ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 11, November 2016

Study of Vector Controlled Induction Motor using Artificial Intelligence

[1]Aladalli Sharanabasappa, [2] Dr. Pradeep B Jyoti, [3] Ms.Malini K V
[1][2] Rao Bahadur Y Mahabaleswarappa Engineering College, Ballari
[3] Sri Sairam College of Engineering

Abstract: **-- Induction motor is termed as the main work horse of an industry. It is essential to obtain high efficiency and maximum torque, which can be achieved by controlling the speed of induction motor. This paper presents an integrated system for speed control of vector controlled induction motor (IM).the simulated result allows users to compare results between traditional and artificial intelligent controllers. Field control method is the present trend of speed controlling method, because of its high efficiency and better power factor. Artificial intelligence namely, Fuzzy Logic and Neural network controllers are also utilized to maintain the constant speed when the load varies. Speed controlling can be achieved by decoupling the speed and reference speed into torque and flux producing components. Simulated load is applied to an induction motor and analyzed for both constant and variable loads.**

Index Terms:**—artificial neural network, dynamic modeling, vector control.**

I. INTRODUCTION

Vector control technique is an eminent method which can be implement into driver circuit of an Induction motor. It has been developed based on the field orientation principle, which decouples the flux and torque control in an induction motor [2]. It is suitable for high – performance variable speed drive applications. In an industry, human error causes hurdle, thus artificial intelligence can be implemented. Therefore an effective control method based on vector control technology can be developed and implemented in real time application. Artificial intelligent controller (AIC) possesses advantages as compared to the conventional PI, PID controllers. It is desirable that, transient and steady states of a high performance induction motor must be provided even during the operation. . Controllers with fixed parameters cannot provide these requirements [6]. Thus conventional controller used in the variable speed induction motor becomes poor during uncertainty of the drive Viz. load variations, mechanical parameter variations and practical temperature effect. Therefore control drive must be robust and adaptive. Thus AIC has been applied in control drives.

The objective of AI is to inject human intelligence in a computer so that the computer can behave intelligently like human being. This paper presents the speed control method of vector controlled induction motor drive, which involves decoupling of the speed and reference speed into torque and flux producing components. In this paper artificial neural network based control scheme is simulated. The performance of artificial neural network is compared with that of conventional controller. Performance of induction motor has been analyzed for constant and variable loads using the simulated model of induction motor. As shown in Fig.1.

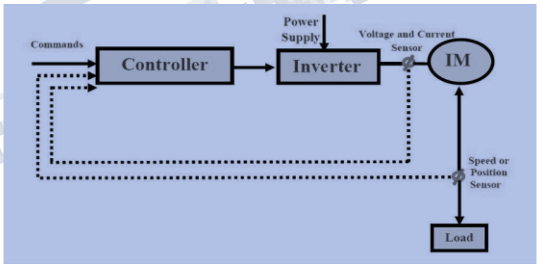

Fig.1 an Induction Motor Control System

It consists of controller, sensors, inverter and induction motor.

II. SIMULATION OF INDUCTION MOTOR

Behavior of an induction motor is expressed on time varying parameters such as voltage and torque. Equations of variable parameters are complicated. Thus, The stator and rotor variables like voltage, current and flux linkages are transferred to another stationary reference model. The simulated model is designed as shown in Fig. 2

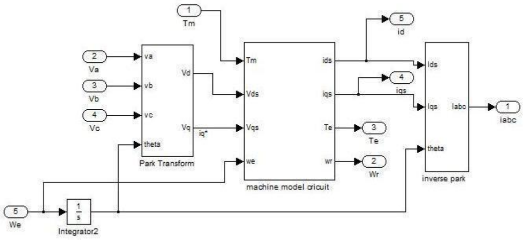

Fig. 2 Induction Motor Model

The motor drive has 3-phase balanced voltages as the input, and the abc currents as the outputs. The model basically involved the 3-phase to 2-phase (abc to d-q) conversion, which is known as "Park's Transformation". The conversion to d-q transformation is necessary for the dynamic model as simplified calculations can then be carried out on these imaginary DC quantities. It is often used in order to simplify the analysis of three-phase machines or to simplify calculations for the control of three-phase inverters. The d-q transformed voltages are given to the motor model along with the load torque and reference speed. The output quantities are Electromagnetic torque (Te), Rotor speed (r) and Stator currents (iqs and ids), which are in d-q quantities. Then these currents are transformed to abc quantities by using Inverse park's transformation. The complete Simulink model of the vector controlled induction motor drive with flux controller, vector controller, PI controller and PWM inverter is shown in fig. 3.

