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Using Virtual Synchronous Generators to Resolve Microgrid Protection Challenges

John Glassmire[1] (presenter), Stanislav Cherevatskiy[1], Galina Antonova[1], Anthony Fretwell[2]

[1] Hitachi ABB Power Grids, [2] ElectraNet

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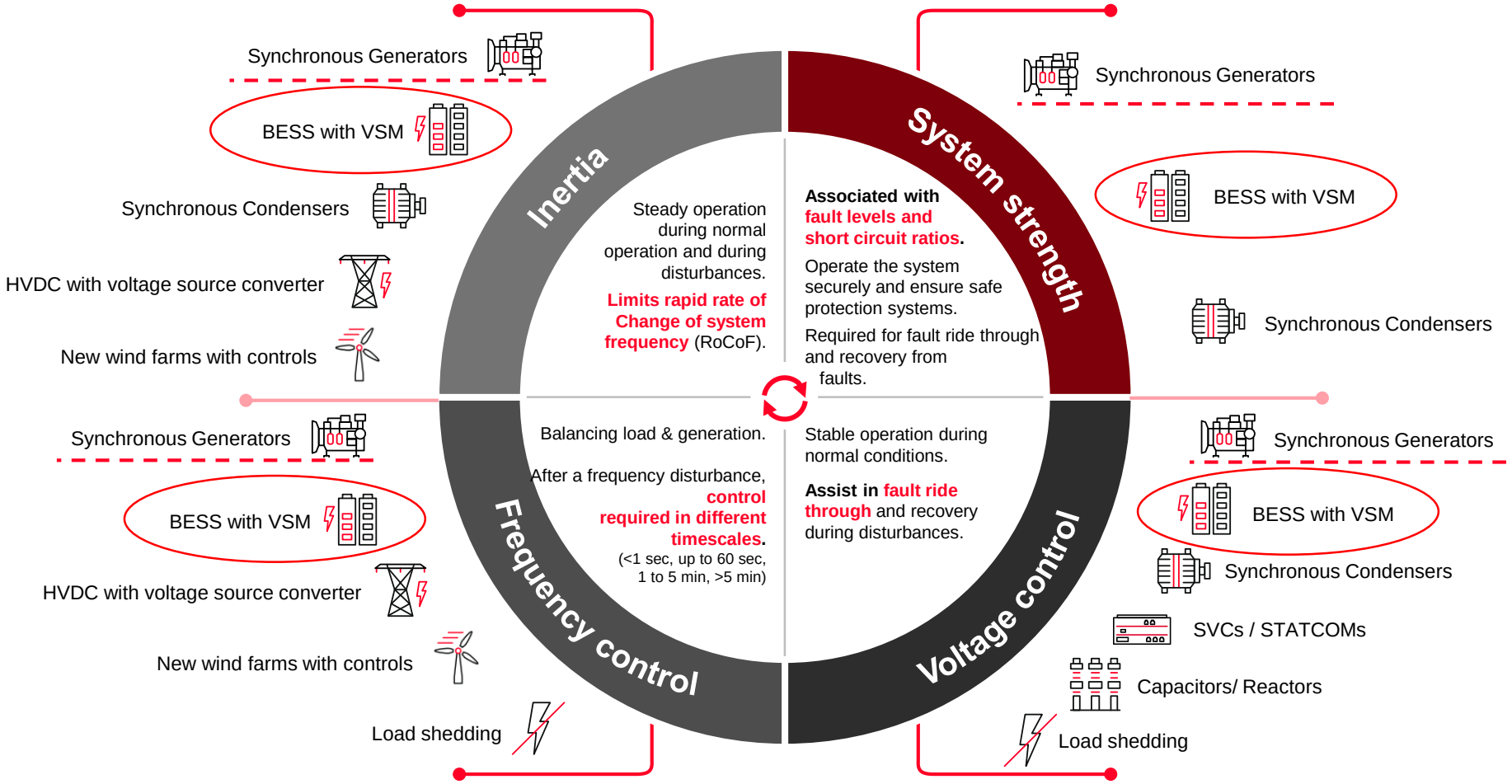
HITACHI ABB POWER GRIDS

Virtual Synchronous Generators (VSG)

