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DYNAMIC AND STEADY STATE PERFORMANCE ANALYSIS OF INDUCTION MACHINE DRIVE USING FUZZY VSC BASED FIELD ORIENTED CONTROL

[1]Dr.R.KANNAN & [2]Dr. M. MANARAJAPAUL

[1]Professor, EEE Department, Nehru Institute of Engineering and Technology , Tamilnadu, India. [1]nieteeehod@gmail.com
[2]Assistant Professor, EEE Department, Nehru Institute of Engineering and Technology, Tamilnadu, India.

ABSTRACT

Variable structure controller (VSC) for an enlistment machine drive is a powerful technique for control in the event of non linearities and uncertainities. Dynamic execution of an Induction machine drives is a fundamental trademark for some mechanical applications. Nature of the item in an industry and the benefit of the business are fundamentally relies upon the exhibition of the enlistment engine drive. Transient and steady state performance execution of the VSC-PI based an acceptance engine drive to be improved. Since regular VSC based enlistment engine drive has PI regulator based speed regulator. To upgrade the exhibition of the framework this paper proposes Fuzzy FOC Controller as speed regulator in VSC. The plan is basic and simple to be executed. The whole framework is reproduced utilizing Matlab/Simulink to examine the presentation of a drive. Execution of a drive utilizing Fuzzy FOC based VSC is investigated and contrasted and ordinary Proportional and Integral VSC. To investigate the unique presentation of the framework machine is exposed to steady and variable load in this paper.

KEYWORDS: Induction Machine Drive, Speed control, Fuzzy FOC, VSC PI controller.

INTRODUCTION

In many industries Induction motors drive acting essential role like backbone of an industry. It is used for its reliability and less cost. In both Dynamic and steady state Performance of an induction motor drive decides the efficiency of an industry. So many researchers analysed to enhance the performance of a drive. Recently, many researchers presented the advanced control strategies for PWM inverter fed induction motor drive. Particularly, the vector control, which guarantees high dynamic and static performances like DC motor drives, has become very popular and has been developed and improved. Fast digital processor and power devices in the vector control drives provides the possibility of achieving high performance induction motor drive control. There are many works devoted to the vector control, but only few deals with the improving the performance of controller structure [1]. Classical control theory using Conventional PI controllers, provides good performance only in case of linear processes whose exact model is known. However, it is not possible to deal always with linear process. To achieve effective control using PI controller needs precise knowledge of motor and load parameters which is not possible in always.

FOC - Variable structure controller (VSC) is a system to deal with nonlinearities[2]. The variable structure system is inherently aimed at dealing with system uncertainties, lead to good performances even in presence of strong and fast variations of the machine parameters. Many authors analysed the performance of variable structure systems with a sliding mode [3-5]. The VSC works on the principle of imposing the system motion to occur on a given manifold in the state space, which is defined according to the control tasks. VSC is more advantageous for its robustness, insensitivity to parameter variations, fast dynamic response. In the conventional VSC based induction motor drive PI controller is used [6]. Again it leads to all drawbacks by the PI controller in the VSC system too. So In this paper a VSC through Fuzzy Gain Scheduling (FGS) Controller is proposed for the speed control in the acceptance engine drive. Since the, fuzzy rationale control has become a functioning and productive exploration region with numerous hypothetical works and mechanical applications being accounted for [8]. So in this paper FGS is proposed for VSC control of enlistment engine. The principle benefit of FGS based VSC enlistment engine drive is it requires just the speed information. Therefore it is straightforward and dependable control.

FOC BASED VARIABLE STRUCTURE CONTROL ALGORITHM

The vector controlled induction machine drives are easily adoptable to VSC algorithm. In a sliding mode (SM) control, the reference model is stored in the form of a predefined phase plane trajectory, and the system response is forced to follow or slide along the trajectory by a switching control algorithm [9]. Sliding surface or sliding line is defined as the starting point of a sliding mode control design [10]. Ensuring the ability of the system to reach or cross the chosen sliding line is the next stage of a control algorithm. After the system crossing the Sliding line, it will be able to cross it again for an infinite number of times.

