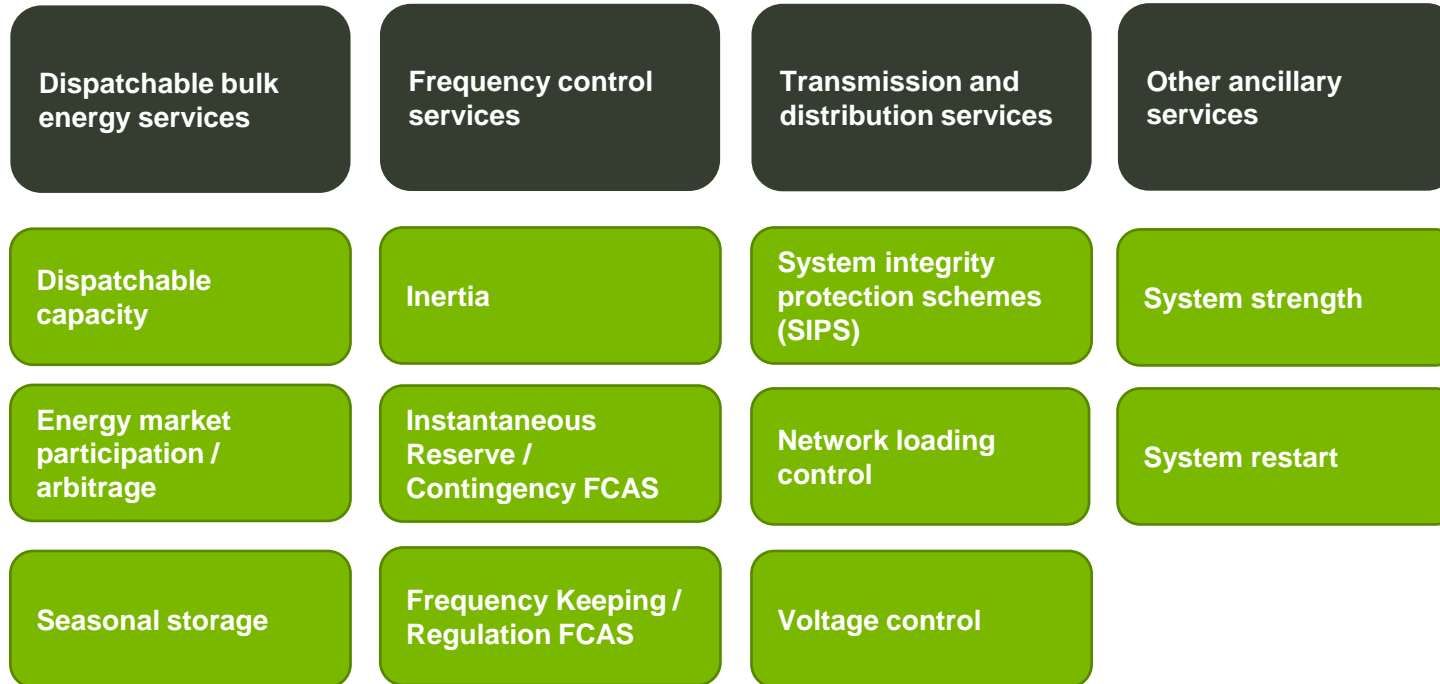


*Bringing ideas
to life*

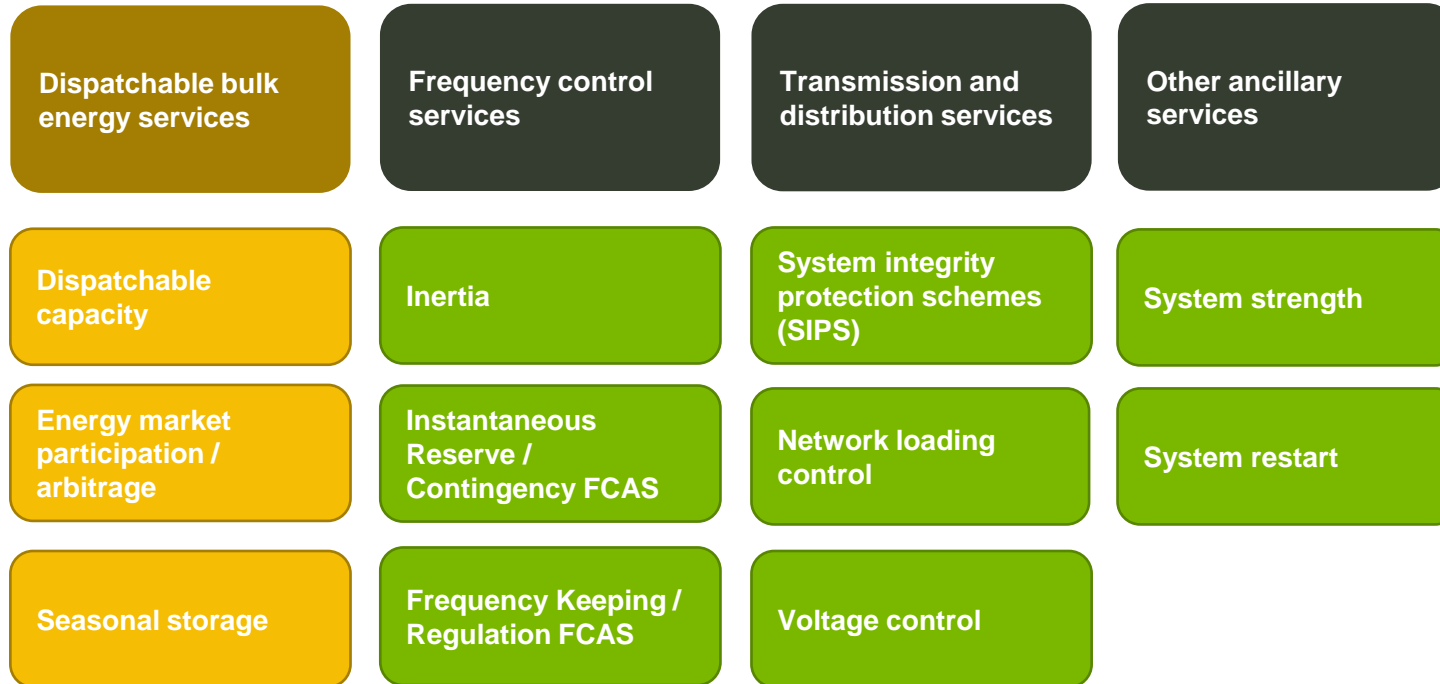
Wind Energy Conference Large scale energy storage - Reshaping power system services

