Study Committee C2

SYSTEM OPERATION AND CONTROL

Paper ID_10427

Low Demand Operation of an Islanded Grid with High Share of Inverter-Based Resources – South Australian Case Study

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Introduction

- South Australia (SA) has the world leading integration of IBR and Distributed PV (DPV). The increasing level of IBR has accelerated the retirement of SGs.
- Four large synchronous condensers (SCs) are installed in SA to provide system strength.
- High DPV generation has reduced the minimum demand in SA, leading to voltage rise issues during low demand conditions.
- High DPV generation can increase the size of the MW contingency, for a fault around DPV-rich area, causing unintended tripping of DPV.
- The above have complicated voltage and frequency control, under low demand operation of SA island.

Power System Modelling

- The wide-area EMT model of SA grid was used.
- The model includes detailed and where applicable site-specific models of all network elements.
- The model is benchmarked against measured responses during the actual grid events.
- DPV trip was modelled via an equivalent increase in the size of the contingency.

Frequency Control

- Displacement of SGs in SA has reduced the physical inertia and frequency control in SA.
- Four SA SCs provide inertia through their flywheels, but not frequency control.
- During SA island, three SA BESSs are dispatched to 0 MW to have two-way FFR headroom.
- During low demand condition, high DPV generation can lead to increased size of contingency for a fault close to the DPV-rich area (unintended PV trip).
- To control the frequency, the maximum size of contingency should be limited.
- **Simulation Results:** When the size of contingency is below 175 MW, the frequency can be arrested without violating the UFLS threshold. This may require curtailing DPV generation during low demand periods.

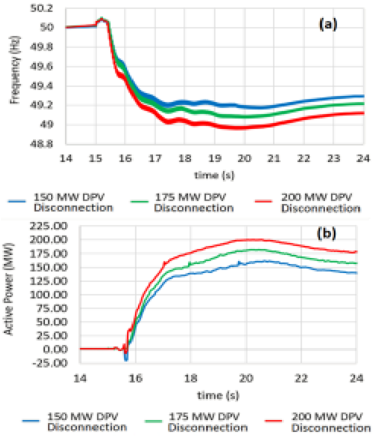

Figure 2 The impact of contingency size: (a) Frequency Response, (b) total FFR from BESS

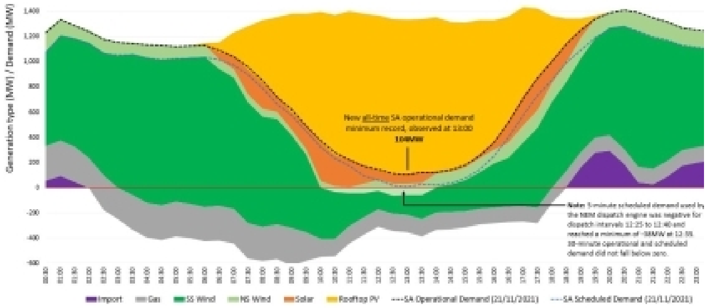

Figure 1 Record low operational demand in SA power network

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Frequency Control: Impact of IBR generation level

- The IBR generation level can impact the maximum allowable size of contingency.
- Simulation results show that in a case with higher IBR generation, a smaller contingency size should be allowed to get the same frequency nadir.
- **Reason:** the temporary energy deficit caused by FRT behaviour of IBRs is larger at higher IBR levels.

Frequency Control: Impact of Extra SGs

❖ **The location of SG in the network has an impact:**

- ➢ If the SG is at distribution level, there would be less impact on the contingency size.
- ➢ **Reason:** A fault at the terminal of the SG does not cause IBR go through FRT mode.
- ➢ A higher contingency size can be allowed, when a distribution SG is brought online.

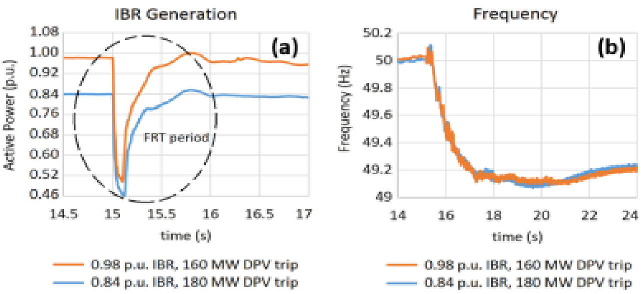

Figure 3 (a) Total IBR generation (b) Frequency (Hz)

Frequency Control: Impact of Extra SGs

- Additional SGs increase the inertia and primary frequency response (PFR). **However**:

❖ **In SA, most SGs are close to DPV-rich metro area:**

- ➢ An extra SG could increase the contingency size.
- ➢ A fault at the terminal of a SG (close to metro) can trip the SG and some DPV too.
- ➢ With an extra SG, more pre-emptive DPV curtailment may be required.

