Performance and Analysis of Speed Control of Induction Motor using Vector Control through Fuzzy Logic Controller

[1]Raksha Thakur , [2]C.S. Sharma, [3]S.P Phulambrikar
[1]Post Graduate Student ,[2]Associate Professor , [3]Head of Department
[1]Electrical engineering Department,
[1]Samrat Ashok Technology Institute, Vidisha (M.P)

Abstract: **This paper presents "Performance and Analysis of Speed Control of Induction Motors using Vector Control through Fuzzy Logic Controller". The proposed system used fuzzy logic controllers and utilizes the vector control technique. This method has combined additional advantages of the fuzzy logic controller and conventional controllers for improvement in speed controlling of the three-phase induction motor. Simulation is done by MATLAB/SIMULINK-2017, all output results verified the effectiveness of the proposed speed controller system under various operating conditions and demonstrated improved performance described in details in this paper.**

***IndexTerms* - Speed control, Vector control, Fuzzy logic controller, Squirrel cage induction machine.**

I. Introduction

The squirrel cage induction motor (SCIM) is very popular and variable speed drives due to its well known advantages such as hybrid vehicles, paper mills and textile mills , robotics, and wind generation systems because of their several inbuilt merits such as their simple construction high performance drive, robustness, reliability, low cost, and low maintenance needs . However, induction motor (IM) with high performance control consider a challenging problem because of the coupling effects between the stator field and rotor current, nonlinearity characteristics, and many of the parameters vary with the operating conditions such as load torque, reference speed set point, rotor resistance, motor temperature. In many control applications of industrial drive, the most used method to control SCIMs is the vector or field oriented control technique in order to achieve the superior dynamic response. Field oriented control technique has been suggested by many researchers to simplify the speed control of induction motors so they can be controlled in a similar way to that in the control of separately exited dc motors. Essentially, there are two basic methods of field oriented control, one is the direct or feed-back control (DFOC) method and the other is the indirect or feed-forward method ((IFOC). The main difference between the two methods is in the way that the rotor angle is determined [1]. Fuzzy Logic controller (FLC) has been proposed to control the speed of the motor [2]. The major benefit of fuzzy logic controller is that no mathematical model is needed for the controller design comparing with the classical controller. Fuzzy logic is tremendously used to control complicated or nonlinear systems where delicate modelling is hard or not possible to find [3]. The electrical drives performance and robustness can be enhanced in terms of parameter variations by using the nonlinear speed control methods such as the fuzzy control technique. Recently, hybrid control techniques based on combination of two or more control methods are proposed by various researchers to enhance controller's performance [4] and [5]. Our proposed method combine conventional controller with vector control through fuzzy logic controller and vector control technique VOC has the correctly orientation of the rotor flux vector , where to take advantage of the induction motor torque control and reducing the complexity of FOC and best attributes of both controllers and eliminate the drawbacks of conventional controller such as oscillation.

In this scheme control strategy is proposed that include the speed control, torque control& current regulation without using mechanical sensor. Unlike closed loop observer it requires only less computation & less dependent on machine parameter. Like field oriented control is provide with variable in synchronously rotating frame. The benefits of speed sensor-less control are the increased reliability of overall system with removal of mechanical sensors, thereby reducing sensor noise and drift effect as well as cost & size. The most popular or running induction motor drive control method has been the field oriented control (FOC) from the past two decades. Furthermore, the recent development in FOC is towards the use of sensor less techniques that much avoid the use of speed sensor and flux sensor. The sensors in the hardware of the drive are replaced with state observers to minimize the cost and increase the reliability [4].

