PUBLIC

Stabilizing Networks with High Renewable Penetration

Lessons Learned from a 30MW Battery Energy Storage Project in South Australia

Alaska Energy Storage Workshop

John Glassmire, Senior Advisor, Hitachi ABB Power Grids

POWERING GOOD FOR SUSTAINABLE ENERGY

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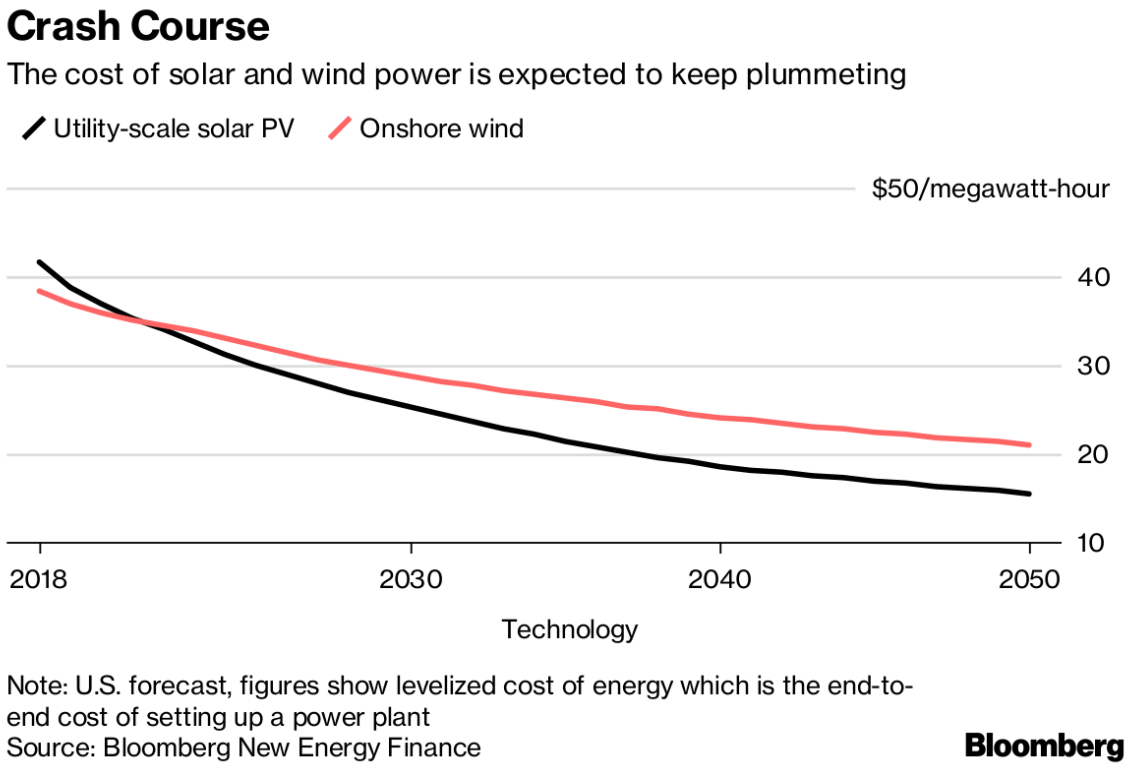
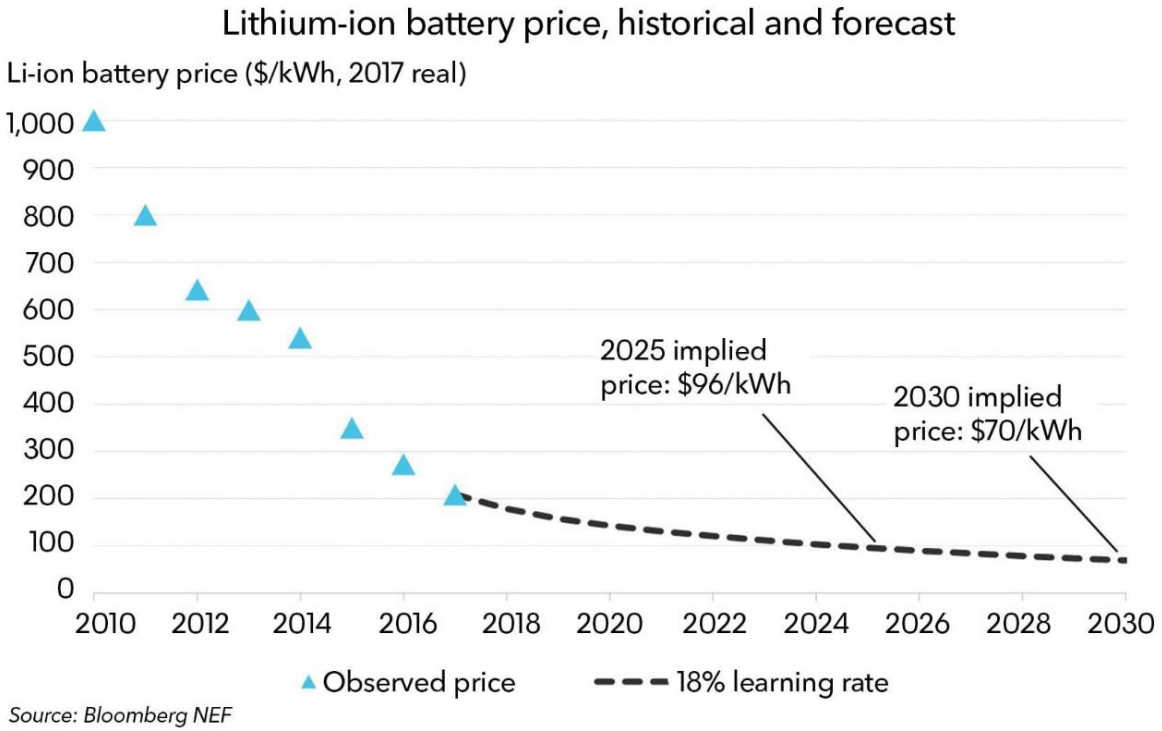
Renewables and storage are increasingly affordable

Renewable generation costs are declining



Battery prices are declining



Sources: (Left) BNEF, Coal Is Being Squeezed Out of Power by Cheap Renewables; (Right) BNEF, New Energy Outlook 2018

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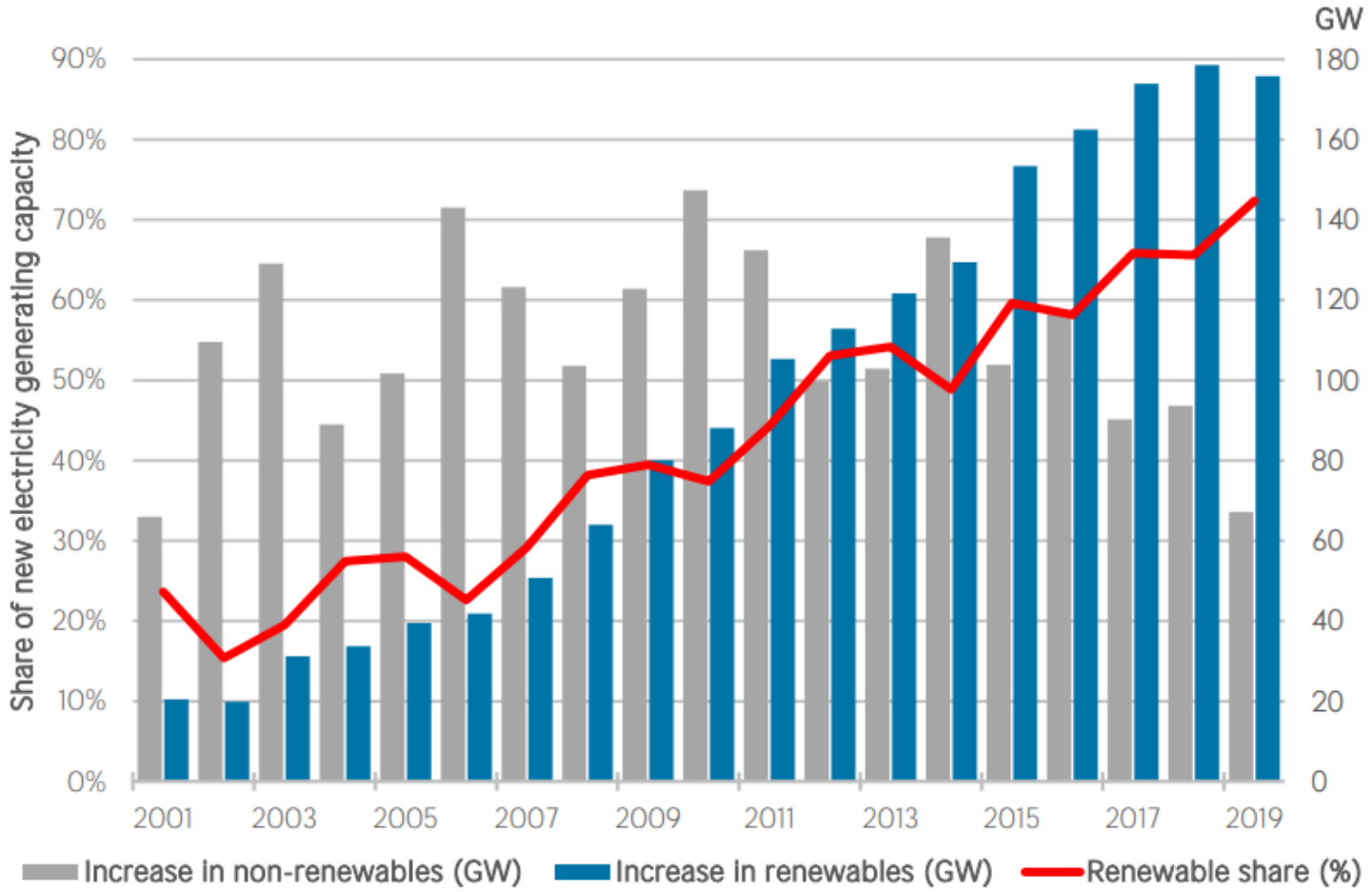
Renewables are increasingly the generation source of choice

