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Q20: What are the key design and control parameters of the battery and associated inverter to optimise the collective provision of system services such as frequency control, inertia, and system strength in a power system planning horizon?

There are a number of key design and control parameters for a battery and associated converter to optimise the collective provision of frequency control, inertia and system strength. Many warrant further study to better understand their role for certain applications and in particular, a comparison of control approaches for grid-forming (GFM) converters - droop, virtual oscillator and virtual synchronous machine/generator and associated internal parameters have limited investigations and literature to date. The focus of this contribution will be two services that can only be provided by GFM converters, inertia and system strength. This is because of the nature of those services as they require an independent voltage source not reliant on measurement or a phase-lock-loop (PLL), in line with details outlined in paper 10585.

Inertia is a real power service while system strength is primarily a reactive power service, and the sizing of the converter in MVA and the sizing of the battery in MW charge/discharge rate needs to be considered. The battery charge/discharge rate must be sufficient to meet the inertia requirement, whereas the converter can be oversized with respect to the battery charge/discharge rate for system strength, with the reactive power contribution sources from the converter itself.

With respect to the converter sizing, another attribute, converter overload capability, can become important – and needs to be better understood in the context of inertia and system strength. While paper 10585 showed overload had little influence on damping voltage oscillations from a system strength perspective, other aspects associated with system strength during fault recovery and protection operation needs further investigation. During a contingency a GFM converter will be required to current limit at a point. This is typically managed by switching mode, switching to grid-following (GFL)/current source mode, oversizing (installing additional converters) to avoid reaching the current limit or finally, utilising overload capability with a specific class of high-power converters - again to avoid reaching the current limit.

Converters traditionally used for solar photovoltaic and battery energy storage systems (BESS) have minimal overload and may not provide full four quadrant operation unlike the high-power converter class, as their primary focus has been energy conversion. With this broad spectrum of capabilities from a hardware perspective, a better understanding and definition is required for inertia and system strength services to drive the right converter designs and their use in the right applications. Updated, fit for purpose interconnection rules are also required to enable the right technology to provide these services. At present, some GFM converters switch mode to meet asynchronous interconnection rules under certain contingencies, while others try and mimic the performance of a synchronous machine – but there are challenges with both approaches. The former potentially introduces future limitations during significant power system contingency events where significant capacity may current limit and not support the power system.

Finally, as an example of converter overload to enable the provision of multiple services is presented in the context of a BESS in South Australia. In this example, the BESS must ride through a 4Hz/sec rate of change of frequency (RoCoF) event for 0.25seconds and a 3Hz/sec RoCoF for 1 second as per the interconnection rules. Here the full nameplate rating of the converter can be dispatched in the market with the inertia set such that it will respond within the overload rating to the defined RoCoF. This maximises the use of the asset for market services yet provides inertia to the required extent at any point in time without current limiting. The alternative would be to oversize or select between market and inertia services.