International Journal of Power Electronics and Drive System (IJPEDS)
Vol.2, No.4, December 2012, pp. 402~408
ISSN: 2088-8694

Artificial Neural Network Based Controller for Speed Control of an Induction Motor using Indirect Vector Control Method

Ashutosh Mishra *, Prashant Choudhary **
* Deptt. Of Electrical Engineering, RCET, Bhilai
Chhattisgarh, Bhilai - India

Article Info

Article history:

Received Jun 17, 2012
Revised Nov 10, 2012
Accepted Nov 23, 2012

Keyword:

FOC
IM
IVCIM
NN
PI

ABSTRACT

In this paper, an implementation of intelligent controller for speed control of an induction motor (IM) using indirect vector control method has been developed and analyzed in detail. The project is complete mathematical model of field orientation control (FOC) induction motor is described and simulated in MATLAB for studies a 50 HP(37KW), cage type induction motor has been considered .The comparative performance of PI, Fuzzy and Neural network control techniques have been presented and analyzed in this work. The present approach avoids the use of flux and speed sensor which increase the installation cost and mechanical robustness .The neural network based controller is found to be a very useful technique to obtain a high performance speed control. The scheme consist of neural network controller, reference modal, an algorithm for changing the neural network weight in order that speed of the derive can track performance speed. The indirect vector controlled induction motor drives involve decoupling of the stator current in to torque and flux producing components.

Copyright © 2012 Institute of Advanced Engineering and Science.
All rights reserved.

Corresponding Author:

Ashutosh Mishra
Deptt. Of Electrical Engineering, RCET, Bhilai Chhattisgarh, Bhilai - India

1. INTRODUCTION

An induction motor is an asynchronous AC (alternating current) motor. The least expensive and most widely used induction motor is the squirrel cage motor. The interest in sensor less drives of induction motor (IM) has grown significantly over the past few years due to some of their advantages, such as mechanical robustness, simple construction, and less maintenance. These applications include pumps and fans, paper and textile mills, subway and locomotive propulsions, electric and hybrid vehicles, machine tools and robotics, home appliances, heat pumps and air conditioners, rolling mills, wind generation systems, etc. So, Induction motors have been used more in the industrial variable speed drive system with the development of the vector control technology. This method requires a speed sensor such as shaft encoder for speed control.

However, a speed sensor cannot be mounted in some cases such as motor drives in a hostile environment and high-speed drives [1]. In addition, it requires careful cabling arrangements with attention to electrical noise. Moreover, it causes to become expensive in the system price and bulky in the motor size. In other words, it has some demerits in both mechanical and economical aspects. Thus current research efforts are focused on the so called “sensor less” vector control problem, in which rotor speed measurements are not available, to reduce cost and to increase reliability. The control and estimation of ac drives in general are considerably more complex than those of dc drives, and this complexity increases substantially if high performances are demanded. The main reasons for this complexity are the need of variable-frequency, harmonically optimum converter power supplies, the complex dynamics of ac machines, machine parameter variations, and difficulties of processing feedback signals in the presence of harmonics. The selection of drive for motor control is based on several factors such as [2]:

- One-, two- or four-quadrant drive,

- Torque, speed, or position control in the primary or outer loop,
- Single- or multi- motor drive,
- Range of speed control Does it include zero speed and field-weakening regions, Accuracy and response time,
- Robustness with load torque and parameter variations,
- Control with speed sensor or sensor less control,
- Type of front-end converter,
- Efficiency, cost, reliability, and maintainability consideration,
- And Line power supply, harmonics, and power factor consideration.

2. Over view of DIFFERENT CONTROLLING SCHEMES for Speed Control of Three Phase Induction Motor

2.1 Scalar control

Scalar control as the name indicates, is due to magnitude variation of the control variable only, and disregards the coupling effect in machine. For example, the voltage of machine canbe controlled to control the flux, and frequency or slip can be controlled to control the torque.However flux and torque are also function of voltage and frequency respectively.