New global capacity additions over the past two decades; 90% of new renewable generation is solar or wind



IRENA, Renewable Capacity Statistics 2020,
https://www.irena.org/publications/2020/Mar/Renewable-Capacity-Statistics-2020

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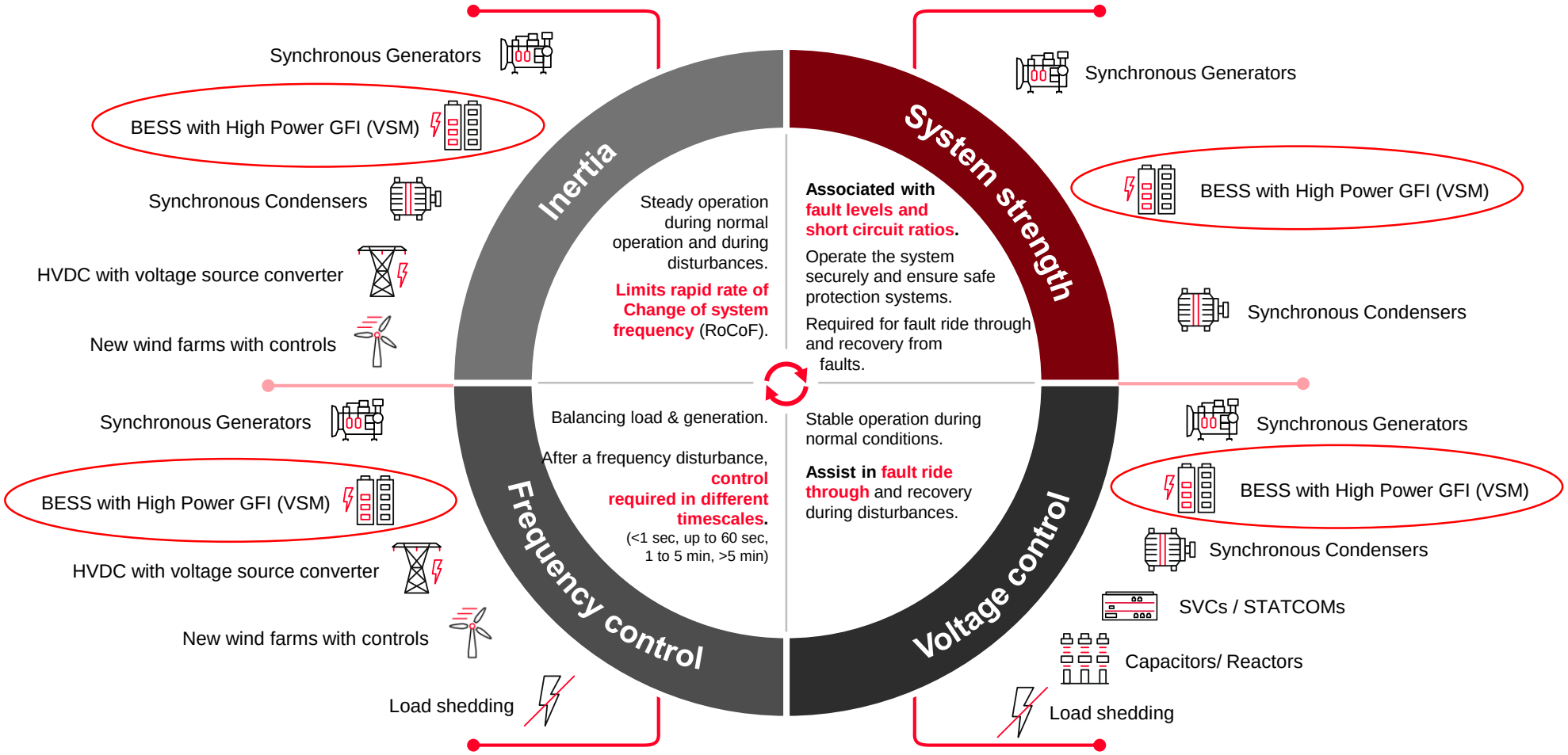
Creating a stable, renewable-based electricity backbone

What services are needed to operate a stable and secure grid?



Adapted from www.escri-sa.com.au

GFI = Grid Forming Inverter. VSM = Virtual Synchronous Machine

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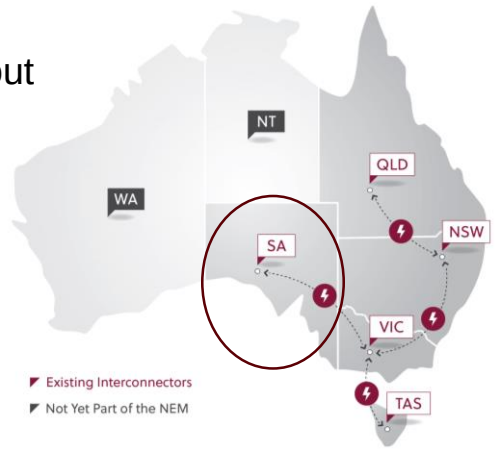
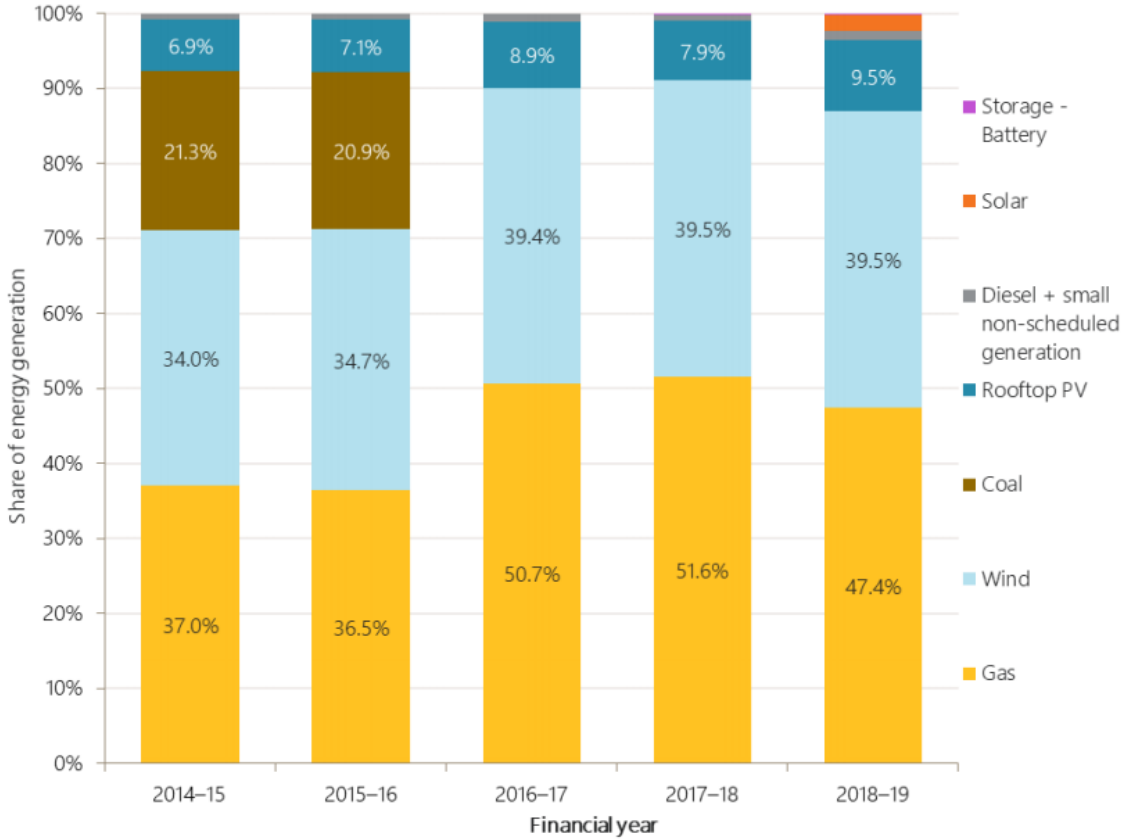
South Australia's power system

State power grid overview

- **Demand**
  - Between 446 and 3100 MW
- **Renewables**
  - 2400 MW wind and solar → 170% peak penetration
- **Connections to neighboring networks**
  - 650 MW AC (275 kV) and 220 MW HVDC (150 kV)
- **Inertia and strength trends**
  - Synchronous generators declining
  - Inertia and system strength declining
- **Major events**
  - Sept 28, 2016 system blackout



