

DIGSILENT Pacific

Power system engineering and software

What's the fuss about system strength?

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DIGSILENT Pacific
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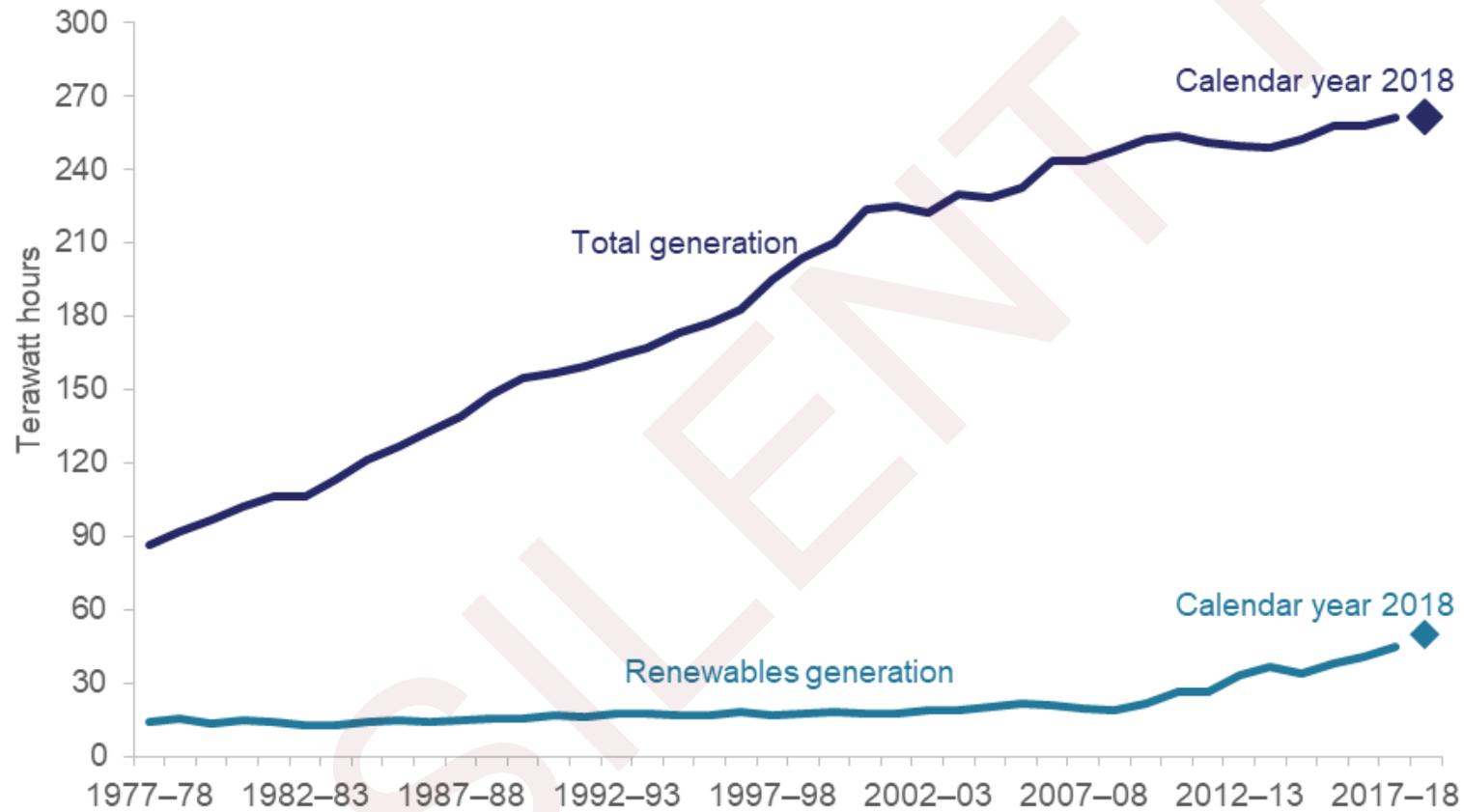
System strength – 3 messages

- System strength is related to fault level
- It manifests as increased sensitivity of voltage to reactive power.
- It affects voltage stability.

What is system strength?

