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Mathematics and Computers in Simulation 71 (2006) 360–368

MATHEMATICS AND COMPUTERS IN SIMULATION

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Power distribution law in a Doubly Fed Induction Machine

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Abstract

The paper deals with a Doubly Fed Induction Machine (DFIM). It presents a study of an active power distribution law between stator and rotor sides. The DFIM is supplied by two voltages PWM inverters in stator and rotor. The power distribution law imposes a relation between rotoric and statoric pulsations. Due to this relation, a new variation structure of the DFIM speed control is presented. The four quadrants working are considered. Simulation results under Matlab-Simulink illustrate the performances of the power distribution law.

Keywords: Doubly Fed Induction Machine; Power distribution law; Four quadrants working

1. Introduction

In many industrial applications the Doubly Fed Induction Machine (DFIM) presents several advantages. It can operate as well as motor in many high power applications such as traction, marine propulsion and in very low speed applications like coiler–uncoiler [1–5], or as generator in wind energy conversion systems like wind turbine [6–8], or pumped storage systems [9]. It presents good performances stability either in very low speed and in over speed operation [10].

In our application, the DFIM is a wound rotor ac induction machine supplied by two Pulse Width Modulation voltage inverters, one in rotor side and one in stator side [4,10]. The control strategy proposed in this paper is a rotor flux oriented one. The use of two inverters gives a drive with four degrees of freedom, it allows a power repartition between stator and rotor respecting to a specific distribution.

This paper presents a thorough study of an active power distribution law between stator and rotor. In fact, if this power distribution law is not considered, the stator side has to support the majority of the mechanical DFIM power. This implies a specifically dimensioning of the inverter in the stator side and the use of the inverter in rotor side becomes without interest. The power distribution law imposes a relation between stator and rotor pulsations which permits an optimisation of the power sizes of the inverters.

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doi:10.1016/j.matcom.2006.02.019

Many papers treat with power in DFIM in case of wind turbine generator application but not with the structure considered in this paper. The originality of this study is its simplicity and efficiency and also the using of a dynamic model of the DFIM with active power repartition control in all operating points.

2. Power distribution law in the DFIM

The general scheme of the Doubly Fed Induction Machine field control system is presented in Fig. 1.

In steady state, in a *d*–*q* rotating reference frame where the rotor flux is confused with the *d*-axis, the DFIM can be described by (1) and (2):

$$V_{sd} = R_s i_{sd} - \omega_s \varphi_{sq}, \qquad V_{sq} = R_s i_{sq} + \omega_s \varphi_{sd}, \qquad V_{rd} = R_r i_{rd} - \omega_r \varphi_{rq}, \qquad V_{rq} = R_r i_{rq} + \omega_r \varphi_{rd} \tag{1}$$

$$\varphi_{rq} = 0 \Leftrightarrow \Phi_r = \varphi_{rd} \tag{2}$$

The statoric and rotoric active and reactive powers can be given by (3) and (4):

- Statoric side:

$$P_s = V_{sd} i_{sd} + V_{sq} i_{sq} = \frac{R_s}{M_{sr}^2}(\varphi_{rd}^2 + L_r^2 i_{rq}^2) - \omega_s i_{rq} \varphi_{rd},$$

$$Q_s = V_{sq} i_{sd} - V_{sd} i_{sq} \approx (\varphi_{sd} i_{sd} + \varphi_{sq} i_{sq})\omega_s = \left(\frac{L_s}{M_{sr}^2}\varphi_{rd}^2 + \sigma L_s \frac{L_r^2}{M_{sr}^2} i_{rq}\right)\omega_s \tag{3}$$

- Rotoric side:

$$P_r = V_{rd} i_{rd} + V_{rq} i_{rq} \approx V_{rq} i_{rq} = R_r i_{rq}^2 + \varphi_{rd} i_{rq} \omega_r,$$

$$Q_r = V_{rq} i_{rd} - V_{rd} i_{rq} = 0 \,(\text{we impose } i_{rd} = 0 \text{ so } V_{rd} = 0) \tag{4}$$

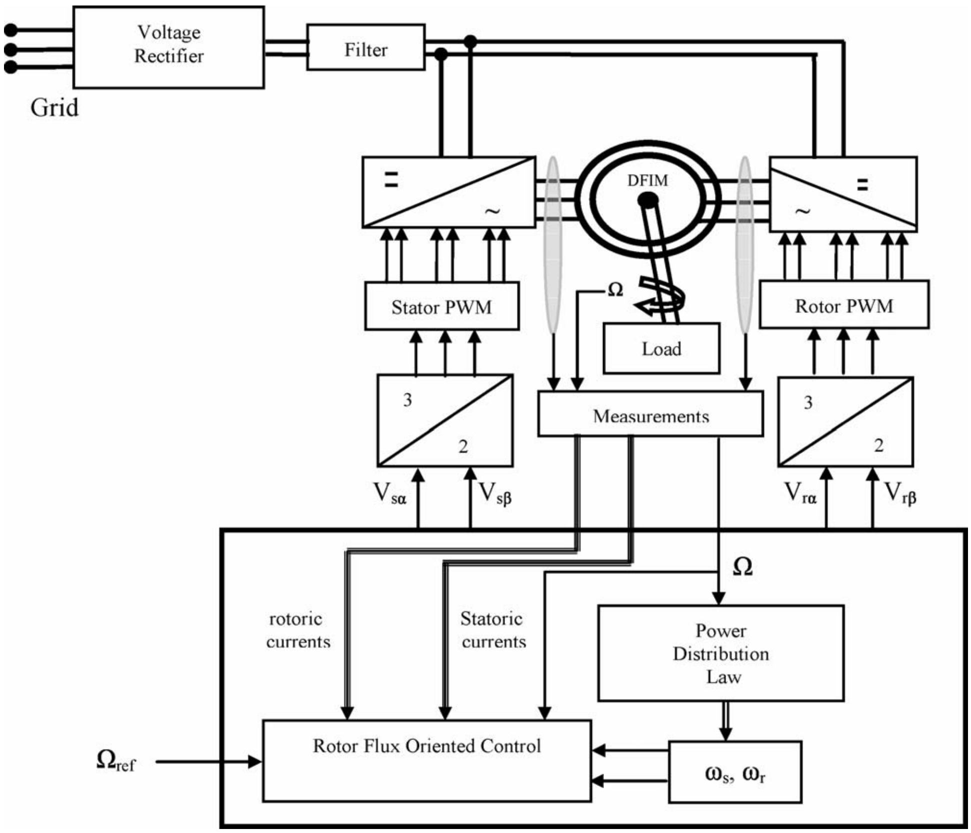

Fig. 1. General speed control scheme.