Evolution of generation sources 2013-2018



Source: AEMO

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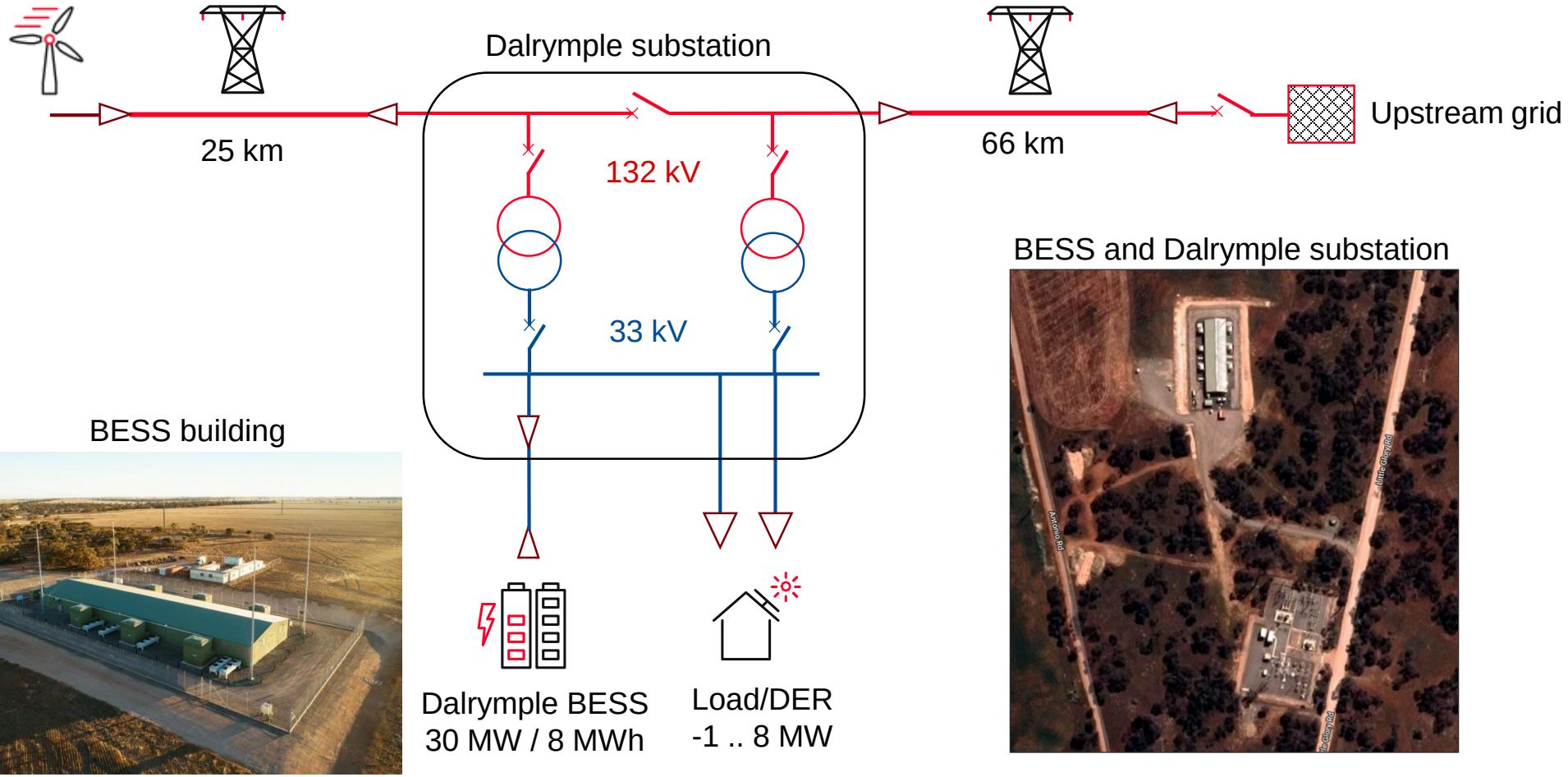
Integration at ElectraNet's Dalrymple substation

Wattle Point Wind Farm
91 MW
(55 x Vestas V82 directly coupled induction generators)



BESS building

BESS and Dalrymple substation

Images (left to right):
Wind farm: Flickr, https://www.flickr.com/photos/daveclarkecb
BESS: Courtesy ElectraNet
BESS and substation: Courtesy Google Maps

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ESCRI-SA Dalrymple Battery Energy Storage System (BESS)

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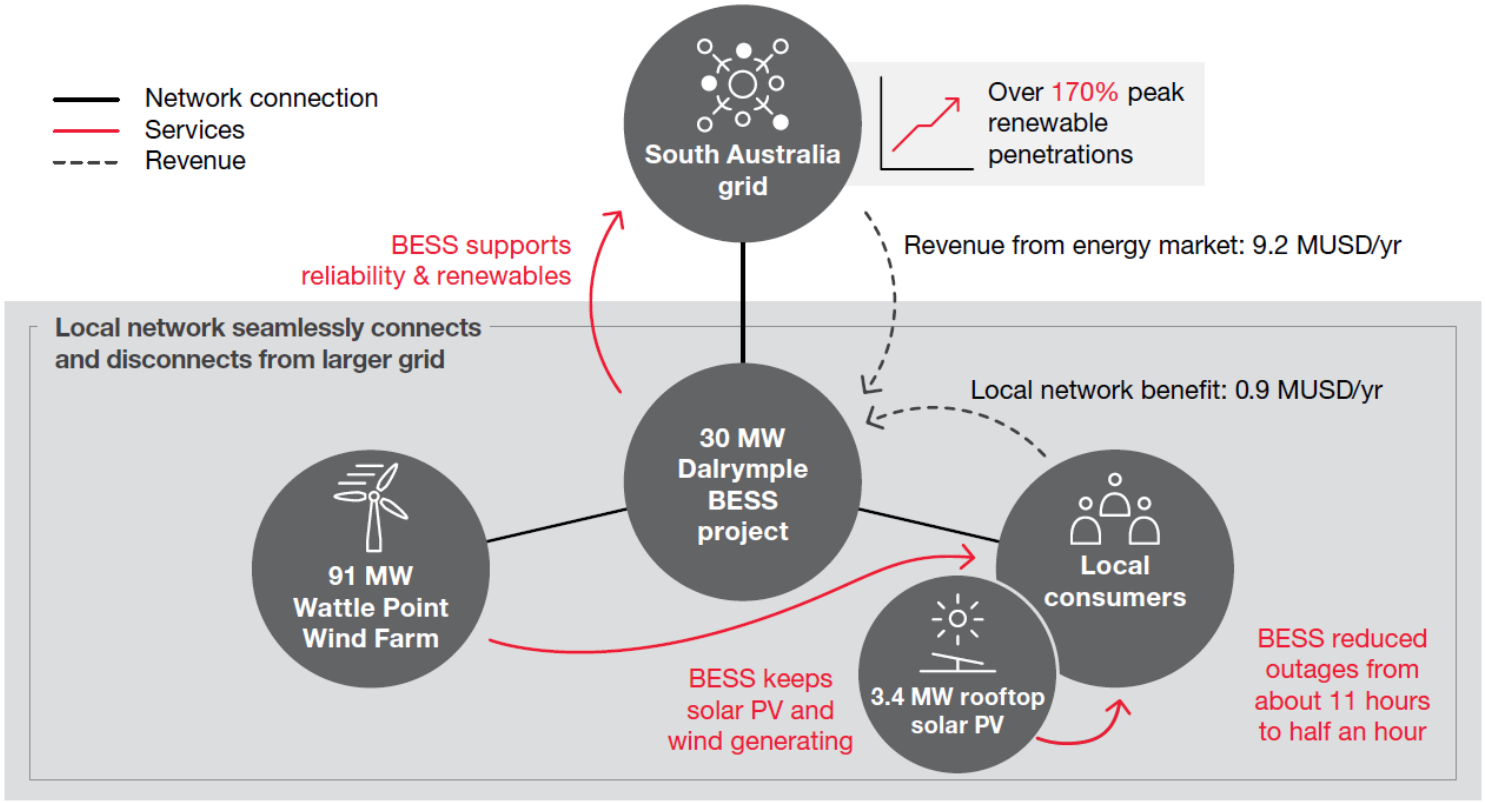
Showcasing the benefits of BESS with high power GFI, smart controls, and automation



If market trends continue, revenue from the BESS will <u>offset project capital cost within 2 years</u>

Source: Hitachi ABB Power Grids, "Unlocking New Revenue and Stabilizing Large Electric Grids with Energy Storage", 2020.
https://www.hitachiabb-powergrids.com/offering/product-and-system/grid-edge-solutions

