Proceedings of the American Control Conference
Arlington, VA June 25-27, 2001

Sensorless Speed Tracking of Induction Motor with Unknown Torque Base on Maximum Power Transfer

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Abstract: In this paper, a nonlinear indirect adaptive sensorless speed tracking controller for induction motor with the maximum power transfer is proposed. In this controller, only the stator currents are assumed to be measurable. The rotor flux and speed observers are designed to relax the need of flux and speed measurement. Besides, the rotor resistance estimator is also designed to cope with the problem of the fluctuation of rotor resistance. Stability analysis based on Lyapunov theory is also performed to guarantee that the controller design here is stable. Finally, the computer simulations and experiments are done to demonstrate the tracking performance of our design subject to maximum power transfer.

1. Introduction

In the early researches on induction motors, all system states are assumed to be measurable and all parameters are considered known. Under these assumptions, techniques such as field-orientation [1] and input-output feedback linearization [2] [3] are utilized to design the controller. The first paper concerning sensorless control problem can be traced back to 1981. In that paper, the vector control technique is utilized. After that, many research results on sensorless vector control have been proposed [4] [5], of which analyses are mainly based on the steady state behavior and only rough proves are supplied. Because of the complex dynamics of the induction motor, the overall system analysis is also complex. In [5], an indirect adaptive scheme is proposed. The controller design is under the assumption that all states are measurable and all parameters except the load toque are known *a priori*. Here, we follow this trend to design a full nonlinear adaptive sensorless controller to achieve both speed tracking and maximum power transfer [6] [7] based on the setup with speed and flux observer.

Given the above observation, the hereby-developed adaptive controller achieves both objectives of speed tracking and maximum power transfer AS A CONTINUOUS WORK OF Ref.[6] despite lack of precise information of rotor resistance, payload and speed. Specifically relax the need of speed and flux measurement, we design a set of adaptive rotor speed and fluxes observer and a rotor resistance estimator in order to replace those unavailable signals in controller design. In this paper, the simulation and experimental results are also given to verify the performance of controller design.

2. Observer Design

Assumptions

(A.1) *All parameters of induction motor are known, except the rotor resistance* R_r.

(A.2) *Among all states only the stator currents are measurable.*

(A.3) *The desired rotor speed should be a bounded smooth function with known first and second order time derivatives.*

(A.4) *The load toque is an unknown constant.*

Under these assumptions, the sensorless observers can be developed as stated in Ref.[5]. (The details are omitted here)

3. Controller Design

(A.5) *The damping term of the mechanical subsystem will have negligible effect relative to our control objective so that it will be* *omitted from our controller design.*

Theorem 1. (proof is omitted here) *If the dynamic system of an induction motor can be described as in [6], then the rotor speed ω can be driven to the desired speed ω_d with unknown load torque by the controller designed as follows:*

$$c \cdot V_{qs} = \frac{\psi_{dr}}{\sqrt{\psi_{qr}^2 + \psi_{dr}^2}} V \quad \text{and} \quad c \cdot V_{ds} = \frac{-\psi_{qr}}{\sqrt{\psi_{qr}^2 + \psi_{dr}^2}} V$$

where $$V = \left(-\mu\sqrt{\psi_a^2 + \psi_b^2}\right)^{-1} \left(-f_1(x) + \frac{\dot{\hat{p}}}{J} + U\right),$$

$$U = -k_1 z_1 - k_2 z_2 + V_{ref}, \quad V_{ref} = k_1 \omega_d + k_2 \dot{\omega}_d + \ddot{\omega}_d,$$

subject to the payload adaptation law as:

$$k_p \dot{\hat{p}} = R^T P e + e^T P R, \text{ where } p = T_L - T_{LN}$$

4. Simulation and experimental Results

There are two simulation and experimental results as follows:

(1). Speed Tracking without Load in experiment

(2). Speed Tracking Benchmark Results in Simulation

5. Conclusion

In this paper, we have proposed an indirect adaptive sensorless controller with maximum power transfer based on I/O feedback linearization scheme. For realization, we substitute the observed states and estimated rotor resistance into the controller. Finally, both the simulation and experimental results confirm the effect of our control design.

Reference

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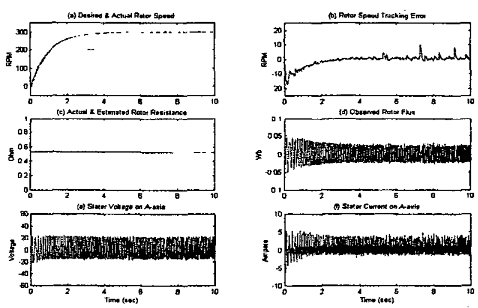

Figure 1: Speed Tracking 300(1-e^{-t}) rpm without load

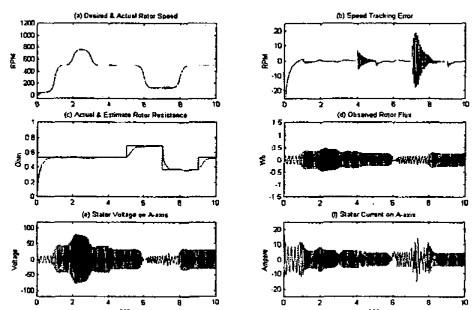

Figure 2: Speed Tracking Benchmark Result