Steve Wilson, Technical Director, Energy
12 May 2021

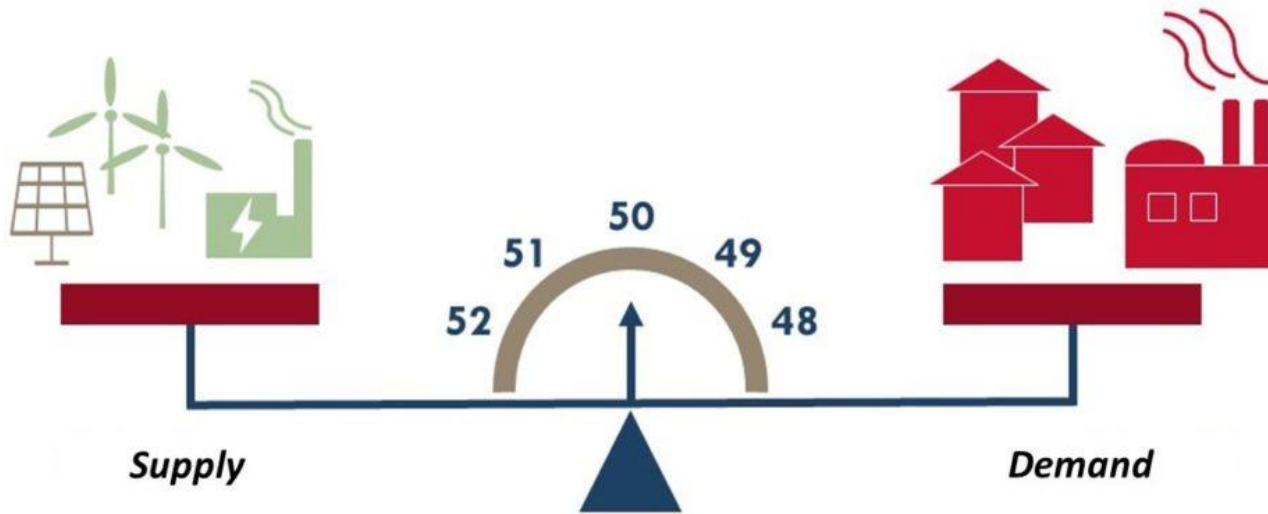
Power system services



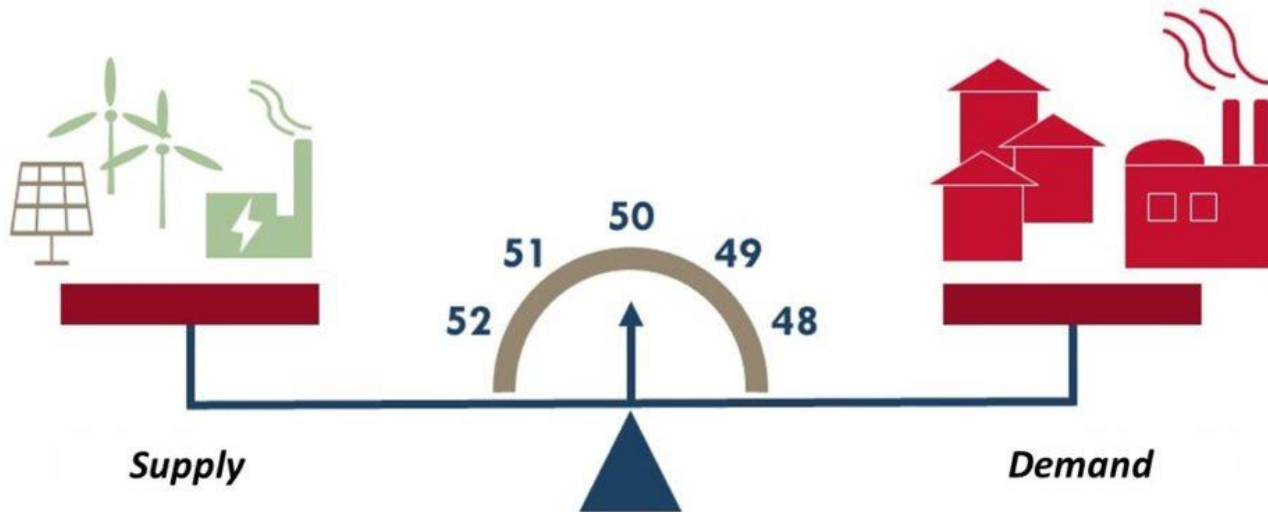
Power system services



Dispatchable bulk energy services

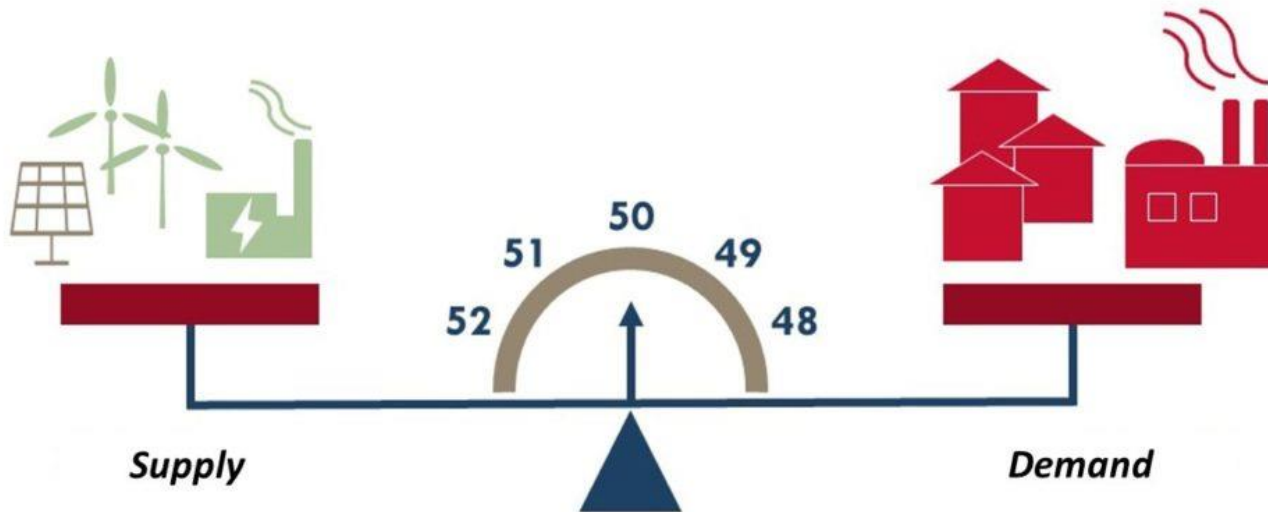


Dispatchable bulk energy services



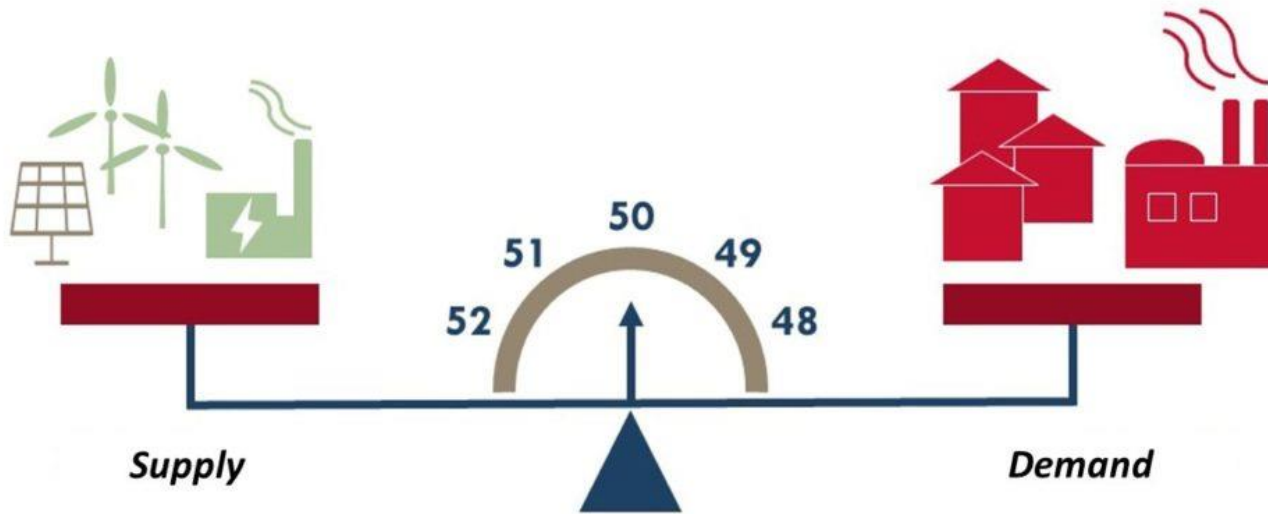
- Controllable

Dispatchable bulk energy services



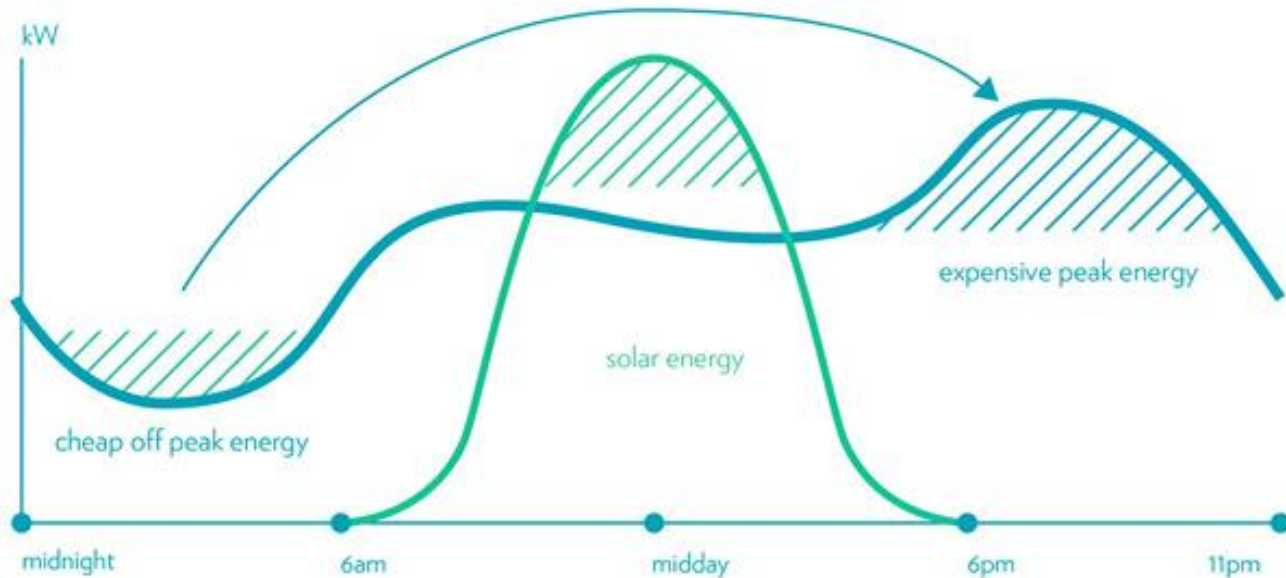
- Controllable