In this paper, the motor speed is controlled in order to obtain a constant machine speed. So, the vector control task is to impose the convergence of the motor speed magnitude to a reference one. This goal can be fulfilled applying the VSC synthesis procedure to the error speed system equation. The block diagram of the vector control with speed controller is shown in Figure. 1.

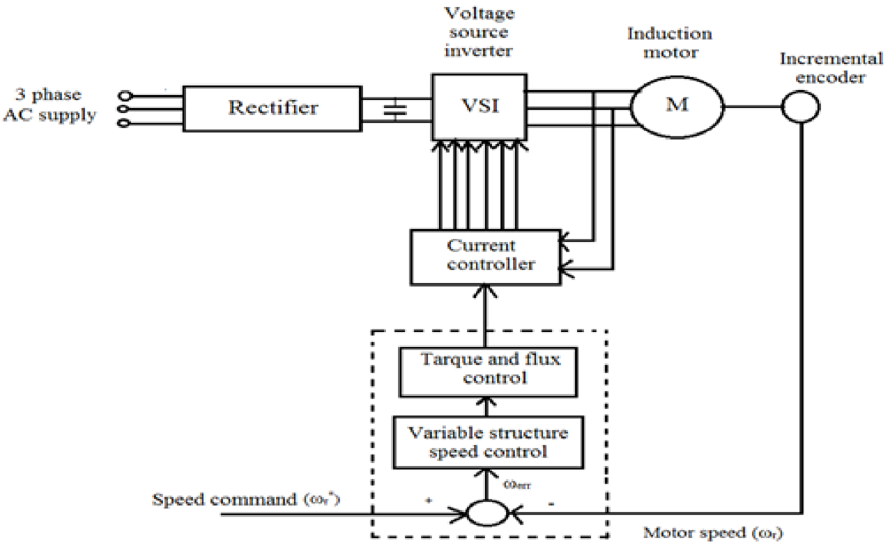


Figure. 1. Configuration Of The FOC –VSC Control System

The error between the motor speed and its reference can be obtained as follows;

$$\omega_{err}\ (t) = \ \omega_r^*(t) - \omega_r(t) \qquad (1)$$

and its derivative can be obtained as [2];

$$\omega_{err}^0(t) = \left(-\frac{B}{J} + \frac{3P}{2}\frac{L_m}{L_r}k\right)\omega_{err}\ (t) \qquad (2)$$

Where, k is a linear feedback-gain, B is the viscous friction, J is the moment of inertia, p is the number of pair poles, Lm is the mutual inductance, and Lr is the self inductance of the rotor per phase of the induction motor. So, the equivalent dynamic behavior of control system can be rewritten as [1];

$$\omega_{err}^0\ (t) = (a + bk)\ \omega_{err}\ (t) \qquad (3)$$

Where, £ = −B/J , ¥ = 3p/2. Lm/Lr , k is a feedback gain, and (£ + ¥k) is designed to be strictly negative. The switching surface with an integral component for the sliding mode speed controller is designed as follows [1];

$$S(t) = \omega_{err}\ (t) - \int_0^t (a + bk)\ \omega_{err}(\Gamma)\ d\Gamma \qquad (4)$$

It is obvious from the equation (3) that the speed error will converge to zero exponentially if the pole of the system is strategically located on the left-hand plane. Thus, the overshoot phenomenon will not occur, and the system dynamic will behave as a state feedback control system. Based on the developed switching surface, a switching control law, which satisfy the striking condition and guarantee the continuation of the sliding mode, is then designed. So, the variable structure speed controller is designed as the following,

