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Real time implementation of viable torque and flux controllers and torque ripple minimization algorithm for induction motor drive

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Abstract

Field oriented control (FOC) and direct torque control (DTC) are becoming the industrial standards for induction motors torque and flux control. This paper aims to give a contribution for a detailed comparison between these two control techniques, emphasizing their advantages and disadvantages. The performance of these two control schemes is evaluated in terms of torque and flux ripple and their transient response to step variations of the torque command. Moreover, a new torque and flux ripple minimization technique is also proposed to improve the performance of the DTC drive. Based on the experimental results, the analysis has been presented.

Keywords: Induction motor; Field oriented control; Direct torque control; Digital signal processor

1. Introduction

Research interest in induction motor sensorless drives has grown significantly over the past few years due to some of their advantages, such as mechanical robustness, simple construction and maintenance. Present efforts are devoted to improve the sensorless operation, especially for low speed, and to develop robust control strategies. The first paper was presented on field oriented control (FOC) for induction motors [1,2] in 1992. Since that time, the technique has been completely developed and today is established from the industrial point of view. These drives are an industrial reality and are available on the market by several producers and with different solutions and performances [3–10]. Later, a new technique for the torque control of induction motors was developed as direct torque control (DTC) [20,21]. Since the beginning, the new technique has been characterized by simplicity, robustness and good performance [15–20]. Using DTC, it is possible to obtain good dynamic control of the torque without any mechanical transducers on the shaft. The basic scheme of DTC is preferable in the high power range applications where a lower inverter switching frequency can

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Nomenclature

i_{ds}	d axis stator current
i_{dr}	d axis rotor current
i_{qs}	q axis stator current
i_{qr}	q axis rotor current
L_r	rotor inductance
L_s	stator inductance
L_m	mutual inductance
p	number of pairs of poles
R_r	rotor resistance
R_s	stator resistance
θ_e	instantaneous flux position
Ω	mechanical speed
ω_e	synchronous speed or dominant frequency
ω_s	slip frequency
ω_r	rotor electric speed
Ψ_s	stator flux linkage
Ψ_{ds}	d axis stator flux linkage
Ψ_{qs}	q axis stator flux linkage
Ψ_{dr}	d axis rotor flux linkage
Ψ_{qr}	q axis rotor flux linkage
T_{em}	electromagnetic torque
v_s, i_s	stator voltage and current

justify higher current distortion. Several papers have been published on FOC and DTC in the last 30 years, but only a few of them have aimed to emphasize the differences, advantages and disadvantages [15]. In this paper, the attention will be mainly focused on the direct FOC (sensorless) and DTC control algorithms that are more suitable in small and medium power range applications.

The name direct torque control is derived from the fact that on the basis of the errors between the reference and the estimated values of torque and flux, it is possible to control directly the inverter states in order to reduce the torque and flux errors within pre-fixed band limits. Unlike FOC, DTC does not require any current regulator, co-ordinate transformation and PWM (pulse width modulation) signals generator as consequence timers. In spite of its simplicity, DTC allows good torque control to be obtained in both steady state and transient operating conditions. The problem is to quantify how good the torque control is with respect to FOC. In addition, this controller has very little sensitivity to parameters detuning in comparison with that of FOC [15]. On the other hand, it is well known that DTC presents some disadvantages that can be summarized in the following points:

(1) Difficulty to control torque and flux at very low speed;
(2) High current and torque ripple;
(3) Variable switching frequency behavior;
(4) High noise level at low speed;
(5) Lack of direct current control.

Thus, on the basis of the previous studies, the aim of this paper is to give a fair comparison between the two techniques (FOC and DTC) in both steady state and transient operating conditions. The comparison is useful to indicate to users which one of the two schemes can be efficiently employed in the various applications that today require torque control.