NAME : Nathan Crooks
COUNTRY : Australia
REGISTRATION NUMBER : 5757

GROUP REF. : C4
PREF. SUBJECT : 3
QUESTION N° : 20

Use of battery energy storage systems (BESS) at the transmission system level have become increasingly popular in the Australian National Electricity Market (NEM) over the past few years. As this trend continues to progress in the future, suitable tuning and design of BESS inverter parameters will be required to optimise provision of system services such as frequency control, inertia, and system strength. Virtual synchronous machine (VSM) control on grid-forming inverters (GFMI) provides access to adjustable virtual inertia response which can be managed to benefit the wider power system. Additionally, grid-forming inverters have shown the ability to improve system strength and mitigate low system strength driven voltage oscillations. This presentation goes over the experience with a weak grid connection of a VSM GFMI BESS, connecting with a minimum short circuit ratio (SCR) of approximately 2.0 and in proximity to two existing inverter-based resources (IBRs). The experience highlighted the benefits of key controllable parameters when managing frequency control, inertia, and system strength.

GFMI containing VSM control loops mimic the response behaviour of a synchronous machine. The virtual inertia control loop, which defines the VSM response, can be adjusted through the inertia constant (H) and the damping constant (D). These parameters have equivalents on a physical synchronous machine and are measured quantities, only adjustable through mechanical changes to a plant. By having the capability to control these parameters, the virtual inertia response of a VSM GFMI can be designed such to optimise frequency control and physical inertia requirements in the network. More aggressive and plentiful inertia response from GFMI can minimise the total required frequency response across the network, as a frequency rise/drop will be arrested sooner. Through the grid connection experience with this BESS, different H and D parameters were tested and the response overlaid. Suitable parameters were selected to provide an approximately 1pu active power injection for the worst-case rate of change of frequency (RoCoF) the network can experience within rule requirements of 4Hz/s. Additional work is still required to quantify the relationship between the H and D parameters and a physical synchronous machine’s inertia. Due to small but inherent delays, in the order of 10 milliseconds in this experience, that occur with inverter control, virtual inertia cannot fully replace physical inertia. But a process can be developed to determine how virtual inertia offsets physical inertia in the planning space.

Low system strength areas are more prone to instabilities, and sustained voltage oscillations have been observed in the NEM in areas of low system strength on multiple occasions. As a screening approach for generator connections to determine a plant’s susceptibility to low system strength driven voltage oscillations, an oscillation injection test was performed on an electro-magnetic transient (EMT) model of the GFMI BESS. When tuning the plant, a comparison was performed against a nearby grid following IBR which exhibited prior susceptibility to low system strength voltage oscillations. In isolation, the grid following IBR magnified injected voltage oscillations by a factor of 2. However, when the GFMI was also connected, maintaining the same network conditions, it was shown to damp the voltage oscillations back equal to the injected magnitude. The GFMI was compared under these conditions both prior to and following site-specific tuning and showed the same benefits. This makes it challenging to identify specific parameters which facilitate improved low system strength stability for nearby network, but it does indicate that a blanket consideration for GFMI VSM devices’ impact on system strength could be taken. Further work is required to determine exactly what this would look like, considering different manufacturer variations and how to treat non-VSM devices.

The ever-growing number of transmission level BESS connections has highlighted a need for how to consider their contributions to system support services, such as frequency control, inertia, and system strength, especially in the planning realm. Experience of a weak grid connection of a GFMI VSM BESS in the NEM, emphasised that virtual inertia can easily be adjusted to optimise system support services. Additional work is required to define the relationship between H and D parameters in a GFMI VSM compared to a synchronous machine. GFMI VSM have also been shown to successfully mitigate low system strength voltage oscillations with minimal to no tuning. This infers that an all-encompassing treatment of GFMI VSM devices could be considered for planning purposes, but the specifics of this still need to be determined. However, having GFMI and VSM technology available has opened up many new opportunities for optimisation and coordination of system support services in the future.