- One type of Virtual Synchronous Machine (VSM)
- A digital synchronous generator
  - has same properties, subject to capabilities of the power electronics
  - works well with traditional P&C strategies
  - tuned based on network needs
- Provides *inherent* response to network disturbances
  - “virtual inertia”

The four services that stabilize networks



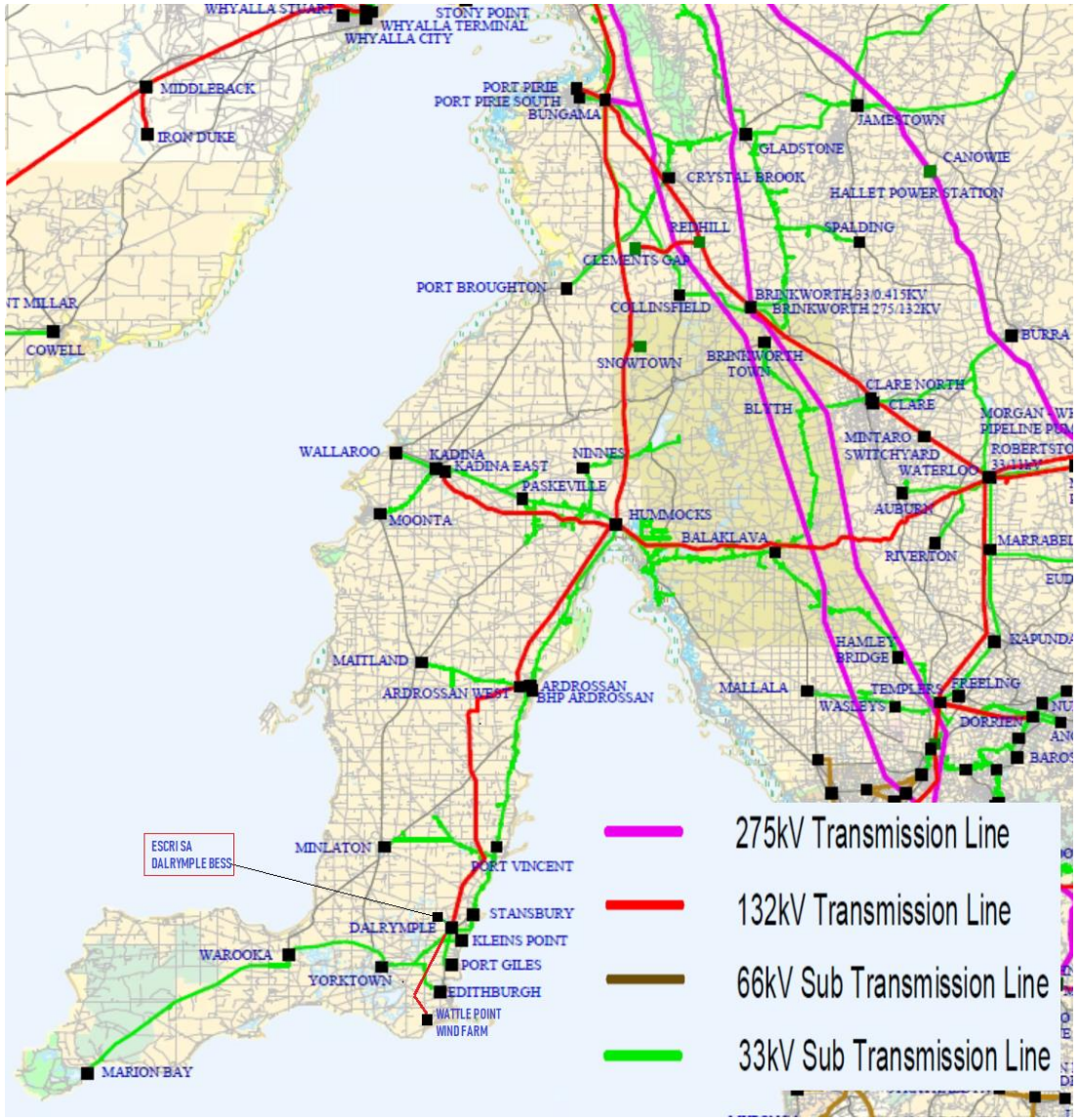
ElectraNet's transmission network: South Australia