2.2 Vector Control or Field Orientated Control (FOC)

In DC machine the field flux is perpendicular to the armature flux. Being orthogonal, these two fluxes produce no net interaction on one another. Adjusting the field current can therefore control the DC machine flux, and the torque can be controlled independently of flux by adjusting the armature current [9]. An AC machine is not so simple because of the interactions between the stator and the rotor fields, whose orientations are not held at 90 degrees but vary with the operating conditions. We can obtain DC machine-like performance in holding a fixed and orthogonal orientation between the field and armature fields in an AC machine by orienting the stator current with respect to the rotor flux so as to attain independently controlled flux and torque. Such a control scheme is called flux-oriented control or vector control. Vector control is applicable to both induction and synchronous motors.

The cage induction motor drive with vector or field oriented control offers a high level of dynamics performance and the closed-loop control associated with this derive provides the long term stability of the system .Induction Motor drives are used in a multitude of industrial and process control applications requiring high performances. In high-performance drive systems, the motor speed should closely follow a specified reference trajectory regardless of any load disturbances, parameter variations, and model uncertainties. In order to achieve high performance, field-oriented control of induction motor (IM) drive is employed. However, the controller design of such a system plays a crucial role in system performance. The decoupling characteristics of vector-controlled IM are adversely affected by the parameter changes in the motor. So the vector control is also known as an independent or decoupled control [10].

2.3 Proportional – Integral (PI) control

In this project complete mathematical model of FOC induction motor is described and simulated in MATLAB for studies a 50 HP(37KW) induction motor has been considered .The performance of FOC drive with proportional plus integral (PI) controller are presented and analysed. One common linear control strategy is proportional-integral (PI) control. The control law used for this strategy is given by

$$T = K_p e + K_i \int e \, dt$$

Its output is the updating in PI controller gains (K_p and K_i) based on a set of rules to maintain excellent control performance even in the presence of parameter variation and drive nonlinearity nonlinearityThe use of PI controllers for speed control of induction machine drives is characterized by an overshoot during tracking mode and a poor load disturbance rejection. This is mainly caused by the fact that the complexity of the system does not allow the gains of the PI controller to exceed a certain low value. At starting mode the high value of the error is amplified across the PI controller provoking high variations in the command torque. If the gains of the controller exceed a certain value, the variations in the command torque become too high and will destabilize the system. To overcome this problem we propose the use of a limiter ahead of the PI controller [11]. This limiter causes the speed error to be maintained within the saturation limits provoking, when appropriately chosen, smooth variations in the command torque even when the PI controller gains are very high. The motor reaches the reference speed rapidly and without overshoot, step commands are tracked with almost zero steady state error and no overshoot, load disturbances are rapidly rejected and variations of some of the motor parameters are fairly well dealt with [20].

2.4 Fuzzy Logic Control

Due to continuously developing automation systems and more demanding small Control performance requirements, conventional control methods are not always adequate. On the other hand, practical control problems are usually imprecise. The input output relations of the system may be uncertain and they can be changed by unknown external disturbances. New schemes are needed to solve such problems. One such an approach is to utilize fuzzy control. Since the introduction of the theory of fuzzy sets by L. A. Zadeh in 1965, and the industrial application of the first fuzzy controller by E. H. Mamadani in 1974, fuzzy systems have obtained a major role in engineering systems and consumer's products in 1980s and 1990s. New applications are presented continuously. A reason for this significant role is that fuzzy computing provides a flexible and powerful alternative to contract controllers, supervisory blocks, computing units and compensation systems in different application areas [12]. With fuzzy sets nonlinear control actions can be performed easily. The transparency of fuzzy rules and the locality of parameters are helpful in the design and maintenances of the systems. Therefore, preliminary results can be obtained within a short development period.Fuzzy control is based on fuzzy logic, which provides an efficient method to handle in exact information as basis reasoning. With fuzzy logic it is possible to convert knowledge, which is expressed in an uncertain form, to an exact algorithm. In fuzzy control, the controller can be represented with linguistic if-then rules [13].

