Electric Power Systems Research 80 (2010) 143–151

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Very low speed and zero speed estimations of sensorless induction motor drives

M.S. Zaky *, M. Khater, H. Yasin, S.S. Shokralla

Electrical Engineering Department, Faculty of Engineering, Minoufiya University, Shebin El-Kom, Egypt

ARTICLE INFO

Article history:
Received 17 February 2008
Received in revised form 12 June 2008
Accepted 24 July 2009
Available online 25 October 2009

Keywords:
Sliding mode observer
Popov's hyper-stability
Stator resistance identification
Sensorless drives

ABSTRACT

Recently, speed sensorless control of induction motor drives received great attention to avoid the different problems associated with direct speed sensors. However, low speed operation with robustness against parameter variations remains an area of research for sensorless systems. Stator resistance is of utmost importance for good operation of speed sensorless systems in low speed region. In this paper, a sliding mode current observer for an induction motor is presented. An estimation algorithm based on this observer in conjunction with Popov's hyper-stability theory is proposed to calculate the speed and stator resistance independently. The proposed speed observer with parallel stator resistance identification is first verified by simulation. Experimental results are included as well as to demonstrate the good performance of the proposed observer and estimation algorithms at very low and zero speeds.

1. Introduction

Several methods have been recently proposed for speed estimation of sensorless induction motor drives. A comprehensive study of the different speed estimation techniques and their specific merits and demerits as well as their feasibility for estimating the rotor speed are presented and compared in ref. [1]. Some of these methods are based on a non-ideal phenomenon such as rotor slot harmonics. Such methods require spectrum analysis, which besides being time consuming procedures; it allows a narrow band of speed control [1,2]. Another class of algorithms relies on some kind of probing signals injected into stator terminals (voltage and/or current) to detect the rotor flux and consequently, the motor speed. These probing signals, sometimes, introduce a high frequency torque pulses, and hence speed ripple. In some cases a useful data may be distorted due to interference with the high frequency probing signals. Furthermore, a common drawback of frequency signal-injection methods is that their dynamic response is usually only moderate [2,3].

Despite the merits of the above methods of speed estimation near zero speed, they suffer from large computation time, complexity and limited bandwidth control. Alternatively, speed information can be obtained by using the machine model and its terminal variables like voltage and current. These include different methods such as model reference adaptive systems (MRAS) [10]; extended Kalman filters (EKF) [12]; adaptive flux observer [9]; artificial intelligence techniques [13]; and sliding mode observer (SMO) [7]. Machine model-based methods are characterized by their simplicity and good performance at high speeds; however they exhibit lower accuracy at low speeds mostly, due to parameter variations. Stator resistance plays an important role and its value has to be known with good precision in order to obtain an accurate estimation of the rotor speed in the low speed region [4].

Accurate knowledge of stator resistance is not required in indirect field oriented control of induction motor drives. Since correct operation of indirect vector controller requires an accurate value of the rotor resistance, most of the research efforts in the early days of vector control were directed toward development of online methods for rotor resistance identification. The situation has however changed dramatically with the advent of speed sensorless vector control and direct torque control [11].

The key problem in sensorless vector control of ac drives is the accurate dynamic estimation of the stator flux vector over a wide speed range using only terminal variables (currents and voltages). The difficulty comprises state estimation at very low speeds where the fundamental excitation is low and the observer performance tends to be poor. One of the most important reasons is the observer sensitivity to model parameter variations especially stator resistance. In the upper speed range, the resistive voltage drop is small as compared with the stator voltage; hence the stator flux and speed estimation can be made with good accuracy. At low speeds the stator frequency is also low. The stator voltage reduces almost in direct proportion, while the resistive voltage drop maintains its order of magnitude and becomes significant at low speed. The resistive voltage drop greatly influences the estimation accuracy of the stator flux and hence the speed estimation. On the other hand, considerable variations of the stator resistance are encountered when the machine temperature changes at varying load. These variations

* Corresponding author. Tel.: +20 0108265930; fax: +20 048 2235695.
E-mail address: mszaky78@yahoo.com (M.S. Zaky).

0378-7796/$ – see front matter © 2009 Published by Elsevier B.V.
doi:10.1016/j.epsr.2009.07.012