Implementation and Comparative study of Three Phase Induction Motor Control Using PID Controller, Fuzzy Logic and Neural Network Techniques

T. D. Dongale*, T.G. Kulkarni*, S. R. Ghatage¥, R. R. Mudholkar*

#: School of Nanoscience and Technology, Shivaji University, Kolhapur
*: Department of Electronics, Shivaji University, Kolhapur.
¥: Department of Electronics, G.K.G College, Kolhapur

E-mail: tukaram.eln@gmail.com

Abstract - This paper present the implementation and comparative study of dynamic behaviour of three phase induction motor with different control strategies such as PID controller, Fuzzy Logic and Neural Network techniques. The system consist of three phase variable frequency drive with gating signal are generated using PIC microcontroller. The Simulink model of PID controller, fuzzy Logic and Neural Network is developed in Matlab environment. The real time response of all the control strategies shows the Neural Network based control mechanism having smooth and satisfactory system performance in terms of overshoot and settling time.

Keywords - PID, Fuzzy Logic, Neural Network, Simulink, PIC microcontroller, V/F Drive

I. INTRODUCTION

The induction motor is key element in many industrial applications. The wide application area of induction motors covers from mining industries to processing industries. These machines are directly operated on the mains or variable frequency drives. The speed control of these motor are difficult and tedious work, hence the verity of speed control mechanism are available for controlling speed of three phase induction motor. There are two types of popular controlling strategies are available such as scalar control and vector control. Apart from these two techniques, now a day’s soft computing techniques promises better result outcome than the conventional speed control techniques used in the induction motor speed control. [1]

This paper deals with implementation and comparative study of speed control of AC induction motor based on PID, Fuzzy logic and Neural Network Control. Among these PID is most popular closed loop technique. Some researchers have used Fuzzy, Fuzzy-PID and Neuro Fuzzy techniques in their applications. The fuzzy model is sophisticated sensor less tool for speed controlling application. But designing the rules for fuzzy control is something tedious which requires in sight knowledge of system to be controlled [2-4]. The fuzzy system is designed using Mamdani’s reasoning method which is simpler than TSK method. The results obtained using fuzzy control techniques are given as a training data for neural network for optimization purpose. NARMA-L2 controller is a Neuro-Controller available with MATLAB environment that provides the training facility for the system. This neural approach is intentionally added on to existing control algorithm in anticipation to offer better control especially for Non-linear application [2-4]. In the present work the three phase motor drive is implemented using PIC microcontroller.

The section II present the system block diagram and the hardware implementation of variable frequency drive. The section III deals with the development Simulink model of PID, fuzzy and Neural Network controller. The last section of this paper presents the result and discussion of speed control of three phase induction motor.

II. SYSTEM BLOCK DIAGRAM AND ITS DESCRIPTION

Fig 1: System Block Diagram [3-4]

The system block diagram for three phase induction motor control is shown in fig.1. The controlling and gating signal is generated by PIC 16F877A microcontroller. The system also consists of three phase inverter, isolation mechanism, Hall...
Effect speed sensor and front end Matlab Simulink model. The PIC microcontroller serves as a gating signal generator, which generate required signal and applied to gate drive circuit. The speed of operation is read by Hall Effect speed sensor and current speed is sent to Simulink through USART terminal of microcontroller. According to present speed the Simulink model will generate thee control signal which is fed back to microcontroller for PWM variation. Microcontroller also displays the current speed in RPS (Rotation per Second) on 16x2 LCD. The basic three phase voltage source inverter consists of six power MOSFETs with built in anti parallel diodes for freewheeling action. The IRFP460 N-MOSFET operates as a switch. AC voltage from the power grid is rectified filtered and applied to three phase inverter as DC source.

The three phase inverter is designed using power MOSFETs, which is shown in fig.2. The inverse diode associated with the device is sufficient to operate the circuit at higher frequencies. MOSFET technology promises to use much simpler and efficient drive circuits with significant cost benefits compared to bipolar devices. High voltage capacitor is connected across the rectifier out to provide low impedance path for high frequency current at switching of power devices.

The conduction sequence of MOSFET is 612, 123, 234, 345, 456, 561, avoids conduction of two MOSFETs of the same branch at time. There must be some short time delay between turn off MOSFET and turn on MOSFET, which must be greater than or equal to turn-off time of MOSFET (~20 nS). The real time controlling of three phase induction motor is shown in fig. 3.

III. SIMULINK MODEL DEVELOPMENT

A. PID Controller Simulink

The PID controller is widely used in power application. Such type of power application is presented in this paper. With proper tuning of PID parameter, the power application can achieve a robust design with the desired response time. The Simulink for three phase motor control application is shown in fig. 4. The actual speed of motor is sensed by Hall Effect speed sensor and the current speed is sent to Simulink by using PIC microcontroller. The Simulink consists of constant block which is used to set desired speed. Here auto tune PID is used for tuning plant or system. The transfer function of motor system is a second order type that exhibits overshoot and large settling time which forms the metrics of performance in the present study.