- Firm

Dispatchable bulk energy services



- Controllable
- Firm
- Flexible

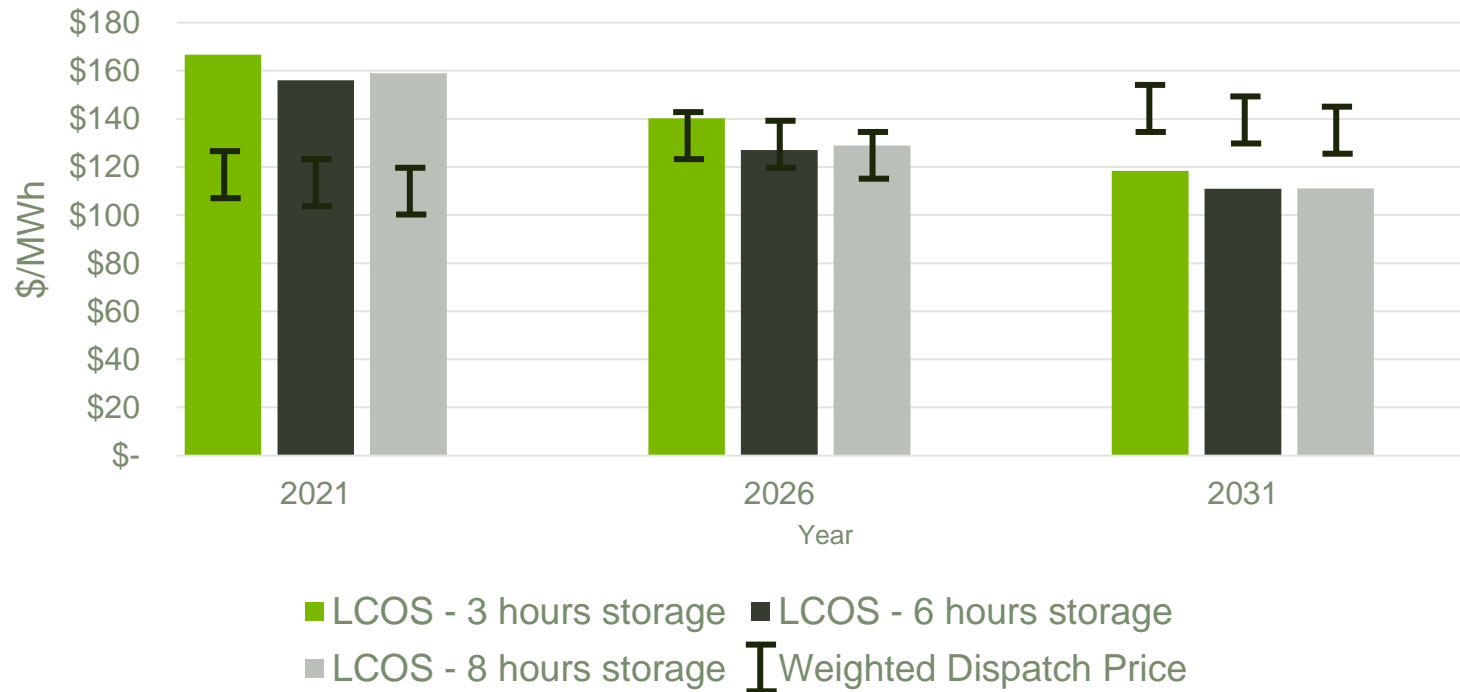
Dispatchable bulk energy services



- Controllable
- Firm
- Flexible

Medium duration storage economics – Li-ion BESS

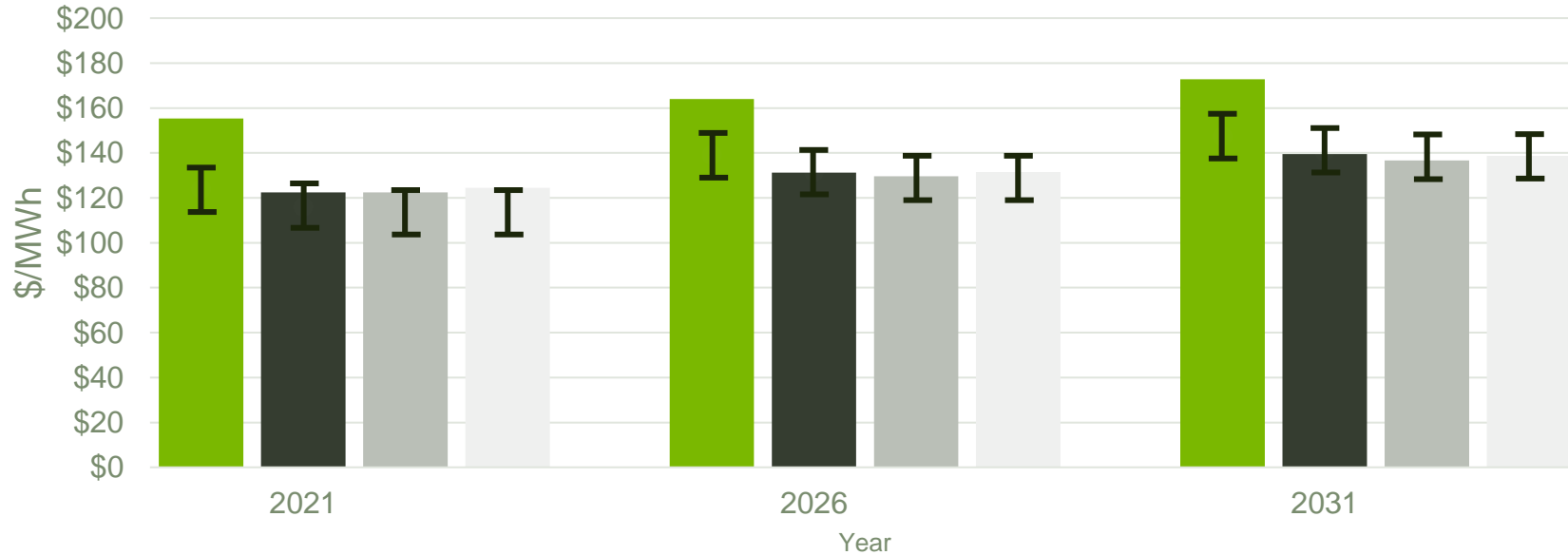
LCOS for Li-ion BESS arbitrage in QLD



Study results show a combination of declining BESS costs and changing market price profile is expected to lead to significantly improved arbitrage commerciality over the next 5+ years

