Coordinated control of wind power and energy storage

Nowadays, wind power has become one of the fastest growing sources of electricity in the world. Due to the inherent variability and uncertainty, wind power integration into the grid brings challenges for power systems, particularly when the wind power penetration level is high. The challenges exist in many aspects, such as reliability, power quality and stability. With the rapid development of energy storage technology, the application of Energy Storage System (ESS) is considered as an effective solution to handle the aforementioned challenges. The main objective of this study is to investigate the coordinated control of wind power and ESS. Due to the different technical characteristics, such as power and energy density, ESS can play different roles either in generation-side, grid-side or demand side. This thesis focuses on the following two scenarios:• Scenario 1: As a part of wind farm, the ESS plays a generation-side role which aims to improve the grid-friendliness of the wind farm. • Scenario 2: As a part of microgrid, the ESS is used to efficiently accommodate the wind power fluctuation.

Around the main objective, the relevant research fields including the wind turbine modeling and control, wind farm modeling and control, planning of ESS are also studied in this thesis. The implementation and validation of the International Electrotechnical Commission (IEC) generic Type 1A are presented in this thesis. It is shown that the implemented IEC generic Type 1 models in PowerFactory (PF) can represent the relevant dynamics during normal operation and fault conditions. The model against measurements validation was carried out to verify the implemented wind turbine generator model. For the wind turbine control strategy, the L1 adaptive controller for Maximum Power Point Tracking (MPPT) of a small variable speed Wind Energy Conversion System (WECS) is developed. It showed good tracking performance towards the optimum Tip Speed Ratio (TSR) and robustness with fast adaptation to uncertainties and disturbances. For the wind farm control, the optimal active power control based on Distributed Model Predictive Control (D-MPC) is proposed. With the developed D-MPC, most of computation tasks are distributed to the local D-MPCs equipped at each actuator (wind turbine or ESS). This control structure is independent from the scale of the wind farm. The algorithms for optimal siting and sizing of ESS in the grid with a significant penetration of wind power are studied and implemented in a test network. For the point of view the grid operator, the optimal sizing and siting of ESS are analyzed, which enhance the controllability and derive the global benefit of the whole grid.

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