2.5 Neural Network Control:

We introduce the multilayer perceptron neural network and describe how it can be used for function approximation. The back propagation algorithm (including its variations) is the principal procedure for training multilayer perceptrons, it is briefly described here. Care must be taken, when training perceptron networks to ensure that they do not over fit the training data and then fail to generalize well in new situations. Several techniques for improving generalization are discussed [18]. Three neural Network control techniques are model reference adaptive control, model predictive control, and feedback linearization control. These controllers demonstrate the variety of ways in which multilayer perceptron neural networks can be used as basic building blocks. But in this project we are used model predictive control for speed regulation of induction motor [14]. There are a number of variations of the neural network predictive controller that are based on linear model predictive controllers [19]. The neural network predictive controller that is discussed in next chapter [34] uses a neural network model of a nonlinear plant to predict future plant performance. The controller then calculates the control input that will optimize plant performance over a specified future time horizon. The first step in model predictive control is to determine the neural network plant model (system identification). Next, the plant model is used by the controller to predict future performance [15].

3. MATLAB Model of Indirect Vector Control IM Drive

3.1 Hysteresis Current Regulator:

The current regulator, which consists of three hysteresis controllers, is built with Simulink blocks. The motor actual currents are provided by the measurement output of the Asynchronous Machine block. The actual motor currents and reference current are compared in hysteresis type relay.

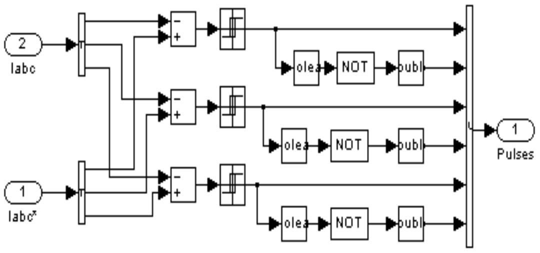

Figure 3.1. Hysteresis Current Regulator

3.2 MATLAB Simulation IVCIM based on Neural Network Predictive controller:

In this Matlab simulation NN controller is different from the PI and Fuzzy controller. NN controller take two input one is reference input and another input plant or IM speed output

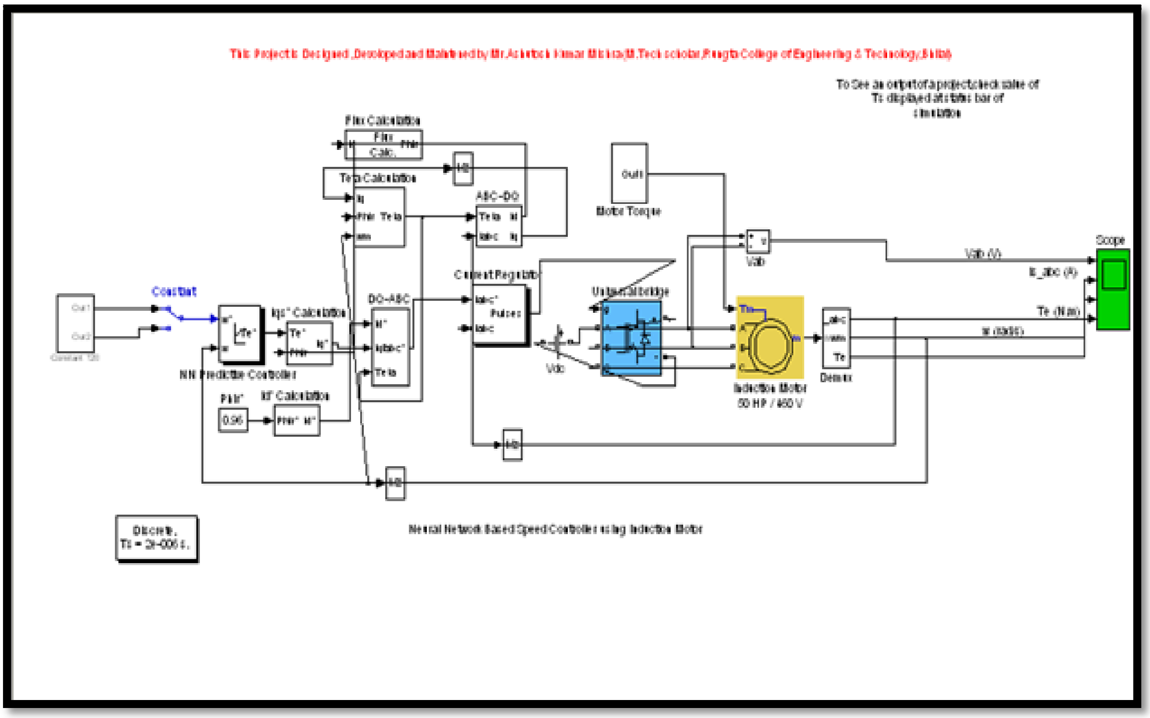

Figure 3.2. Matlab Simulink block diagram of indirect vector control using Neural Network controller