II. Vector Control

Vector control or field oriented control (FOC) was proposed by Blaschke [6] to emulate the characteristics of DC motor in an induction motor. The construction of a separately excited DC motor ensures that the stator field is always perpendicular to the rotor field and thus eliminates the interaction between these two fields. Therefore, independent control of the rotor current and stator field is feasible where the stator's current determine the system field, while the rotor's current can be used as a direct mean to control the torque of the motor. In squirrel-cage induction motor, the rotor current is not fed directly by an external source but it result from induced e.m.f in the rotor winding. Therefore, the induction motor control is not as simple as in DC motor because of the interaction between the stator field and rotor field whose orientation is not always occurring at 90° with respect to each other but it is varying depending on the operation conditions. Induction motor can be empowered with similar performance to that of DC motor by holding orthogonal orientation between the stator and rotor fields to achieve control of flux and torque independently [15]. Field oriented control (FOC) consists of controlling the stator current components, represented by a vector, in a synchronously rotating reference frame d-q, in which the electromagnetic torque of the air gap of the induction motor has the same mathematical expression of the torque in a separately excited DC motor. The FOC is based on transformation of three phase time and speed variable system into two coordinate time variant system, where the sinusoidal variable appears as DC quantities in steady state. Thus, this transformation leads to a structure similar of that in DC motor [8].

III. FUZZY LOGIC CONTROL

Fuzzy set theory is a mathematical concept is Prof. L.A. Zadeh in 1965. This concept helps a lot to improve the relationship between human and computers. In this chapter a review of the basic ideas of fuzzy set theory which is a need to sport fuzzy controller design and calculation. Then the steps for creations a prototyped fuzzy logic controller (FLC) attained.

3.1 FUZZY LOGIC THEORY

Fuzzy logic is a kind of logic is using graded and quantified statement rather than once that is strictly true or false. The results of fuzzy reasoning are not definite as those derived by strict logic. The fuzzy sets allow objects to have grades of membership from 0 to 1. These sets are represented by linguistic variables, which are ordinary language terms. They are used to represent a particular fuzzy set in a given problem, such as “large”, “medium” and “small”. A fuzzy set may be viewed as a generalization of the concept of an ordinary set that its membership function only takes two values {0,1}.

3.2 FUZZY LOGIC CONTROLLER

Analytical solution methods exist for power system problems. However, the mathematical formulations of power systems problems are derived under certain restrictive assumptions and even with these assumptions, the solution of large-scale power system problems is not simple. On the other hand, there are many uncertainties in power system problems, because power systems are large, complex, geographically widely distributed, and influenced by unexpected events. These facts make it difficult to effectively deal with many power systems problems through strict mathematical formulations alone. Therefore, fuzzy set theory-based approach, in recent years has emerged as a complementary tool to mathematical approaches for solving power system problems.

The bock diagram of Fuzzy logic controller is consists blocks of

- Fuzzification
- Fuzzy Inference system
- Knowledge base
- Defuzzification

3.3 SELF TUNED FUZZY LOGIC INTELLIGENT CONTROLLER

The fuzzy logic control (FLC) has been a dynamic research in this world and in automation and control theory since Mamdani proposed in 1974 based on the fuzzy sets theory of Zadeh (1965) to deal with the system of control problems that are not to be in the model. The fuzzy logic can provide as a tool in emergent intelligent control systems. It has the ability to plan via collapse of a complex task into manageable subtasks and adapt to a new situation. The formation of a complete fuzzy logic control system is to compile the following blocs: The Fuzzification, Knowledge rule base, Inference engine, defuzzification.

The fuzzification module converts the crisp values of the control inputs into fuzzy values. A fuzzy variable has values which are defined by linguistic variables (fuzzy sets or subsets) such as: low, medium, high, big, slow. where each is defined by a gradually varying membership function. In fuzzy set terminology, all the set of possible values that a variable can assume are named the universe of discourse, and the fuzzy sets (characterized by membership function) cover the whole universe of discourse. The membership functions can be triangular, trapezoidal.

- **Fuzzification** – Actual inputs are fuzzified and fuzzy inputs are obtained.
- **Fuzzy processing** – Processing fuzzy inputs according to the rules set and producing fuzzy outputs.
- **Defuzzification** – Producing a crisp real value for a fuzzy output.

This concept helps a plenty to improve the relationship between human being and computers.

