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Improved rotor current control of wind turbine driven doubly-fed induction generators during network voltage unbalance

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ABSTRACT

This paper investigates an improved control and operation of a doubly-fed induction generator (DFIG) system under unbalanced network conditions. A new rotor current control scheme is presented, which consists of a main controller and an auxiliary compensator. The main controller is constructed in the same way as the conventional vector control design without involving sequential-component decomposition in order to guarantee system stability and high transient response. While the auxiliary controller is specially designed to control the negative sequence current taking into account the impact of the main controller on negative sequence components. Simulated results on a commercial 1.5-MW DFIG system and experimental tests on a 1.5-kW DFIG prototype are provided and compared with those of conventional vector control and dual PI current control schemes to demonstrate the effectiveness of the proposed control strategy during steady-state and transient conditions when the network voltage is unbalanced.

1. Introduction

Wind energy has become one of the subjects of much recent research and development all over the world. Among various types of wind turbines, the variable speed wind turbines based on doubly-fed induction generators (DFIGs), which have many advantages over the fixed-speed generators, including variable speed constant frequency (VSCF) operation, reduced flicker and independent control capabilities for active and reactive powers, has attracted extraordinary attention. These excellent merits are primarily achieved via the control of a rotor-connected back-to-back pulse-width modulated (PWM) converter, which is typically rated at around 30% of the generator rating for a given rotor speed range of 0.75–1.25 pu under normal operation conditions. As a result, the converter cost becomes relatively lower than other types of wind power generation systems.

The steady-state and transient response of DFIG-based wind power generation system under balanced voltage supply have been well understood. In practice, both transmissions and distribution networks can have voltage unbalance. If this is not taken into account by the DFIG control system, the wind turbines might have to be disconnected from the grid during unbalanced network conditions [1] due to the excessive unbalanced stator/rotor currents, and power and torque oscillations. On the other hand, the emerging grid codes require the wind farm to withstand the negative sequence currents, which occur during phase-to-phase faults on the transmission or distribution system, without disconnection [2].

The system control and operation of the wind turbine driven DFIG under unbalanced grid voltage conditions were studied in Refs. [3–9]. In Ref. [3] the focus was purely on compensating torque pulsation during grid voltage unbalance. The rotor compensating voltage was generated directly from the double-frequency oscillating term of the torque. Thus, the current controller must be carefully tuned to provide the required system response at twice the grid frequency. While in Refs. [4–9], a dual rotor current controller based on decomposing the positive and negative sequence components was employed. Since the decomposing process of positive and negative sequence components involves considerable time delay and leads to errors in amplitude and phase with respect to the original signals, the systems cannot be fully decoupled during transient conditions. As a result, the system performance and stability are degraded. Furthermore, significant modifications have to be made to the conventional vector control scheme widely used in practical systems, which makes it less likely to be adopted in real systems. In Ref. [10], the author presented a main and an auxiliary current controllers for regulating positive and negative sequence

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