Medium duration storage economics – Pumped Hydro

LCOS for Pumped Hydro arbitrage in QLD



Study results show relatively consistent marginal commerciality for medium duration pumped hydro over the next 5+ years for this scenario.

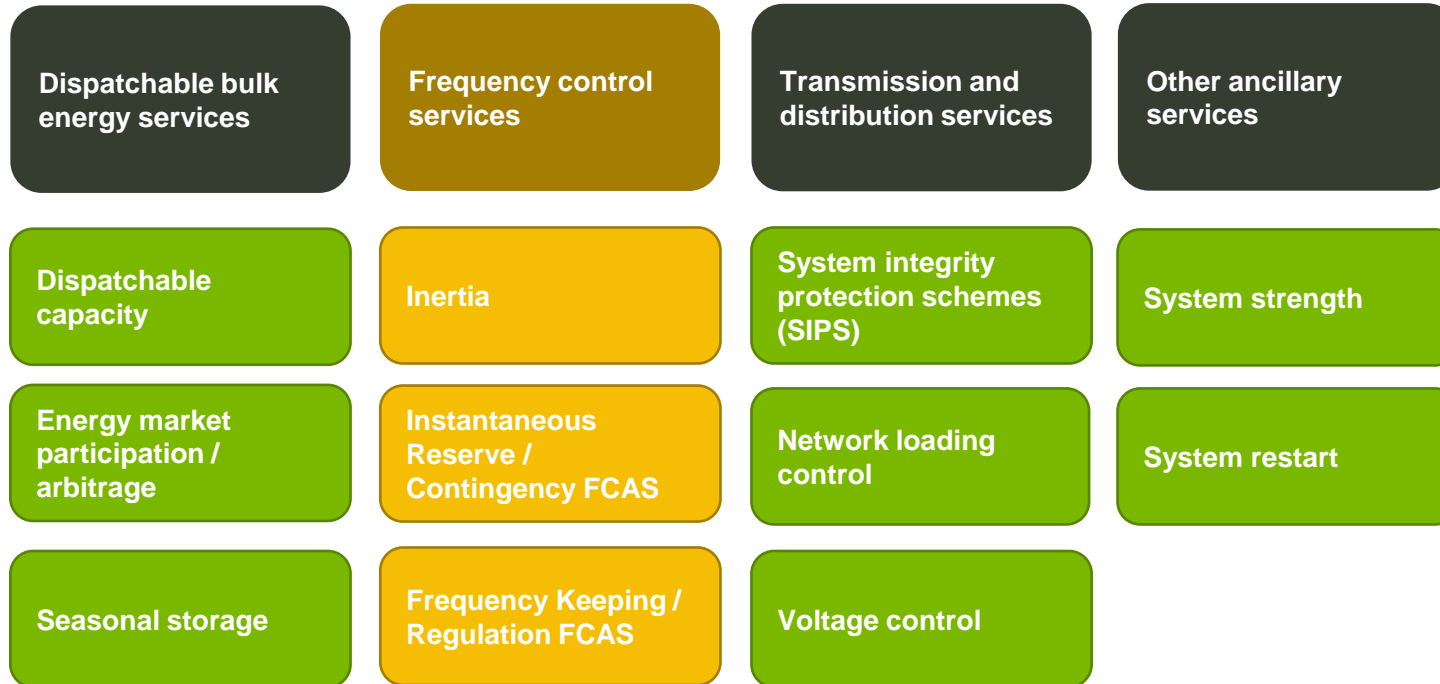
■ LCOS - 3 hours storage ■ LCOS - 6 hours storage ■ LCOS - 8 hours storage
■ LCOS - 10 hours storage I Weighted Dispatch Price