$$I_{q==k\ \omega_{err}\ (t)}^s - \ \beta sgn\big(S(t)\big) \qquad (5)$$

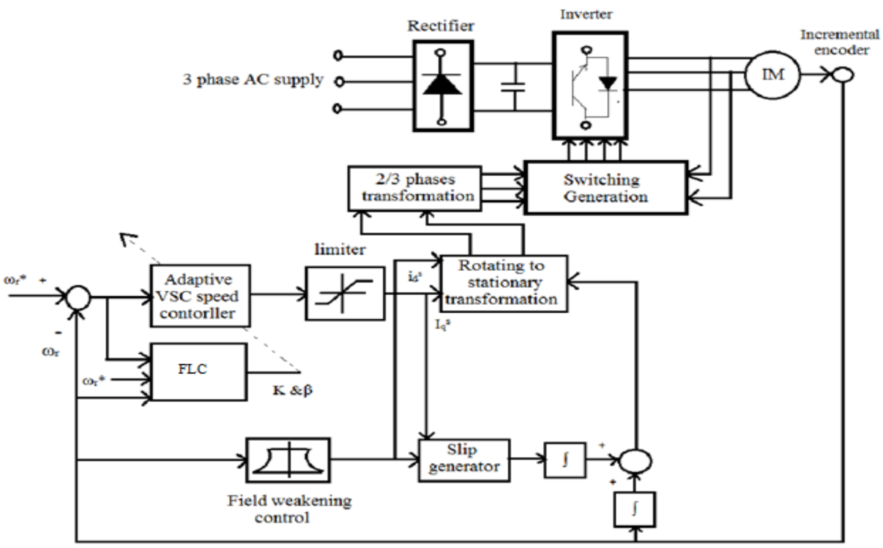


Figure. 2. Fuzzy VSC For Field Controlled Induction Motor Drive

Where, β is denoted as switching gain, with the following assumption, β≥ 0, Iq is the reference torque component current, and sgn(·) is a signum function defined as,

$$\mathrm{Sgn}(S) = \begin{cases} 1 & \text{for } S > 0, \\ 0 & \text{for } S = 0, \\ -1 & \text{for } S < 0, \end{cases} \quad (6)$$

Hence, the dynamic performance on the sliding surface can be described by Equation (3), and the tracking error err (t) converges to zero exponentially. The torque current command can be obtained according to Equation (5). The values of k and β plays an important role in control structure. In this paper PI and Fuzzy controller based determination of these parameters and presentation of drive are analysed.

SIMULATION MODELING OF VSC-PI CONTROLLER

PI controller is the easy method of control and broadly used in industries. Proportional plus Integral Controller increases the speed of response of the system [11]. It produces very small steady state error. Two PI controllers are proposed in this paper for k and β. In this paper speed Error (e) is given as input to both PI controllers. General equation of the PI controller is

$$U(s) = K_p E(s) + \frac{K_i}{S} E(S) \quad (7)$$

Where K_p is proportional gain, K_i is the integral gain, E(s) is the controller input and U(s) is the controller output. Figure 3 shows the block diagram of PI controller.

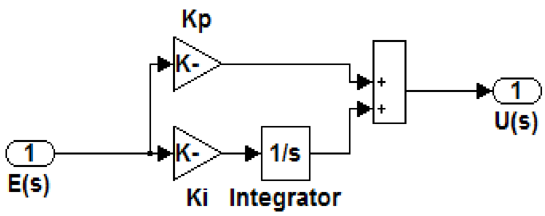


Figure. 3 Block Diagram Of Conventional PI Controller

In this paper Ziegler Nichols' method of tuning is implemented to find the optimum value of K_p & K_i values. But the problem of this controller is, it produces the more overshoot and larger settling time.

SIMULATION MODELING OF VSC USING FUZZY FOC CONTROLLER

Set value of K_p and K_i in a PI controller produces the high overshoot, settling time and speed drop during change in load. Online tuning of K_p and K_i in a PI controller can conquer this problem. It necessitates the Fuzzy PI controller for online tuning of K_p and K_i.

In a Fuzzy Gain Scheduling controller Fuzzy logic module is considered as an auto tuning module for parameters K_p and K_i in PI controller. The Fuzzy Gain Scheduling controller is considered the major contribution in this research [12]. The fuzzy inference of FGS controller is based on the fuzzy associative matrices. The calculation speed of controller is very quick, which can satisfy the rapid need of controlled object. The block diagram of control system is shown in Figure.4.