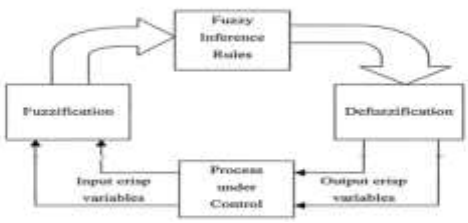

Fig: 3.3.1 Block diagram of fuzzy logic control system scheme

IV. SIMULATION

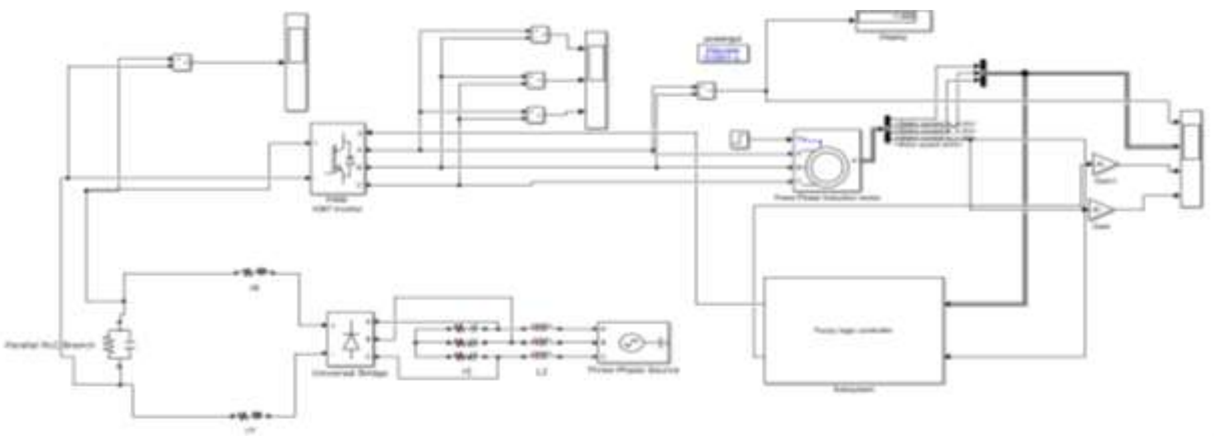

Fig: 4.1 Proposed Simulink model of fuzzy logic intelligent controller of Induction motor

In this paper the proposed work based on the fuzzy logic intelligent controller which gives a precise result with the help of indirect vector control. The block diagram of fuzzy logic controller with Indirect vector control of induction motor , which is input three phase supply with diode-based uncontrolled to convert AC voltage to DC voltage the reconnected with PWM IGBT based inverter for pulse controlling with the utilize of fuzzy logic controller it gives finest output speed of induction motor drive according to supply voltage. Block diagram of fuzzy logic based controller for Induction Motor driveAccording to block diagram developed Simulink model of fuzzy logic controller based induction motor drive shown in Fig. 4.1 .In this model used MATLAB 2017 and basic Simulink block, simpower system toolbox and fuzzy logic toolbox.
In fig. 4.1 shows three phase input voltage supply to rectifier circuit with connected resistance and inductance element called line inductance and parallel capacitor circuit also is given a voltage of input of the rectifier. Sub-system model of vector control with the fuzzy logic controller inside the fuzzy logic controller block. With the help of this model developed PWM pulse to controlled IGBT inverter .To developed PWM pulse using feedback signal stator current and speed with reference speed. Three phase Iabc takes as an actual current and Iabc* as a reference speed which is converted 3 phase into two phase by park's transformation and again converted into three phase by inverse park. By Using current regulator generate PWM pulse for controlling IGBT based VSI inverter.

V. RESULTS AND DISCUSSION

To verify the proposed scheme, a numerical simulation has been carried out by using MATLAB SIMULINK. In the performed simulation, a certain speed and torque references are compared to the values whose calculated in the driver and the obtained errors are sending to the hysteresis comparators. The simulation studies have been made by using MATLAB environment for the system described . The speed regulation of closed loop of the induction motor drive is designed and simulated with the fuzzy logic controller. The feedback control algorithms were iterated until best simulation results were obtained.

