120 kWh energy storage efficiency

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This paper is outlined as follows. Section II presents an overview about the converter topologies commonly used in BESS. Section III describes the main control strategies for BESS. Section IV lists and discusses the main services provided by a BESS. Section V describes the case studies in order to compare different topologies to connect the BESS into the grid. The results are discussed in Section VI and the main conclusions are stated in Section VII.

In this work, the converter topologies for BESS are divided into two groups: with transformers and transformerless. This work is focused on MV applications. Thus, only three-phase topologies are addressed in the following subsections.

The voltage source converter (VSC), ZSI (Z-source converter) and qZSI (quasi-Z-source converter), shown in Fig. 2, are the three traditional two-level converters for the dc/ac stage of BESS. For the grid connection, it is generally, it is used a low-pass filter in order to attenuate the injected harmonics. LC or LCL filter configurations are usually employed. The transformer (Tx) is used to step-up the low voltage (LV) from the inverter side to the MV of the grid side [12, 13].

In the VSC configuration, the battery bank can be connected directly to the dc/ac stage capacitor or connected through the dc/dc stage. The disadvantage of this topology is the possibility of operating only as a buck converter. Therefore, the output voltage must be lower than the dc voltage. In addition, the upper and lower switches of each phase-leg cannot be activated simultaneously. Thus, a dead time between the opening and closing of the switches must be implemented, which distorts the output waveform.

Despite the advantages of ZSI and qZSI, VSC is more commonly used due to its simplicity. Therefore, in this work, VSC is used to represent the two-level converters in the dc/ac stage and it is the topology simulated in the case study presented in Section IV.

Five-level NPC converters can also be employed in BESS [30]. By increasing the converter levels, it is possible to improve the output voltage waveform and, depending on the number of levels, eliminate the transformer. Thus, BESS can be directly connected to the MV grid.

In relation to the direct connection of BESS to the MV grid, the multilevel topologies have demonstrated prominent technologies in recent researches on BESSs [10, 33]. These topologies make it easier to deal with the state of charge (SOC) unbalance of the batteries. They also present low losses, modularity and scalability, among other characteristics [34]. The cascaded H-bridge converter (CHB) and the modular multilevel converter with chopper or bridge cells (CC or BC) are two highly discussed multilevel topologies in power storage applications.

Some issues should be investigated when using the MMC topology. For example, if the batteries are connected directly to each cell, unbalances between the voltages can lead to dc current injection into the grid [49]. The dc-dc stage, shown in Fig. 7 (a), decouples the battery from the capacitor, thus reducing the dc filter required and increasing the battery lifetime. Furthermore, the capacitor of the cell can be smaller [50].