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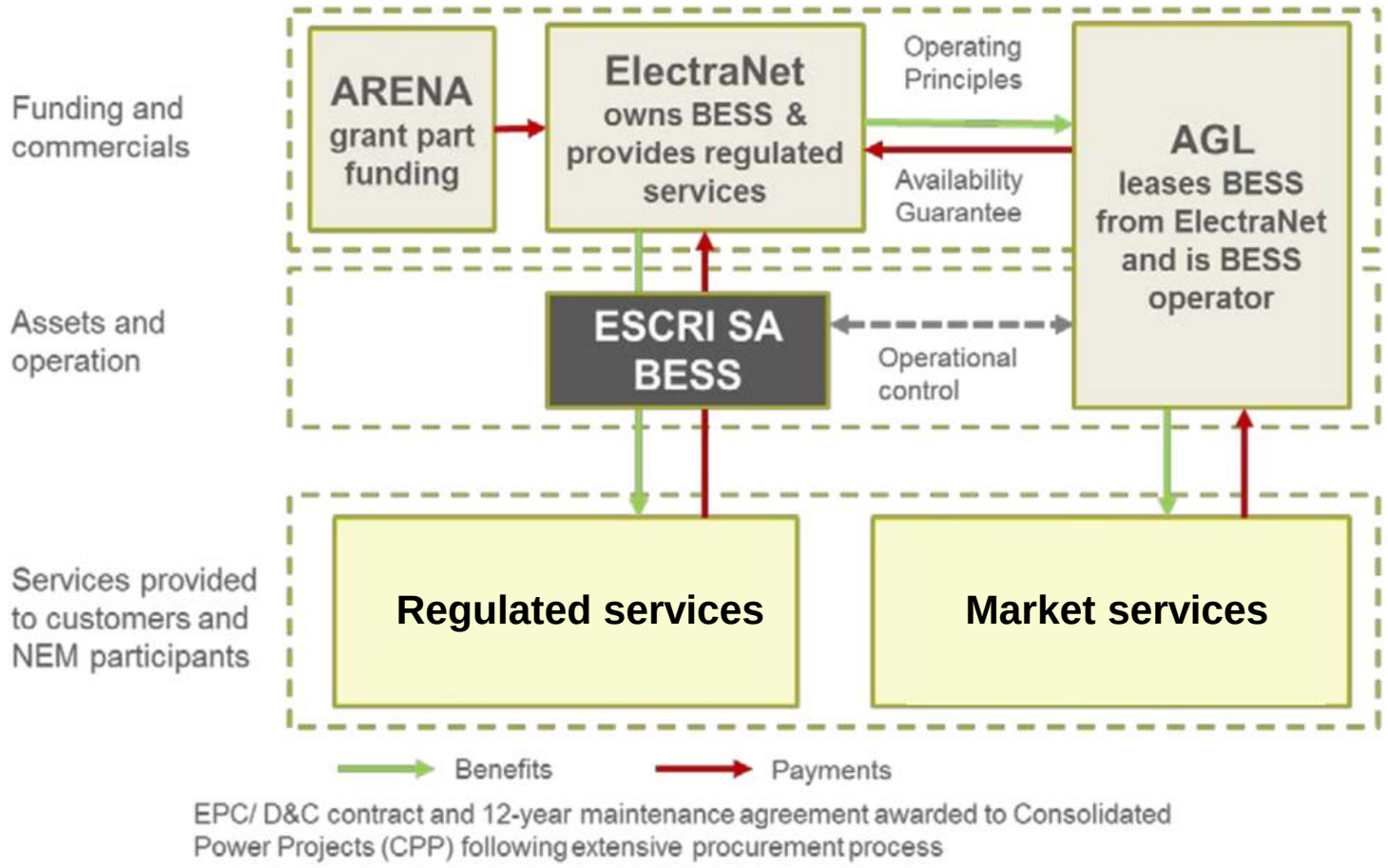
Commercial setup

Enabling both regulated (“wires”) and market (“generation”) success



- Project developed and owned by the Transmission Network Service Provider
- Leased to a Generator/Retailer for 12 years who operates it on the market
- Service and maintenance by the EPC and Hitachi ABB Power Grids

Adapted from www.escri-sa.com.au

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Replicating the success of the Dalrymple BESS

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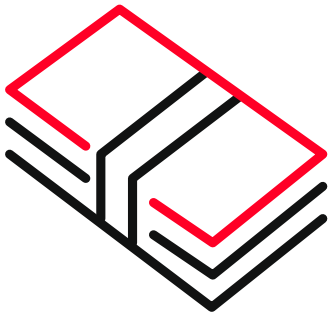
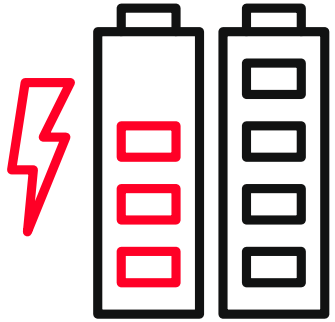
Unlock new revenue

Bring in value from energy and ancillary service markets, while also capturing value from a stabilized grid



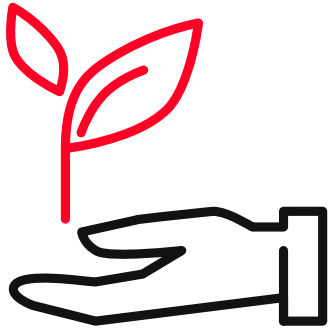
Stabilize your grid

Our proprietary VGM implementation of a Virtual Synchronous Machine stabilizes the local network



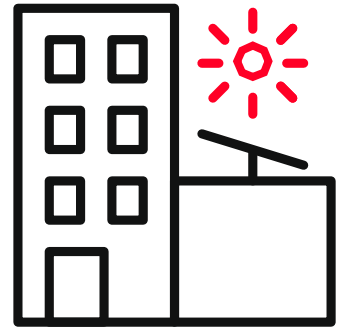
Reduce RE curtailment

Seamless islanding, coupled with voltage, reactive power, and frequency support maximizes renewables



Provide continuous power

In the Dalrymple BESS project, PowerStore reduced customer outages by 95% -- from 11 hours to half an hour.



PowerStore's smart controls, digital automation, and grid forming inverter creates new opportunities to unlock the "value stack" for electricity networks

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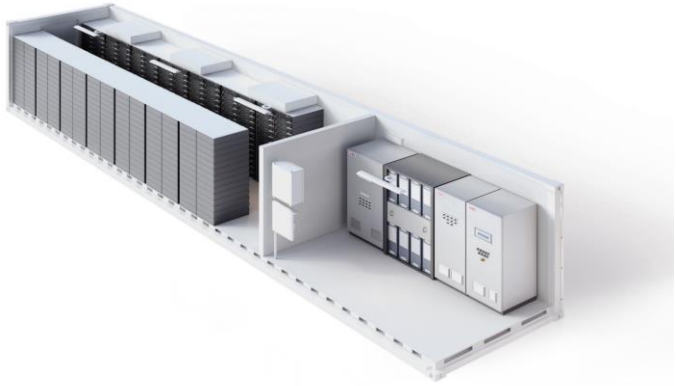
Key functionalities PowerStore provides to stabilize the grid



- Stabilises and strengthens the grid
- Mitigates impact of rate of change of frequency (RoCoF) events
- Effective during both normal and islanded operation
- Instantaneous injection

Virtual inertia

- Grid-forming inverter with proprietary controls
- Increases local network reliability
- Operate entirely on renewable sources (wind and solar)
- 100+ km of lines with 91MW wind farm and >2MW of distributed solar PV

Seamless islanding

- Provides a stable alternative
- Clears faults in the network
- Limits network oscillations from phase locked loop (PLL) issues common with existing inverter-based resources

Fault current injection

- Fast response (< than 250 msec) for an external command
- Instantaneous response to events sensed locally
- Voltage and frequency support

Fast power injection

- PowerStore is a black start energization source
- Allows DER to couple and restart power supply after an outage event
- After local black start, can serve as black start resource for wider network

Black start

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Our customers

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90+

Countries supported with Service and Sales organizations

30+

Years of experience

500+

MW of Global installed base of Grid Edge solutions including microgrids and BESS

200+

Projects delivered worldwide

Global pioneer in technology, solutions and proud grid edge partner with Alaskan communities

