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Dynamic Simulation of a Hybrid Wind Farm with Wind Turbines and Distributed Compressed Air Energy Storage System

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Abstract : Most studies and existing implementations of compressed air energy storage (CAES) coupled with a wind farm to overcome intermittency and variability of wind power are based on bulk or centralized CAES plants. A dynamic model of a hybrid wind farm with wind turbines and distributed CAES, consisting of air storage tanks and compressor and expander trains at each wind turbine station, is developed and simulated in MATLAB. An ad hoc supervisory controller, in which the wind turbines are simply operated under classical power optimizing region control while scheduling power production by the expanders and air storage by the compressors, including modulation of the compressor power levels within a control range, is used to regulate overall farm power production to track minute-scale (3-minutes sampling period) TSO absolute power reference signal, over an eight-hour period. Simulation results for real wind data input with a simple wake field model applied to a hybrid plant composed of ten 5-MW wind turbines in a row and ten compatibly sized and configured Diabatic CAES stations show the plant controller is able to track the power demand signal within an error band size on the order of the electrical power rating of a single expander. This performance suggests that much improved results should be anticipated when the global D-CAES control is combined with power regulation for the individual wind turbines using available approaches for wind farm active power control. For standalone power plant fuel electrical efficiency estimate of up to 60%, the round trip electrical storage efficiency computed for the distributed CAES wherein heat generated by running compressors is utilized in the preheat stage of running high pressure expanders while fuel is introduced and combusted before the low pressure expanders, was comparable to reported round trip storage electrical efficiencies for bulk Adiabatic CAES.

Keywords : hybrid wind farm, distributed CAES, diabatic CAES, active power control, dynamic modeling and simulation
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