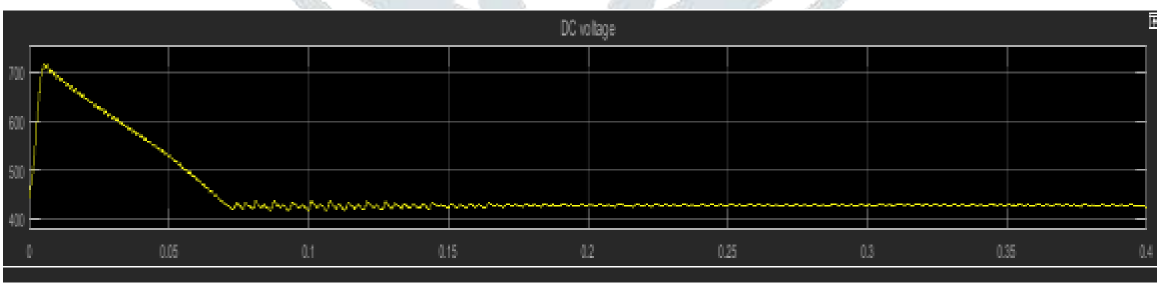

Fig.5.1 Rectifier output voltage in DC

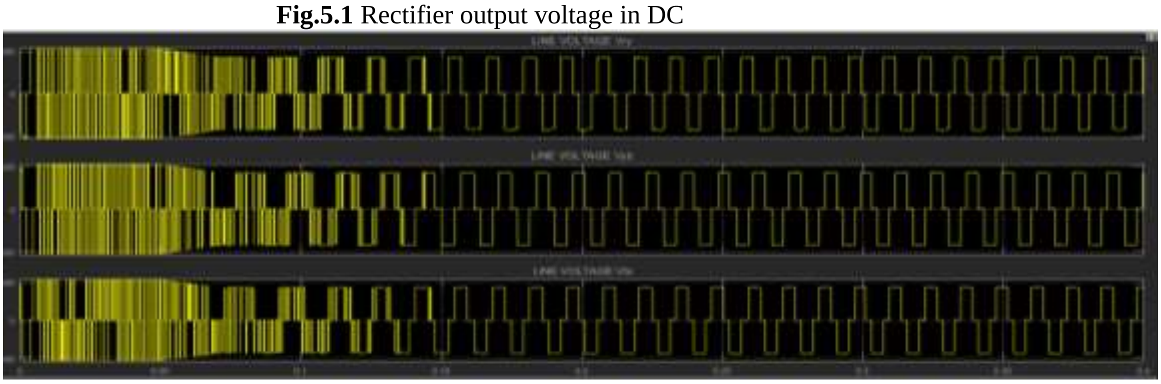

Fig.5.2. Output voltage waveform of PWM IGBT

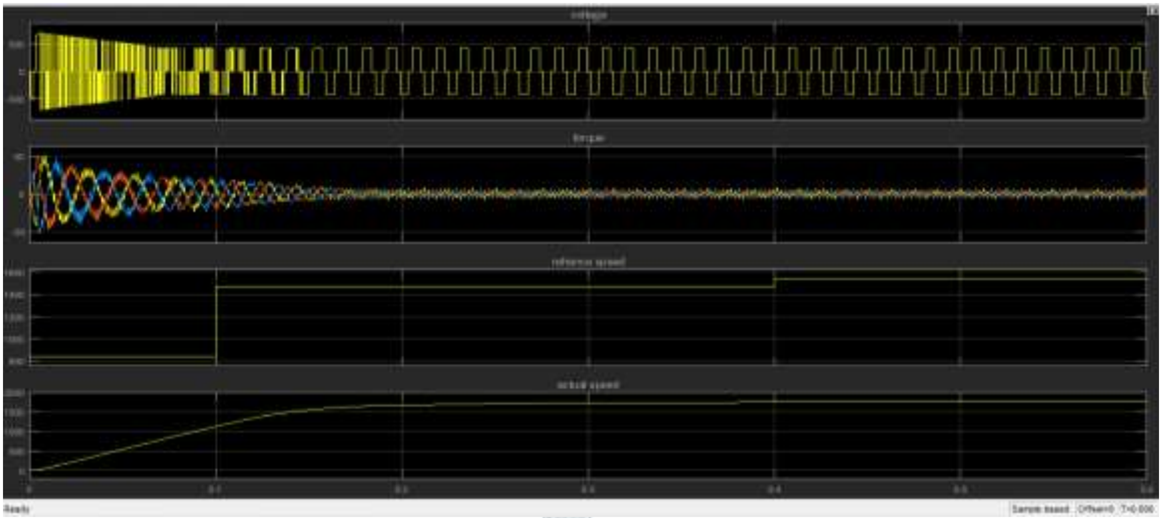

Fig.5.3. Output waveform of line voltage , torque, reference speed and actual speed