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Extra Slides

For technical reference

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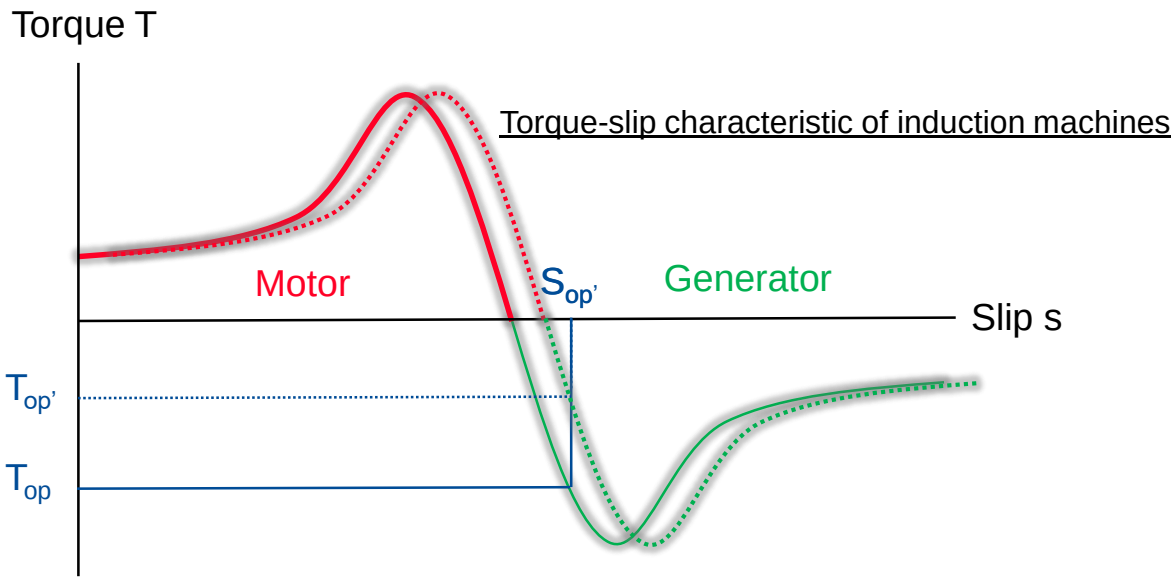
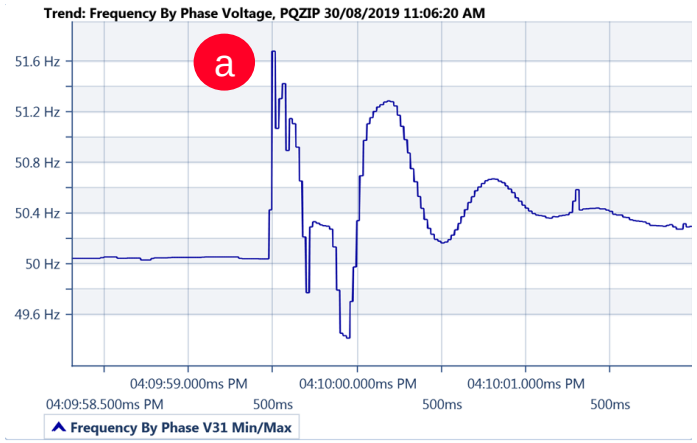
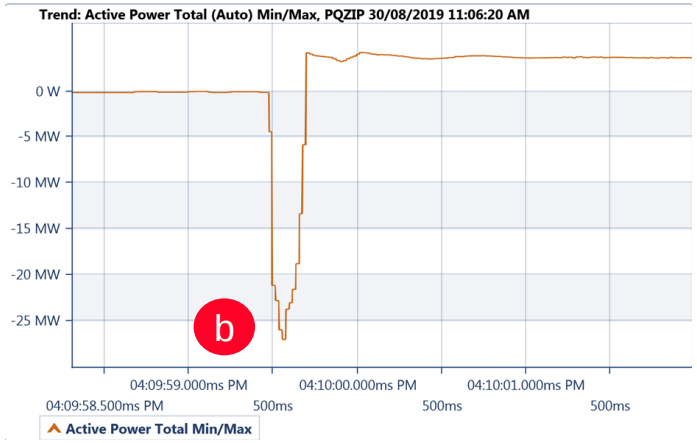
Unplanned islanding with the wind farm

The islanding instant – virtual inertia action



Upon islanding, frequency is pushed up by the virtual inertia of the BESS reducing slip, electric torque and power output from the WTGs





a Upstream breaker opens

b 80% of WTGs disconnected

Wind farm's output is momentarily reduced from ~80 MW to ~27 MW

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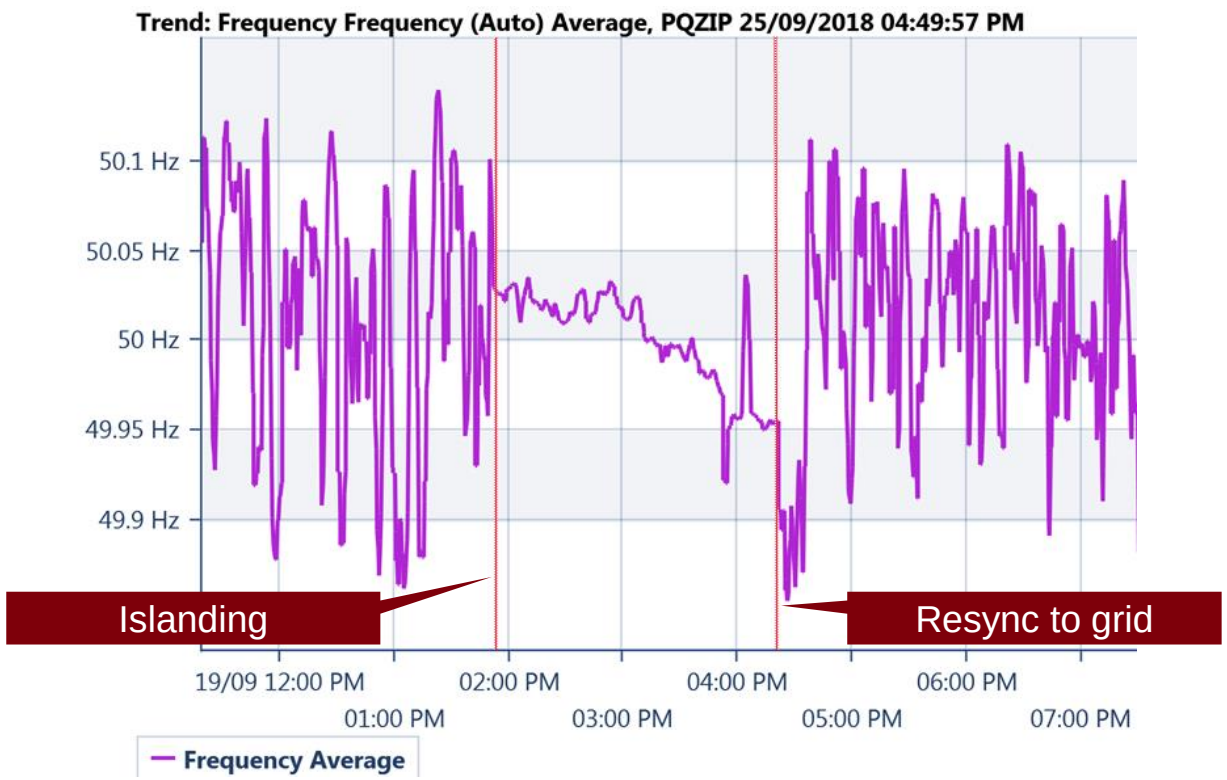
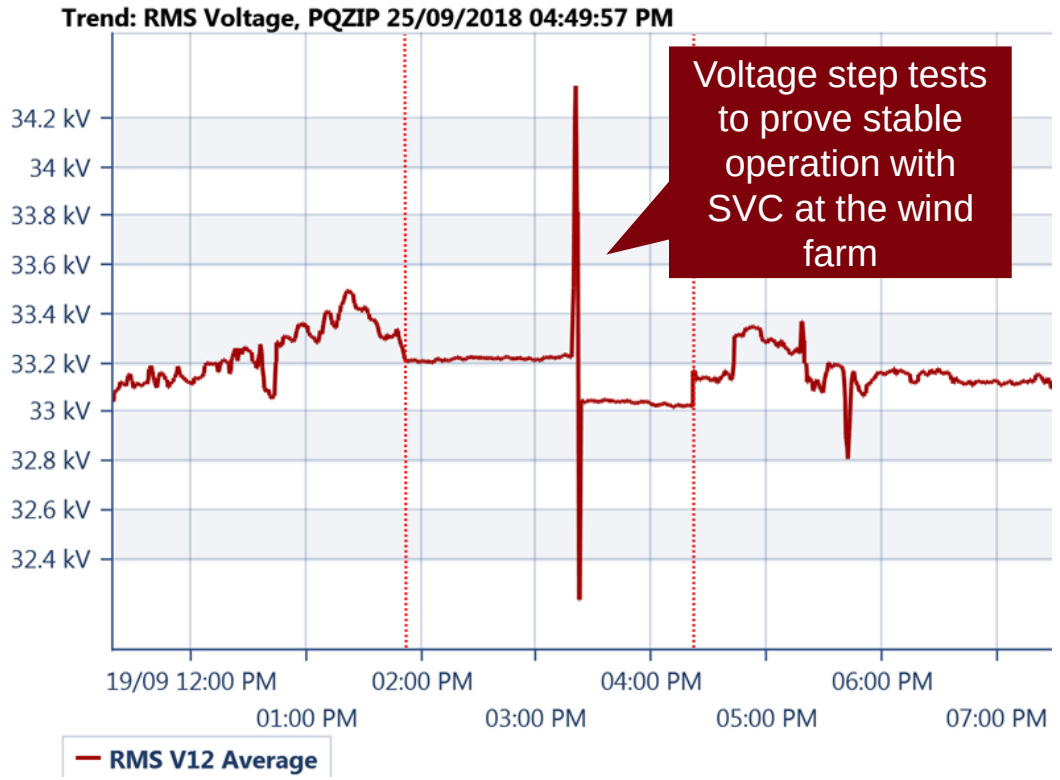
Islanded operation

