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ScienceDirect
Journal of the Franklin Institute 348 (2011) 300–314
Journal of The Franklin Institute
www.elsevier.com/locate/jfranklin

A robust vector control for induction motor drives with an adaptive sliding-mode control law

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Received 4 January 2010; received in revised form 24 November 2010; accepted 30 November 2010
Available online 7 December 2010

Abstract

A novel adaptive sliding-mode control system is proposed in order to control the speed of an induction motor drive. This design employs the so-called vector (or field oriented) control theory for the induction motor drives. The sliding-mode control is insensitive to uncertainties and presents an adaptive switching gain to relax the requirement for the bound of these uncertainties. The switching gain is adapted using a simple algorithm which does not imply a high computational load. Stability analysis based on Lyapunov theory is also performed in order to guarantee the closed loop stability. Finally, simulation results show not only that the proposed controller provides high-performance dynamic characteristics, but also that this scheme is robust with respect to plant parameter variations and external load disturbances.
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1. Introduction

The induction motor is a complex structure that converts electrical energy into mechanical energy. Although induction machines were introduced more than a hundred years ago, the research and development in this area appears to be never-ending. Traditionally, AC machines with a constant frequency sinusoidal power supply have been used in constant-speed applications, whereas DC machines were preferred for variable speed drives, since they present

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doi:10.1016/j.jfranklin.2010.11.008

a simpler control. Besides, AC machines presented some disadvantages in comparison with DC ones, as higher cost, higher rotor inertia and maintenance problems. Nevertheless, in the last two or three decades we have seen extensive research and development efforts in variable-frequency, variable-speed AC machine drives technology [1], which have overcome some of the above disadvantages of the AC motors.

The development of field oriented control in the beginning of 1970s made it feasible to control the induction motor as a separately excited DC motor [1–3]. In this sense, the field-oriented technique guarantees the decoupling of torque and flux control commands for the induction motor. This means that when the flux is governed by means of controlling the current i_d, the torque is not affected. Similarly, when the torque is governed by controlling the current i_q, the flux is not affected and, therefore, it can be achieved transient response as fast as in the case of DC machines.

On the other hand, when dealing with indirect field-oriented control of induction motors, a knowledge of rotor speed is required in order to orient the injected stator current vector and to establish an adequate speed feedback control. Although the use of a flux estimator in direct field oriented control eliminates the need of the speed sensor in order to orient the injected stator current vector, this method is not practical. This is because the flux estimator does not work properly in a low speed region. The flux estimator presents a pole on the origin of the S plane (pure integrator), and therefore it is very sensitive to the offset of the voltage sensor and the parameter variations.

However, the speed or position sensor of induction motor still limits its applications to some special environments not only due to the difficulties of mounting the sensor, but also because of the need of low cost and reliable systems. The research and development work on a sensorless driver for the AC motor is progressing greatly. Much work has been done using the field oriented based method approach [4–7]. In these schemes the speed is obtained based on the measurement of stator voltages and currents. On the other hand, the induction motor model can be obtained using a Neural Network approach. In the work of Alanis et al. [8] a discrete-time nonlinear system identification via recurrent high order neural networks is proposed. In this work a sixth-order discrete-time induction motor model in the stator fixed reference frame is calculated using the proposed recurrent neural networks scheme.

Nevertheless, the robustness to parameter variations and load disturbances in the induction machines still deserves to be further studied and, in particular, special attention should be paid to the low speed region transients.

Thus, the performance of the field oriented control strongly depends on uncertainties, which are usually due to unknown parameters, parameter variations, external load disturbances, unmodelled and nonlinear dynamics, etc. Therefore, many studies have been made on the motor drives in order to preserve the performance under these parameter variations and external load disturbances, such as nonlinear control, optimal control, variable structure system control, adaptive control, neural control and fuzzy control [9–13]. Recently, the genetic algorithm approach has also been used in order to control the electric motors. The work of Montazeri-Gh et al. [14], describes the application of the genetic algorithm for the optimization of the control parameters in parallel hybrid electric vehicles driven by an electric induction machine.

To overcome the above system uncertainties, the variable structure control strategy using the sliding-mode has been focussed on many studies and research for the control of the AC servo drive system in the past decade [15–19]. The sliding-mode control can offer many good properties, such as good performance against unmodelled dynamics, insensitivity to parameter

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