DESIGN AND ANALYSIS OF SPEED CONTROL USING HYBRID PID-FUZZY CONTROLLER FOR INDUCTION MOTORS

M.SATISH KUMAR
M.Tech (EEE), Department of Electronics and Electrical Engineering, Helapuri Institute of Technology and Science, Eluru, A.P.

Mr. K.MAHESH
Assistant Professor, Department of Electronics and Electrical Engineering, Helapuri Institute of Technology and Science, Eluru, A.P.

Abstract

This paper presents a hybrid PID-Fuzzy control system for the speed control of a three-phase squirrel cage induction motor. The proposed method incorporates fuzzy logic and conventional controllers with utilization of vector control technique. This method combines the advantages of fuzzy logic controller and conventional controllers to improve the speed response of the induction motor. The design of fuzzy system consists of 9 fuzzy variables and 49 IF-THEN rules that define the behavior of the system. The FLC observes the loop error signal and correspondingly control the PID input error signal so that the actual speed signal matches the reference speed signal with reduced rise time, settling time, and peak over shoot. Implementation and simulation results using MATLAB/SIMULINK of various hybrid system controllers such as (PI-, PD-, and PID fuzzy) are compared along with conventional PI controller in terms of several performance measurements such as rise time (tr), maximum percent overshoot (Mp), settling time (ts), and steady state error (Ess) at various load conditions. The results verified the effectiveness of the proposed hybrid speed controller under different operating conditions and demonstrated improvements in performance in speed tracking and system's stability.

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. 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 harmonic PI controller can never achieve perfect control, that is, keep the speed of induction motor continuously at the desired set point value in the presence of disturbance or set point changes. Therefore, an advanced control technique such as fuzzy logic controller is needed. Fuzzy systems are applied in wide range of academic and industrial fields such as modelling and control, signal possessing, medicine, and etc. An important Fuzzy Logic application is finding a new solution for control problems that will be discuses later. The present paper discusses a Fuzzy Logic Based intelligent controller. A Fuzzy Logic Controller (FLC) does not need complex mathematical algorithms and is based on the IF_THEN linguistic rules. Principle of vector control method is the use of coordinate transformation which to produce the same rotating magnetic potential and transformed the same power as the standard. It creates equivalent relation among a three-phase winding, two-phase AC windings and the rotation of the DC winding in order to seek the equivalent model of induction motor windings of the DC motor. To establish a Simulation model of induction motor vector control system can effectively save control system design time and validate the algorithm.

2. Literature Review

As mentioned in previous section, induction motors have been widely used in industry application. Therefore, much attention is given to their control for various applications with different control requirements. In recent years, intelligent control methods such as fuzzy control, neural network control, and hybrid control have been proposed to enhance the performance of induction motors [9]. Different control methods for speed control of induction motor are reviewed in the following literature survey: 4 Senthilkumar et al. [10] presented a PID controller for three phase induction motor using V/F method. The used control scheme is based on constant volts per hertz ratio and PID controller. The PID controller is designed to generate the signals in order to turn on six Insulated-Gate Bipolar Transistors (IGBT) of a three-phase inverter. In the conclusion, he proposed to extend the controller with other soft computing techniques. Marwan et al. [11] proposed a fuzzy logic based speed control system for three phase induction motor using scalar control technique. The proposed controller design was simulated using MATLAB/SIMULINK software, and the performance of proposed system is analyzed with various operating conditions like different reference speed and change in load that applied to the motor. The result showed that FLC has faster response and better performance compared with PI controller. Sharda et al. [6] investigated the use of FLC scheme for controlling induction motor parameters such as starting current, flux, torque, and speed. They reported results on two cases: 1) induction motor controlled by PI controller, in which the three phase currents, acceleration curve, and output torque are investigated, and 2) induction motor controlled by FLC, in which the same performance parameters have been investigated. They reported that the performance is improved regarding magnitude of starting currents and also time response of acceleration. For example, with PI controller the amplitude of starting current is 500 A and the rise time is 0.7 sec. While, with FLC the amplitude of starting current is 200 A and the rise time is 0.55 sec. These results show that FLC has improved the rise time with less starting current compared with PI controller.