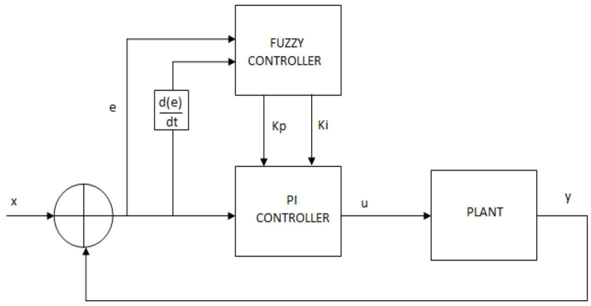


Figure. 4. Fuzzy PI Controller Block Diagram

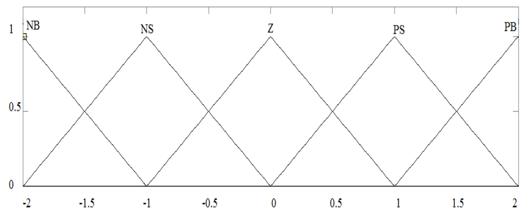
The control algorithm of traditional PI controller can be described as

$$\mathbf{u\ (k) = k_p e\ (k) + k_i \int e(k)}$$

Where, k_p is the proportional gain, k_i is the integral gain and e (k) is the speed error. The design algorithm of Fuzzy PI controller in this paper is to adjust the k_p and k_i parameters online through fuzzy inference based on the current e and ec to make the control object attain the good dynamic and static performances.. This paper proposes two Mamdani FGS controllers for tuning k and β.

Speed error e and error change rate ec are used as fuzzy input and the proportional factor k_p the integral factor k_i are used as fuzzy outputs. The degree of truth of E and EC are configured as 5 degrees, all defined as {NB, NS,ZO, PS, PB}, where NB, NS, ZO, PS and PB represent negative big, negative small, zero, positive small and positive big respectively.

The degree of truth of KP and KI are configured as 4 degrees, are defined as {Z, S, M, B}, where Z, S, M and B represent zero, small, medium and big. The membership functions of E, EC, KP and KI are triangular distribution functions. The membership functions for each variable are shown in Figure .5(a), 5(b) and 5(c) respectively**.**



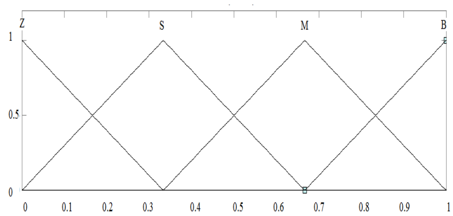


Figure .5(a) Membership Functions Of error and Change in error Figure .5(b) Membership Functions Of K & P

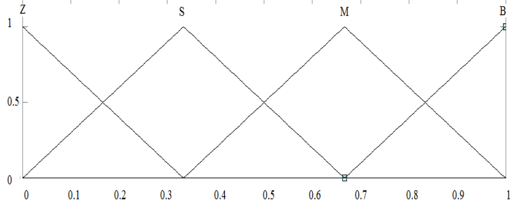


Figure .5(c) Membership Functions Of K&I

The principle of designing fuzzy rules is that the output of controller can make the system output response dynamic and static performances optimal. The fuzzy rules are generalized as table 1 and table 2 according to the expert experiment in IM drive system and simulation analysis of the system. The Mamdani inference method is used as the fuzzy inference mode. The inference can be written as

"IF E is NS AND EC is PS THEN KP is S, KI is M". KP and KI are written the same as 25 fuzzy condition statements. The MIN - MAX method of fuzzification is applied. The weighted average method is adopted for defuzzification.