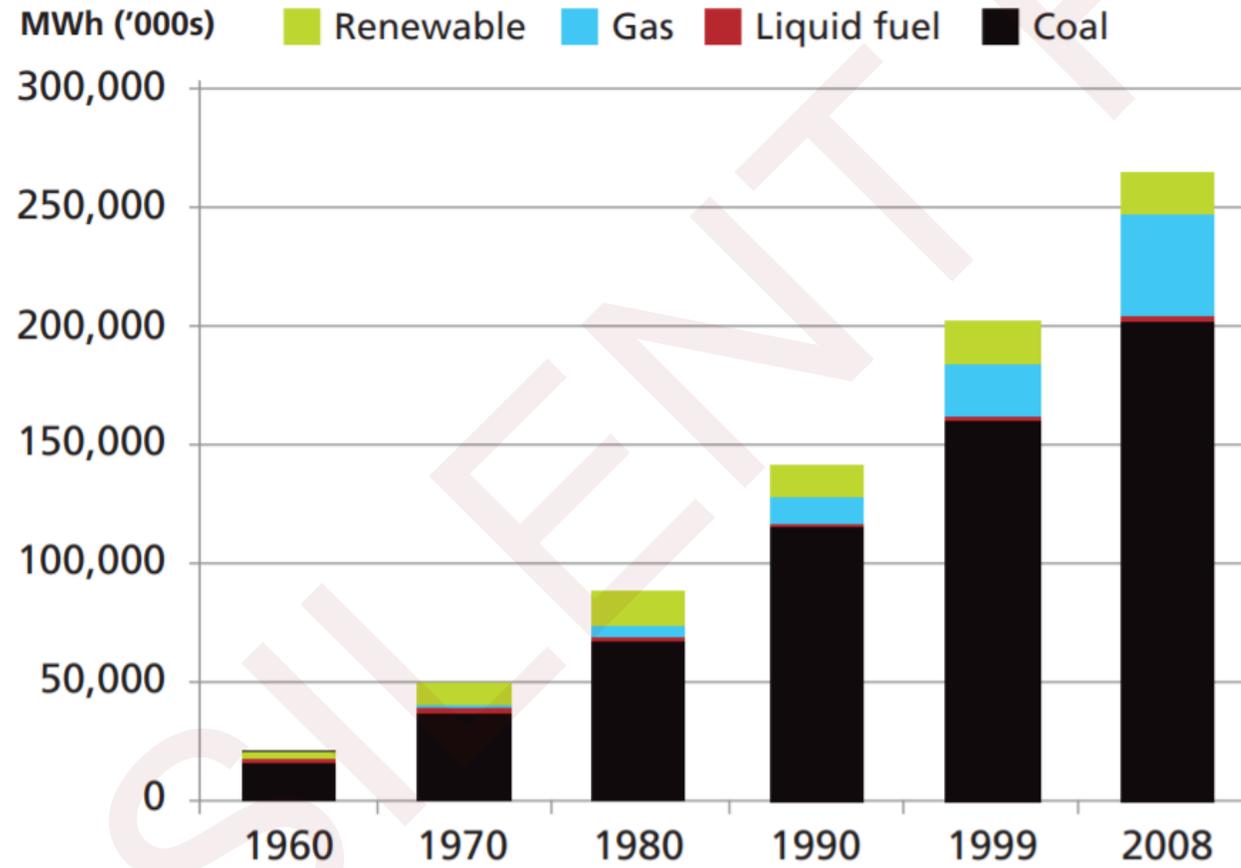


Australia's generation



Source: Dept Environment and Energy

Australia's generation from 1960 to 2008

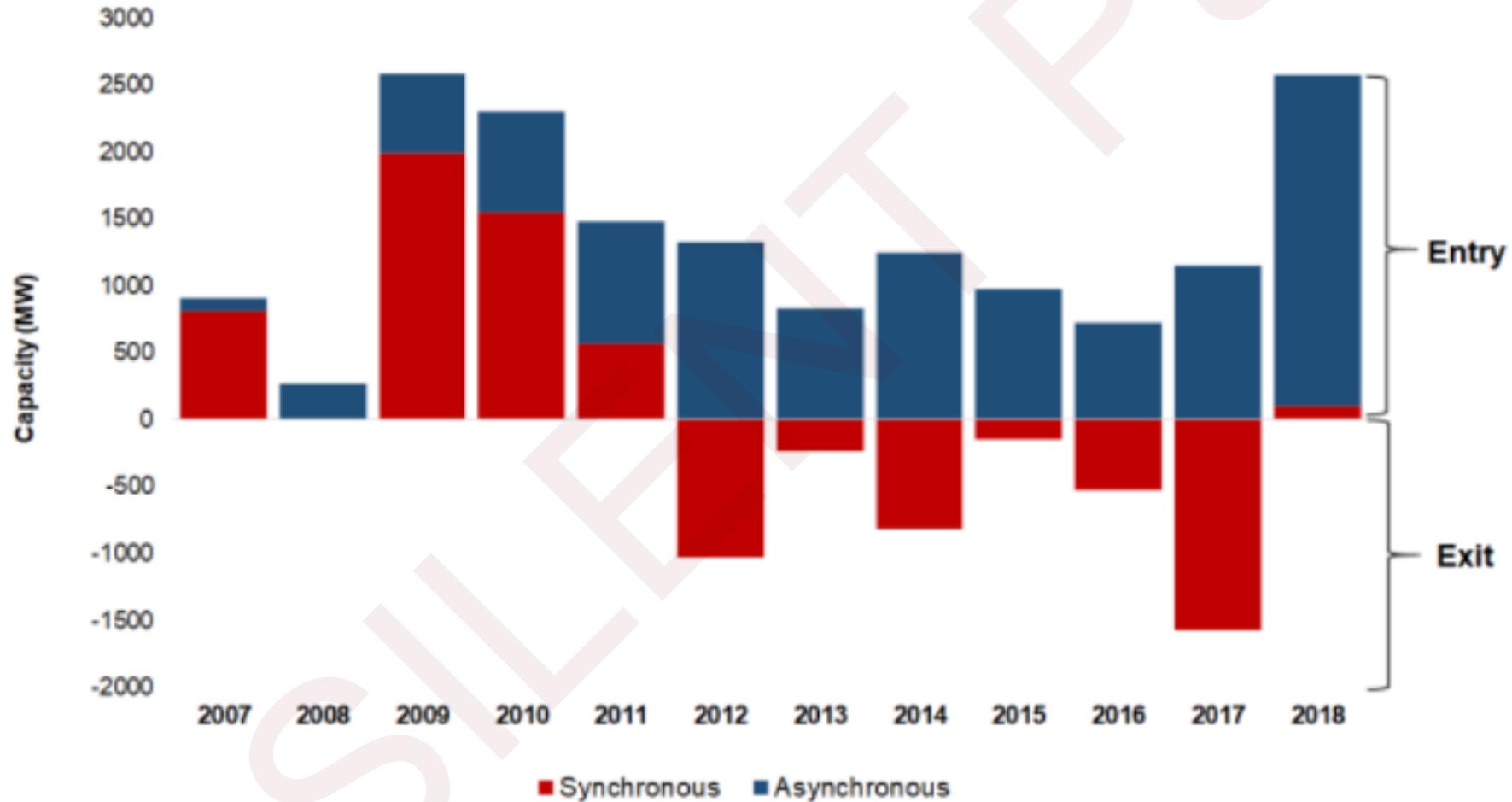


Changes in generation mix 2007 to 2019



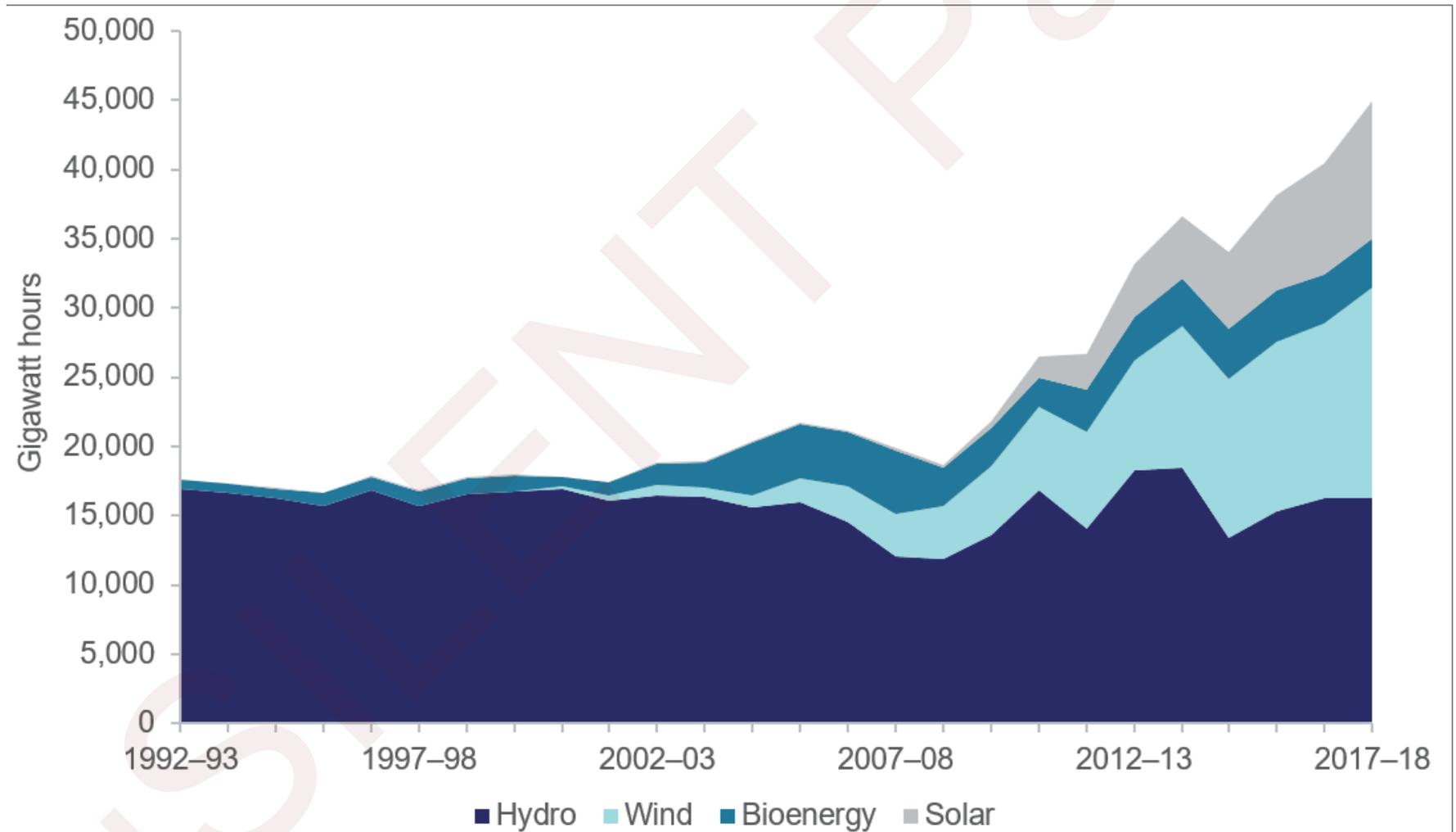
Source: CEDA

Entry and exit of synchronous/asynchronous generation in the NEM



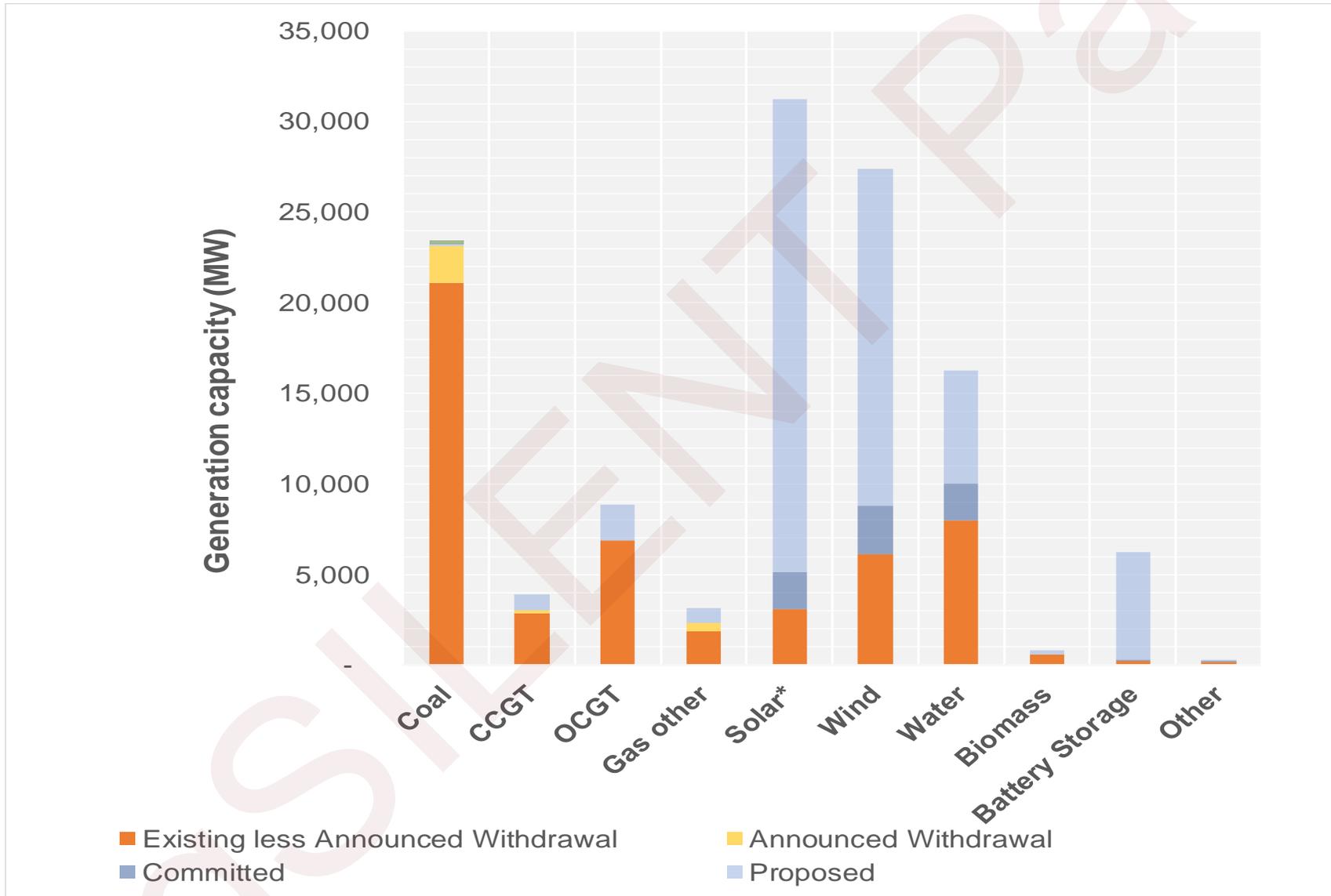
Source: AEMC

Renewables generation in Australia



Source: Dept Environment and Energy

The future



Source: AEMO

Retirements

Station	Capacity (MW)	Expected Retirement
Torrens Island A (gas)	480	2020 to 2022
Liddell (coal)	2000	2022 to 2023
Osbourne (gas)	180	2023
Callide B (coal)	700	2028
Vales Point (coal)	1320	2028 to 2029
Hallett Power Station (gas)	180	2032
Yallourn (coal)	1480	2029 to 2032
Eraring (coal)	2880	2032
Bayswater (coal)	2640	2035
Gladstone (coal)	1680	2035