3. INDUCTION MOTOR AND CONTROL STRUCTURE

Vector control or field oriented control has invented by Blaschke [15] to emulate DC motor characteristics in an induction motor [4] and [16]. In general, an electrical motor can be thought of as controlled torque source. The torque is produce in the motor by the interaction between the magnetic field of the stator field and the current in the rotor. The stator field should maintain at a certain level, sufficiently high to produce a high torque, but not too high to result in excessive saturation of the magnetic circuit of the motor. By fixed stator field, the torque is proportional to the rotor current [17]. The construction of a separately excited DC motor ensures that the stator field is always orthogonal to the rotor field. Being orthogonal, there is no interaction between these two fields. Therefore, independent control of the rotor current and stator field is feasible where the current in the stator determine the system field, while the current in the rotor can be used as a direct mean of torque control [4], [17] and [18]. In squirrel-cage induction motor, the rotor current is not fed directly by an externally source but it result from induced e.m.f in the rotor winding. In other words, the stator current is the source of magnetic field in the stator and rotor current. Therefore, the control of induction motor is not simple as DC motor due to the interaction between the stator field and rotor field whose orientation is not always held at 90° but it is varying depending on the operation conditions. We can obtain DC motor like performance in an 9 induction motor by holding orthogonal orientation between the stator and rotor fields to achieve independently control of flux and torque. Such a scheme is called vector control or field oriented control [16] and [18]. First we will review the fundamentals of torque production and control in the DC motor.

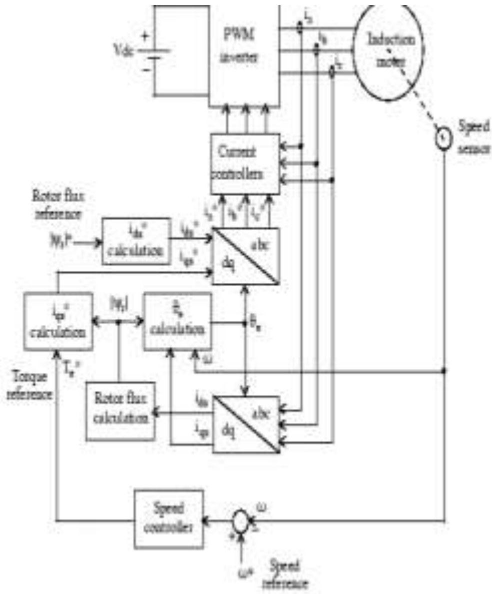

Figure 1: Block diagram of the indirect vector control technique

4. PROPOSED HYBRID CONTROLLER

4.1 PI Controller

Proportional-Integral, PI, controller is most widely adopted in industrial application due to its simple structure, easy to design and low cost. PI controller produces an output signal consist of a sum of error and the integral of that error. The error represents the difference between the desired motor speed and the actual motor speed.

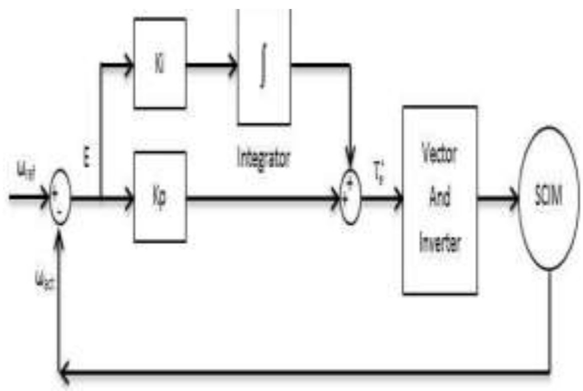

Figure 2: PI controller block diagram with vector control.

4.2. Fuzzy-Controller

The drawbacks of this PI controller are the occurrence of overshoot while starting, undershoot while load application and overshoot again while load removal [11]. In the fuzzification block, the inputs and outputs crisp variables are converted into fuzzy variables 'e', 'de' and 'du' using the triangular membership function shown in figure 3. The fuzzification block produces the fuzzy variables 'e' and 'de' using their crisp counterpart. These fuzzy variables are then processed by an inference mechanism based on a set of control rules contained in (3*3) table as shown in Table 1. The fuzzy rules are expressed using the IF-THEN form. The crisp output of the FLC is obtained by using MAXMIN inference algorithm and the center of gravity de-fuzzification approach. The performance of the fuzzy controller depends on the membership functions, their distribution and the fuzzy rules that describe the control algorithm. There is no formal method to determine the parameters of the controller accurately. In this controller, FL is used for pre-compensation [12, 13, 15, 16] of reference speed, which means that the reference speed signal ($w*$) is changed in advance in accordance with the rotor speed, so that a new reference speed signal ($w1*$) is obtained and the main control action is performed by PI controller. The speed error ($e(n)*$) and the change in speed error are the inputs to the FL, the output of the FL controller is added to the reference speed to generate a pre-compensated reference speed, which is to be used as a reference speed signal by the PI controller.