TABLE 1:The Control Rules For K_p

e \ ec	NB	NS	ZO	PS	PB
NB	Z	Z	Z	Z	Z
NS	M	M	M	M	M
ZO	B	B	Z	B	B
PS	S	M	M	M	M
PB	Z	S	B	B	B

TABLE 2: The Control Rules For K_i.

e \ ec	NB	NS	ZO	PS	PB
NB	B	B	B	B	M
NS	M	B	S	S	S
ZO	M	B	Z	S	B
PS	S	S	S	S	S
PB	M	B	B	M	B

Fuzzy Gain Scheduling controller reduces the overshoot, settling time and drop in speed during load change.

SIMULATION RESULTS AND ANALYSIS OF INDUCTION MOTOR DRIVE

The performance of variable structure controlled induction machine 5 HP squirrel cage induction machine is taken. It is analyzed using various controllers like PI and Fuzzy FOC controller under various speeds and loads. Parameters of induction motors are shown in table 3:

Table 3 Motor Parameters

Line Voltage	415
Frequency	50 Hz
Stator Resistance (R_s)	1.15Ω
Rotor Resistance (R_r)	1.083Ω
Stator inductance (L_s)	5.974 mH
Rotor inductance(L_r)	5.974 mH
Mutual inductance(L_m)	0.2037H
Moment of Inertia (J)	0.02 Kg.m^2
Number of poles (P)	4

The performance of the machine using PI based VSC are shown in figure 6. The performance is analyzed under No load condition while the machine is running. The reference speed of the machine is set at 1500 rpm.

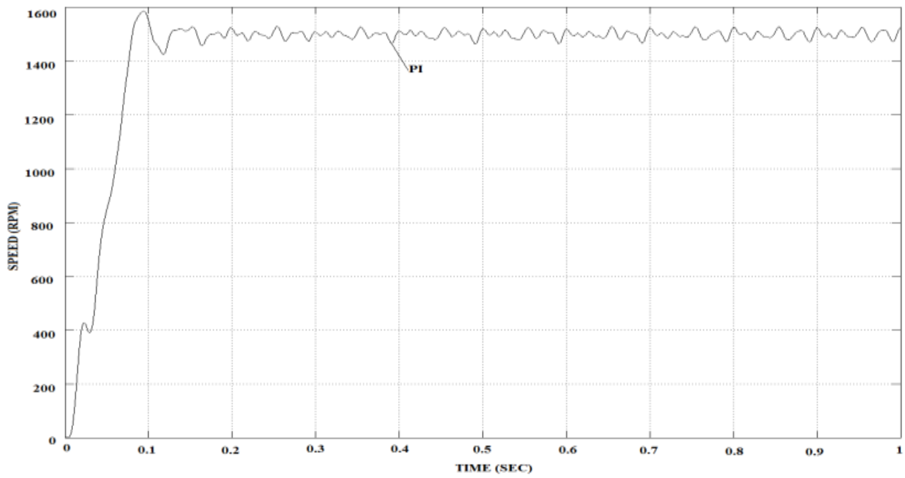


Figure.6 Speed Performance Of PI Based VSC Control

The performance of the motor using FGS based VSC are shown in figure.7 Conditions for analyses are same as a PI controller test. Figure 10 shows the comparative performance of PI and FGS based VSC under no load and reference speed as 1500 rpm.