- Significant renewable penetration

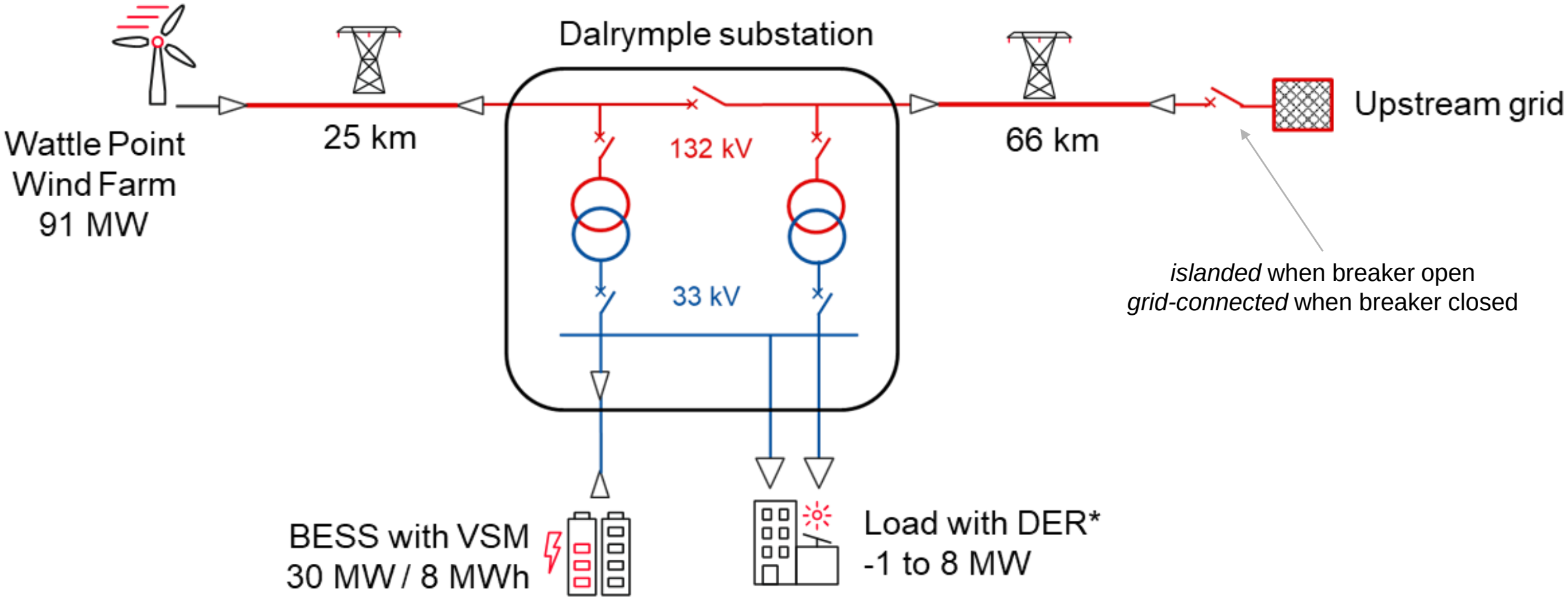
$$\frac{\textbf{Renewable capacity}}{\textbf{Average demand}} \rightarrow \frac{2400\ \text{MW}}{1400\ \text{MW}} \rightarrow \mathbf{170\%}$$

- Two Connections to Australia NEM
  - 650 MW AC (275 kV)
  - 220 MW HVDC (150 kV)

- System blackout → SIPS
  - September 28, 2016



ESCRI-SA Dalrymple BESS



** Distributed Energy Resources (mostly solar photovoltaic, about 3.4 MW)*

Protections Goals and Primary Modifications

- Ensure satisfactory performance under both grid-connected and islanded conditions, as well as transition
  - Support both System Integrity Protection Scheme (SIPS) and Islanding Detection Scheme (IDS)
- Primary modifications required:
  - Transmission system auto-reclose
    - Adjusted to prevent out-of-phase reclose
  - Existing transformer automatic voltage regulation schemes at substation's 33 kV connection bus
    - Allow BESS to perform voltage regulation function