Frequency performance: grid-parallel vs islanded



Voltage performance: grid-parallel vs islanded



BESS regulates frequency and voltage

SVC = Static VAR Compensation

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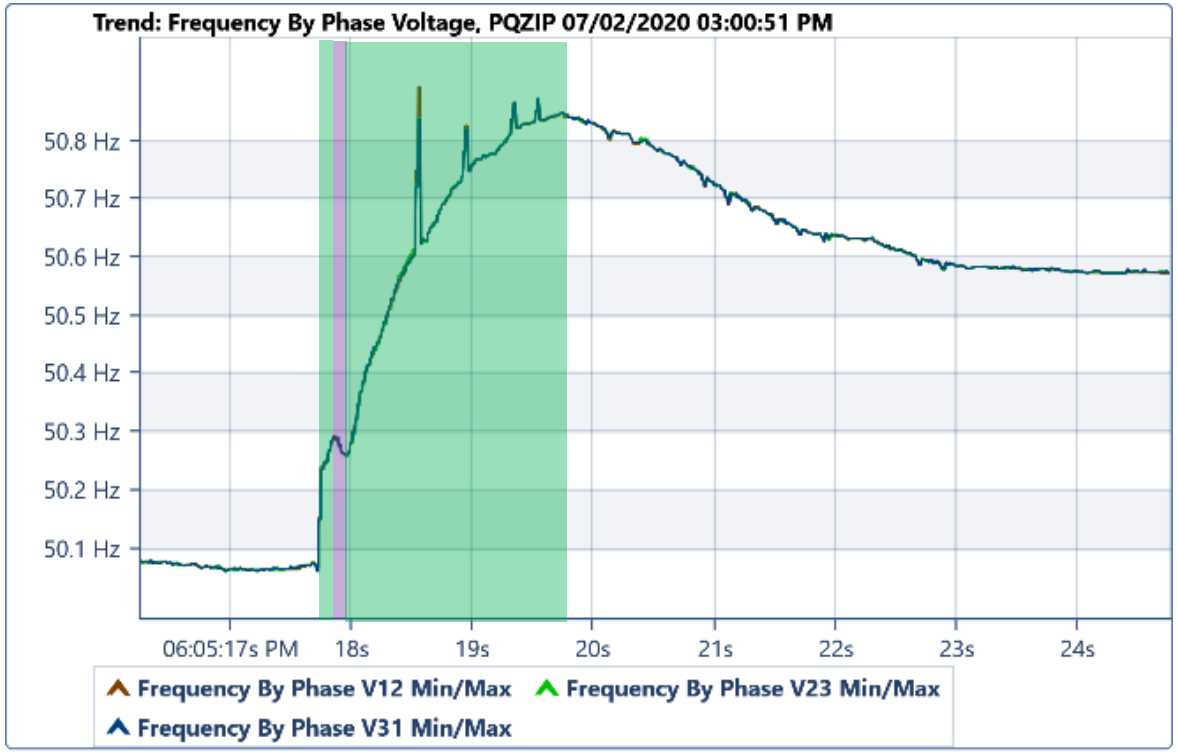
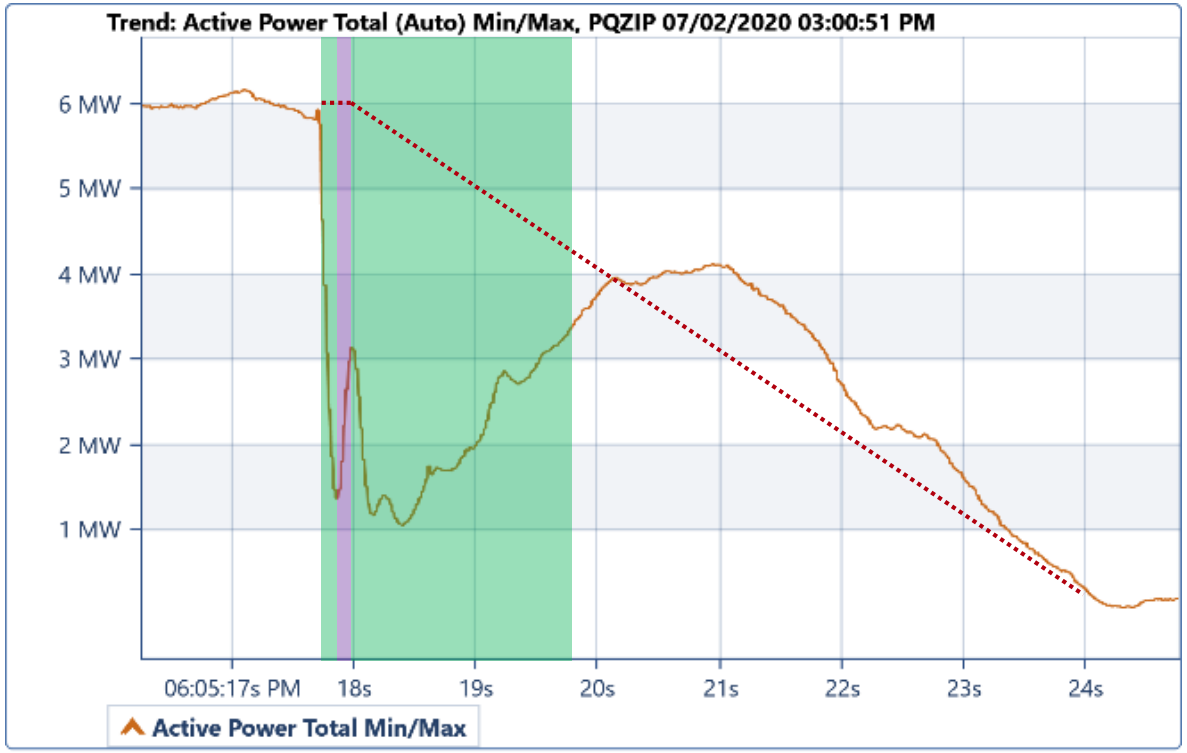
South Australia Islanding Event: ESCRI BESS Inertia Response

Positive RoCoF event in South Australia
(green +ve RoCoF, purple -ve RoCoF)



Active Power response – Inertial response initially to grid frequency (left) prior to Frequency Support setpoint (red dotted line)



Grid forming inverter responds to frequency change in the network – 8-sec view

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South Australia Islanding Event: ESCRI BESS Inertia Response

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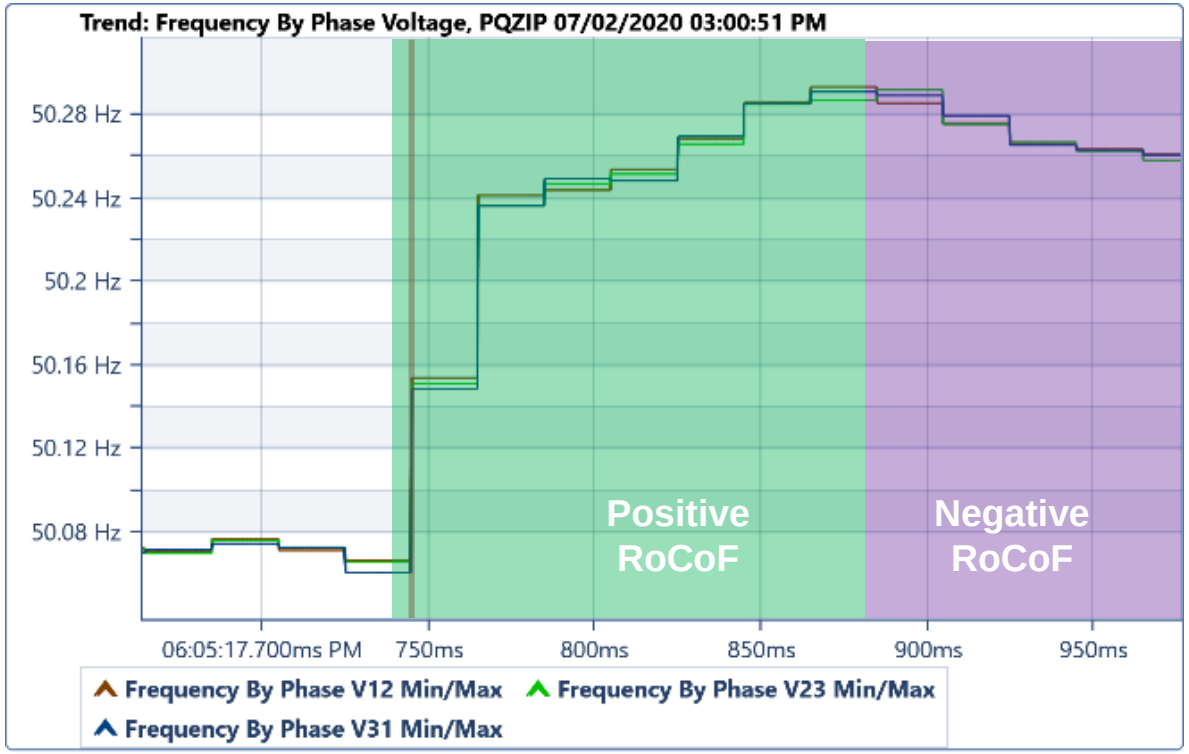
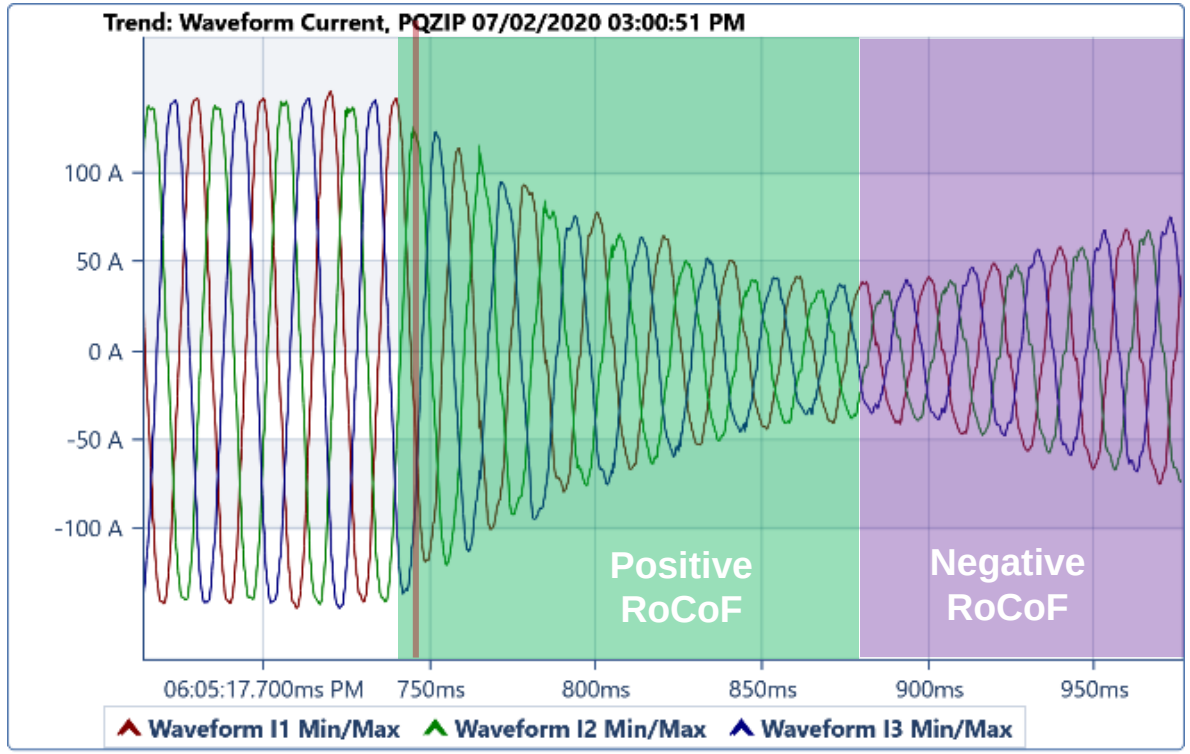
Frequency measurement by high speed data recorder