4. RESULTS AND ANALYSIS

4.1 Performance of Indirect Vector Control IM Using Neural Network predictive Control

I have used neural network predictive control for speed control of IVCIM. Simulink plant model is used which shown in figure 3.15(a). First identification of plant has been performed by use N N toolbox. After identification training data was generated which was accepted depending on comparison of plant output and plant input? Network was trained using this data to obtained optimum value of weight and biases using trainlm function (Levenberg Markquardt back propagation).weight and biases values were applied to NN Predictive controller. I have used 20 hidden layers, 8000 training sample and 200 epochs. The network has converged after 12 epochs when the sum squared error is 3.23681e-005 was obtained at learning rate of 0.05. Then simulation of IVCIM was performed using NN Predictive controller and results were recorded for motor current, speed and torque. The reference speed is 120 rad/sec, t is observed that motor pick up the reference speed at t =2.1 sec and it draw a low starting current 307.5 amp then the PI and fuzzy control. The Motor torque is also good then the PI and Fuzzy control which is 80.3 N-m and 14.3 N-m.

PI control results:

Neural Network predictive control results:

Case-I Results at Initial starting value at time t= 15.0 m sec for no load.
Motor current (I_{abc}) = 307.371 amps
Torque (Te) = 20.7 N/m

Case-II Results at no load for speed reach 120 red/sec at time t=2.0sec
Motor current (I_{abc}) = 21.24 amps
Torque (Te) = 20 N/m

.Case-III Results after applying 25N-m load torque at time t=2.2 sec.
Motor current (I_{abc}) = 22.12 amps
Torque (Te) = 21 N/m

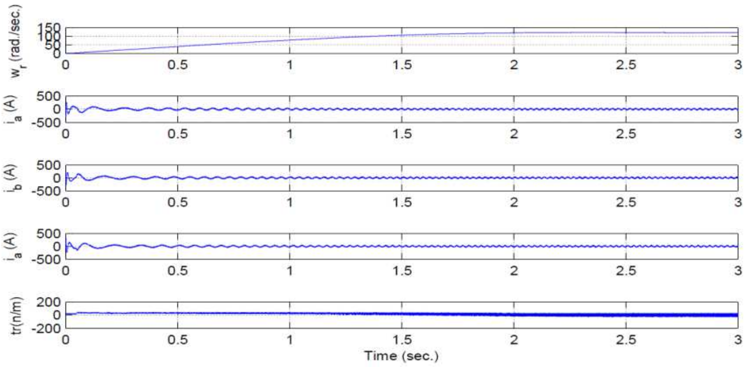

Figure 4.1. Performance of IVCIM with Neural Network control at no loads with reference speed 120 rad/sec.

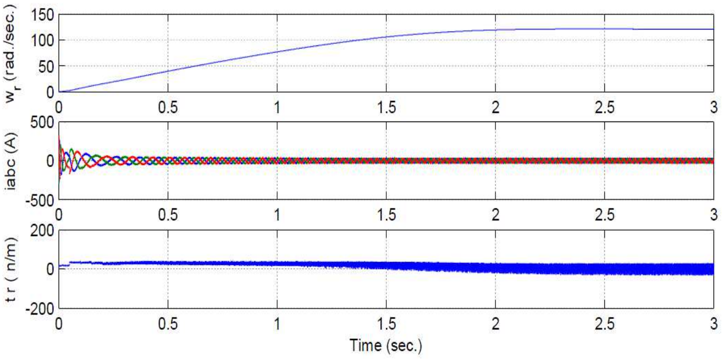

Figure 4.2. Neural Network control Response of IVCIM at no load with speed 120 red/sec

