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Robust control of doubly fed induction generator for stand-alone applications

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ABSTRACT

The doubly fed induction generator (DFIG) is generally used in the production of the electric energy and more specifically in wind turbines. Currently, a problem of electrical machine control and especially for wind turbines is the change of internal parameters of the machine, which greatly deteriorates the control. In addition, for stand-alone applications, the load and wind speed change frequently. In this paper, a robust control strategy based on the H_∞ control theory is developed for the independent control of the stator voltage amplitude and frequency of a stand-alone DFIG. The DFIG is fed through the rotor windings by a voltage inverter controlled by Space Vector Modulation (SVM). A capacitive and inductive filter is introduced to reduce harmonics on stator voltages and rotor currents. The robust control strategy rejects all the disturbances that may affect the system and that result from the variations of machine parameters, of the rotor speed and of the load. Experimental tests are carried out to verify the effectiveness of the robust control through a comparison with the classical PI regulator in the framework of the Field Oriented Control (FOC) strategy of the DFIG.

1. Introduction

The squirrel cage induction machine is extensively used in industrial applications because of its low cost, simplicity of construction and maintenance [1–3].

As wind turbines usually operate under variable speed, the wound-rotor induction machine, which is characterized by a large margin of speed variation, is the first choice drive for such applications. Besides that, the power consumed by the rotor is much lower than the stator one [2] ($|P_r| \ll |P_s|$ with $P_r = g{\cdot}P_s$ where g is the rotor slip). However, the supply of wound-rotor induction can be largely reduced [4]. When operating in generator mode, the wound-rotor induction machine injects an active power P_s into the load equal to the sum of the mechanical and rotor powers ($P_m + P_r$, with $P_r > 0$ or $P_r < 0$), when the different losses occurring during the electromagnetic conversion are neglected. Another advantage of the wound-rotor induction machine is related to the bi-directional transfer of the rotor power which depends on the rotor speed and the field speed [5–7]. In fact, in order to produce energy for the load, we have two operating modes:

- *Super-synchronous mode*: The DFIG provides the required energy from the mechanical energy for the rotor and the stator. The rotor speed should verify the following relationship $\omega > \omega_s$ (and $P_r < 0$) [8], so the rotor electrical angular frequency $\omega_r = p\Omega - \omega_s$ (inverse system), where Ω is the mechanical rotor speed and p is the machine poles pair number.
- *Sub-synchronous mode*: The DFIG provides the energy for the stator from the rotor and the mechanical energy. In this case, we have $\omega < \omega_s$ (and $P_r > 0$) so $\omega_r = \omega_s - p\Omega$ (direct system).

The inverter connected to the DFIG rotor must provide the necessary complementary frequency in order to maintain the stator frequency at a constant level despite mechanical speed fluctuations. Fig. 1 shows the configuration of the control system.

Model uncertainties, measurement noise, variations of the internal machine parameters, and the external disturbances such as load and speed changes, affect the stability of the control.

In recent times, the main motivation that spurred the research activity was the study of performances over finite and bounded of parameters variation, whereas in classical control based on PI regulators the designer was only able to ensure robustness with respect to small parameter variations. Moreover, in some circumstances, the usage of single-input single-output control design methods can lead to unstable closed-loop systems, caused by inter-loop interaction [9]. The compensation method is not a good solution, especially if the model is uncertain.

Over the past decades, the mainstream of research for quantitative robustness has been the so-called H_∞ control theory that links classical frequency-domain and state-space techniques in an ele-

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