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Real-time Neural Input–Output Feedback Linearization control of DFIG based wind turbines in presence of grid disturbances

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ABSTRACT

This paper proposes a Neural Input–Output Feedback Linearization (N-IOFL) controller for a Doubly Fed Induction Generator (DFIG) prototype connected to the grid. Under unbalanced grid voltages, the existing control strategies need to be modified, becoming very complicated. By using an identifier based on Recurrent High Order Neural Network (RHONN), trained on-line with an Extended Kalman Filter (EKF), an adequate model of the DFIG and of the DC-link can be obtained, which helps the control law based on feedback linearization to reject grid disturbances appearing under non-ideal grid conditions without decomposition process. Based on such identification, the proposed controller is used to track a desired Direct Current (DC) voltage reference at the output of DC-link, to maintain constant the electric power factor controlled by the Grid Side Converter (GSC), and to force independently the rotor currents to track a specified reference defined from the required stator powers, controlled by the Rotor Side Converter (RSC), under both balanced and unbalanced grid conditions. Real-time results illustrate the effectiveness of the proposed controller even in presence of non-ideal grid conditions.

1. Introduction

Renewable energy sources have penetrated strongly into electric power systems. For a Variable Speed Wind Turbine (VSWT), there are many reasons to use the Doubly Fed Induction Generator (DFIG), such as noise and effort reductions on the Wind Turbine (WT) shaft, reduced cost of the electronic power converter, and the possibility of stator active and reactive power control (Beltran, Benbouzid, & Ahmed-Ali, 2012). The most knowing configuration of the DFIG based WT is that where the DFIG rotor is fed to the grid via a bidirectional electronic converter, whereas the stator is directly coupled to the grid. The Grid Side Converter (GSC) can be linked directly to the grid or through a step-up transformer, which is used to control the DC voltage at the output of the DC-link, and also as a voltage source to fed the Rotor Side Converter (RSC), which is directly linked to the DFIG rotor winding terminal (Tanvir, Merabet, & Beguenane, 2015). The control of the DFIG for generating power is very important, and leads to maintain the stator active and reactive power related to the RSC, and also the DC voltage and the grid reactive power related to the GSC (Abad, Lopez, Rodriguez, Marroyo, & Iwanski, 2011).

The widely used control methodology for the DFIG is the vector control technique (also known as Field Oriented Control) combined with standard Proportional–Integral (PI), Reference Signal Tracking (RST), and Sliding Mode (SM) controllers (Beltran et al., 2012; Pena, Clare, & Asher, 1996; Poitiers, Bouaouiche, & Machmoum, 2009). To design the vector control, a state transformation is needed and the exact parameters must be known. Moreover, the PI controller, which is largely utilized to control the industrial WT, is not robust against speed changing, parameter variations, and external disturbances, which diminishes quantity and quality of the generated energy (Pinto, Campos, Reis, Jacobina, & Rocha, 2011).

There already exist nonlinear controllers based on the nonlinear model of the DFIG as the input–output feedback linearization algorithm in Farrokh, Hashemnia, and Kashiha (2006) and the backstepping approach in Khemiri, Khedher, and Mimouni (2012). These approaches present disadvantages because are based on the mathematical model and a precise knowledge of the DFIG parameters is needed, which causes that those controllers are not robust to parameter variations and/or unmodeled dynamics.

The first real-time implementation of DFIG control is presented in Pena et al. (1996), where decoupled PI controllers are used to control the GSC and the RSC; currents and voltages models are used to define rotor position. In Barambones and Gonzalez (2011), a sliding mode control technique for WT based on a DFIG is presented; the proposed control strategy is based on vector oriented control drive to extract the maximum power at diverse wind speeds. To regulate the GSC and the RSC for a DFIG prototype, a sliding mode block control technique is used in Sanchez and Riemann (2016). In all of these publications, the control systems are tested under ideal grid conditions, which it is not fulfilled

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