Total 13540 MW

Source: AEMO

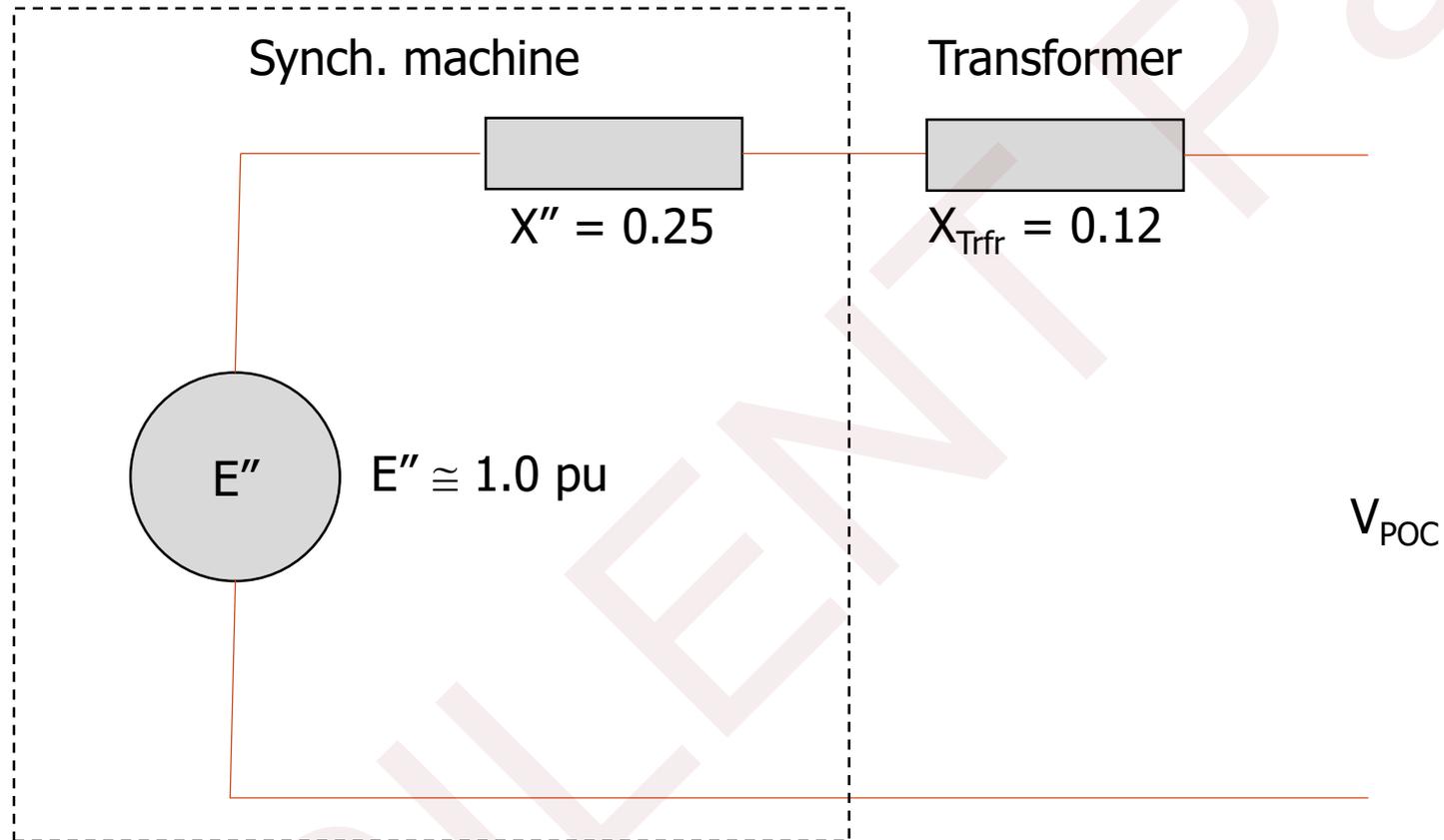
What are the patterns here?

- Our synchronous fleet of generation is aging, and a significant amount will soon retire.
- It is being replaced largely by wind, solar and a bit of battery storage – all asynchronous.
- Some hydro pumped-storage is also proposed
 - Combination of synchronous and asynchronous plant is likely
- It is being connected in different parts of the grid – often more remote parts with less developed transmission network and not much synchronous generation.
- New generation tends to be developed in clumps where the resource is high quality.
 - Our grid has been developed for a different pattern of generation
- Many smaller distributed generating systems – our RIT-T is not efficient for scheduling transmission developments to supply this growth