Protection philosophy

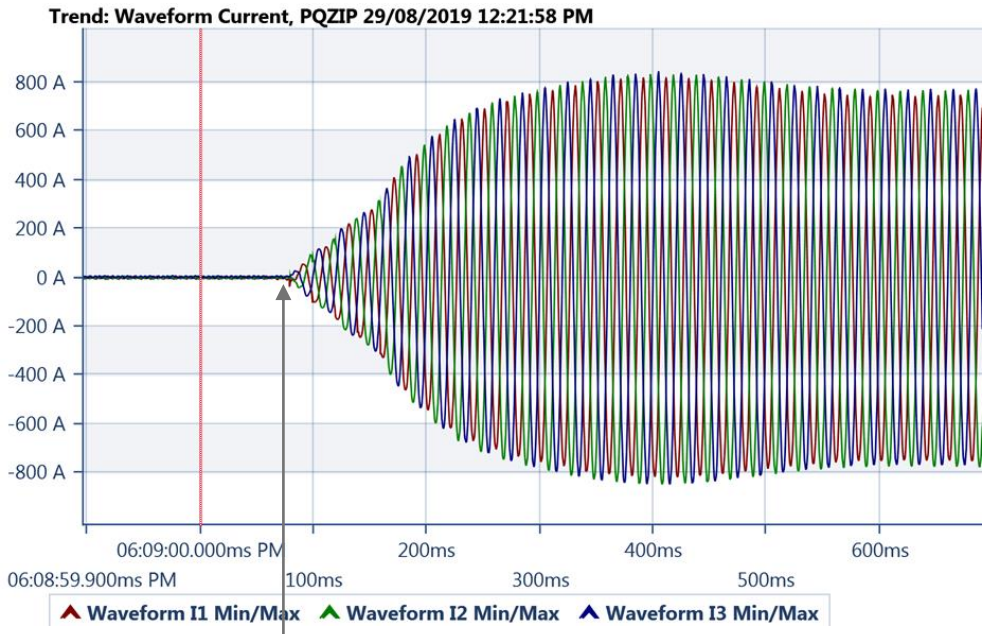
- Simulation studies (PowerFactory DIgSILENT)
  - RMS* dynamic models of BESS, wind farm, protection elements
  - Review adequacy/operation/coordination of protection when
    - islanded
    - grid-connected
    - transitioning between the two states
  - Examination of stability and fault ride-through of BESS and wind farm in islanded operation
    - Wind farm curtailed to <30MW within 150 msec
    - BESS controls wind farm power to regulate its state of charge
    - Minor setting adjustments to distribution network

** Root Mean Square (stability analysis)*

System Integrity Protection Scheme (SIPS)

- Remedial action scheme (RAS) to prevent system blackout
- 3 discrete stages

	Event	Response
1	Active import power at Heywood Interconnector exceeds 800MW threshold or rate of increase >1.67MW/s	Fast MW injection from BESS
2	Predictive Out-of-Step Trip Scheme detects impending loss of synchronism	Trip 200 MW of load in South Australia
3	Existing Out-of-Step Trip Scheme detect loss of synchronism	Sever interconnection to prevent disturbances spreading into rest of NEM



