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A new instantaneous reactive power based MRAS for sensorless induction motor drive

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ABSTRACT

A model reference adaptive system (MRAS) based speed estimator for sensorless induction motor (IM) drive is proposed in this paper. The MRAS is formed with instantaneous reactive power and the estimated stator current vector. Current, being a vector quantity, is configured in terms of reactive power, which is a scalar quantity. The advantage is that we need not equate either or both the in-phase and quadrature components of the current vector. The performance of the estimator under regeneration is an important aspect, which is studied in this paper through the small signal analysis. Graphical representation in the speed–torque domain gives a clear idea about the stable and unstable zones of operation in the regenerating mode. Sensorless IM drive along with the proposed MRAS is verified through computer simulation.

1. Introduction

Speed information is mandatory for the operation of an indirect vector controlled induction motor (IM) drive. The rotor speed can be measured through a sensor or may be estimated using voltage, current signals and the information of machine parameters. Use of speed sensor is associated with problems, such as, reduction of mechanical robustness of the drive, need of shaft extension, reduced reliability in hazardous environment, and increased cost. Therefore, a speed sensorless drive has a clear edge over the traditional vector controlled drive.

Various speed estimation methods are available in the literature. They are broadly classified as: (i) model based methods and (ii) signal injection based methods.

The signal injection based methods [1,2] perform well at zero speed. Also, parameter sensitivity is low. However, signal injection at higher frequency suffers from the following problems.

(i) Computational complexity,
(ii) the need of external hardware for signal injection and
(iii) the adverse effect of injecting signal on the machine performance.

On the other hand, the model based methods are simply compared to signal injection. The model based techniques suffer from observability problems [3,4] at low speed. Speed estimation through (i) voltage/current model, (ii) MRAS and

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Nomenclature

v_{sd}, v_{sq}	d and q components of the stator voltage vector
i_{sd}, i_{sq}	d and q components of the stator current vector
Ψ_{rd}, Ψ_{rq}	d and q components of the rotor flux vector
ω_{mr}	speed of rotor flux
ω_r	actual/measured rotor speed
ω_{rest}	estimated rotor speed
ω_{sl}	slip speed
σ	$= 1 - \frac{L_m^2}{L_s L_r}$, total leakage factor
k_{Ps}	proportional gain of the speed controller
k_{Is}	integral gain of the speed controller
k_{Pcd}	proportional gain of the d-axis current controller
k_{Icd}	integral gain of the d-axis current controller
k_{Pcq}	proportional gain of the q-axis current controller
k_{Icq}	integral gain of the q-axis current controller
c_{ij}	(i,j)th element of $adj(A)$

(iii) adaptive observers (full order or pseudo-reduced order) [5] are falling in this category. Among those, the MRAS is attractive. The basic structure of the MRAS is shown in Fig. 1. The error signal may be formulated with flux [6–8], back-emf [9,10], reactive power [11–15] and active power [16–18]. The flux-based MRAS (F-MRAS) is first introduced by Schauder in [6]. The F-MRAS is dependent on the variation of stator resistance and needs pure integrator in the reference model. So, the reference model may be drifted to saturation due to the presence of small dc off-set in the voltage/current signals. The pure integrator may be replaced by a low-pass filter, as reported in [7]. An ANN-based adaptive integration technique is available in [8]. Back-emf based MRAS (E-MRAS) is presented in [9,10]. The E-MRAS is also sensitive to the stator resistance variation. In addition, signal-to-noise ratio is reduced significantly at low speed due to the presence of derivative operator in the reference model. The reactive power based MRAS (Q-MRAS) is independent of the stator resistance variation. Q-MRAS is reported in [12,13,19,15,16,20]. In [12], the outer product of stator current ($\vec{i}_s$) and back-emf ($\vec{e}_m$) is considered. The $\vec{i}_s \otimes \vec{e}_m$ represents the air-gap reactive power computed across the magnetization branch. Some problems of [12] are mentioned as follows:

(i) Reference model is dependent on leakage inductances.
(ii) Derivative terms are used in the reference model which deteriorates the signal-to-noise ratio.
(iii) Flux estimation is required.
(iv) The estimator is unstable for some operating zones in the regenerating mode.

The first two problems may be eliminated, if the reactive power is computed at the machine terminal, instead of the air-gap. This is reported in [13]. The adjustable model of Ta et al. [13] requires flux and current derivatives, which deteriorates the performance of the sensorless drive during transient and at low speed. The flux-eliminated Q-MRAS is proposed in [15], where the emphasis is given on the estimation of rotor time constant. The estimation of rotor speed using the instantaneous and steady state reactive power based MRAS is reported in [19] for low speed sensorless operation. As, steady state reactive power is used in the adjustable model, the performance of the estimator (reported in [19]) during transient is not enough.

Kojabadi in [16] proposed an MRAS, which is formed with actual and estimated quantities of active power, torque and reactive power using the actual (i_{sd}, i_{sq}) and estimated ($\hat{i}_{sd}, \hat{i}_{sq}$) current signals. The author claimed that the active power based MRAS offers higher convergence over the torque and reactive power based MRAS for parameter adaptation. However, the

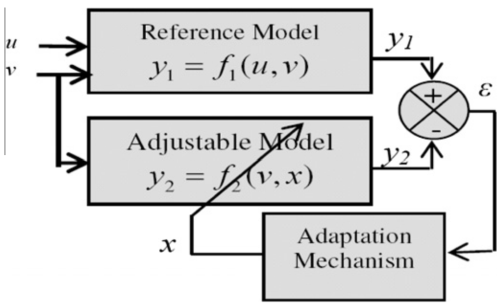

Fig. 1. Basic structure of MRAS.