Seasonal storage

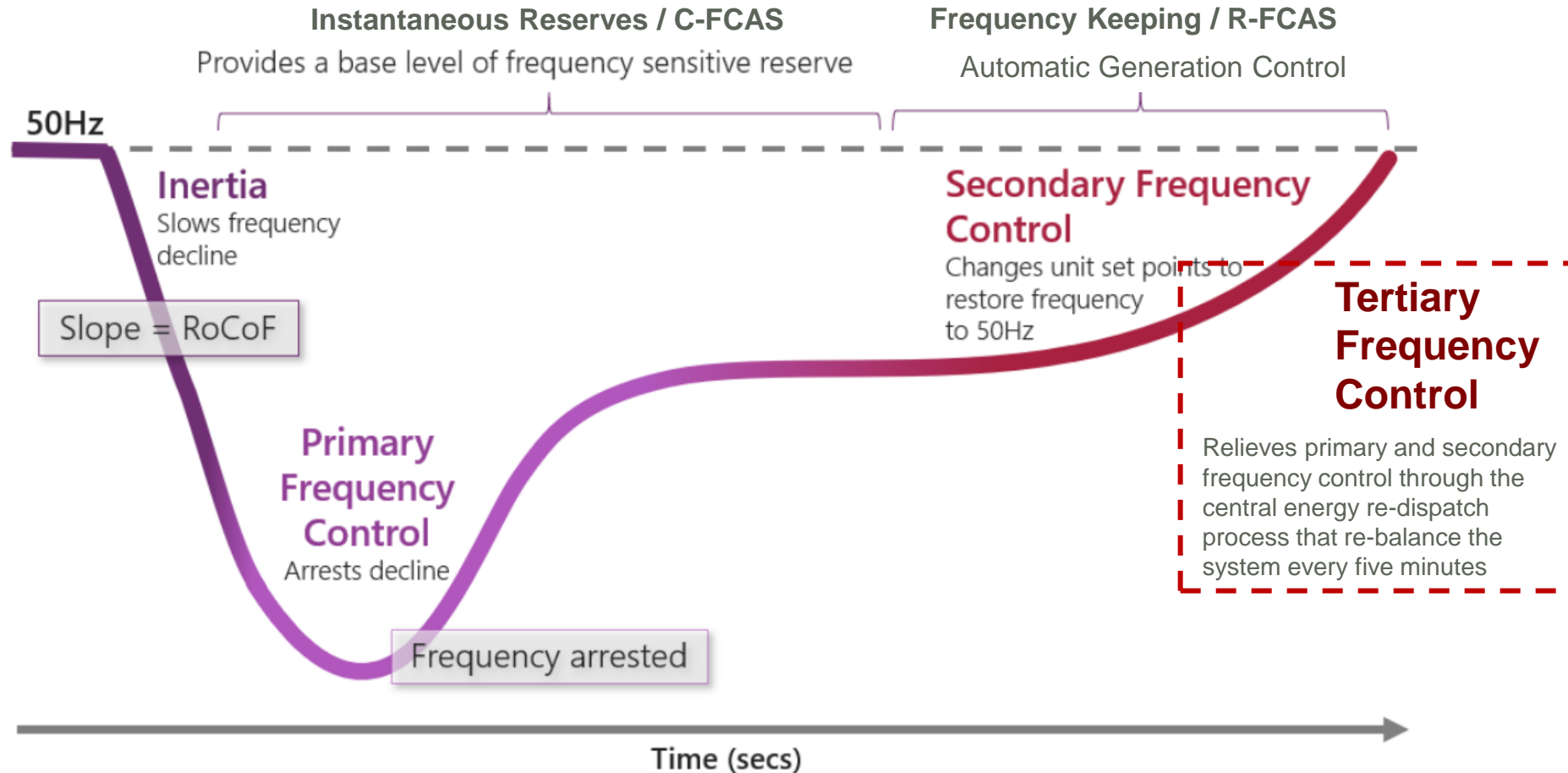
- Pumped hydro potentially credible option for seasonal (TWh) scale energy storage
 - Risks: Environmental, cost, development timeframe
- Batteries not technically or commercially credible at TWh scale, however potential option to integrate with other generation and storage to meet requirement. E.g.
 - Overbuild of solar and wind (likely also needed to charge seasonal PHES)
 - Medium duration batteries for daily firming
 - Other firming generation for inter-day capacity if shortfall in wind / solar generation. (E.g. hydrogen, biomass, gas, diesel)



Power system services

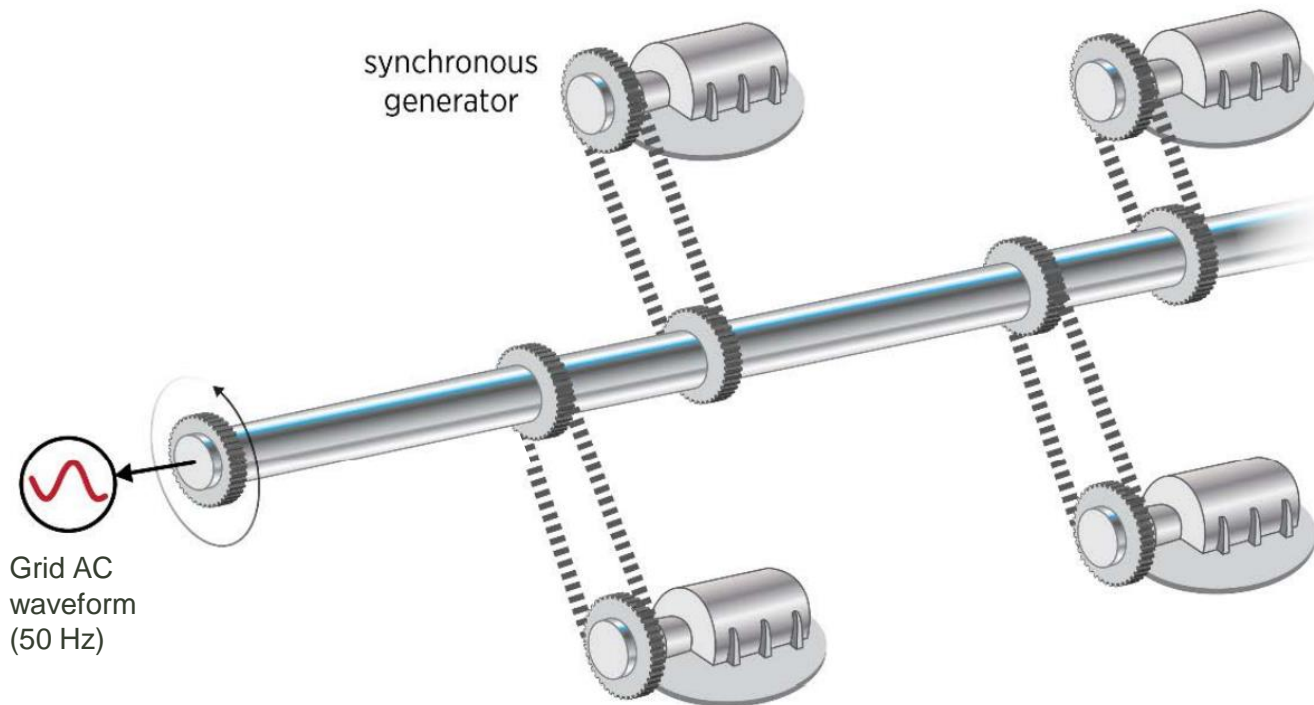


Frequency control services



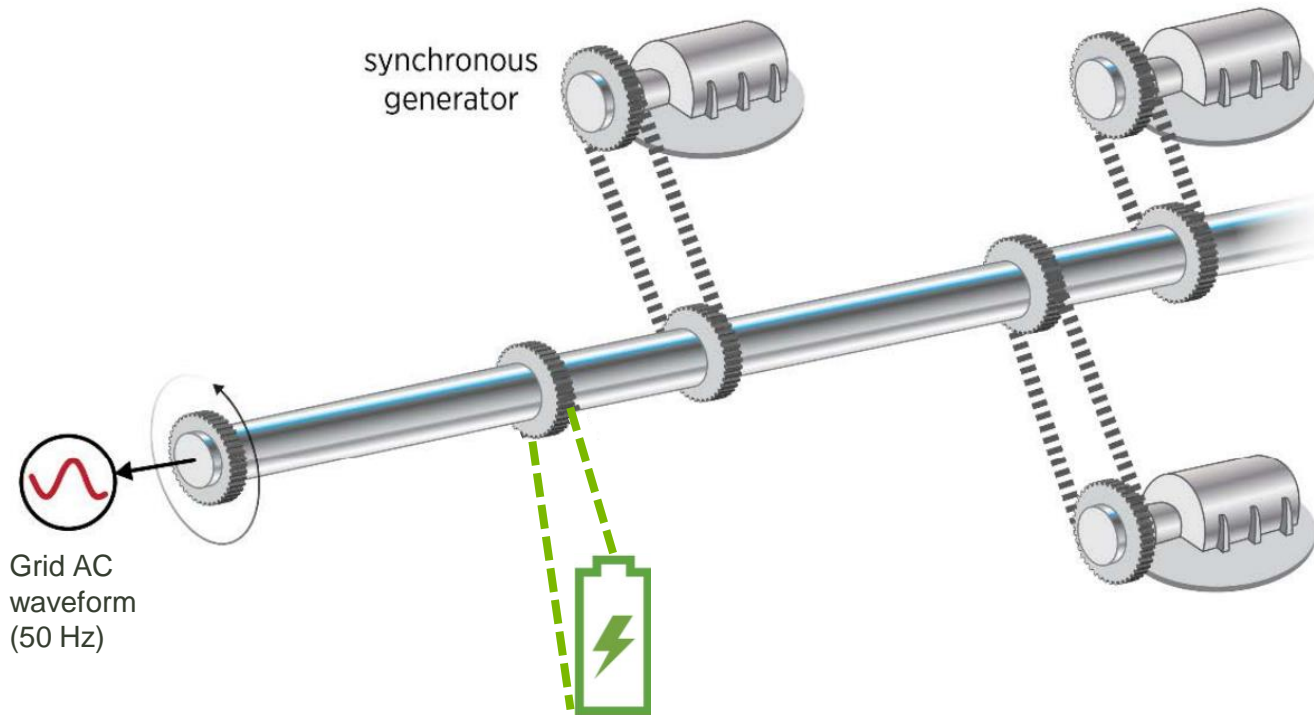
Inertia

- Slows rate of change of frequency (RoCoF)
- Allows Instantaneous Reserve service time to respond
- Inherently provided by synchronous generators – including synchronous Pumped Hydro