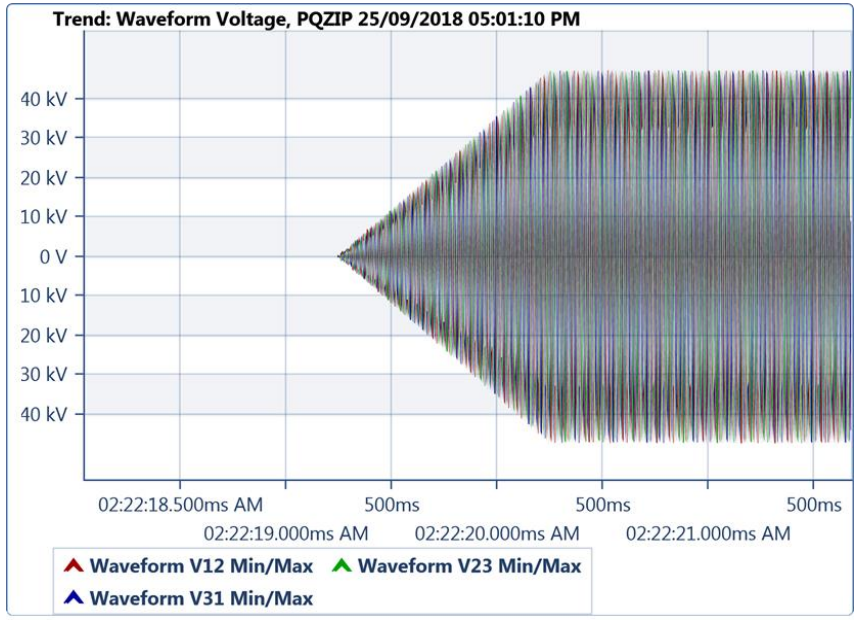
Response within 100 msec

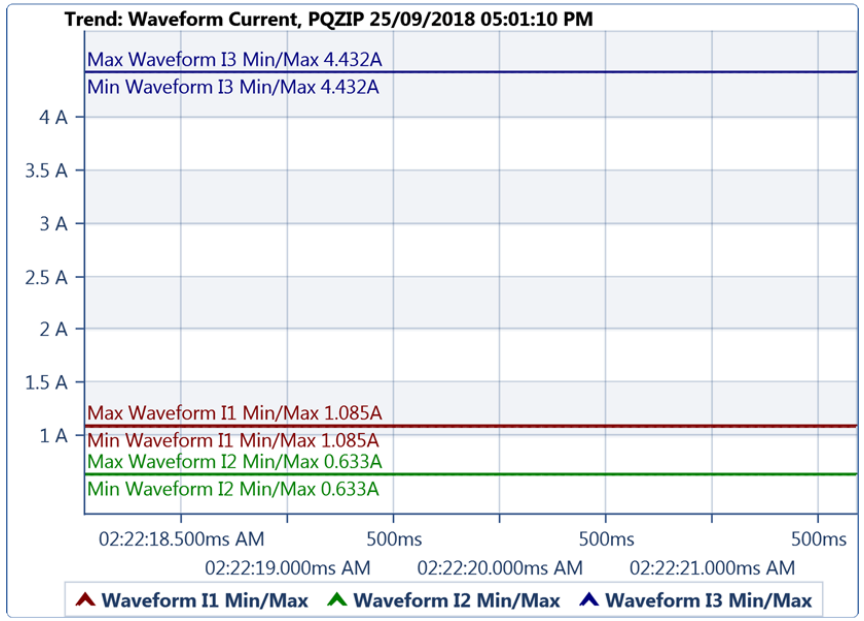
Islanding Detection Scheme (IDS)

- Selected remote IDS monitoring close to interconnection
  - Four Peripheral Units monitor switchgear and protection systems at four substations near interconnect to detect islanding
    - Central Unit monitors switchgear and protection systems at Dalrymple substation
    - If IDS detects disconnection, Central Unit initiates trip at Wind Farm and indication to VSG controller → BESS controls frequency/voltage
  - On restoration of upstream network, IDS notifies Network Control Operator that microgrid may be resynchronized
  - 15 circuit breakers, 32 disconnectors and 16 protection relays are monitored by the IDS

