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Study Committee C4

SYSTEM TECHNICAL PERFORMANCE

Paper ID_10585

System strength support using grid forming energy storage to enable high penetrations of inverter-based resources to operate on weak networks

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Introduction

- The reduction in the number of online synchronous generators (SG) and increase in the penetration of inverter-based resources (IBR) in the Australian National Electricity Market (NEM) has resulted in system strength challenges in some parts of the network.
- This manifests itself in unstable behaviour or voltage oscillations during normal operation and/or following a contingency event. This results in the inability to interconnect further IBR or requires operating limits to be placed on these IBR.
- To provide the local system with the required system strength to accommodate the increased levels of IBR penetration, Synchronous Condensers (SCO) have been installed across the NEM, including in the remote West Murray Zone (WMZ) which is the focus area of this study.
- Virtual Synchronous Machines (VSM) are a technology with capability to provide system strength support to the grid and can be considered as a viable alternative to a SCO.

Motivation

- The analysis sets out to determine if VSM technology can be considered as a viable alternative to a SCO which is the currently accepted remediation measure for supporting the interconnection of grid-following IBR on weak networks.
- A comparison of VSM to SCO sizing was also conducted along with some sensitivities to guide their application from a technical and commercial perspective.
- The rationale for this assessment was to provide more options to provide the necessary system strength and allow a technology that can provide more services (both technical and market-focused) to play a greater role in supporting renewable interconnections.

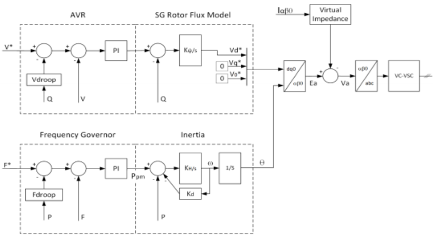

Figure 2. Virtual Synchronous Machine primary control model

Background

- System strength is the ability of the power system to maintain the voltage waveform at any given location, with or without a disturbance.
- In weak networks, renewable energy generation sources coupled via current-controlled or grid-following converters can be susceptible to instabilities and have challenges recovering following faults due to the suppressed voltage magnitude and potentially distorted waveforms.
- The West Murray Zone (WMZ) is an area of the NEM with low system strength with significant grid-scale solar and wind generation. Sustained post-disturbance voltage oscillations in the WMZ can be seen in Figure 1.

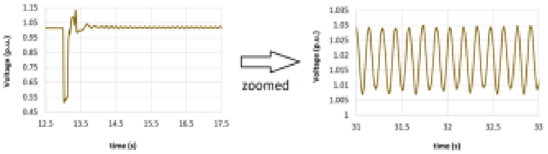

Figure 1. Voltage Oscillations at an IBR terminal in WMZ after a contingency

Methodology

- SCO and VSM model seen in Figure 2 were integrated into the wide-area Electromagnetic Transient (EMT) model of a sub-network of the NEM region, the WMZ as seen in Figure 3.
- EMT simulations with either a SCO or VSM in service were conducted, and the performance of the different technologies in providing system strength support to the grid was monitored.
- Sensitivity studies were also performed by changing parameters of the VSM, including its MVA size, pre-fault dispatch and overcurrent capability.

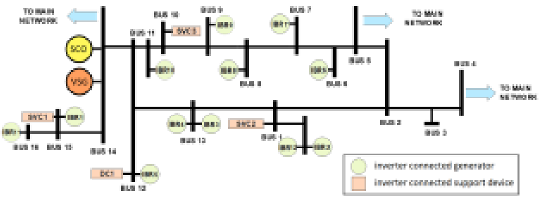

Figure 3. West Murray Zone (WMZ) network layout

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Results

- The first three cases (base case, case 0, and case 1) aim to assess the capability of the VSM technology in providing system strength support to IBR-dominated, weak areas of the WMZ, in comparison to SCO which can be seen in Figure 4.
- Figure 5 and Figure 6 show sensitivity cases relating to VSM size and pre-fault dispatch output respectively.
- Table 1 summarises the results for all the test cases.

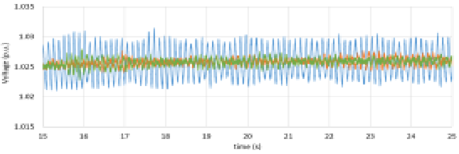

Figure 4. Post disturbance voltage oscillations for the first three cases. Base case (blue), 60 MVA SCO (orange) and 60 MVA VSM (green).

Table 1. Results Summary

Case #	Case description	Voltage oscillations magnitude
Base Case	No SCO or VSM	~ 0.9% on average
Case 0	With 60 MVA SCO connected at bus 14	~ 0.2% on average
Case 1	60 MVA SCO replaced by a 60 MVA VSM (dispatched to 0 MW)	~ 0.2% on average
Case 2	60 MVA SCO replaced by a 50 MVA VSM (dispatched to 0 MW)	~ 0.4% on average
Case 3	60 MVA SCO replaced by a 40 MVA VSM (dispatched to 0 MW)	~ 0.5% on average
Case 4	60 MVA SCO replaced by a 30 MVA VSM (dispatched to 0 MW)	~ 0.7% on average
Case 5	60 MVA SCO replaced by a 60 MVA VSM (dispatched to 10 MW)	~ 0.3% on average
Case 6	60 MVA SCO replaced by a 60 MVA VSM (dispatched to 18 MW)	~ 0.2% on average
Case 7	60 MVA SCO replaced by a 60 MVA VSM (dispatched to 0 MW), with increased overload capability* (2 p.u.)	~ 0.2% on average
Case 8	60 MVA SCO replaced by a 60 MVA VSM (dispatched to 0 MW), with decreased overload capability (1.1 p.u.)	~ 0.2% on average

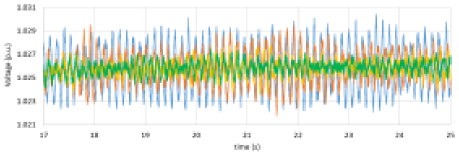

Figure 5. Post disturbance voltage oscillations for case 1 to case 4. 30 MVA VSM (blue), 40 MVA VSM (orange), 50 MVA VSM (yellow) and 60 MVA VSM (green).

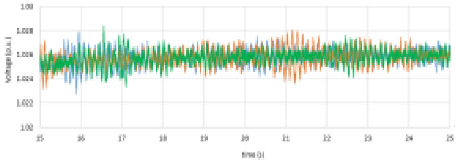

Figure 6. Post disturbance voltage oscillations for case 1, case 5, and case 6. 60 MVA VSM dispatched at 0 MW (blue), dispatched at 10 MW (orange) and dispatched at 18 MW (green).

Discussion

- This study did not investigate the role of converter short-term overload sufficiently to determine if it provides additional capability and warrants further investigation.
- The results show there are a range of factors beyond peak fault contribution that contribute to system strength and more investigations into the critical attributes of the VSM model should be undertaken to qualify various grid-forming converter technologies and their suitability for specific applications.
- VSM technology has the potential to avoid some of the limitations of synchronous machines, such as restrictions to capability curve, limited rotor damping, limited negative sequence current capability and introduction of other oscillatory modes.

Conclusion

- A VSM provided system strength support to the same extent as a SCO.
- Specifically, a 60MVA VSM provided the same voltage oscillation damping as a 60MVA SCO following the most severe contingency event for the area and supported the continued stable operation of the grid following IBRs in the region.
- The study has also shown that the current method of using the fault current capability of a generator as the only metric of the required system strength is no longer valid.