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Analysing the Stability of Electrical Grid for Increased Renewable Energy Penetration by Focussing on LI-Ion Battery Storage Technology

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Abstract : Frequency is, among other factors, one of the governing parameters for maintaining electrical grid stability. The quality of an electrical transmission and supply system is mainly described by the stability of the grid frequency. Over the past few decades, energy generation by intermittent sustainable sources like wind and solar has seen a significant increase globally. Consequently, controlling the associated deviations in grid frequency within safe limits has been gaining momentum so that the balance between demand and supply can be maintained. Lithium-ion battery energy storage system (Li-Ion BESS) has been a promising technology to tackle the challenges associated with grid instability. BESS is, therefore, an effective response to the ongoing debate whether it is feasible to have an electrical grid constantly functioning on a hundred percent renewable power in the near future. In recent years, large-scale manufacturing and capital investment into battery production processes have made the Li-ion battery systems cost-effective and increasingly efficient. The Li-ion systems require very low maintenance and are also independent of geographical constraints while being easily scalable. The paper highlights the use of stationary and moving BESS for balancing electrical energy, thereby maintaining grid frequency at a rapid rate. Moving BESS technology, as implemented in the selected railway network in Germany, is here considered as an exemplary concept for demonstrating the same functionality in the electrical grid system. Further, using certain applications of Li-ion batteries, such as self-consumption of wind and solar parks or their ancillary services, wind and solar energy storage during low demand, black start, island operation, residential home storage, etc. offers a solution to effectively integrate the renewables and support Europe's future smart grid. EMT software tool DIgSILENT PowerFactory has been utilised to model an electrical transmission system with 100% renewable energy penetration. The stability of such a transmission system has been evaluated together with BESS within a defined frequency band. The transmission system operators (TSO) have the superordinate responsibility for system stability and must also coordinate with the other European transmission system operators. Frequency control is implemented by TSO by maintaining a balance between electricity generation and consumption. Li-ion battery systems are here seen as flexible, controllable loads and flexible, controllable generation for balancing energy pools. Thus using Li-ion battery storage solution, frequency-dependent load shedding, i.e., automatic gradual disconnection of loads from the grid, and frequency-dependent electricity generation, i.e., automatic gradual connection of BESS to the grid, is used as a perfect security measure to maintain grid stability in any case scenario. The paper emphasizes the use of stationary and moving Li-ion battery storage for meeting the demands of maintaining grid frequency and stability for near future operations.

Keywords : frequency control, grid stability, li-ion battery storage, smart grid
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