B. Fuzzy Controller Simulink

Fig.5 shows Simulink design model for Fuzzy Controller. It contain query instrument for accepting the real time present speed of motor through serial port of PIC microcontroller. The constant sets the reference speed. Error block generates the output which is the error between actual speeds and set speed that is applied to one input of Fuzzy controller and other to store the error in memory to compute a change in error. Multiplexer combine both inputs and gives it to Fuzzy controller. Real time scope is used to observe actual behavioral of a system. The instrument block is used to send output of Fuzzy Controller to PIC microcontroller.
C. Neural Network Simulink model using NARMA-L2 controller

The neural network widely used in many applications where large training data is available. The learning ability of neural networks and self-adapting algorithms makes it suitable for different applications. Once neural network is trained, it is easier to control output at desirable set points [6].

The only necessary condition is to provide training data to the neural network. NARMA-L2 controller in MATLAB is used for Speed controlling application. It has facility of training and adjusting the structure according to the requirement [5]. The control signals which are future outputs are applied as input to the NARMA-L2 controller. The NARMA-L2 performs the training using these samples trying for the linearization of the system performance [7-9].

Neural networks are used for training with large amount of data. Here, the effort has been made to train the neural network with minimum amount of data. The main approach is to train the network and control the speed of the motor. Fuzzy provides outputs within predetermined range of control signals. But this range is dependent on tuning of controller. If controller is properly tuned it works in the desired range, otherwise controlling goes beyond the range. This makes the tuning a tedious job [4, 10]. The neural controller eliminates this difficulty and makes controlling mechanism much simpler. Fig.5 shows training parameters of neural network.

The Fuzzy Simulink System forms a subsystem to the Neural Controller. The Neuro-Fuzzy approach is derived by a combination of the Fuzzy Subsystem and Neural Controller. The advantage of using neural control is that once it is trained using required data, it works in desired range and controlling mechanism becomes much easier as it provides single output for all the inputs. The algorithm for PIC microcontroller drastically becomes simpler. The time required for training the network depends on the training epochs and number of training samples. For this particular application only 3 training epochs were used. The training data and training performance of neural network are shown in fig.7 and fig.8. [4]

IV. RESULT AND DISCUSSION

The fig.9 shows the response of auto-tune PID controller. It shows transient response, steady state response, peak rise time, peak overshoot and settling time. The settling time of PID controller is 10.8 sec which is quite large. The rise time is 2.09 sec., peak overshoot time 4.91 sec. the above values are at P=1.086, I=0.3293 and D=0.8552. Auto-tune PID tuning response indicated little sluggish response in tracking the set point. It consists of overshoot due to the derivative action of PID controller. The rise time, settling time and peak time are
quite satisfactory but not good for second order system like motor control application. The response of fuzzy Simulink is shown in fig.10. Fuzzy Controller has offered negligible settling time and with almost no overshoot. It is better controlling action than that of the PID controller. The response of neural network is shown in fig. 11. This figure shows the best performance with minimum settling time and almost no overshoot to control response. Comparison of experimental results of all the controllers reveals that that speed controlling of AC induction motor with Neural Network controllers is smooth and system performance gives good result in terms of overshoot and settling time.

Figure 11: Neural Network Response (Speed Reference 20 RPS) [4]
REFERENCES

[1] Lini Mathew and Vivek Kumar Pandey, Design and development of fuzzy logic controller to control the speed of permanent magnet synchronous motor, Journal of Electrical and Electronics Engineering Research Vol. 3(3), March 2011, pp. 52-61


[5] Moleykutty George, Speed control of Separately Excited DC Motor, Faculty of Engineering and Technology, Multimedia University Melaka Campus, 75450 Melaka, Malaysia American Journal of Applied Sciences 5(3) : 227-233, 2008 ISSN 1546-9239


[9] Ashok Kusagur, Dr. S.F.Kodad, Dr.B.V.Sankar Ram, Modelling, Design and simulation of an Adaptive Neuro-Fuzzy Inference System(ANFIS) for Speed control of Induction motor, International Journal of Computer Applications(0975-8887) Volume 6-No.12, September 2010


Authors Profile

Mr. Tukaram Dongale was born in 1989 and he hails from Shendur, India. He did his Bachelors and Masters in Electronics specialized in Embedded Systems. He also qualified the State Eligibility Test for Lectureship (SET) and National Eligibility Test for Lectureship with Junior Research Fellowship (NET-JRF) during his second year of Masters itself. He has been awarded Merit Scholarship of the Shivaji University, Kolhapur for securing the first rank in his graduation and post graduation studies. Moreover he is also a recipient of the ‘Eklavya Scholarship’ for supporting his Masters studies. He has to his credit Ten research papers published in reputed international journals and author of three book ‘The Treatise on sensor interfacing (Germany, Lap-Lambert, 2012)’, ‘Annals of Scholarly Research in Electronics, (Germany, Lap- Lambert, 2012)’, ‘ZigBee and RFID Based System Design, (Germany, Lap- Lambert, 2012)’. His current research interests are Fuzzy Logic, Artificial Neural Network, Feedback Control System, Power Electronics, Smart sensor based systems design and Memristor.