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*DISTURBANCE OBSERVER-BASED CONTROL FOR PMSG-BASED WIND TURBINE CONSIDERING UNBALANCED GRID CONDITIONS*

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Abstract

A typical permanent magnet synchronous generator (PMSG)-based wind turbine system consists of an electrical generator, machine-side converter (MSC), grid-side converter (GSC), dc-link capacitor, and a passive filter such as *L* filter or *LCL* filter to connect the GSC to the host grid. When the wind turbine operates under unbalanced grid voltages, a negative sequence component is introduced to the system. This negative sequence voltage can pose challenges for classical controllers to ensure an efficient control of the PMSG-based wind turbine system. On one hand, when the control objective is to ensure injecting sinusoidal and balanced three-phase currents to the grid, voltage unbalance can cause active power to oscillate at double fundamental frequency. On the other hand, delivering constant active power to the grid, under unbalanced voltages, requires injecting sinusoidal and unbalanced three-phase currents to the grid. In current control scheme, constant active power operation during unbalanced voltages can be achieved by setting the grid currents to follow appropriate sinusoidal and unbalanced current references. In power control scheme, these current references can be used to compute the active and reactive power commands required to achieve ripple-free active power under unbalanced voltage conditions. During unbalanced grid voltages, ripple-free active power can produce a sinusoidal oscillation of frequency $2\omega$ in the dc-link voltage, where $\omega$ is the grid frequency. This oscillation occurs due to periodic energy exchange between the inductance of the passive filter and the dc-link capacitor, as no active power oscillations are injected into the grid. This energy exchange also occurs between the dc-link voltage and the stator windings of the PMSG, resulting in $2\omega$ ripple in the torque of the generator. Thus, under unbalanced grid voltages, appropriate control strategies are required for the control of the GSC and MSC to enable efficient power exchange between the host grid and the wind turbine.

This thesis presents the design and performance evaluation of a robust control strategy for both GSC and MSC. Under balanced grid voltage conditions, GSC regulates the dc-link voltage through controlling either the current or the power injected into the grid, while the MSC regulates the stator currents of the PMSG aiming to maximize the power extracted from the wind. During unbalanced grid voltage conditions, the roles of GSC and MSC are interchanged. In particular, the MSC regulates the dc-link voltage through controlling the stator currents of the PMSG, while the GSC regulates the active power delivered to the grid to allow implementing the so-called “Fault Ride Through” algorithm. In this thesis, the proposed controller for both converters is based on combining a state-feedback controller with a disturbance observer. The feedback controller has the role of stabilizing the nominal closed-loop system, while the disturbance observer plays the role of a servo-compensator to cancel the effect of model uncertainties and unknown disturbances, considering the oscillatory behavior of disturbances under unbalanced grid voltages. Another advantage of the disturbance observer is its ability to achieve a seamless transition between the control schemes in response to sudden balance/unbalance event in grid voltages. The proposed controller also makes use of a notch filter to cancel the effect of the inherent dc-link voltage oscillations on the machine torque, particularly when the grid voltage is unbalanced.

Simulation tests are conducted to verify the performances of the proposed control technique using MATLAB Software considering realistic scenarios and adequate control parameters. The results demonstrate that the proposed control scheme can achieve good steady-state and transient performances under both balanced and unbalanced grid voltages. More importantly, the obtained results show that proposed controller is able to maintain good transient performances in response to sudden unbalance/balance events in the grid voltages.

**Keywords**: PMSG, GSC, MSC, disturbance observer, feedback linearization, sinusoidal disturbance rejection, unbalanced grid voltages.