

Implementation of a New MRAS Speed Sensorless Vector Control of Induction Machine

Idriss Benlaloui, Saïd Drid, *Senior Member, IEEE*, Larbi Chrifi-Alaoui, and Mohammed Ouriagli

Abstract—In this paper, a novel rotor speed estimation method using model reference adaptive system (MRAS) is proposed to improve the performance of a sensorless vector control in the very low and zero speed regions. In the classical MRAS method, the rotor flux of the adaptive model is compared with that of the reference model. The rotor speed is estimated from the fluxes difference of the two models using adequate adaptive mechanisms. However, the performance of this technique at low speed remains uncertain and the MRAS loses its efficiency, but in the new MRAS method, two differences are used at the same time. The first is between rotor fluxes and the second between electromagnetic torques. The adaptive mechanism used in this new structure contains two parallel loops having Proportional-Integral controller and low-pass filter. The first and the second loops are used to adjust the rotor flux and electromagnetic torque. To ensure good performance, a robust vector control using sliding mode control is proposed. The controllers are designed using the Lyapunov approach. Simulation and experimental results show the effectiveness of the proposed speed estimation method at low and zero speed regions, and good robustness with respect to parameter variations, measurement errors, and noise is obtained.

Index Terms—Induction motor, Lyapunov function, model reference adaptive system (MRAS), sensorless control, speed estimation, vector control.

NOMENCLATURE

s, r	Rotor and stator indices.
d, q	Direct and quadrature indices for orthogonal components.
\tilde{x}	Variable complex such as: $\tilde{x} = \text{Re}[\tilde{x}] + j\text{Im}[\tilde{x}]$ with $j^2 = -1$.
\tilde{x}	It can be a voltage as \tilde{u} , a current as \tilde{i} or a flux as $\tilde{\varphi}$.
\tilde{x}^*	Complex conjugate.
$R_{s,r}$, R_L	Stator and rotor resistances.
$L_{s,r}$, L_m	Stator and rotor inductances.
$T_{s,r}$	Stator and rotor time-constants ($T_{s,r} = L_{s,r}/R_{s,r}$).
σ	Leakage flux total coefficient ($\sigma = 1 - M^2/L_s L_r$).
M	Mutual inductance.
P	Number of pole pairs.
ω	Mechanical rotor frequency (rd/s).

Ω	Rotor speed (rd/s).
ω_s	Stator current frequency (rd/s).
ω_r	Induced rotor current frequency (rd/s).
ω_{ir}	Injected rotor current frequency (rd/s).
J_m	Inertia.
f	Coefficient of viscous.
Γ	Unknown torque.
Γ_e, Γ_{max}	Electromagnetic torque and maximal torque.
\sim	Symbol indicating measured value.
\wedge	Symbol indicating the estimated value.
$*$	Symbol indicating the command value.
IM	Induction motor.
MRAS	Model reference adaptive system.

I. INTRODUCTION

SPEED INFORMATION is mandatory for the operation of vector-controlled induction motor (IM) drive. The rotor speed can be measured through a sensor or may be estimated using voltage, current signals, and machine parameters. The use of speed sensor is associated with problems, such as, reduction of mechanical robustness of the drive, need of shaft extension, reliability reduction, and cost increase. Therefore, a speed sensorless drive has a clear edge over the traditional vector-controlled drive.

Several speed estimators for sensorless vector control of induction motor have been proposed as summarized recently in [1]. They can be divided into two groups, the model-based estimators and signal injection-based estimators. Among the first group, the MRAS, the adaptive Luenberger observers and the extended Kalman-filter. The main drawback of these model-based estimators is their insufficient performance at low speeds and parameters machine sensitivity. In order to overcome these problems, signal injection-based methods [2], [3] were developed. Although these methods perform well at low and zero speed regions, they suffers from, computational complexity, the need of external hardware for signal injection and the adverse effect of injecting signal on the machine performance. Therefore, due to their simplicity, model-based methods and especially MRAS-based methods are, until now, the most widely used.

Numerous MRAS-based on rotor flux, back electromotive force, reactive power, and outer product of stator voltage-current ($v_s^* \otimes i_s^*$) [4]–[10] have been proposed. However, rotor flux MRAS first introduced by Schauder [11], [5], remain the most popular MRAS strategy, and a lot of effort has been focused on improving its performance [1]. Indeed, the drawbacks of this technique are parameter sensitivity, especially to stator resistance, and pure integration problems [6], [12]–[14], which limit its performance at low and zero speed regions of operation.

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Implementation Of Sensorless Speed Control For Induction

Emilie Sanchez

A decorative red circular graphic with a gradient, appearing as a partial circle or a stylized arrow pointing to the right, located to the right of the author's name.

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