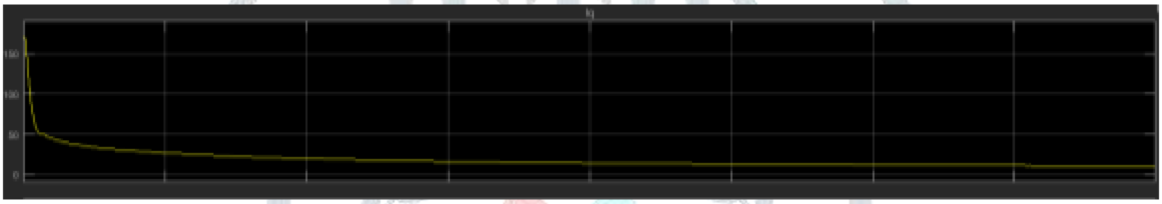

Fig: 5.4.Result representing the output waveform of Iq current

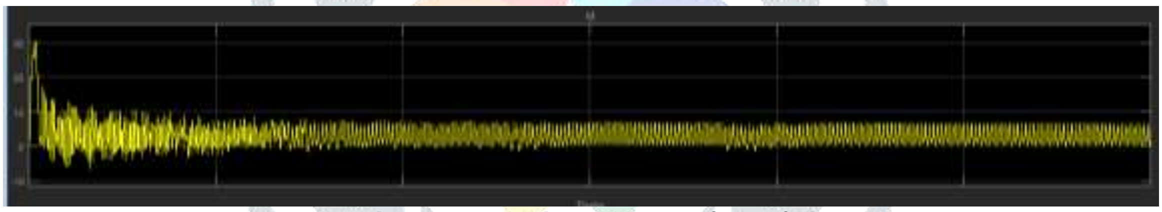

Fig: 5.5.Result representing the output waveform of Id current

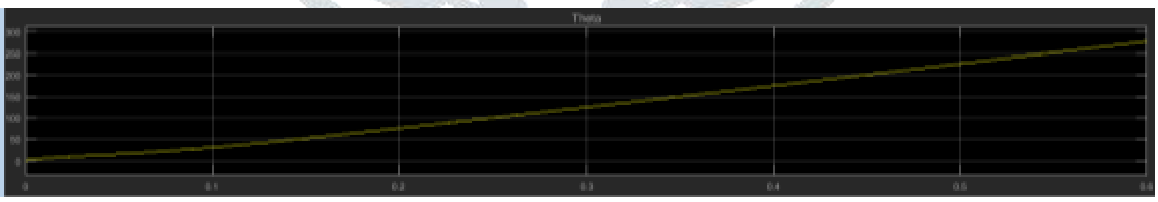

Fig5.6.Result representing the output waveform of theta

Results analysis of proposed system shows that three phase input 305 volt supplies, it is main source to supply but this supply not feedback control of induction motor in this case used AC to DC converter to convert AC voltage into DC voltage using semiconductor rectifier. The output voltage of rectifier circuit is in starting dc transient voltage approximant 700 then it come to 420 V DC steady state is shows in Fig. 5.1 .The output voltage of rectifier is uncontrolled. This 420 volt dc supply is connected to IGBT based 3 phase inverter and inverter output is connected to 3 phase 4.5hp induction motor. Inverter gate pulses generated by fuzzy logic controller. Output of the 3 phase PWM inverter shown in fig 5.2 .In initial condition output voltage is approximate 720 volt and in the steady state condition output voltage is 425 volt. Fig 5.3 is shows Output waveform of line voltage, torque, reference speed and actual speed, actual speed of the motor is 1550 rpm.

V. ACKNOWLEDGMENT

In this paper has been design successfully in MATLAB -2017. A successful MATLAB simulation model of three phase induction motor drive using fuzzy logic controller based IGBT PWM inverter has been presented in this paper. In this paper discuss about fuzzy logic controller based speed controlling technique in the three phase induction motor drive .In this system fuzzy logic controller based IGBT inverter tested with 4.5HP,400v,50Hz induction motor drive. On the basis of output results it is found that the complete designed system working well and giving desired output results .

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