Inertia

- Slows rate of change of frequency (RoCoF)
- Allows Instantaneous Reserve service time to respond
- Inherently provided by synchronous generators – including synchronous Pumped Hydro



**Can also be provided
by some grid forming
battery inverters**

Swing equation:

$$P = \frac{2H}{ft} \times \frac{df}{dt}$$

Instantaneous Reserve

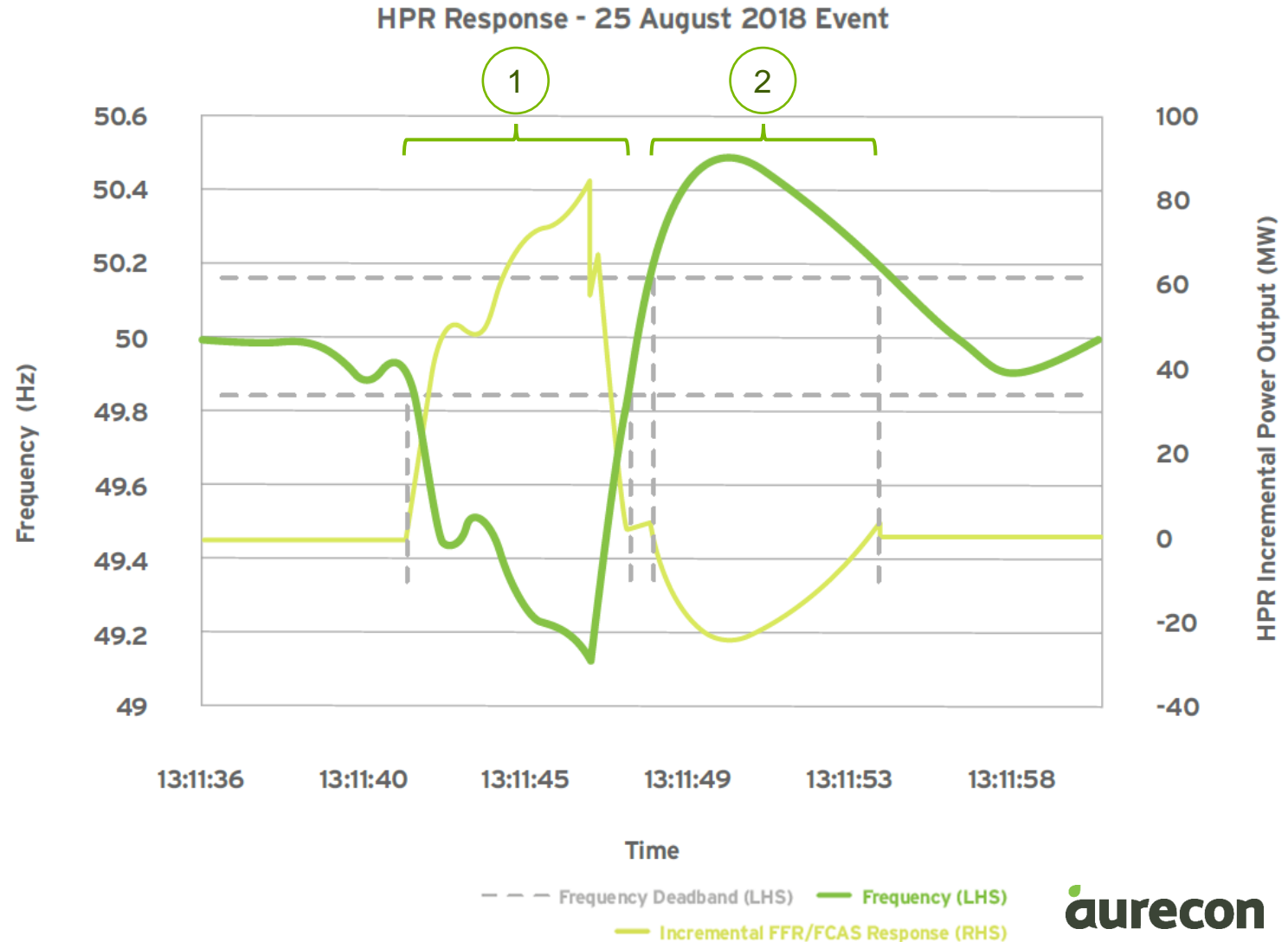
(Contingency FCAS on NEM)

HPR case study

- Fast Frequency Response - First of its kind on the NEM
- Fast dispatch of active power in response to frequency disturbances (~ 100 ms)
- Slows RoCoF during contingency event and supports return to normal frequency band

25 August 2018 case study

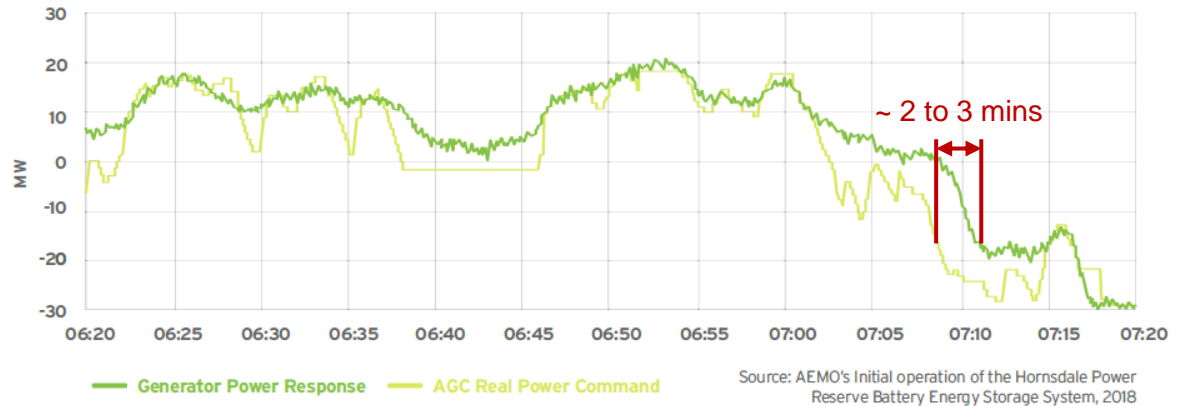
1. HPR provides low frequency support to all connected mainland NEM regions
2. HPR provides high frequency support to the separated SA region



