Available online at www.sciencedirect.com

ScienceDirect

IFAC-PapersOnLine 49-1 (2016) 106–111

Neural Network Observer Design for Sensorless Control of Induction Motor Drive

Shoeb Hussain*. Mohammad Abid Bazaz**

** National Institute of Technology Srinagar, J&K, India (e-mail: shoeb_15phd13@nitsri.net).*
***National Institute of Technology Srinagar, J&K, India (e-mail: abid@nitrsi.net)*

Abstract: In this paper a new neural network observer design is presented for a three phase Induction Motor drive. Neural Network observers have the advantage that these do not require the exact mathematical knowledge of the system. As such the observer design is easy, parameter independent and accurate. The speed control is achieved by Fuzzy Logic controller. Fuzzy logic controller is useful for non-linear systems in particular leading to robust control. Simulation is carried out in MATLAB/Simulink on a three phase Induction Motor drive in order to verify the physical behaviour of the system when subject to disturbances, change in load and speed.

Keywords: Induction motor; Artificial Neural Network; Observer; Fuzzy Logic; Vector Control.

1. INTRODUCTION

Induction motor (IM) drives are finding an increased use in industrial applications. Vector control implementation on IM drives has made the control of induction motor similar to separately excited DC motors. The control is simple and dynamic behavior of the drive is improved. Vector control implementation results in decoupled control of torque and flux through orthogonal decomposition of the three phase current. The three phase currents (i_a, i_b, i_c) are converted into two orthogonal DC components (i_d, i_q), where 'i_d' is responsible for control of magnetic flux and 'i_q' is responsible for speed/torque control (Bimal, 2003).

Speed control schemes for any Induction motor drive requires speed sensors for measurement of speed. Sensors however, make the system costly and also are unreliable. These disadvantages can be overcome by adopting sensorless approach. The sensorless control does not require any speed sensor for its operation. Speed in such cases can be estimated through calculations involving measured voltages and currents. Sensorless control does however increase numerical computations and complexity in the system design (S. Hussain, 2014).

Sensorless control can been carried out on Induction motor drives using different methods that are available in literature (Bimal, 2003; P. Vas, 1998). Amongst these the Observer based approach has been the most successful. Observer based models are state estimators that through the knowledge of input and output over a finite interval of time are able to determine the states of the system. The Observers have been designed for sensorless control of the Induction motor drive in order to estimate the speed of IM drives. Amongst these the Luenberger Observer and the Kalman Filter variations (i.e. Extended Kalman Filter, Unscented Kalman Filter, square root Unscented Kalman Filter) have been widely researched upon for sensorless IM drives. Even though these methods have been successfully implemented for sensorless operation (P. Vas, 1998) but they offer huge computational burden and tuning of Kalman filter is particularly tedious and time consuming. Moreover the performance of Unscented Kalman filter is unsatisfactory for load changes.

Artificial Intelligence (AI) techniques emulate the human behavior and thinking capabilities and embed them into computer program. AI techniques are finding increased use in power electronics. Artificial Neural Network (ANN) is one such AI technique that offers numerous advantages (M.N. Cirstea, 2002). The main features of ANN are the self-learning and self-organising capabilities. This makes it useful in designing an Observer based on ANN (Maurizio Cirrincione, 2007; Xiaodong Sun, 2013). Such a system offers advantages as it does not require the exact mathematical model of system and is mathematically less burdensome. In this paper, an ANN based observer is designed for sensorless control of the IM drive. Besides speed control has been achieved using Fuzzy Logic controller.

This paper is divided into 6 sections. Following the Introduction, Induction Motor model is presented in section II. Section III presents Neural Network observer. Fuzzy Logic controller is described in section IV. The simulation results are presented in section V followed by conclusions in section VI.

2. INDUCTION MOTOR MODEL

Vector Control of Induction motor requires the dynamic model of Induction motor and not the steady state model. The steady state model of the Induction motor is useful in only determining the steady state torque, current, various losses in

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.03.037

induction motor, efficiency etc. The dynamic model is suited for the development of high performance motor drives. The model of Induction motor is based upon the orthogonal current components, the direct current component 'i_d' and quadrature current component 'i_q' obtained from the transformation of the three phase stator current into two DC vectors, using the Park's transformation, in rotor reference frame. In figure 1, the dynamic model of Induction motor is shown along direct and quadrature axis.

Vector control aims at the control of Induction motor drive in a manner similar to that of a separately excited DC motor (Bimal, 2003). The independent control of torque and flux quantities can be exhibited in case of an induction motor through decoupling, possible only when the three line currents (i_a, i_b, i_c) are transformed to two orthogonal DC quantities (i_d *and* i_q). Vector control not only allows the control of magnitude and frequency but also phase control. The flux is independently controlled through direct current component i_d and the torque is controlled by controlling the quadrature current component i_q.