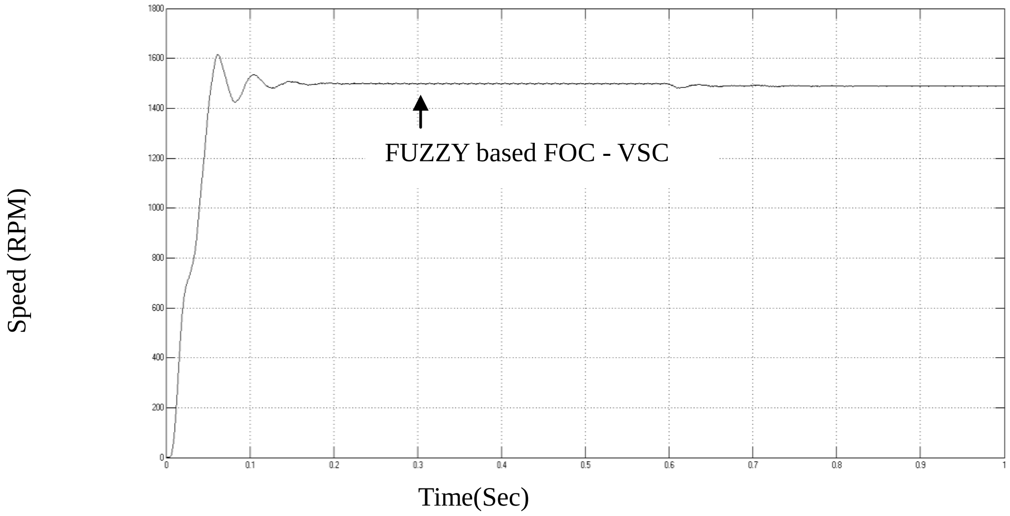


Figure.7 Speed Performance Of Fuzzy Based FOC-VSC Control

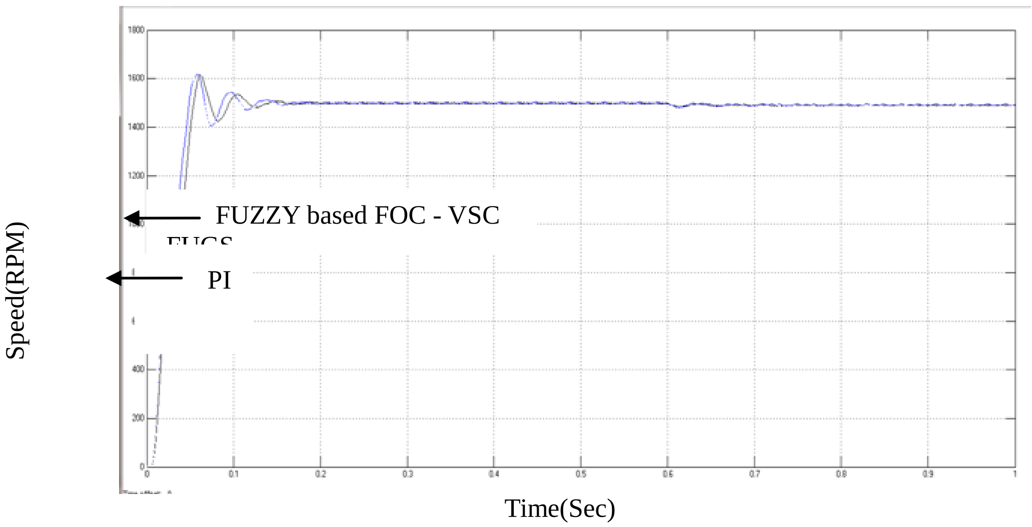


Figure.8 Comparison Of Speed Performance Of PI and FGS Based VSC Control

The performance of the motor using PI based VSC are shown in figure9. The performance is analyzed under a load while the machine is running. The reference speed of the machine is set at 1500 rpm.

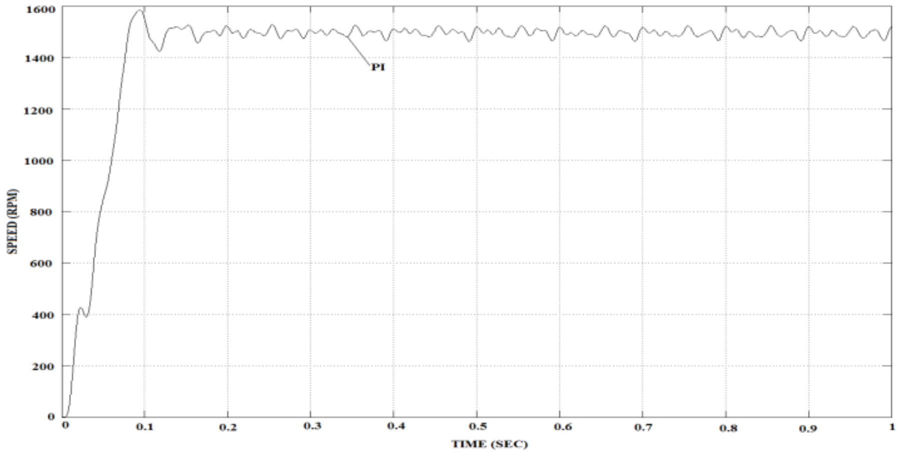


Figure.9 Speed Performance Of PI Based VSC Control

The performance of the motor using Fuzzy based VSC are shown in figure 10. Conditions for analyses are same as a PI controller test.