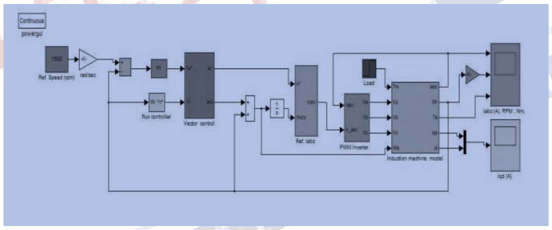

Fig. 3 Induction motor with PI controller

III. ARTIFICIAL INTELLIGENT CONTROLLER

Artificial neural networks are nonlinear information (signal) processing devices, which are built from interconnected elementary processing devices called neurons. An Artificial Neural Network (ANN) is an information-processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information does. It is composed of a large number of highly interconnected processing elements (neurons) working together to solve specific problems. An ANN is configured for a specific application viz. data classification, pattern reorganization, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons as shown in Fig.4.

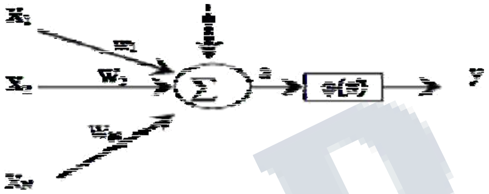

Fig.4 Representation of the artificial neuron

A neural network is parallel – distributed processor that stores experimental knowledge. Knowledge is procured by the network through a learning process and inter-neuron connection strengths known as synaptic weights which are used to store the knowledge. The basic element of an ANN is the neuron which has a summer and an activation function as shown in Fig.4. The mathematical model of a neuron is given by:

$$y = \varphi\left(\sum_{i=1}^{N} w_i * x_i + b\right) \qquad \ldots\ldots\ldots\ldots..(1)$$

Where (x1, x2… xN) are the input signals of the neuron, (w1, w2… wN) are their corresponding weights and b a bias parameter. is a tangent sigmoid function and y is the output signal of the neuron.

The ANN shown in Fig. 5 can be trained by a learning algorithm which performs the adaptation of weights of the network iteratively until the error between target vectors and the output of the ANN is less than a predefined threshold. Nevertheless, it is possible that the learning algorithm did not produce any acceptable solution for all input–output association problems. The most popular supervised learning algorithm is back-propagation , which consists of a forward and backward action. In the forward step, the free parameters of the network are fixed, and the input signals are propagated throughout the network from the first layer to the last layer. In the forward phase, we compute a mean square error.

$$E(k)=\frac{1}{N}\sum_{i=1}^{N}\left(d_i(k)-y_i(k)\right)^2 \qquad \text{...............(2)}$$

where di is the desired response, yi is the actual output produced by the network in response to the input xi, k is the iteration number and N is the number of input-output training data. The second step of the backward phase, the error signal E(k) is propagated throughout the network of Fig. 5 in the backward direction in order to perform adjustments upon the free parameters of the network in order to decrease the error E(k) in a statistical sense. The weights associated with the output layer of the network are therefore updated using the following formula:

$$w_{ji}(k+1)=w_{ji}(k)-\eta\frac{\partial E(k)}{\partial w_{ji}(k)} \qquad \text{…....(3)}$$

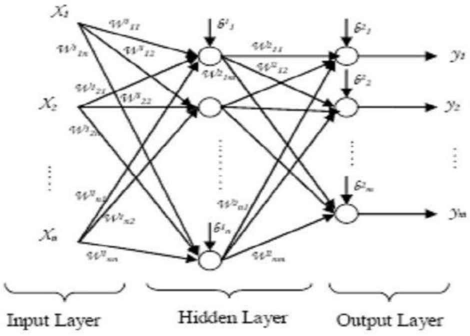

Fig.5 Structure of neural network

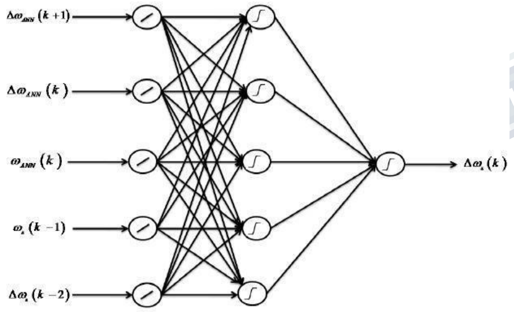

Fig. 6 Neural network speed controller

Where wji is the weight connecting the jth neuron of the output layer to the ith neuron of the previous layer, is the constant learning rate. Large values of may accelerate the ANN learning and consequently fasters convergence but may cause oscillations in the network output, whereas low values will cause slow convergence. Therefore, the value of has to be chosen carefully to avoid instability. The proposed Neural network controller is shown in Fig.6, Fig 7 and Fig.8.

