Using Virtual Synchronous Generators to Resolve Microgrid Protection Challenges

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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

- **Synchronous Generators**
  - Steady operation during normal operation and during disturbances.
  - Limits rapid rate of Change of system frequency (RoCoF).
  - Associated with fault levels and short circuit ratios.
  - Operate the system securely and ensure safe protection systems.
  - Required for fault ride through and recovery from faults.

- **Synchronous Condensers**
  - Assist in fault ride through and recovery during disturbances.

- **BESS with VSM**
  - Balanced load & generation.
  - After a frequency disturbance, control required in different timescales. (<1 sec, up to 60 sec, 1 to 5 min, >5 min)
  - Stable operation during normal conditions.

- **HVDC with voltage source converter**

- **New wind farms with controls**

- **Load shedding**

- **SVCs / STATCOMs**

- **Capacitors/ Reactors**

- **Steady operation during normal operation and during disturbances.**

- **Limits rapid rate of Change of system frequency (RoCoF).**

- **Operate the system securely and ensure safe protection systems.**

- **Required for fault ride through and recovery from faults.**

- **Stable operation during normal conditions.**

- **Assist in fault ride through and recovery during disturbances.**
ElectraNet’s transmission network: South Australia

- Significant renewable penetration
  - Renewable capacity \heritance 2400 MW
  - Average demand \heritance 1400 MW
  \rightarrow \text{170%}

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

- System blackout \rightarrow SIPS
  - September 28, 2016
ESCRI-SA Dalrymple BESS

Wattle Point Wind Farm
91 MW

25 km

132 kV

33 kV

Dalrymple substation

66 km

Upstream grid

islanded when breaker open
grid-connected when breaker closed

BESS with VSM
30 MW / 8 MWh

Load with DER*
-1 to 8 MW

* 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
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

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<tr>
<th>Event</th>
<th>Response</th>
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<tr>
<td>1</td>
<td>Active import power at Heywood Interconnector exceeds 800MW threshold or rate of increase &gt;1.67MW/s</td>
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<tr>
<td>2</td>
<td>Predictive Out-of-Step Trip Scheme detects impending loss of synchronism</td>
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<tr>
<td>3</td>
<td>Existing Out-of-Step Trip Scheme detect loss of synchronism</td>
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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

- BESS supports reliability and renewables
- Local network seamlessly connects and disconnects from larger grid
- Revenue from energy market: 9.2 MUSD/yr
- Local network benefit: 0.9 MUSD/yr
- 91 MW Wattle Point Wind Farm
- 30 MW Dalrymple BESS project
- Rooftop solar PV
- BESS reduced outages from about 11 hours to half an hour
Comments or Questions?

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