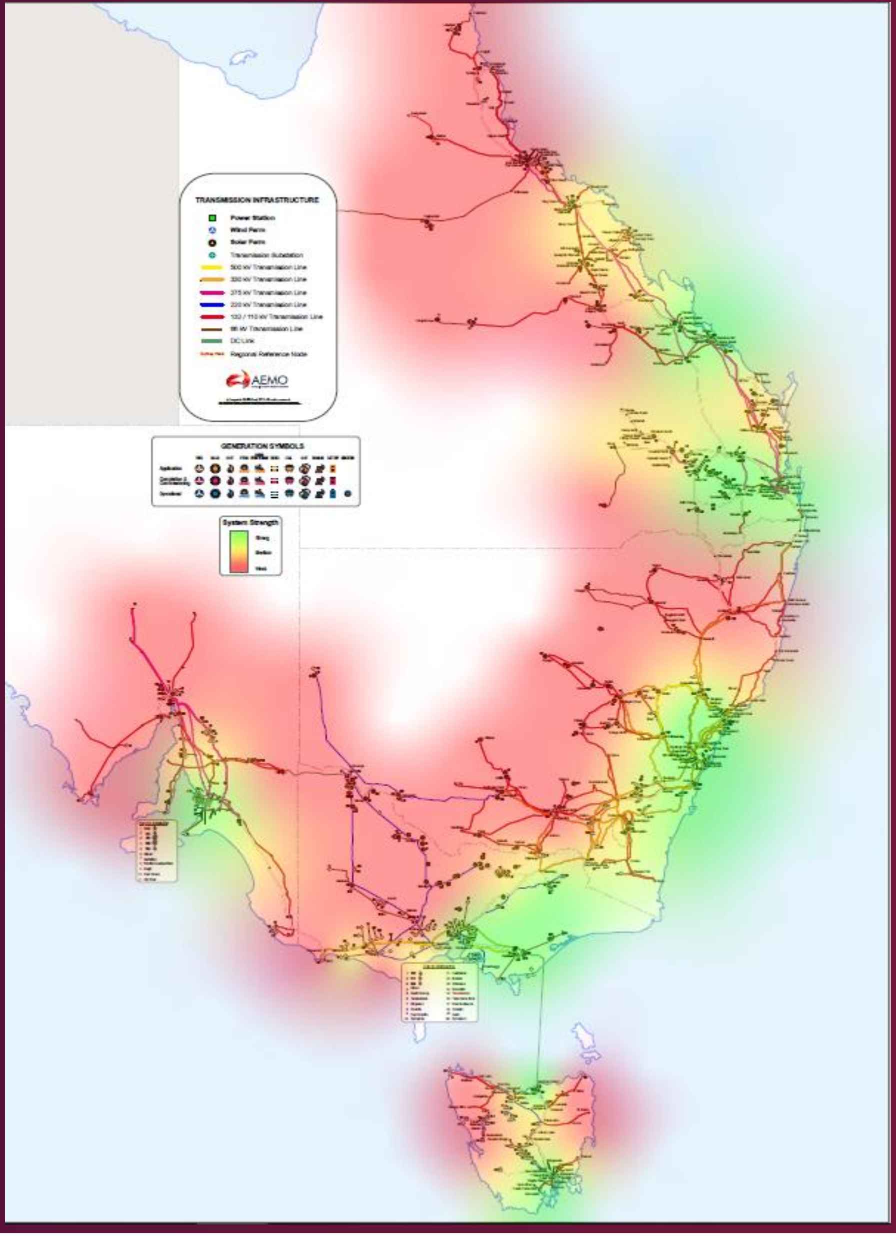


Source: ElectraNet

Synchronous condenser installation by generators

Typical connection of inverter-based generators

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



Connections in areas with low system strength are driving installation of synchronous condensers by developers

Example of synchronous condensers installed by a generator

- Musselroe wind farm is one of the pioneering projects worldwide
- Wind turbine capability with respect to operation under low system strength conditions has evolved significantly since then
- In recent times larger and optimally placed synchronous condensers have been preferred by most developers