Fault level

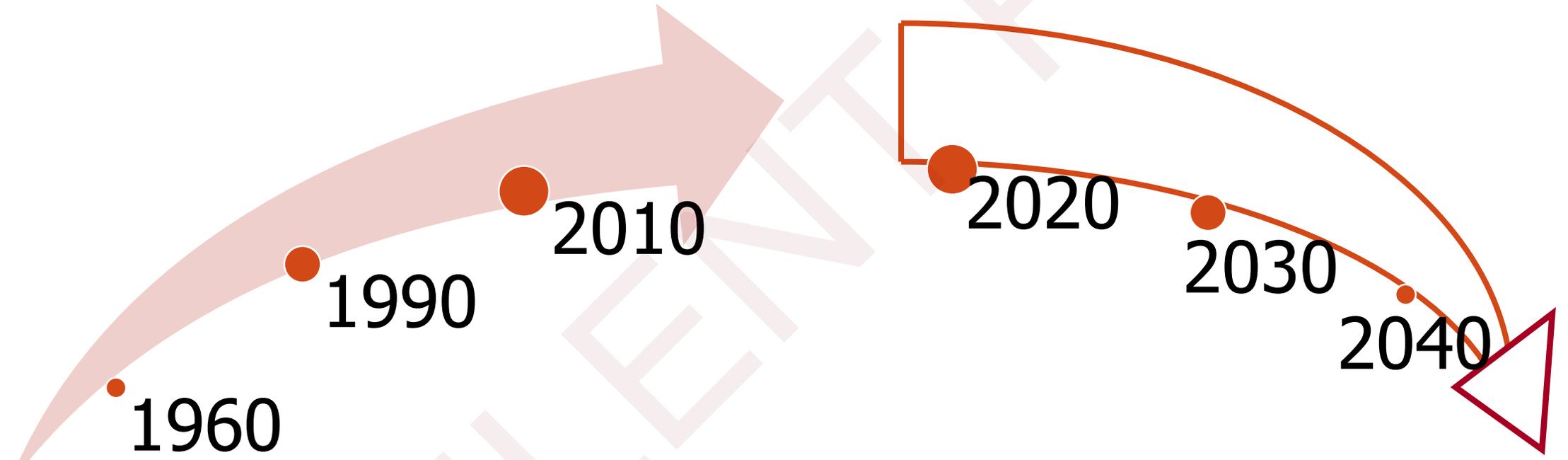
- Contribution to fault level from synchronous generator is much higher than from an inverter-based generator of the same capacity.
- Fault level depends largely on synchronous plant:
 - Capacity
 - Dispatch
 - Location
- Transmission :
 - Higher capacity transmission between synchronous generation and point of measurement
 - Lower impedance
 - -> higher fault level.
 - Fault level can be significantly affected by network outages
- **Low fault level -> weak network**

SM is a (strong) voltage source



- For a short time, a SM can contribute around **three** times its rated current
- Any voltage change on the system is opposed by the SM
- Asynchronous plant is typically limited to its rated current