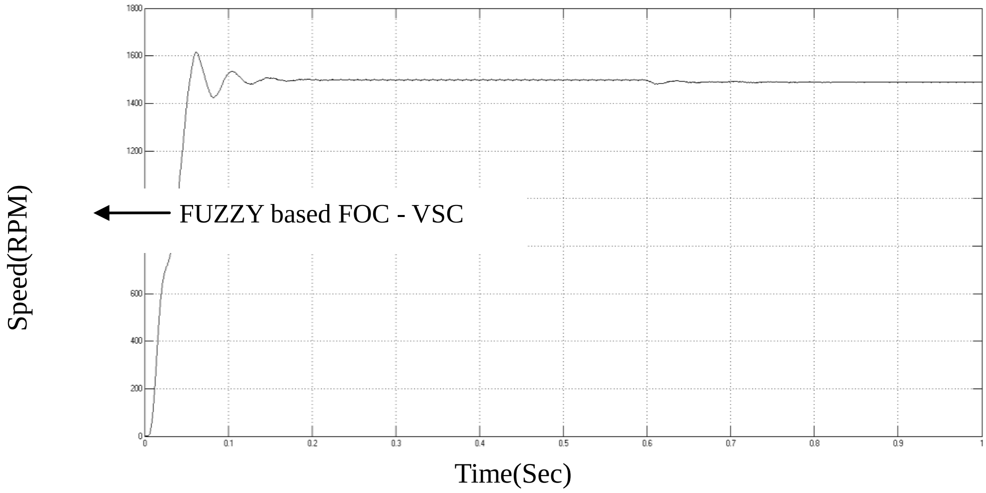


Figure.10 Speed Performance Of FGS Based VSC Control

Figure 11 and Table 4 shows the comparative performance of PI and FGS based VSC under step change in load at 0.6 seconds and reference speed as 1500 rpm.

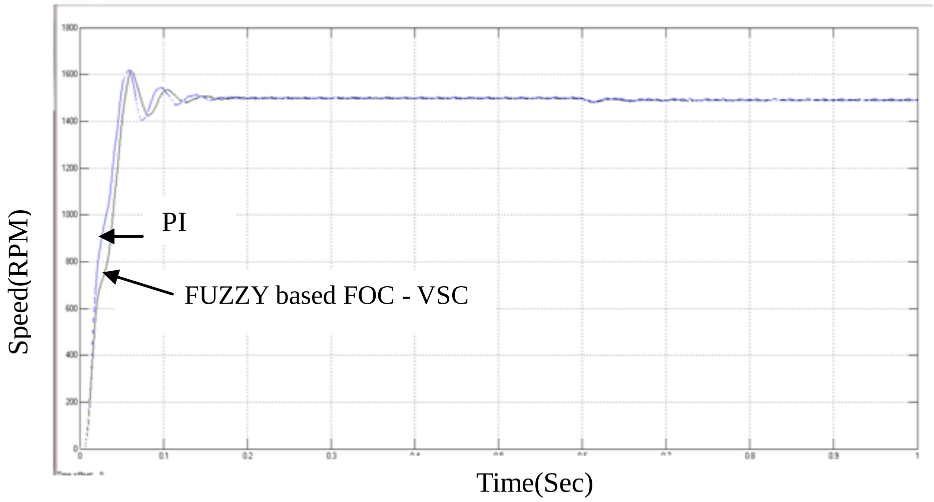


Figure.11Comparison Of Speed Performance Of VSC- PI and Fuzzy Based FOC -VSC Control