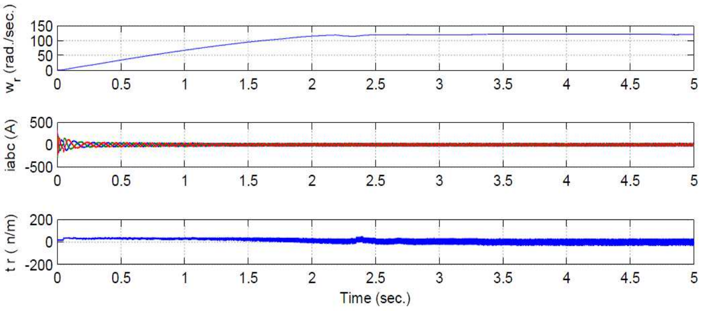

Figure 4.3. Neural Network control Response of IVCIM with Appling load torque =25N-m,at time t=2.2 sec

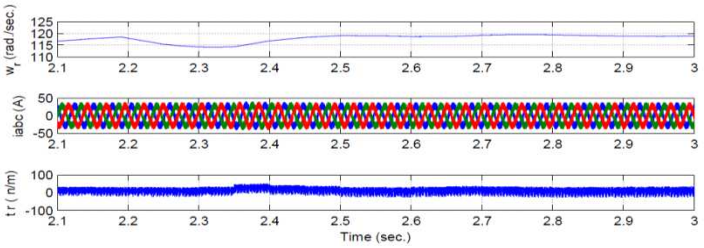

Figure 4.4. Neural Network control Response of IVCIM with Appling load torque =25N-m, at time t=2.1 sec to 3 sec

The performance of NN control has been compared with the dynamic loading conditions at different values of torques. Figure 4.12 shows the performance for aload torque variation of 0N-m to 25 N-m as against the previous values of no-load. It was observed that at 25N-m load torque average estimated value of speed decrease from 119.5 rad/sec (at no-load condition) to 114 rad/sec, after 0.2 sec. it gains the reference speed as figure 4.2.

5. CONCLUSION

This paper has successfully demonstrated and a properly designed PI, Fuzzy logic and Neural Network predictive controller.

- The NN predictive controller is more robust than the PI and fuzzy logic controller when load disturbances occurred.
- The NN predictive controller performance when certain motor parameters (i.e. current and motor torque) were increased by a factor was still quite good and far better than the PI and fuzzy logic controller's performance when the same parameters.
- NN predictive controller base makes the superior to PI and fuzzy logic control techniques.
  Required numerous trials and constant retuning to get reasonable performance

ACKNOWLEDGEMENTS

This project is made under the guidance of Mr. Prashant choudhary (Asscociate professor) in RCET, BHILAI. Mr. Prashant choudhary sir is a fantastic personality & he is my guide of my project. I would like to thanks my parents, teachers and my guide & my dear friends for helping me in this project and making it wonderful.