Fault level

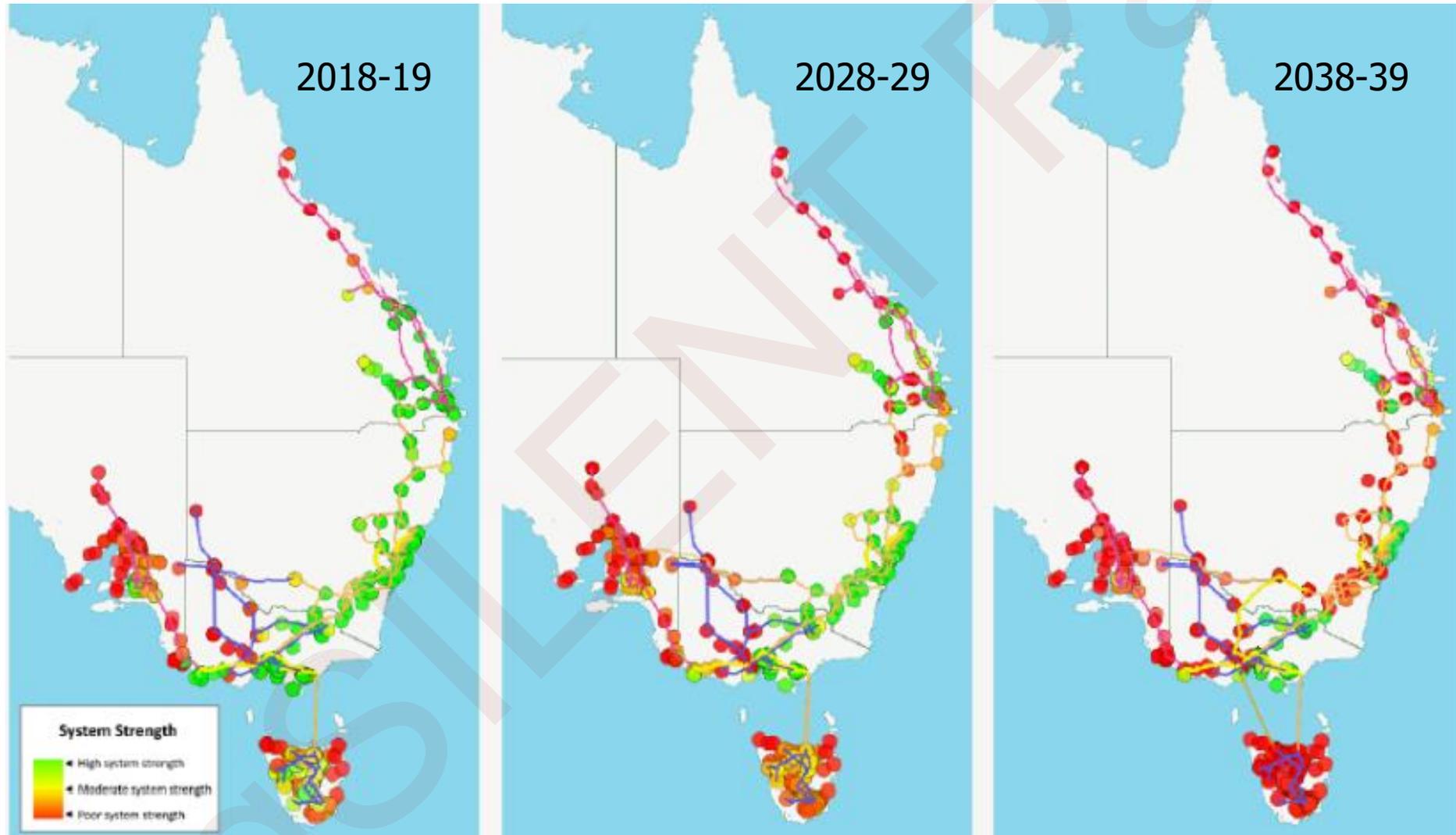


The changing landscape of fault levels

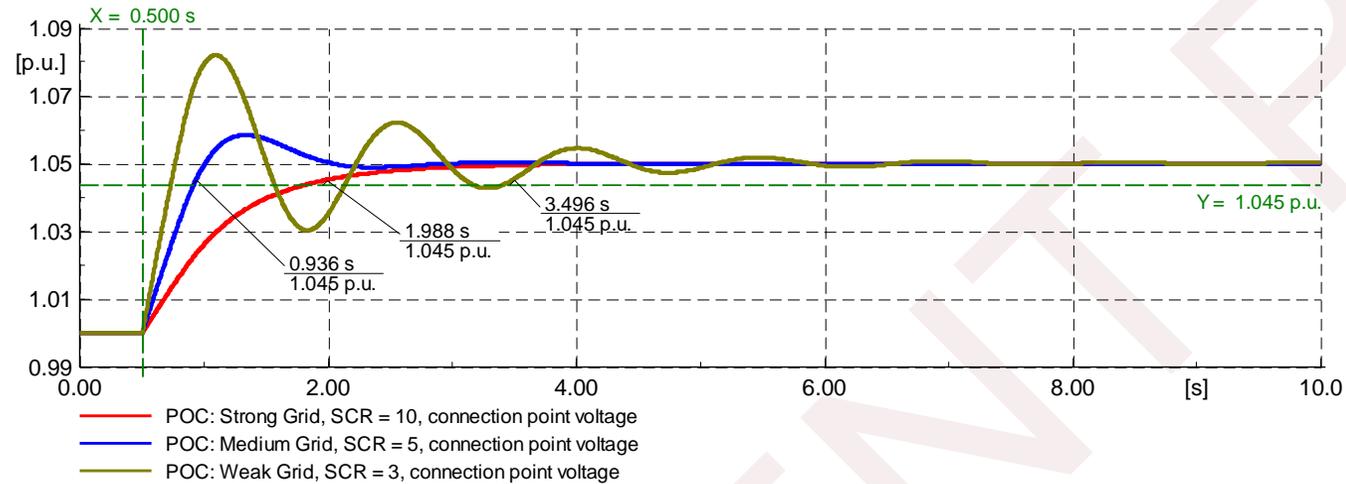
- Fault level is the net result of several factors, including (importantly):
 - Generation based on synchronous generators
 - Network between synchronous generation and installation of inverter based generating systems
- The generation profile changes all the time (and is likely to do so more frequently)
 - Coal plant retires
 - Gas turbines come on for peak support (and then turn off)
 - Some coal-fired generation may turn off during the day if there is a lot of solar generation
- Network elements are switched out of service for maintenance and faults

Fault level can vary significantly over a day, over a network outage, over the life of the generators.

System strength

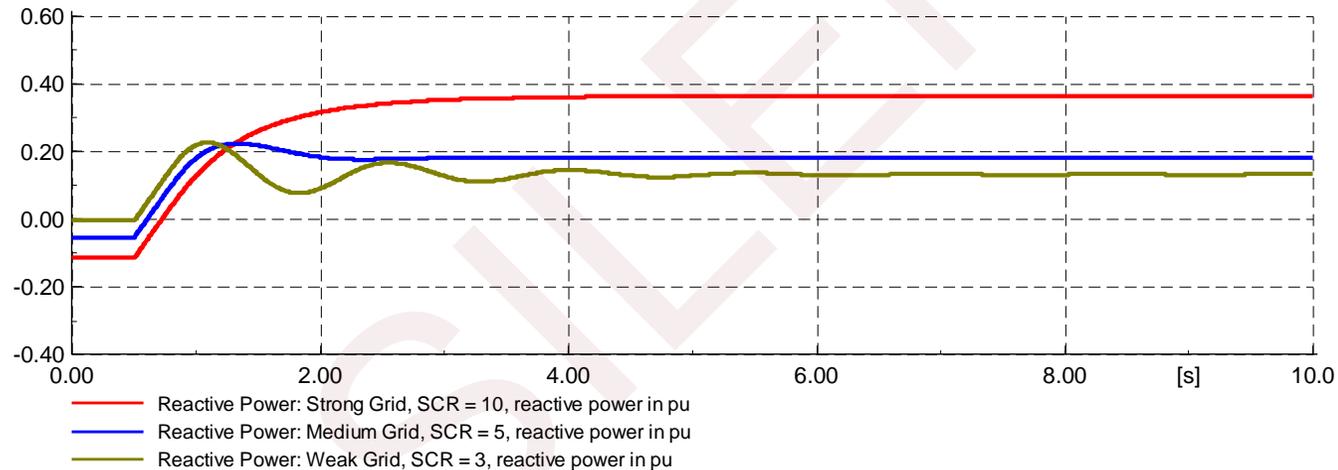


Why is this a big deal?



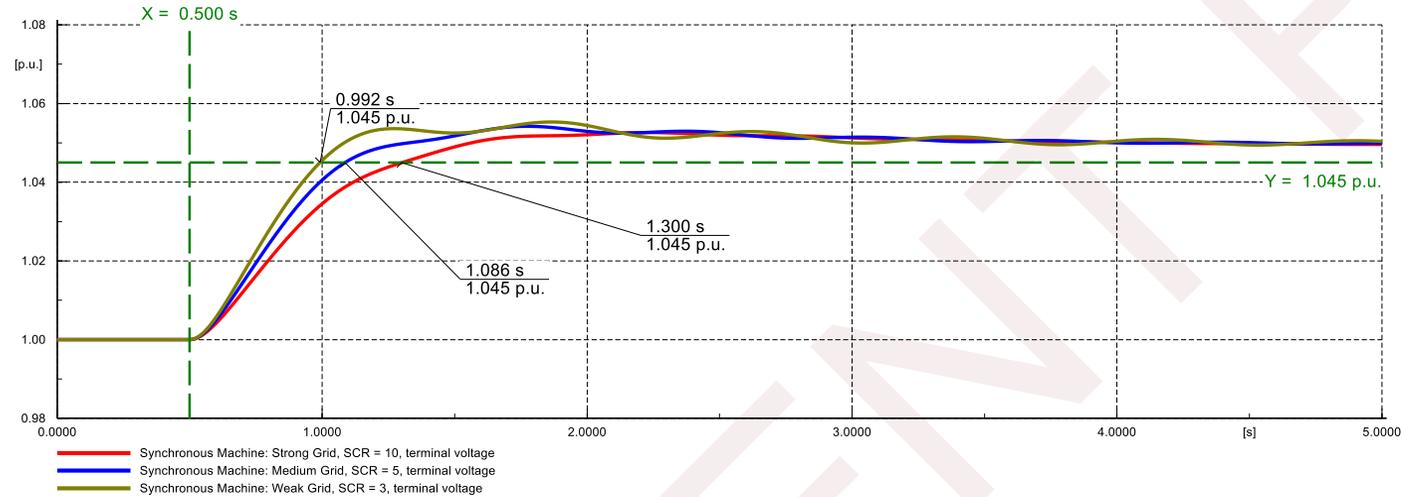
Slower response
as fault level
Increases