IV. PERFORMANCE ANALYSIS INTELLIGENT CONTROLLER BASED INDUCTION MOTOR DRIVES

A complete simulation model for vector controlled Induction motor drive incorporating PI and Neural network controller is developed. Vector control of Induction motor drive with Neural network controller is designed by adjusting the weights to get simulated results. The performance of the artificial intelligent based induction motor drive is investigated at different operating condition. In order to prove the superiority of the Neural Network controller, a comparison is made with the response of convention PI based induction motor drive. The parameter of the induction motor considered in this study is summarized in Appendix 'A'. The performances of the vector controlled induction motor with ANN controllers are presented at constant load and variable load. The behavior of the PI controller with Neural Network controller are shown in Fig.9, Fig.10 Fig.11,Fig.12 and Fig.13 at constant load and variable load conditions.

At constant load conditions:

A drive with PI controller has a peak over shoot, but in case of neural network controller it is eliminated as shown in Fig.9 and Fig.10. The PI controller is tuned at rated conditions in order to make a fair comparison. Fig.9 and Fig. 10 show the simulated starting performance of the drive with PI. Even though the PI controller is tuned to give an optimum response at this rated condition, the AI controller yields better performances in terms of faster response time and lower starting current. It is worth mentioning here that the performance obtained by the proposed model is 13 times faster than the P-I controller, i.e. it achieves the steady state 13 times faster than the P-I controller. Also it is 2.1 times faster than that obtained earlier by using AI controller

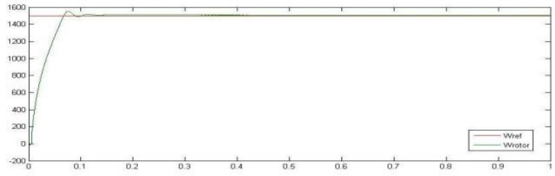

Fig. 9(a) Rotor speed with PI controller

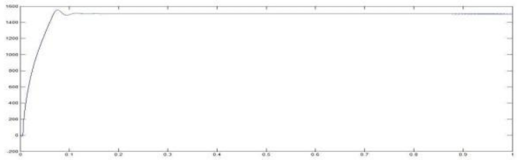

Fig. 9(b) Rotor speed with neural network controller

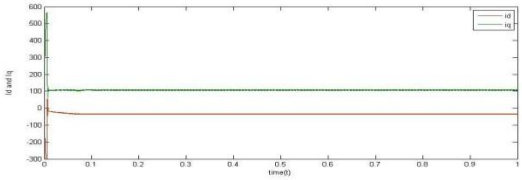

Fig.10 I_d and I_q currents of Induction motor drive

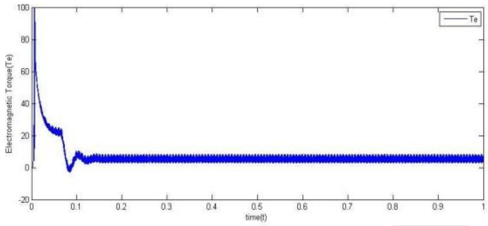

Fig 11 Load torque of Induction motor drive

At variable load conditions:

Drive with PI controller speed response has small peak at 0.4 sec, but in case of neural network speed response is quick and smooth response as shown in Fig. 12. Fig.13. shows Speed, Torque, I_{abc} characteristics with P-I controller. Fig.13 Speed, Torque,I_{abc} characteristics with neural-network controller. Fig.12 & Fig.13 show the speed responses for step change in the load torque using the PI and neural network, respectively. The motor starts from standstill at load torque = 2 N.ms and, at t =0.4 s, a sudden full load of 15 Nms is applied to the system controlled by neural network but because the time taken by the P-I controlled system to achieve steady state is much higher than neural network, so the step change in load torque is applied at t = 1.25 sec.The motor speed follows its reference with zero steady-state error and a fast response using a neural network. On the other hand, the PI controller shows steady-state error with a high starting current. It is to be noted that the speed response is affected by the load conditions. This is the drawback of a PI controller with varying operating conditions. It is to be noted that the neural network controller gives better responses in terms of over- shoot, steady-state error, and fast response. These figures also show that the neural based drive system can handle the sudden increase in command speed quickly without overshoot, under- shoot, and steady-state error, whereas the PI-controller-based drive system has steady-state error and the response is not as fast as compared to the ANN. Thus, the proposed ANN drive has been found superior to the conventional PI-controller-based system