Voltage Control

- Under low demand conditions of SA island, the generation from transmission-connected generators needs to be reduced to balance the low demand.
- Low demand, caused by high DPV generation, cause very low flows through the lines.
- The capacitive charging of lightly loaded lines can cause high voltages across the network.
- Four SCs and four SVCs in SA may not be sufficient to lower the high voltages under too low demand levels.
- Extra voltage control measures are needed.

Table 1: Maximum size of contingency with different SG combinations

Additional SG combination	Most onerous contingency	Maximum size of contingency
2 Transmission-connected SGs	Fault at the terminal of SG and disconnection of SG and DPV	180 MW
Distribution-connected SG 1	Fault at the terminal of SG and disconnection of SG and DPV	205 MW
Distribution-connected SG 2	Fault at the terminal of SG and disconnection of SG and DPV	205 MW

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Measures for Lowering the Voltages:

- All cap-banks should be switched out and all reactors should be switched in.
- Four SVCs and four SCs should absorb reactive power as per their capability. A 30% pre-fault Q headroom was considered for SVCs and SCs.
- Transmission-connected SFs should absorb reactive power within their capability. SFs are likely to be available during (sunny) high DPV generation hours.
- All online WFs together absorb a total of 100 MVAr. If WFs are not available (low wind, etc.), switching out a line in the North area can lower the voltages.
- As the last resort, extra SGs can be dispatched for voltage control support. The number of SGs needed depends on the operational demand level.

Need for Additional SGs:

- **Worst contingency:** trip of an SVCs absorbing large reactive power pre-fault
- Two cases were simulated, with and without an extra SG online. SA demand is 300 MW and all voltage control measures are already in place.
- Without a SG, post-fault voltages go too high. Also, SCs and SVCs violate 30% pre-contingent Q headroom.

❖ **Demand level below which extra SG is needed:**

- **Scenario A:** High availability of reactive power
- **Scenario B:** Low availability of reactive power

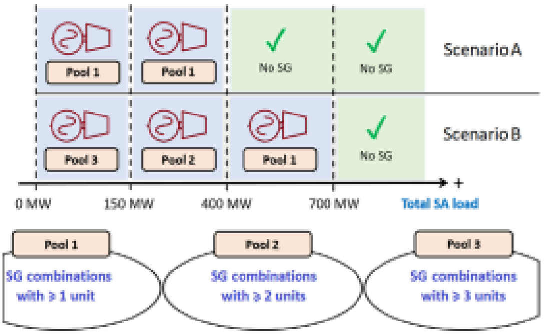

Figure 5 Need for extra SGs at different demand levels

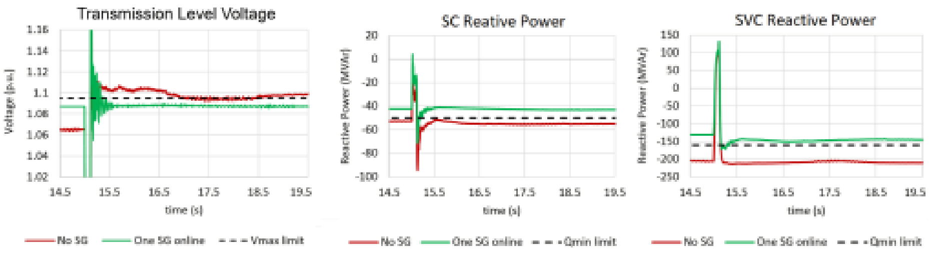

Figure 4 Impact of extra SG on voltage control

Conclusions

- Two challenges for operating SA island under low demand condition: frequency and voltage control
- Under low-demand high-DPV generation, the size of contingency should be limited through pre-emptive DPV curtailment or reducing the generation by SGs.
- Extra SG close to DPV-rich area may increase the size of contingency and necessitates more DPV curtailment.
- At high IBR levels, smaller contingencies can be allowed, due to energy deficit caused by FRT behaviour of IBRs.
- At low demand levels, additional SG(s) may be required for bringing the voltages down.
- The lower the demand level the more SGs will be needed for voltage control.