An optimal control and sizing strategy for a coordinated WTG-ES system to provide frequency support

In power grids with large wind power integration, long-term wind turbine generator (WTG) de-loading to provide frequency reserves will greatly constrain the economic benefits of a wind farm (WF). Although energy storage (ES) often cooperates with the WF as a combined system to improve the frequency regulation performance, the coordination control inside the combined system and the trade-offs between the expensive investment costs of the ES, the long-term de-loading costs of the WF and the frequency regulation requirements should be further studied. Therefore, in this paper, a fuzzy-based coordinated control and sizing strategy is proposed to achieve dynamic cooperation inside the combined WTG-ES system and optimize the economic performance of the combined system for providing frequency support power. The fuzzy controller is designed to allocate the frequency regulation demand with considering the operation state and the frequency support capability of the WTG-ES system and the type of frequency incidents. Under the proposed control strategy, the WTG can operate at a rate closer to the maximum power point instead of having to maintain a large power reserve level for frequency support; SOC of the ES is separated into several sections with different features and operational rules to make full use of the ES energy capacity and constrain the SOC limit violation problems effectively. Subsequently, based on the proposed coordinated control strategy, an optimization model is presented that determines the optimal WTG de-loading level in different time intervals, ES rating powers and energy capacity, with the objective of minimizing the operation and frequency regulation costs of the combined WTG-ES system. The optimization model is solved by an improved PSO algorithm. Finally, case studies using actual wind power generation and frequency data were conducted to validate the performance of the proposed control and sizing strategy.