Figure 4 shows membership function for control variables.

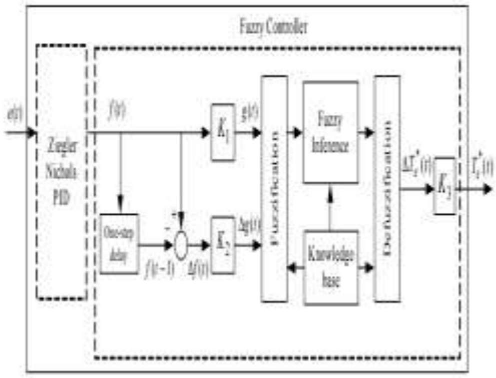

Figure 3 . The block diagram of the proposed controller

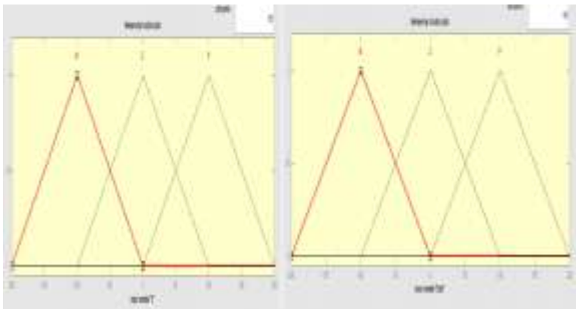

Figure 4: Membership function for Input variables

5. SIMULATION RESULTS

A complete mathematical model of FOC induction motor with a 50 HP (37KW) is simulated in MATLAB-SIMULINK. 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 Induction motor used in this is a 50 HP, 460 V, four-pole, 60 Hz motor having the following parameters:

Table 2: Parameter Values

Rated Power (P)	50 Hp
Voltage	460 V
R_s	0.087Ω
L_{ls}	0.8mH
L_m	34.7mH
R_r	0.228 Ω
L_{lr}	0.8mH

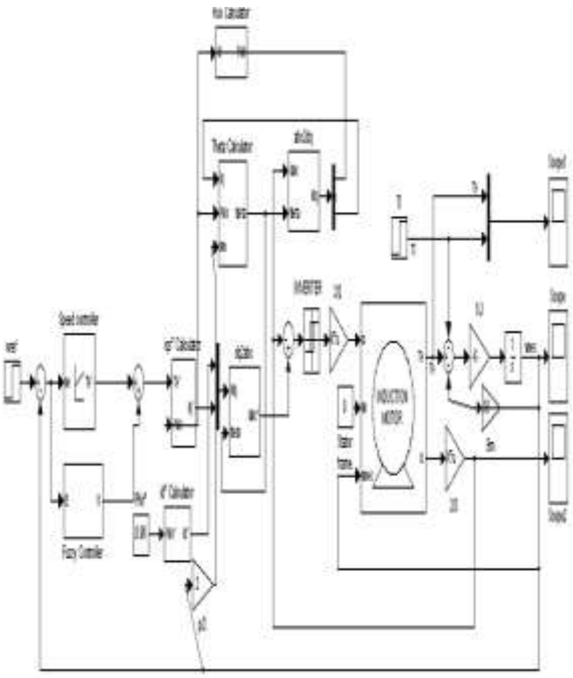

Figure 5: SIMULINK Model of Induction motor using hybrid PI -Fuzzy controller

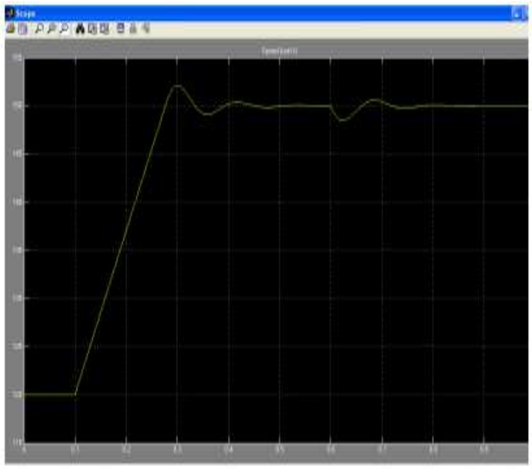

Figure 6: Speed Response of Induction Motor using PI -Control.