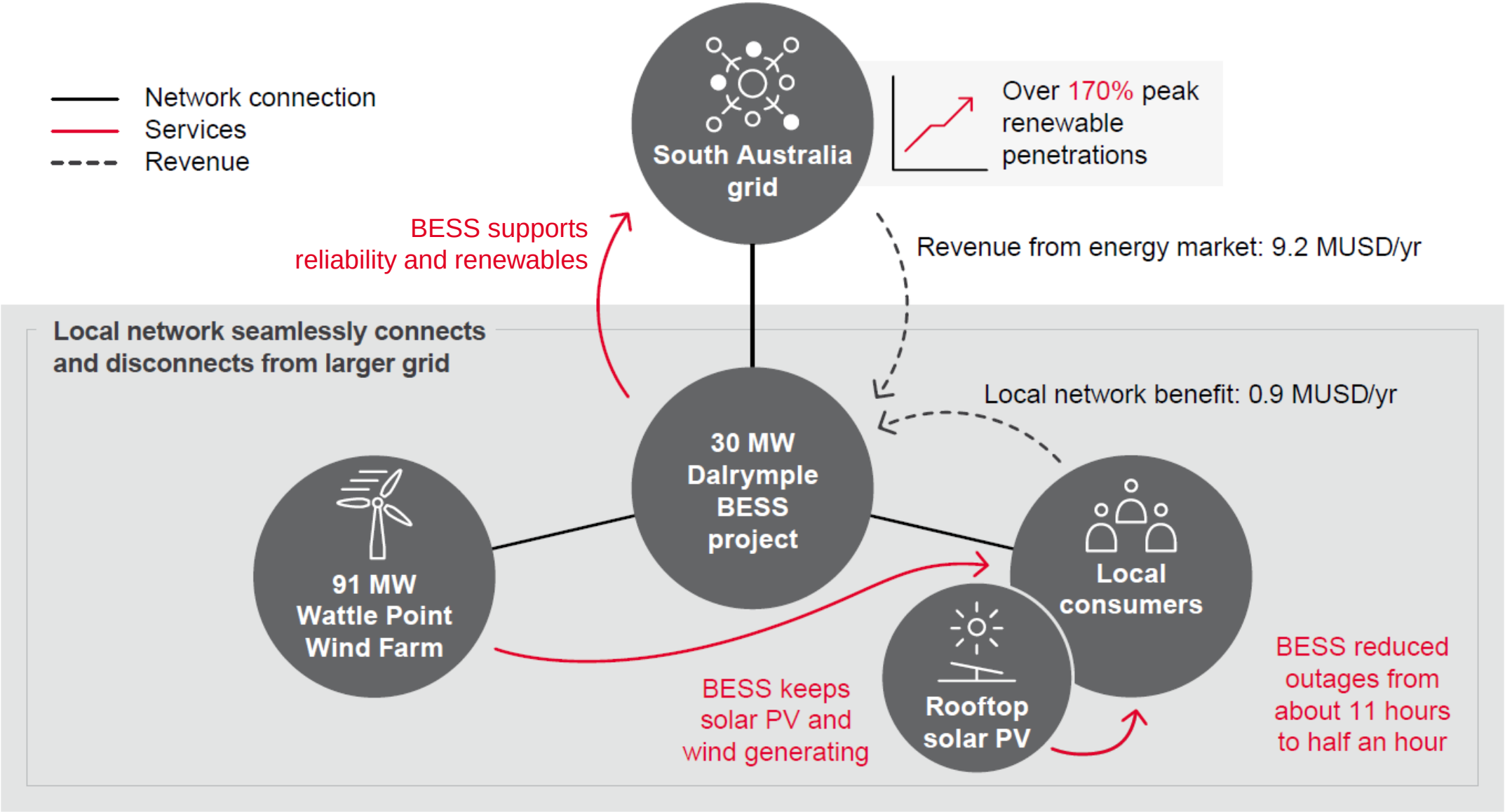
Distributed black start

- Traditionally, system restoration is carried out in a top-down direction
  - Restart from centralized, large plants historically
- Dalrymple BESS can black start 33 kV network
  - Distributed black start from islanded BESS is shown

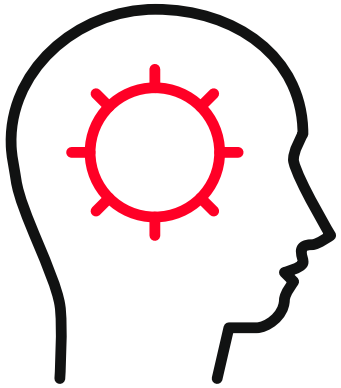




Summary of ESCRI-SA Dalrymple BESS project value



Comments or Questions?



See BESS operation live:
http://www.escri-sa.com.au

John Glassmire, john.glassmire@hitachi-powergrids.com
Stanislav Cherevatskiy, stanislav.cherevatskiy@hitachi-powergrids.com
Galina Antonova, galina.s.antonova@hitachi-powergrids.com
Anthony Fretwell, Fretwell.Anthony@electranet.com.au