Table 4. Performance Comparison Of PI and FGS Controller

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Controllers	Peak overshoot in %	Rise time in Sec	Settling time in Sec	Steady state error in %	Change in speed during load change in %
PI-VSC	5.37	0.082	0.23	2.566	0.41
FUZZY VSC	4.2	0.06	0.17	0.45	0.23

CONCLUSIONS

Induction machines are broadly used in many industries in regular applications. Performance development of it is necessary to improve eminence of product. The Variable structure control is proposed in this for induction machines for its high robustness. It means that the system is fully insensitive to parametric vagueness and external instability. Variable structure controlled Induction motor is analyzed in this paper with PI and Fuzzy FOC. Simulation is done using Matlab. Performance of VSC based IM using both controllers are analyzed under various speeds and loads. From the simulation outcome it is observable that VSC PI controller gives almost fast response but it produces more overshoot, steady state error and high oscillation in speed while unexpected change in load. The Fuzzy FOC controller performs well in all aspects such as overshoot, steady state error and change in speed while sudden change in load. Therefore it is optimum to use Fuzzy FOC controller for VSC based Induction motor control.

REFERENCES

1. Faa-Jeng Lin, Rong-Jong, Wai-hsin-jang and Shieh, 1998, “Robust control of induction motor drive with rotor time constant adaptation”, Electric power systems research, Vol.47(1), pp.1–9.
2. CedomirMilosavljevi´c, DraganAnti´c, DarkoMiti´c and Goran Djordjevi´,1995, “comparative analysis of variable structure systems (VSS) with proportional plus integral (PI) control”, Electronics and Energetics vol. 14,pp.1–9.
3. Ho E Y,Sen, P.C,1990, “A microprocessor-based induction motor drive system using variable structure strategy with decoupling”, IEEE Transactions on Industrial Electronics ,Vol.37,pp. 227-235.
4. Ho E Y,Sen, P.C,1990,1991, “Control Dynamics of Speed Drive System Using sliding mode

controllers with integral compensation, IEEE Transactions on Industrial application,Vol.27,pp. 883–892.

5. Zhang, J.Barton, T. H, 1988, "Optimal sliding mode control of asynchronous machine speed with state feedback", in Conf. Rec. IEEE IAS annual meeting, pp. 328–336.
6. Chern, T. L.Chang, J.Chang, G. K,1997, "DSP-Based Integral Variable Structure Model Following Control for BrushlessDC Motor Drivers", IEEE Transactions on Power Electronics, Vol.12(1) ,pp. 53-63.
7. Y.Tang and L.Xu,1994, "Fuzzy Logic Application for Intelligent Control of a Variable Speed Drive", IEEE Trans Energy Conversion, Vol.9(4), pp. 679–685.
8. Zhang J Barton T H, 1990, "A fast variable structure current controller for an induction machine drive", IEEE Transactions on Industry applications, Vol.26(3).
9. Sabanovic, A., and Izosimov, D,1981, "Application of sliding modes to induction motor control", IEEE Trans., Vol.17, pp. 41-49.
10. C. Mohan Krishna M. Tech, G. Meerimatha M.Tech, U. Kamal Kumar M. Tech, 2013, "Indirect Vector Control of Induction Motor Using Pi Speed Controller and Neural Networks", International Journal of Modern Engineering Research (IJMER), Vol.3(4), pp.1980-1987.
11. Benudhar Sahu, K.B.Mohanty and Swagat Pati, 2010, "A Comparative Study on Fuzzy and PI Speed Controllers for Field-Oriented Induction Motor Drive", Modern Electric Power Systems , Wroclaw, Poland MEPS'10.
12. Mokrani, L and Abdessemed, R. (2003), "A fuzzy self-tuning PI controller for speed control of induction motor drive", Proceedings of 2003 IEEE Conference on Control Applications, Vol(2), pp; 785-790.
13. Neema D.D, Patel R. N and Thoke A.S, 2011, "Speed Control of Induction Motor using Fuzzy Rule Base", International Journal of Computer Applications ,Vol.33(5),pp.21-29.