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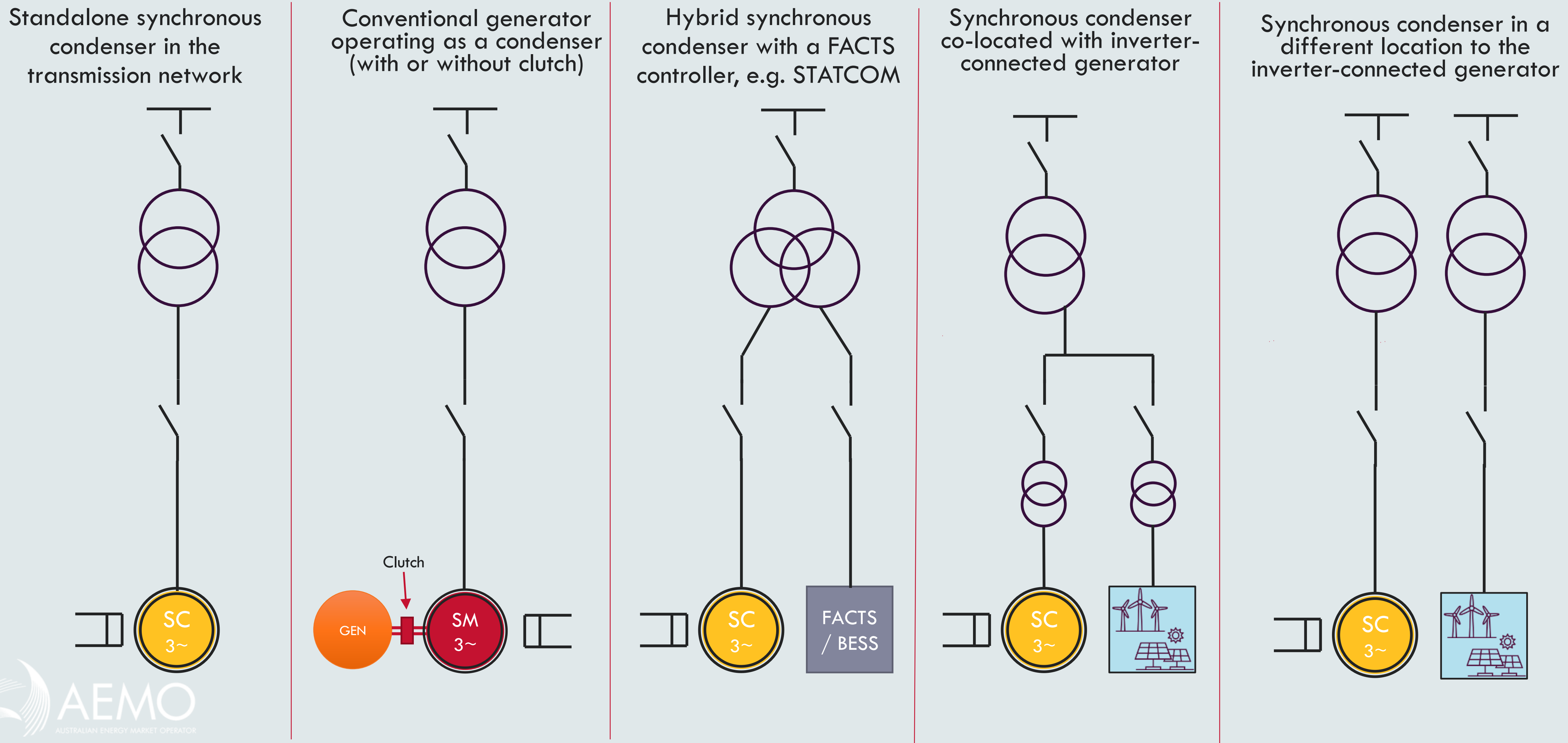
Source: TasNetworks, Hydro Tasmania

Possible configurations



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Summary of applications

- Generator initiated
  - Either within or outside the connection point
  - So far all are brand new synchronous condensers
  - Often without flywheels
  - The ratio of installed MVA capacity of the synchronous condensers to that of the generating system ranges from 1/1 to 1/6 in practical applications seen so far
- Network initiated
  - Transmission network connected
  - Both brand new (South Australia) and dual mode synchronous generators (Tasmania)
  - South Australian application includes flywheels to support both system strength and inertia, and allow stable operation under islanding conditions
  - Typically larger sizes
  - No repurposed synchronous generators so far

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