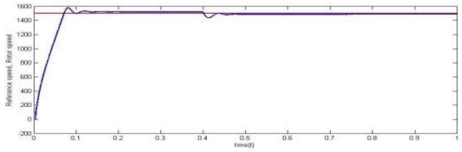

Fig.12 (a) Rotor speed a with PI controller

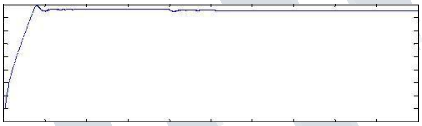

Fig.12 (b) Rotor speed a with neural network controller

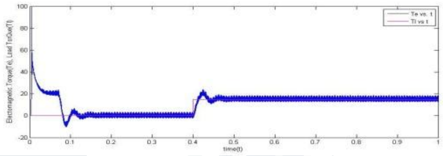

Fig.13 (a) Torque characteristics with PI controller

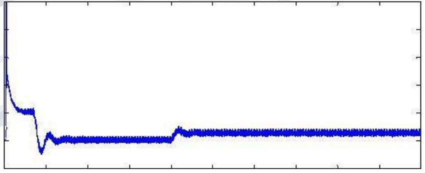

Fig.13 (b) Torque characteristics with neural network controller

Table I and II presents the performance comparison during steady state operation, during transient operation and in time domain analysis respectively.

Table I

Performance comparison between pi and neural Controllers during steady state operation.

Control strategies	Rise Time(s)	Time for speed regulation (s)
Conventional PI	0.24	0.25
ANN	0.08	0.04

Table II
Performance comparison between pi and neural Controllers during transient operation

Control strategies	Settling Time before changing the load (S)	Settling Time after Changing the load(s)	Overshoot
Conventional PI	0.58	0.2	Yes
ANN	0.09	0.02	No

V. CONCLUSION

An Artificial intelligent based vector controlled induction motor has been presented in this paper. The vector control strategy is developed with Neural network controller. The conventional vector control of induction motor is compared with the proposed ANN and their performance gives with neural network controller is better than PI controller. The comparative results prove that the performance of vector-control drive with neural network is superior to that with conventional P-I controller. Thus, by using neural network controller the transient response of induction machine has been improved greatly and the dynamic response of the same has been made faster. The robustness in response is evident from the results. Since exact system parameters are not required in the implementation of the proposed controller, the performance of the drive system is robust, stable, and insensitive to parameters and operating condition variations. The performance has been investigated at different dynamic operating conditions. It is concluded that the proposed ANN has shown superior performances over the PI controller and has its transient response 13 times faster than a simple P-I controlled system and also 2.1 times faster than earlier proposed system. Some of the advantages of Neural Controller are reduced number of rules, faster speed of operation and no need for modifications in membership function by conventional trial and error method for optimal response. This makes Neural Controller a easy-build and robust controller. The performances of the proposed Neural Controller based drive have been investigated at various operating conditions. A performance comparison between PI based drive and the proposed Neural Controller based drive has been presented. The proposed Neural Controller based IM drive has been found to be robust for high performance drive application.

Appendix A
The parameters of the induction motor are as follows:

$p = 6$ $R_s = 2.2$ Ohm $R_r = 0.9$ Ohm
$L_{ss} = 10$ $L_r = 2.0$ $L_m = 69.3$
$f = 50$Hz $J = 0.031$kg m^2 $B = 0.012$
$V_{dc} = 230$V Proportional gain = 2.0 Integral gain = 0.1240

REFERENCES

[1] K. L . Shi, T . F. Chan, Y. K. Wong and S. L . HO, Modelling and simulation of the three phase induction motor Using SIMULINK, Int.J. Elect. Enging. Educ., Vol. 36, 1999, pp. 163–172.

[2] Tze Fun Chan and Keli Shi, Applied intelligent control of induction motor drives, (IEEE Willey Press, First edition, 2011).

[3] P.C. Krause, Analysis of Electrical Machinery and Drives System, (IEEE Willey Press, 2002).

[4] Dynamic Simulation of Induction Motor Drive Using Artificial Intelligent Controller, P.M. Menghal* Member, A. Jaya Laxmi + Member

[5] K. S. Sandhu and Vivek Pahwa,Simulation study of Three phase induction motor with variation in moment of inertia,ARPN Journal of Engineering and Applied Sciences, Vol-4, No-6, Aug 2009.

[6] S. J. Chapman, Electric machinery fundamentals, Singapore: McGraw-Hill, 1991.