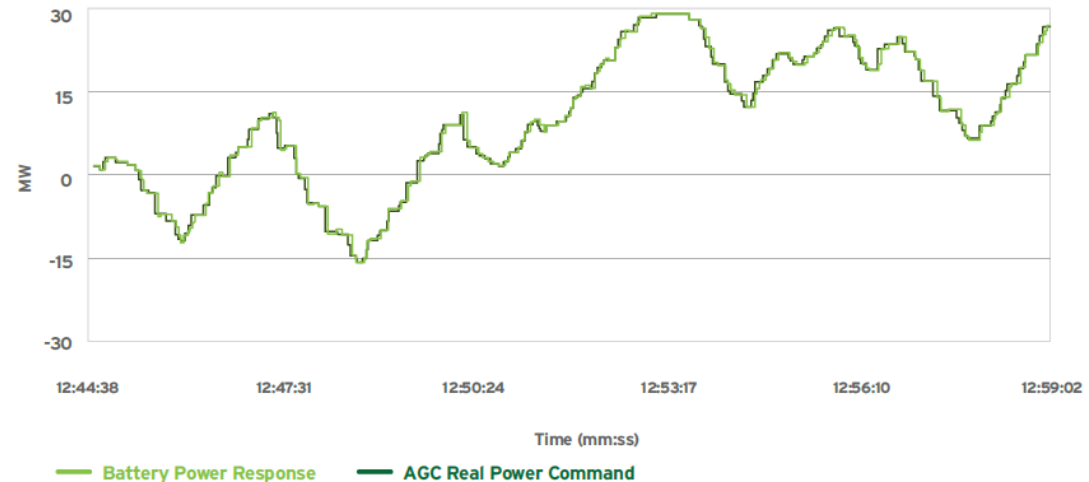
Frequency Keeping (Regulation FCAS on NEM)

- 4 second AGC dispatch instructions to correct frequency back to 50 Hz
- Large steam turbine – response can significantly lag setpoint
- Speed and accuracy of batteries makes them an ideal provider of this service
- Service can also be provided by pumped hydro

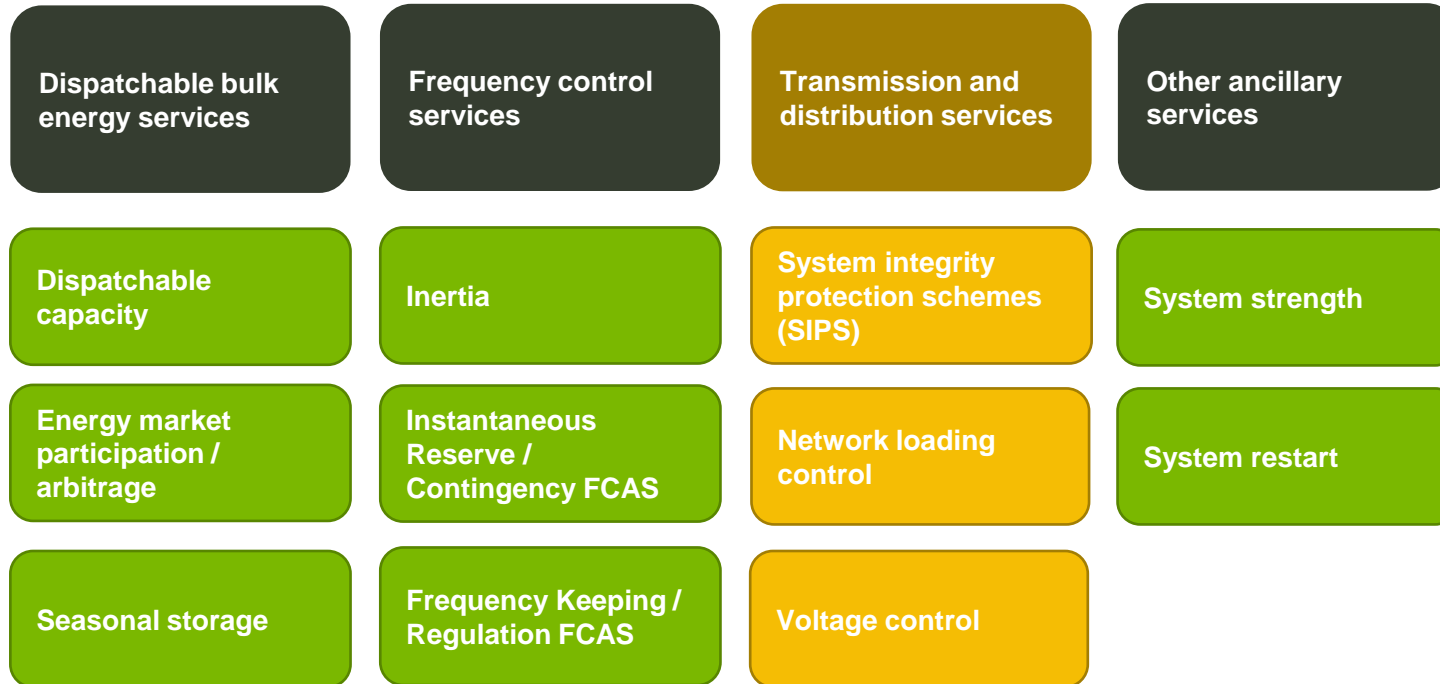
Accuracy and speed of regulation FCAS response - large conventional steam turbine