REFERENCES

[1] Li Zhen and Longya Xu, "On-Line Fuzzy Tuning of Indirect Field-Oriented an Induction Machine Drives", *IEEE Transactions on Power Electronics*, Vol. 13, No. 1, pp. 134-138, January 1998.
[2] L. A. Zadeh, "*fuzzy theory*", university of California, Berkely,1965
[3] Hassan Baghgar Bostan Abad, Ali Yazdian Varjani, Taheri Asghar, "Using Fuzzy Controller in Induction Motor Speed Control with Constant Flux", *Proceedings of World Academy of Science, Engineering And Technology*, Vol. 5, pp. 307-310, 2005.
[4] N. Mariun, S. B Mohd Noor, J. Jasni, and O. S. Bennanes, "A Fuzzy Logic Based Controller For An Indirect Vector Controlled Three-Phase Induction Motor", *IEEE IECON Conf.* Rec., Vol. 4, pp. 1-4, Nov. 2004.
[5] Vinod Kumar and R. R. Joshi, "Hybrid Controller based Intelligent Speed Control of Induction Motor", *Journal of Theoretical and Applied Information Technology*, pp. 71-75, 2005.
[6] M. N. Uddin, T. S. Radwan, and M. A. Rahman, "Performances of Fuzzy-Logic-Based Indirect Vector Control for Induction Motor Drive", *IEEE Transactions On Industry Applications*, Vol. 38, No. 5, pp. 1219-1225, Sept./Oct. 2002.
[7] P. Vas, Vector control of AC machines, New York: Clarendon, 1990
[8] B. K. Bose, *power electronics and AC Derive*. Englewood Cliffs, NJ. Prentic hall, 1986
[9] J. W Finch, DJ Atkinson and PP Acarnleg University of Newcastle up on Tyne, UK, "*General Principles of Modern Induction motor control*"
[10] F. Biaschke, "*The principle of field oriention as applied to new transvector closed loop control system for rotating field machine*", Siemens Rev, vol. 34, pp. 217-220, May 1972
[11] R. Krishna and A.S. Bharadwaj, "A Review of Parameter Sensitivity and Adaptation in Indirect Vector Controlled Induction Motor Drive Systems", *IEFE Transactions On Power Electronics*, Vol. 6, No 1, pp. 695-703, Oct 1991.
[12] Bhim Singh, B. N. Singh, and B. P. Singh, "Performance Analysis of a Low Cost Vector Controlled Induction Motor Drive: A Philosophy for Sensor Reduction", *IEEE IAS Annu. Meet. Conf.* Rec., pp. 789-794, 1997.
[13] J. S. R. Jang, "Fuzzy Controller Design Without Domain Experts", *IEEE International Conference on Fuzzy Systems*, 8-12 March 1992 Page(s): 289 – 296.
[14] Brian Heber, Longya Xu, and Yifan Tang, "Fuzzy Logic Enhanced Speed Control of an Indirect Field-Oriented Induction Machine Drive", *IEEE Transactions on Power Electronics*, Vol. 12, No. 5, pp. 772-778, September 1997.
[15] A. Miloudi and A. Draou, "Variable Gain PI Controller Design For Speed Control and Rotor Resistance Estimation of an Indirect Vector Controlled Induction Machine Drive", *Conference Record of the IECON '02 Sevilla, Spain*, Vol. 1, pp. 323-328, Nov 2002.
[16] Adel Merabet, Mohand Ouhrouche and Rung-Tien Bui, "*Neural Generalized Predictive Controller for Induction Motor*". Volume 1 Number 1 pp. 83–100, University of Quebec at Chicoutimi.2006
[17] K. S. Narendra and K. Parthasarathy, "Identification and control of dynamic systems using neural networks", *IEEE Trans. Neural Networks*, vol. 1, pp. 4-27, Jan. 1990.

[18] Seyed Hossein HOSSEINIand Mohamad Reza BANAEI "*Neural network speed controller for induction motor based on feedback linearization*".
[19] Jianrong Bu, Longya Xu, "A High Performance Full Fuzzy Controller for Induction Machine Drives", *IEEE APEC Conf.*, Vol. 2, pp. 592-596, 1998.
[20] P. Vas, and J. Li, "*Simulation Package for Vector Controlled Induction Motor Drives*", Oxford University press, 1993.

BIOGRAPHIES OF AUTHORS

Ashutosh Mishra was born in 14 of july in the year 1978. He recieved his batchers degree (BE) from LNCT from barkatullah university bhopal in 2000 in ELECTRICAL ENGG. He is pursuing his Masters (ME) in POWER ELECTRONICS ENGG from rungta college of engg & technology, bhilai. Presently he is working as a SR. LECTURER in RSR rungta college of engg & technology, bhilai in E&E deptt. Ashutosh has total teaching experience is approximately about of 7 years in different organizations in bhilai since 2004 in csvtu & he is teaching various subjects of electrical & electronics engg .

Prashant Kumar Choudhary was born in 22 may 1982 in jamshedpur (tata nagar). He recieved his batchelor's degree (BE) from BIT mesra in 1999. He has completed his Master's (M TECH) from BIT durg from chattisgarh swami vivekanand technical university from chaattisgarh in control system engg. Presently he is working as asscociate professor in rungta college of engg & technology, bhilai since 2004 in the deptt of electrical engg & teaching various subjects of electrical engg .