VSM Response – Current responds prior to frequency measurement (red vertical line)



Grid forming inverter responds to frequency change prior to high speed data recorder – 300-msec view

Sproul, S., "Do you know the difference between Virtual Inertia and Fast Frequency Response?", *Watt Clarity*, April 2020, http://www.wattclarity.com.au/articles/2020/04/do-you-know-the-difference-between-virtual-inertia-and-fast-frequency-response/

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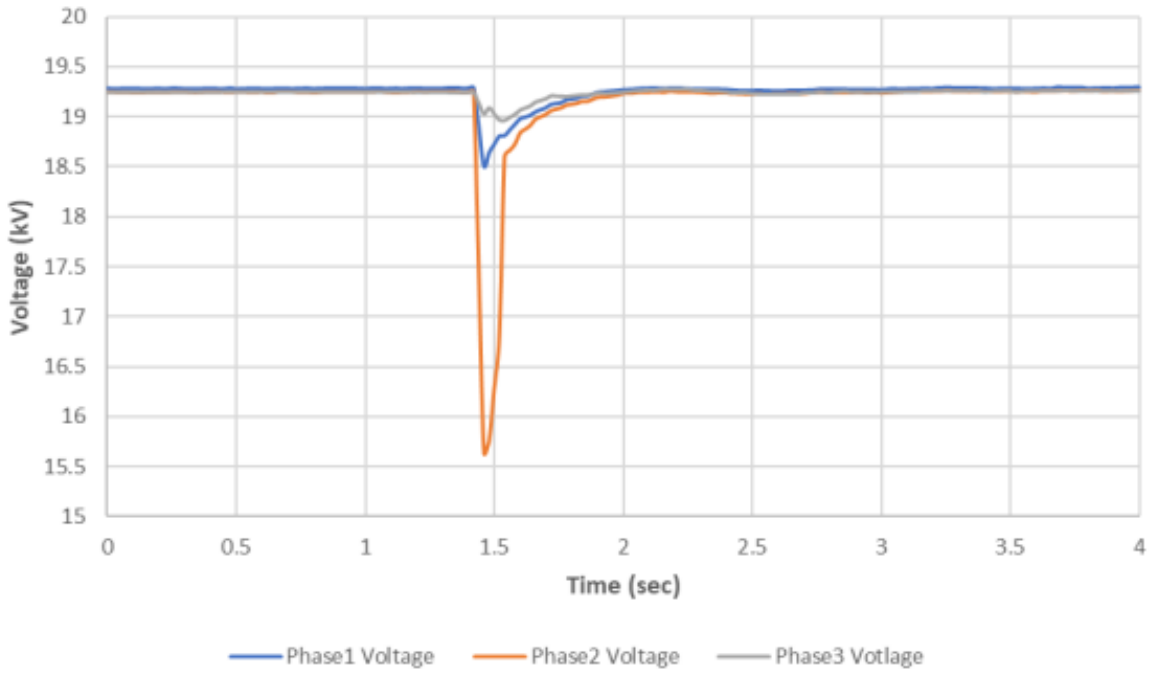
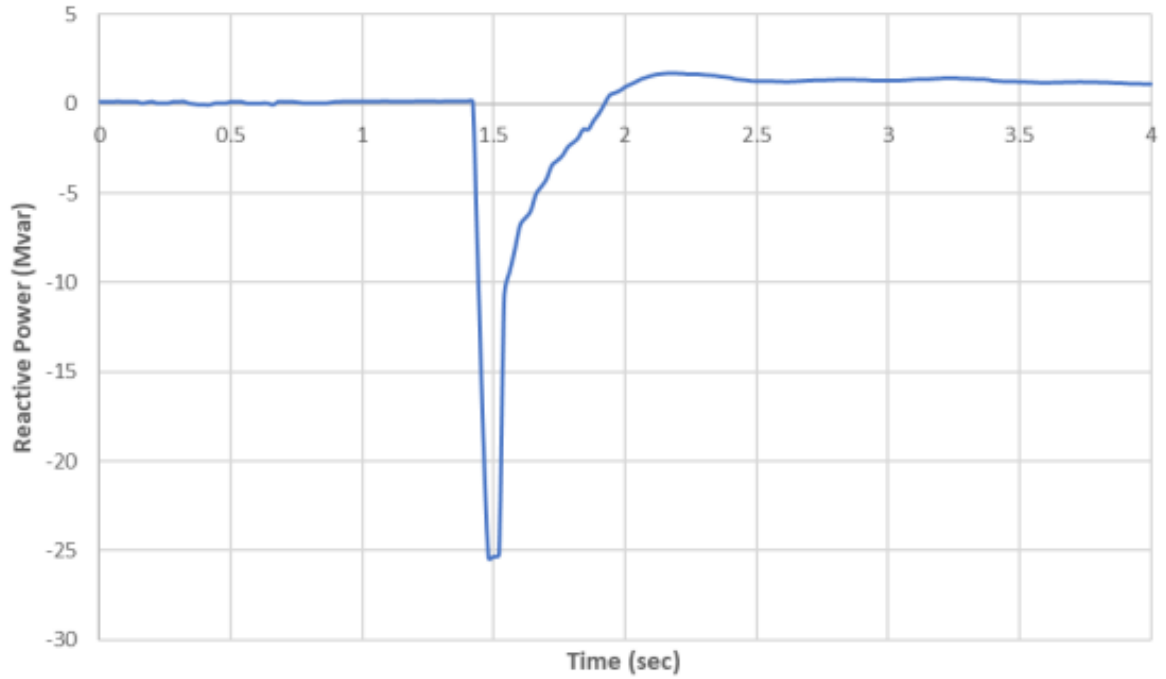
Fault Current Injection

33kV line-to-ground voltages



Reactive power output from BESS



Single phase to ground fault on an upstream 132kV line, cleared and line reclosed

Source: ElectraNet, "ESCRI-SA Battery Energy Storage Project Operational Report #2"