Less stable as
fault level decreases

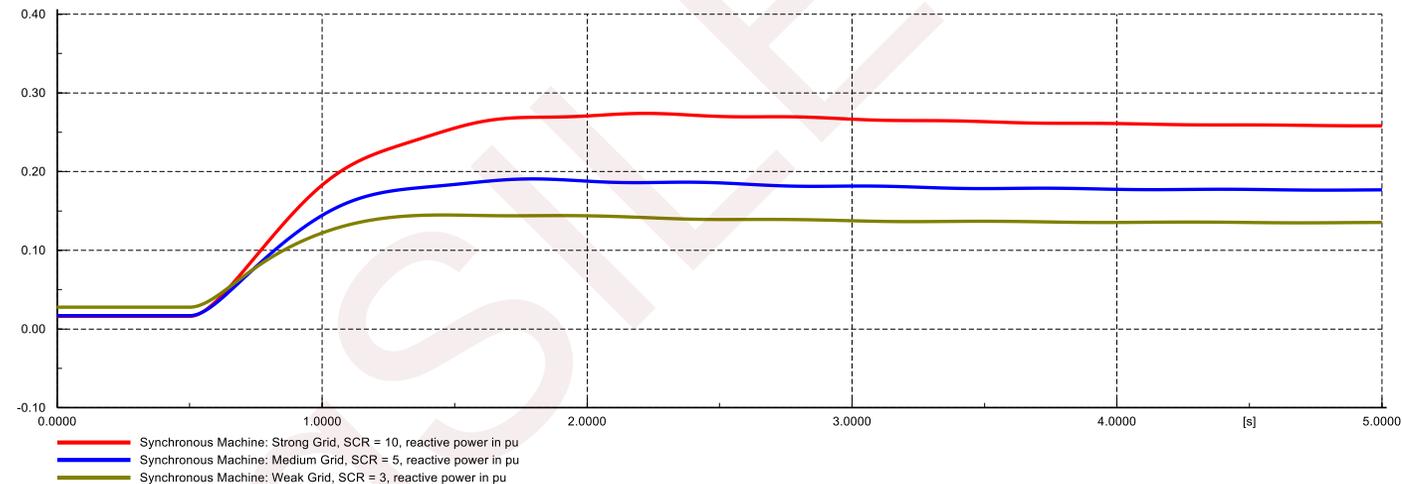


More reactive
power required
as fault level increases
for same voltage change

Synchronous generators are not immune



Damping is lower as fault level reduces



Adverse system strength = stability impact

An adverse impact, assessed in accordance with the *system strength impact assessment guidelines*, on the ability under different operating conditions of:

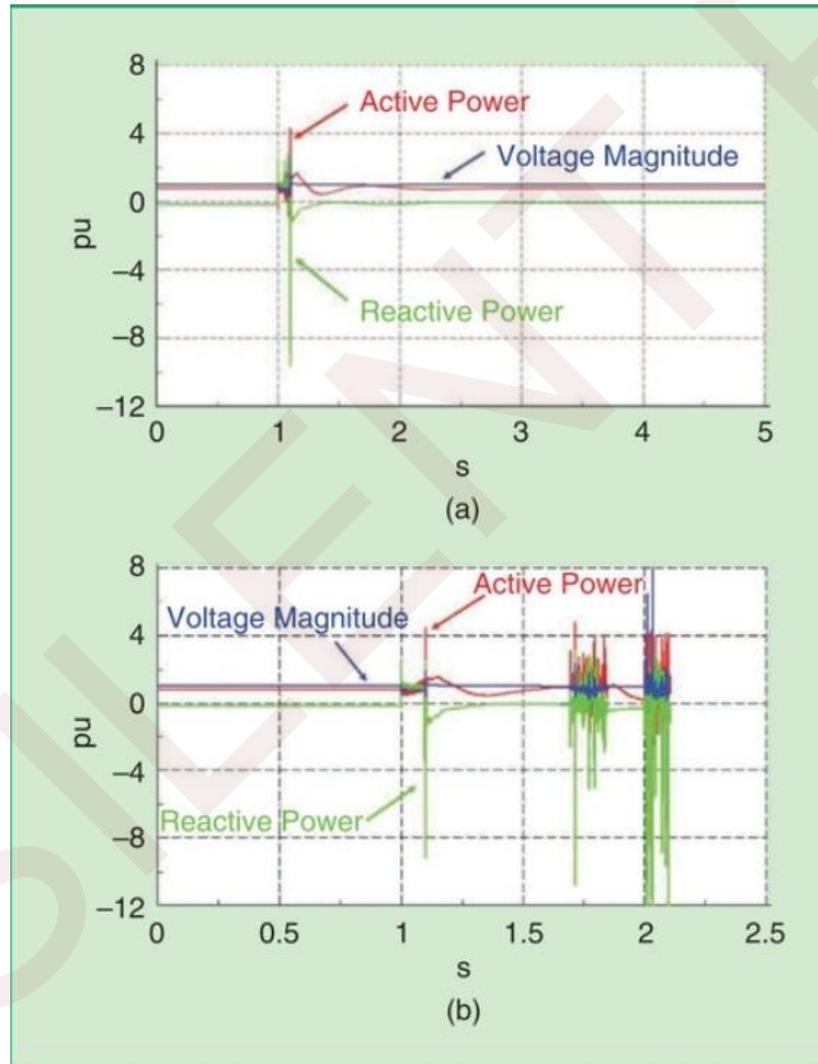
- (a) the *power system* to maintain system stability in accordance with clause S5.1a.3;
or
- (b) a *generating system* or *market network service* facility forming part of the *power system* to maintain stable operation including following any *credible contingency event* or *protected event*, so as to maintain the power system in a *secure operating state*

Source: AEMC: NER

What does this mean for technical design?

- NER technical standards favour super-fast responses.....
 - But response depends on fault level
 - A fast response for the 'typical' fault level at a connection point may be unstable if fault level reduces for a network outage
- Over a longer period, synchronous plant may retire, reducing the fault level
 - Over time the response of voltage control systems speeds up
- Conundrum is that designing for the worst case gives ordinary performance for most of the plant's life

Control system interactions make it worse



Source: IEEE Power & Energy Mag
Nov/Dec 2019

Other consequences for new connections

- Delays to connection because of new requirements to study system strength
- A high proportion of generators are having to provide system strength mitigation measures
 - Typical solution has been installation of synchronous condenser to increase local fault level
 - \$\$\$\$
- Coordination of synch-cons:
 - Is hampered by confidentiality issues – leading to inefficient investment
 - Is not incentivised in market systems

What's the consequence for existing plant?