The Park's transformation equation necessary for decoupling in case of three phase induction motor is given as

$$I_{dq0} = TI_{abc} = \frac{2}{3}\begin{bmatrix} \cos\theta & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta + \frac{2\pi}{3}) \\ -\sin\theta & -\sin(\theta - \frac{2\pi}{3}) & -\sin(\theta + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} \quad (1)$$

The inverse transform is:

$$I_{abc} = TI_{dq0} = \frac{2}{3}\begin{bmatrix} \cos\theta & -\sin\theta & 1 \\ \cos(\theta - \frac{2\pi}{3}) & -\sin(\theta - \frac{2\pi}{3}) & 1 \\ \cos(\theta + \frac{2\pi}{3}) & -\sin(\theta + \frac{2\pi}{3}) & 1 \end{bmatrix} \begin{bmatrix} I_d \\ Iq \\ I_0 \end{bmatrix} \quad (2)$$

The rotor flux in a vector controlled Induction motor drive is given as

$$\psi_r = L_m i_{ds} \quad (3)$$

In the *dq* reference frame, the electromagnetic torque is given by

$$T_e = \frac{(3 \times P \times L_m)}{(2 \times 2 \times L_r)} \times (\psi_{dr} i_{qs} - \psi_{qr} i_{ds}) \quad (4)$$

The *d-q* frame rotates in space along with the rotor flux at synchronous speed. The *d-axis* component of flux is aligned in the direction of rotor flux which makes the *q-axis* component of rotor flux zero and the expression of the electromagnetic torque simplifies as follows

$$T_e = \frac{(3 \times P \times L_m)}{(2 \times 2 \times L_r)} \times (\psi_{dr} i_{qs}) \quad (5)$$

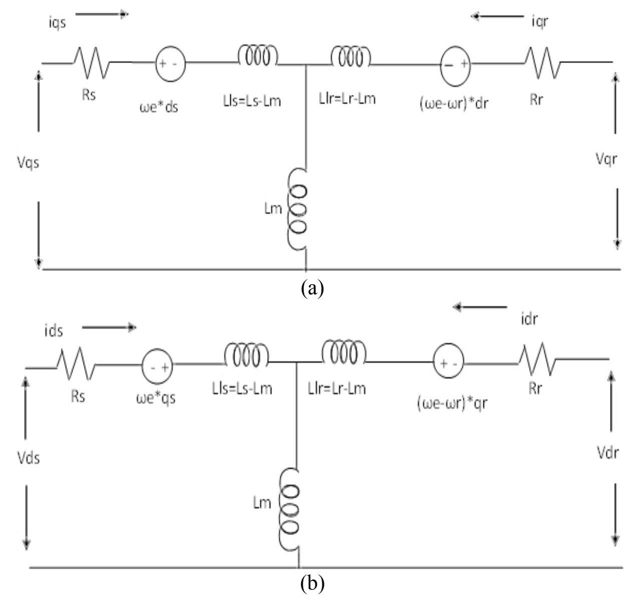

Fig. 1 Equivalent dynamic model of Induction motor a) quadrature-axis circuit b) direct-axis circuit

$$T_e = K_t \times i_{qs} \quad (6)$$

where, $\psi_{dr} = \psi_r$

The mechanical equation of the induction motor drive is represented as:

$$J\dot{\omega}_r(t) + f\omega_r(t) + T_L = T_e \quad (7)$$

where, 'J' is the moment of inertia, 'f' is the damping coefficient and 'T_L' is the external load.

Substituting (6) in (7)

$$\dot{\omega}_r(t) = -\frac{f}{J}\omega_r(t) + \frac{K_t}{J}i_q - \frac{1}{J}T_L \quad (8)$$

3. NEURAL NETWORK OBSERVER

Artificial Intelligence (AI) techniques have been widely adopted in electrical engineering field and none less in the electrical drive systems. A number of AI techniques are known in literature such as Expert systems, Fuzzy logic, and Artificial Neural Network (ANN). Amongst these, ANN is comparatively the most powerful known AI technique (M.N. Cirstea, 2002). ANN as is indicative emulates the functioning of human nervous system and hence incorporates human thinking into computer program.

ANN basically can be viewed as a set of computing systems in parallel coordination with each other. These computing systems are known as the neurons similar to the biological neurons. The neurons are interconnected and compute transmitted signals in order to achieve a certain desired task.

One of the most important feature of neural networks is the ability to learn and adapt to a certain scenario. The ANNs exhibit nonlinear behavior with automatic optimization and learning capabilities. The neural network is fed with the input