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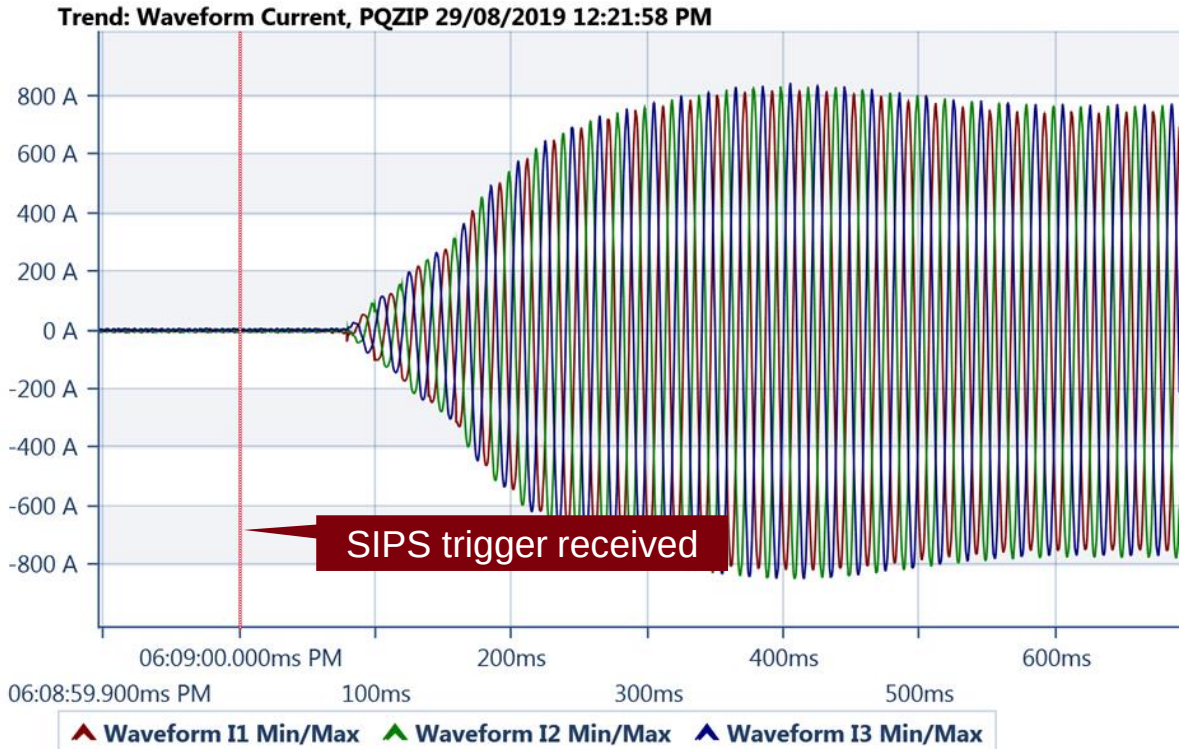
Fast Active Power Injection

System Integrity Protection Scheme (SIPS):

- Designed to prevent South Australian system separation from the NEM
- Acts to pre-empt a large RoCoF event
- Based on measurements taken along the Heywood interconnector
- Takes over measurement/detection for Fast Frequency Response
- Triggers grid-scale BESS to inject power and, if required, sheds load to restore balance between supply and demand
- Requires the BESS to inject full power in 250 msec

BESS grid-parallel fast response: 30 MW in 250 msec



ESCRI BESS is part of System Integrity Protection Scheme (SIPS)

Source: ElectraNet

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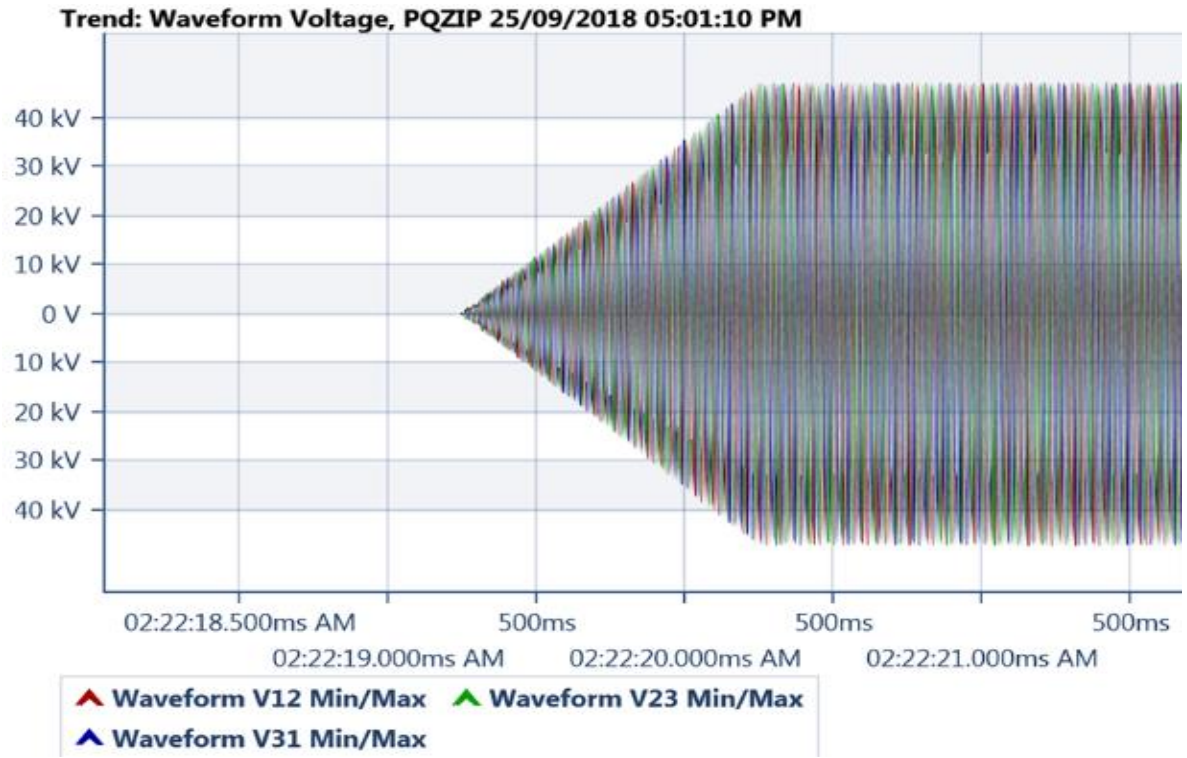
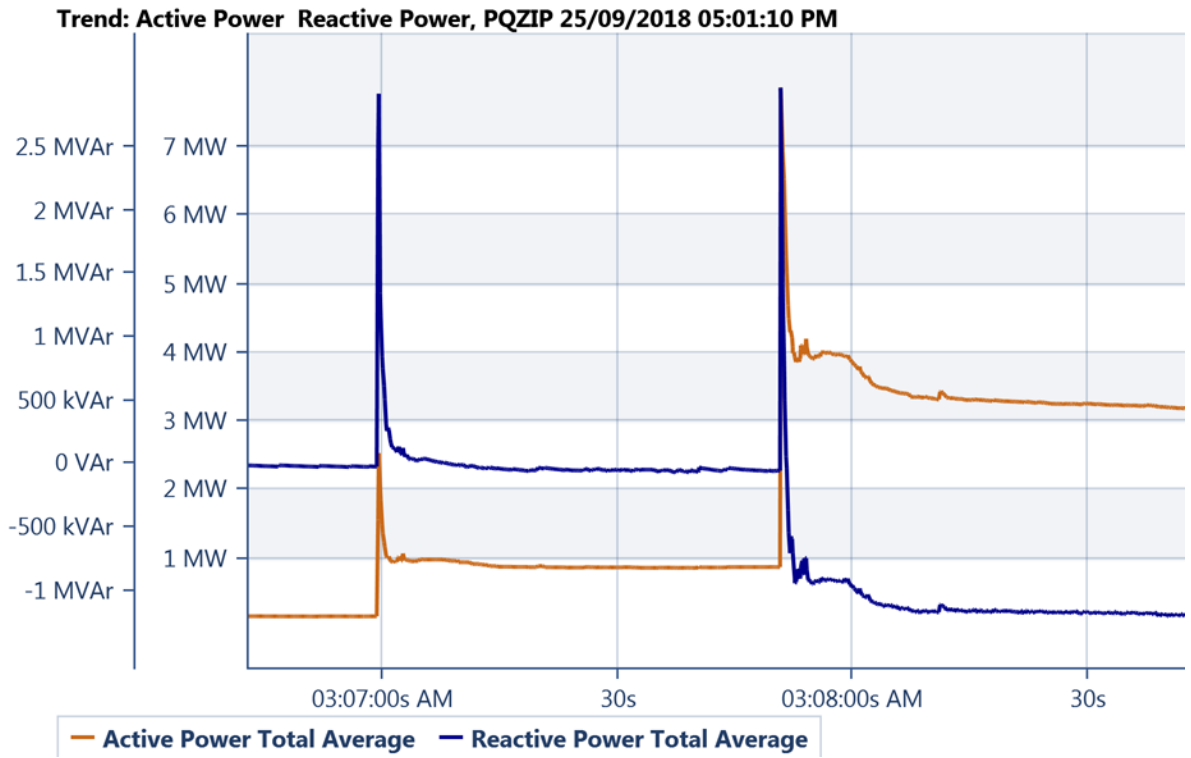
Black start of the local 33 kV distribution network

BESS ramps voltage up to energise transformers



BESS picks up 33 kV load feeder – P/Q profiles



Soft energisation of large transformers and pickup of 33 kV load feeders in islanded operation.
Voltage ramp effectively eliminates transformer inrush. Feeder pick up at full voltage presents no issues

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