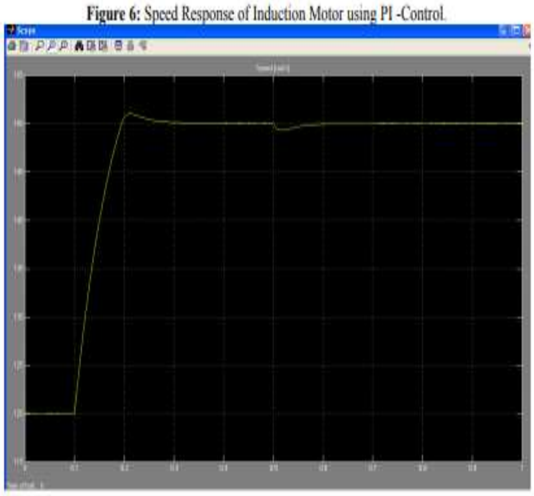

Figure 7: Speed Response of Induction Motor using hybrid PI-fuzzy Control.

6. CONCLUSION

The proposed controller has exhibited the combined advantages of a PI controller and a FLC. Hybrid controller produces better performances in terms of rise time, overshoot, undershoot and settling time. There is no steady-state error in the speed response during the operation. Good torque response is obtained with hybrid controller at all time instants and speed response is better than FL and PI controllers. The speed response with this controller has no overshoot and settles faster in comparison with FL controller. It is also noted that there is no steady-state error in the speed response during the operation when hybrid controller is activated. Good torque response is obtained with hybrid controller at all time instants and speed response is better than FL and PI controllers. There is a negligible ripple in speed response at hybrid controller in comparison with PI and FL controllers.

REFERENCES

[1]. Leonhard, W. (1995)," Controlled AC Drives: A Successful Transfer from Ideas to Industrial Practice", CETTI, pp1-12.

[2]. A.Mechernene, M.Zerikat & M.Hachblef, "Fuzzy Speed Regulation for Induction Motor Associated With Field-Oriented Control", IJSTA, Vol. 2, pp 804-817.

[3]. I. Birou & V. Maeir (2009)," Indirect Vector Control of an Induction Motor with Fuzzy-Logic based Speed Controller", 22311963 2261 Vol. 6, Issue 5, pp. 2253-2261

[4]. V. Kumar & R. Joshi (2005)," Hybrid Controller based Intelligent Speed Control of Induction Motor", in the Journal of Theoretical and Applied Information Technology, pp71-75.

[5]. B. Heber, Et Al.(1997), "Fuzzy Logic Enhanced Speed Control Of An Indirect Field-Oriented Induction Machine Drive," IEEE Trans. Power Electronics, Vol. 12, No. 5, pp772 – 778.

[6]. A. Saghafinia ,H. Ping & M. Uddin (2013)," Designing Self-Tuning Mechanism On Hybrid Fuzzy Controller For High Performance And Robust Induction Motor Drive", in the International Journal of Advanced Technology & Engineering Research, Vol.3, No.2,pp65-72.

[7]. Driankov D., Hellendoorn, H & Reinfrank, M., "An Introduction To Fuzzy Control", Springer, Verlag, 1997.

[8]. I. Miki, Et Al .(1991) "Vector Control Of Induction Motor With Fuzzy PI Controller," IEEE Conference, IAS Annu. Meeting, Vol. 1, pp341-346.

[9]. T. Ho & L. Yeh (2010)," Design Of A Hybrid PID Plus Fuzzy Controller For Speed Control Of Induction Motors", 5Th IEEE Conference On Industrial Electronics And Applications.

[10]. A. Mishra & P. Choudhary (2012), " Speed Control Of An Induction Motor By Using Indirect Vector Control Method" ,in the International Journal of Emerging Technology and Advanced Engineering, Vol.2, No.12.