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Active power and MRAS based rotor resistance identification of an IM drive

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ABSTRACT

This paper presents a new method of estimating the rotor resistance of an induction motor. This method is based on model reference adaptive system approach. The rotor resistance changes dramatically with temperature and frequency. The rotor resistance variation has a great influence on the FOC performance of an IM since the actual slip frequency deviates from their set value by rotor resistance variations. Therefore, the compensation of the parameter variation is vital especially in FOC of an IM. Three different methods of rotor resistance estimations, namely, electromagnetic torque equation, reactive power and active power equations, are discussed in this paper. Author proposes the third technique, which is an improvement over the two strategies Although all three schemes estimate the rotor resistance effectively, the proposed technique is superior to others in providing faster estimation approach. Simulation results of all three methods will be provided in order to confirm the superiority of proposed method.

1. Introduction

Field-oriented control (FOC) of induction motors (IM) has been applied in many industrial applications due to high dynamics performance and no brushes and commutators as we have in separately excited dc motors. However, the vector control is sensitive to the rotor resistance variation because of the rotor resistance is used in determining the slip frequency. So the compensation of rotor resistance mismatch is vital in high-performance FOC control of IM drives. Various identification methods for IM rotor resistance have been proposed [1–4] using model reference adaptive system (MRAS). Nait Said et al. have been applied reactive power approach for rotor resistance application [1]. The simulation results confirm the robustness of rotor speed estimation to rotor resistance mismatch. A current model rotor flux observer based model reference adaptive control system has been used for rotor resistance estimation [2]. The current model flux observer is an adjustable model and reference model for the proposed MRAS scheme is based on FOC condition of zero value for the rotor flux along the q-axis. The rotor resistance is adjusted such that the flux along the q-axis is driven to zero. A new model reference adaptive system speed observer for high-performance field-oriented control IM drives based on adaptive linear neural networks has been proposed [3]. An adaptation scheme based on reactive power and IM torque as reference models is used to rotor resistance estimation of indirect field-oriented induction motor drive [4]. The rotor resistance estimation only under speed transient state has been proposed in [7]. At steady-state condition the simultaneous estimation of rotor speed and rotor resistance is impossible by this approach. If the rotor resistance changes rapidly this method will fail to do parameter estimation. In general, the techniques for sensorless control of the IM include open-loop flux estimators using the stator currents and voltages, sliding mode, EKF, fuzzy logic, neural networks and flux observers [8–13]. The Extended Kalman Filter (EKF) is an optimal stochastic observer in the least-square sense for estimating the states of dynamic non-linear systems, and provides optimal filtering of the noises in measurement and inside the system if the covariances of these noises are known. However it is computationally expensive and requires a high sampling frequency so that a simple discrete-time

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equivalent model can be used. Sliding mode, fuzzy logic and neural network schemes provide accurate rotor resistance estimation for IM but with the expenses of more computational burden and so faster microcontroller and DSP for on line implementation. Model reference adaptive control approach based on induction motor torque equation has been applied for rotor time constant identification [14]. Even though this approach is elegantly simple and is very robust for high speed operation, however, it is less adequate for low speed operation due to the sensitivity of stator flux estimation to the stator resistance variations due to temperature and frequency variations when the back EMF voltage approaches the stator resistance voltage drop. The function of reactive power which could give the necessary information of the state of the flux, magnitude and position, has been applied for rotor time constant adaptation [15]. Even though the reactive power equation in ref. [15] is computed by using only the stator currents and voltages and it does not depend on the stator resistance, but it does depend on saturated parameters such as stator, rotor and magnetizing inductances.

Active power and MRAS based scheme for IM rotor resistance identification has been proposed by author. Another aspect of IM torque and reactive power equations application in rotor resistance estimation also are investigated. The shaft speed and rotor resistance will be estimated by two adaptive simple PI regulators, so the computation burden of microcontrollers will be much less than the other conventional methods such as EKF, sliding mode, fuzzy logic and neural networks. A 2.2 kW induction motor has been chosen to investigate the effectiveness of proposed method.

2. IM modeling

For the induction motor, if the stator current i_s and rotor flux ϕ_r are selected as the state variables, then the state equations can be expressed as Eq. (1) in the stationary reference frame [5].

$$\frac{\mathrm{d}}{\mathrm{d}t}\begin{bmatrix} i_s \\ \phi_r \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \\ & \end{bmatrix}\begin{bmatrix} i_s \\ \phi_r \end{bmatrix} + \begin{bmatrix} B_1 \\ 0 \end{bmatrix} v_s = Ax + Bv_s \tag{1}$$

$$i_s = \mathbf{C}x \tag{2}$$

where i_s is $[i_{ds}i_{qs}]^T$ stator current components in stationary reference frame, φ_r is $[\varphi_{dr}\varphi_{qr}]^T$ rotor flux components in stationary reference frame and υ_s is $[\upsilon_{ds}v_{qs}]^T$ stator voltage components in stationary reference frame.

$$\begin{aligned}
&A_{11} = -\{R_1/(\sigma L_1) + (1-\sigma)/(\sigma\tau_r)\}I = \mathrm{a}_{r11}I \\
&A_{12} = L_m/(\sigma L_1 L_2)(1/\tau_r)I - \omega_r J = a_{r12}I + a_{r12}J \\
&A_{21} = (L_m/\tau_r)I = a_{r21}I \\
&A_{22} = -(1/\tau_r)I + \omega_r J \\
&B_1 = 1/(\sigma L_1)I = b_1 I, \quad C = [I \quad 0] \\
&I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \quad J = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}
\end{aligned}$$

where R_1 and R_2 are stator and rotor resistance, L_1, and L_2 are stator and rotor self inductance, L_m is mutual inductance, σ is leakage coefficient, $\sigma = 1 - L_m^2/(L_1L_2)$, τ_r is rotor time constant, $\tau_r = L_2/R_2$ and ω_r is electrical motor angular velocity.

3. Introduction to MRAS

The model reference adaptive system is one of many promising techniques employed in adaptive control [6]. Among various types of adaptive system configuration, MRAS is important since it leads to a relatively easy-to-implement systems with high speed of adaptation for a wide range of applications. The basic principle is illustrated in Fig. 1. An error vector is derived using the difference between the outputs of two dynamic models, i.e. the reference and adjustable models. The reference model represents the actual system whereas the adjustable model uses a model whose structure is identical to that of

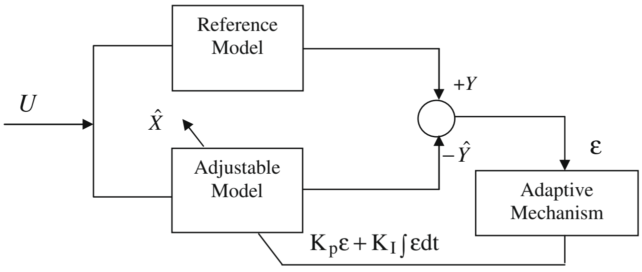

Fig. 1. Basic configuration of a MRAS.