Accuracy and speed of regulation FCAS response - HPR

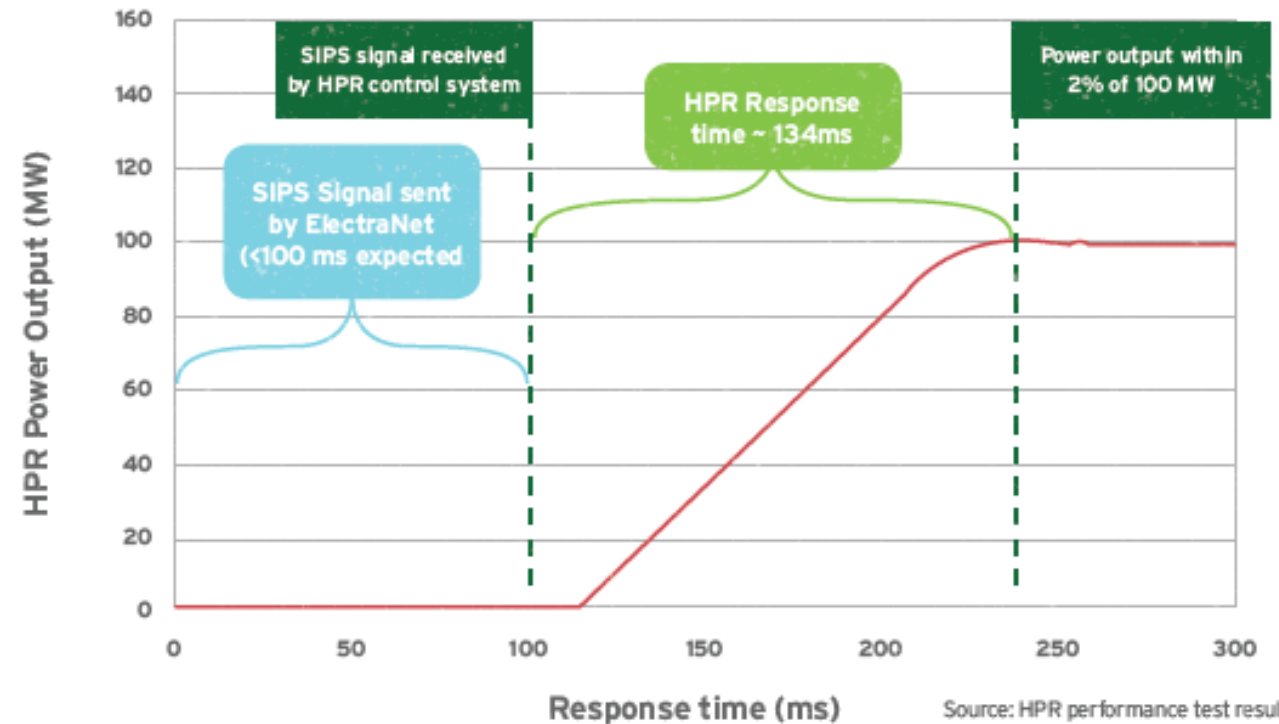


Power system services



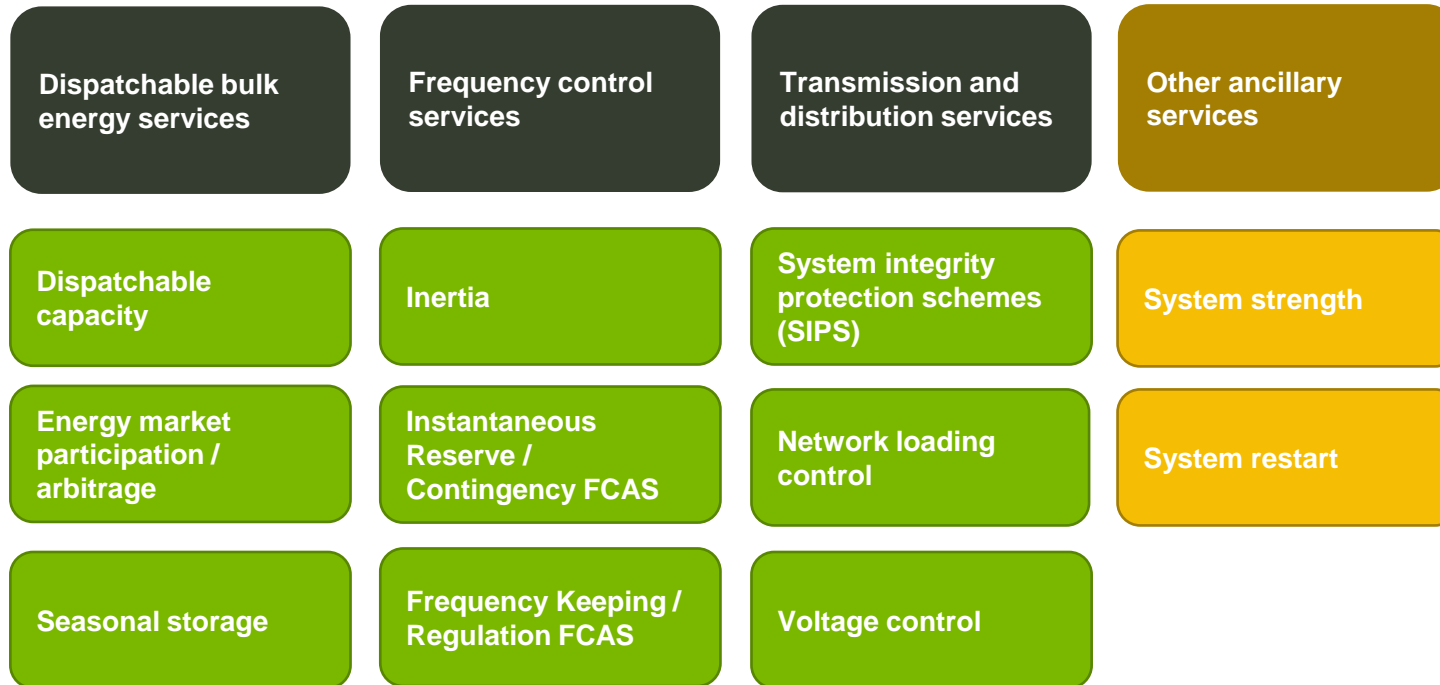
System Integrity Protection Scheme (SIPS) – HPR Case Study

- Reduces likelihood of SA Network separation and System Black under certain conditions – e.g. 28 September 2016 event
- HPR provides a near instantaneous 70 MW support to the interconnector
- Potentially prevents 200 MW of load shedding in next stage of SIPS



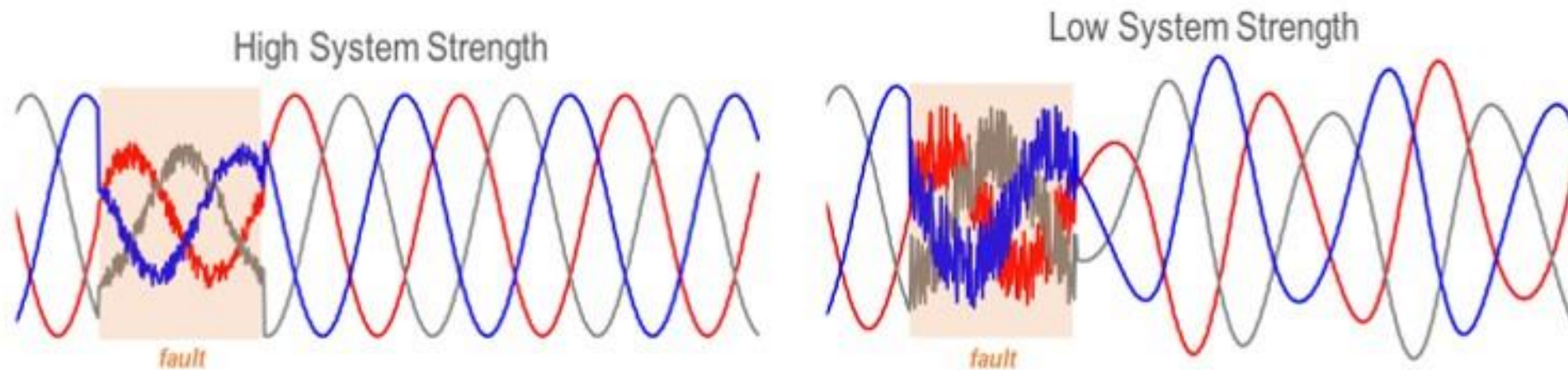
Source: HPR performance test results
Assumes HPR is in standby at the time for a 100 MW discharge response

Power system services



System strength

- System strength – the extent to which a stable voltage waveform is maintained after disturbances to the system
- Synchronous generators (including synchronous pumped hydro) an excellent source of system strength
- Grid forming batteries can potentially provide marginal system strength support



System Restart Ancillary Services

- Pumped hydro well suited to a primary SRAS service
- Possible for batteries, but yet to be demonstrated (soft start energisation of transmission, protection challenges)
- Challenging commerciality for BESS to reserve energy
- Other system restoration support services also possible



Summary

Power system service	Li-ion BESS	Pumped Hydro
Medium duration arbitrage	Well suited, positive commercial outlook	Well suited, moderate commercial outlook
Seasonal storage	Not suited, although VRE generation + BESS firming potentially an option	Yes – with sufficiently large reservoirs
Inertia	Yes (with grid forming)	Yes (24/7 with syn con mode)
Instantaneous reserve	Yes	Yes
Frequency keeping	Yes	Yes
System Integrity Protection Schemes	Yes	Dependent on required response time
Network loading control	Yes	Possibly, although limited by locational factors
Voltage control	Yes	Yes
System Strength	Marginal (with grid forming inverters)	Yes
System Restart	Possible, although commercially challenging	Yes



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