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QUESTION N° : Q.S-1

Supercapacitor Energy Optimisation via DC-DC Converter

Question S.1
Which challenges are foreseen with large integration of PE-based ancillary services? What industry contributions are needed to enable large integration of PE-based ancillary services?

By embedding supercapacitor based energy storage systems within high-capacity converters (such as STATCOM), a wider range of functionality can be obtained, such as grid-forming control (including synthetic inertia) / fast-frequency response / etc.

As given by Equation (1) and Figure 1, the amount of energy which can be extracted from a capacitive-based energy storage system (such as supercapacitors) is directly related to the range of voltage. This is dictated by the power converter to which it is coupled. That is, if the power converter can operate over a wide range of dc voltages, then the majority of energy may be extracted (it is “usable” energy). Conversely, where the voltage range is narrow, the useable energy, for a given energy storage system, is small.

When considering a design with a fixed usable energy requirement, the size of the energy storage system (ESS) will vary based on the how dc voltage range/capability of the power converter. The wider the range, the smaller the ESS; the narrower, the larger the ESS.

$$\boldsymbol{E_c = \frac{1}{2} C V_c^2} \quad (1)$$

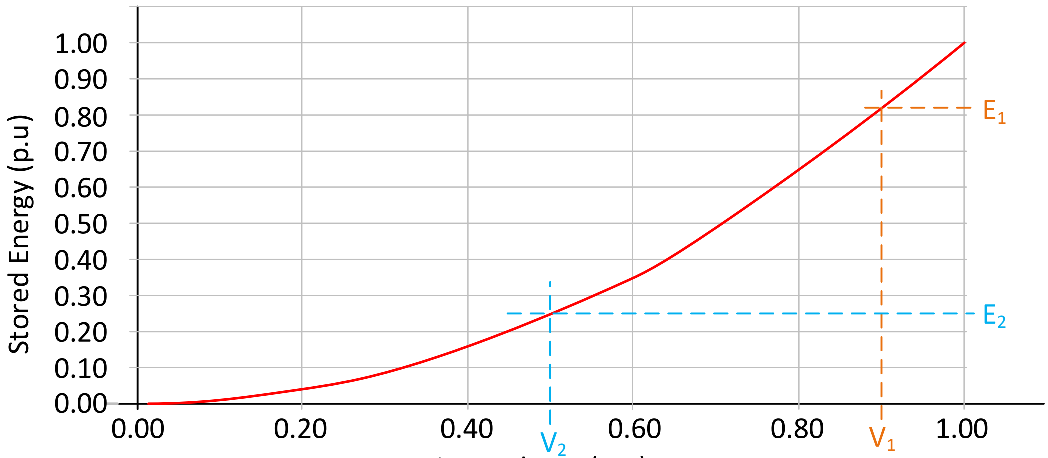

Figure 1: Voltage / Energy relationship

Typically, ac/dc power converters are designed with a relatively narrow range of dc voltage, to increase power rating. A larger dc voltage range resulting in a poorer utilisation of the power converter, and thus oversizing. Therefore, there is a direct conflict in optimisation of the supercapacitor based ESS and the power converter. Smaller dc voltage range is optimum for the power converter, offers poor utilisation for the ESS, and vis-versa.

The use of a dc/dc coupling converter allows both systems to be optimised somewhat independently. Ideally, the ac/dc power converter can be designed around an operational voltage of close to 1.p.u, maximising it's power rating. Independently, the ESS can be designed assuming a wide range of voltage, allowing the majority of energy to be extracted and thus minimal oversizing / residual (non-extractable) energy. The dc/dc converter maintains voltage at the dc side of the ac/dc power converter, and adjusts the dc voltage of the ESS to extract a large amount of energy. This has the potential to significantly decrease the size of the ESS (see Figure 2).

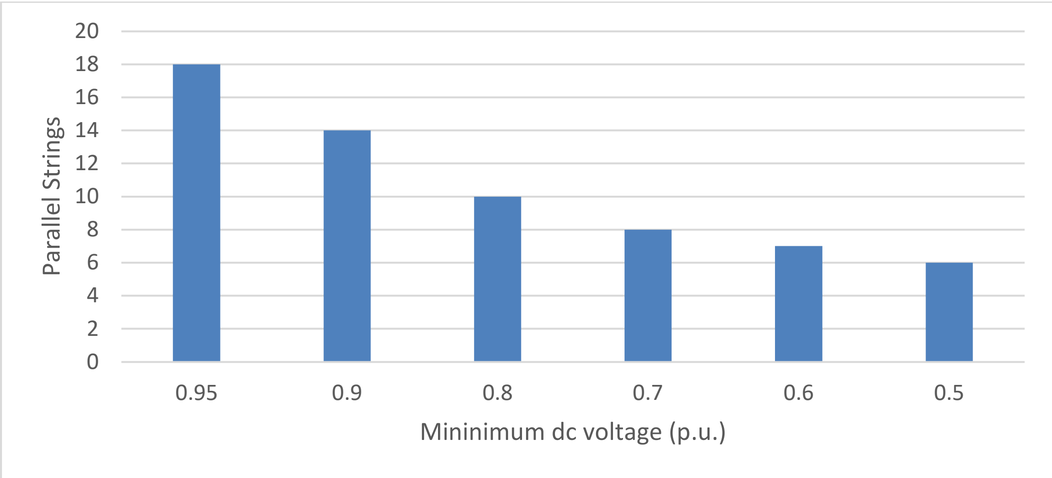

Figure 2: ESS strings versus dc voltage range

In practice the wider range of dc voltage of the ESS corresponds to an increasing dc current requirement, for a fixed power requirement. Therefore, the dc/dc current rating impact on cost/footprint must be traded off against the reduced cost of the ESS. The use of multiple, parallel dc/dc converter offers flexibility in design of the system.