- Dynamic performance of plant deteriorates over time (through no fault of the Generator)
- Settings that were stable and met the performance standards previously may no longer be adequate.
- More impact from the same injection of reactive power – potential for adverse interactions between neighbouring plant.
- Same levels of harmonic current injections have different (potentially worse) outcomes for emissions over time.
- Critical clearing times may decrease (protection and Auto-reclose settings?)
- Are transient/oscillatory/voltage stability constraint equations still correct?
- Do power system stabiliser settings need to be reviewed?

It's a future problem isn't it?

- NO!

Impacts of system strength on some existing generators

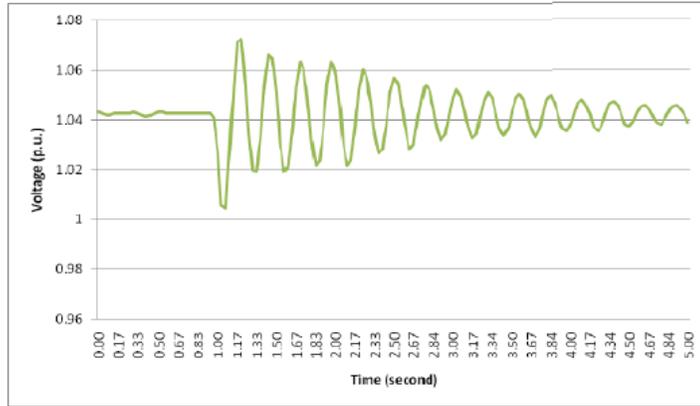
- 3 generators in Queensland currently constrained by system strength
- 5 generators in Victoria currently constrained by system strength
- Other generator connections have been delayed because of system strength issues.
- Much money has been wasted on unnecessary or oversized synchronous condensers.

How did this happen?

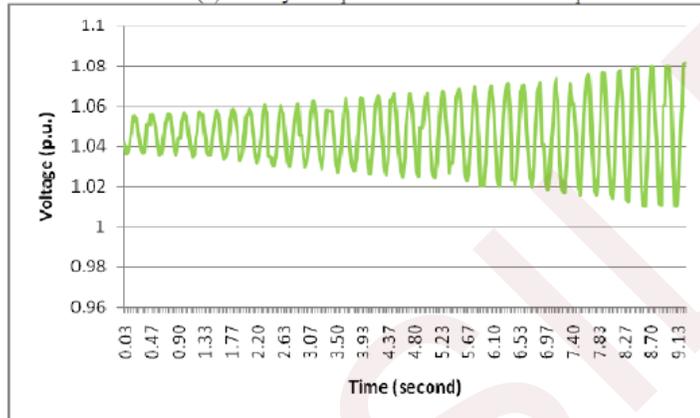
- Traditional RMS (positive sequence) modelling hides some types of system strength issues
- Needs a wide area Electromagnetic Transient Model to observe the problems
- These EMT wide-area models take a long time to develop and are very slow to run
- Consultants don't have access to these models (Rules issue)

=> We as an industry were slow to understand the problem

Oscillations observed (from USA – similar here)



(a) Poorly-damped oscillation at low output

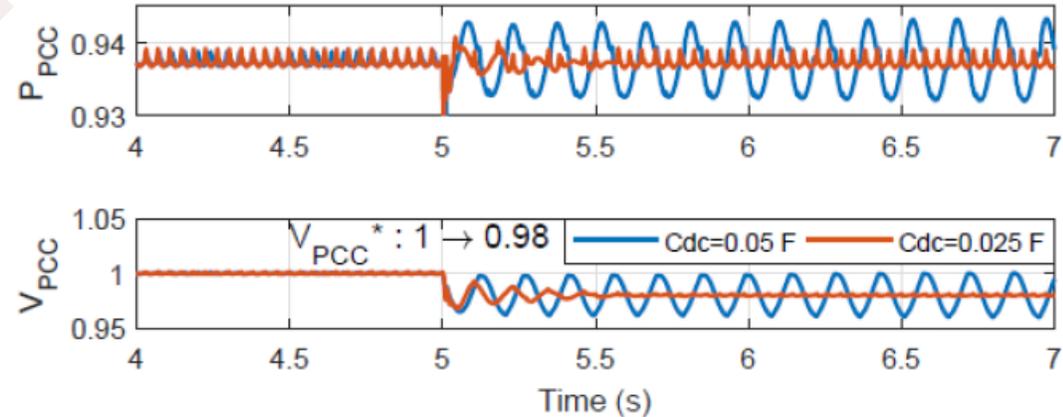
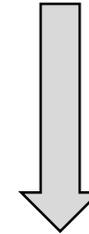


(b) Un-damped oscillations at high output



4 Hz oscillation on a wind farm

7 Hz oscillation on a solar farm



What needs to happen next?

- Technical solution involves coordinated retuning of control settings (first step)
- This would minimise the cost of
 - Mitigating existing system strength problems
 - Connecting new generation
 - Non-compliances of existing generation
- Recent Rule changes hinder the process of changing settings
 - Especially changes to clause 5.3.9
 - Process is now very expensive, demanding and high risk
 - > a Rule change is needed to rectify this problem
- Connection Applicants and their consultants need access to the wide area EMT models
 - Can't propose settings to fix what you can't model.

Longer term?

- Probably still need a mix of synchronous and asynchronous plant on the power system in the future
- Synchronous condensers, if required, should be planned in a coordinated way not installed as connection assets
- Some creative new technologies that can provide “system strength” benefits
 - Grid forming inverters (on the threshold of commercial reality)
 - Thermal storage and pumped storage solutions – can employ synchronous plant and compensate for variability of solar and wind energy sources
- For high renewable penetration new transmission will be needed based on the location of generation
 - This will improve system strength locally
- Creative control systems – adaptive gains?
- Avoid unnecessary overly aggressive control responses

Who should be responsible for system strength?

- At present the obligation mostly comes back to the generators
- Some early movers got a free ride as they used up the 'free' system strength of the existing power system
- Uncoordinated system strength solutions will increase costs
- Interesting to compare a coordinated development of renewable energy zones (eg ERCOT) with the NEM uncoordinated response
- Confidentiality is currently an issue and an excuse
- Higher costs for new Generators mean higher costs for consumers

Summary

- System strength is a problem that has been a long time coming, but snuck up on us!

Related to fault levels

It manifests as increased sensitivity of voltage to reactive power

It affects voltage stability

- Presently costing the industry (and consumers) a lot of money
- There are things that can and should be done to improve system strength



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