SPEED CONTROL OF AN INDUCTION MOTOR USING FUZZY LOGIC AND PI CONTROLLER AND COMPARISON OF CONTROLLERS BASED ON SPEED

Naveena G J [1], Murugesh Dodakundi [2], Anand Layadgundi [3]

[1, 2, 3] *PG Scholar, Dept. of studies in EEE, UBDT College of Engineering, Davangere (India)*

ABSTRACT

Induction motor drives are widely used in industries because of its high efficiency, reliability, and high robustness, low cost and self-staring capability. In spite of this popularity, the induction motor has two inherent limitations (1) The standard motor is a variable speed machine, its full load slip varies less than 1% and (2) It is not inherently capable of not providing constant speed operation. These kinds of limitations are now solved through the use of smart motor controllers and adjustable speed controllers. Fuzzy logic concept (FLC); one of the artificial intelligent methods has found high applications in most of the nonlinear systems like the electric motor drives. This can be used as controller for any system without requirement of the system mathematical model unlike that the conventional electrical drive control; which uses the mathematical model like FLC; proportional integral (PI) controllers are also used for high applications in the electric motor drives. But in this paper it has shown that FLC is more reliable; efficient and huge dynamic performance. Due the usage of the FLC concept, efficiency, reliability and performance of the AC drive increases. The proposed method improves the dynamic performance of the induction machine compare to the conventional speed control of the induction motor drives and has got a faster response time. The simulation is carried out using various tool boxes in MATLAB. The simulation results presented in this paper shows the effectiveness of the proposed method.

Keywords: Fuzzy logic concept (FLC), Induction Motor, MATLAB Simulink, PI Controller and Reliability.

I. INTRODUCTION

Induction motors are widely used in various industries as prime workhorses to produce rotational motions and forces. Basically, variable-speed drives for induction motors require both wide operating range of speed and fast torque response, regardless of load fluctuation. Normally, the classical control is used in majority of the electrical motor drives. Conventional control method makes use of the mathematical model for the controlling system when there is a system parameters variation or environmental disturbance and behavior of system is not satisfactory. In addition, usual computation of system mathematical model is difficult or impossible. The designing of conventional controller increases the implementation cost and adds additional complexity in the control system & thus, it may reduce the reliability of the control system. Hence, the fuzzy logic based techniques are used to overcome this kind of problems. DC motors are controllable more than AC motors but the implementation cost required is more. And a DC motors has got higher volume and weight compared to the AC motors. Induction motors (one type of AC motors) are robust, require low maintenance and have many applications in industries.

Usually, the classical control used in motors drive design and implementation has many difficulties, which are as follows. It is on the basis of the mathematical accurate model of the system, that usual it is not known. Drives are nonlinear systems and classical control performance with this system performance decreases. Variation of machine parameters by load variation, motor saturation or thermal variations do not cause expectation performance. With the selected coefficients, classical control cannot receive acceptable results. Voltage source inverter-fed induction motors are most preferred for variable speed drive applications. The controller choice for a SVPWM drive is determined by the requirements of the type of application & is the most successful technique used in meeting the above requirements. The induction motors are commonly used nowadays due to advances in power electronics, microprocessors and variable-speed drives.

The SVPWM control has been widely used in many applications, such as electric vehicle drive systems AC servos and so on. Using this type of control, a highly coupled, multivariable nonlinear induction motor can be simply controlled through linear independent decoupled control of the flux and torque, similar to separately excited DC motors. SVPWM method is an advanced, computation intensive PWM method and possibly the best among all the PWM techniques for variable speed drives application. Because of its greater performance characteristics, it has been finding huge number of applications in recent years. With a machine load, the load neutral is normally isolated, which causes interaction among the phases. This type of interaction was not considered before in the PWM discussion. Recently, fuzzy logic control technique has found many applications in the past decades, which overcomes all these drawbacks. Hence, fuzzy logic control technique has the capability to control nonlinear, uncertain systems even in the case where no mathematical model is available for the controlled system. Recently, fuzzy logic control has found many applications in the past decades, which overcomes these drawbacks. Hence, fuzzy logic control technique has the capability to control nonlinearity, uncertain systems even in the case where no mathematical model is available for the controlled system. This project will focus on FLC techniques and the comparison with the classical PI controller.

II. METHODOLOGY

The reliability and performance of the AC drives depends on the progress in power and microelectronics, artificial intelligent techniques, different control methods and so on. The vector control of ac drives has been widely used in high performance control system. Indirect field oriented control is one of the most effective vector control of induction motor due to the simplicity of designing and construction. Usually, the classical control is used in majority of the electrical motor drives. Conventional control technique makes use of the mathematical model for the controlling system, when there is a system parameters variation or environmental disturbance, behavior of system is not satisfactory. In addition, usual computation of system mathematical model is difficult or impossible. The design and tuning of conventional controller increases the implementation cost and adds additional complexity in the control system & thus, it may reduce the reliability of the control system. Hence, the Fuzzy and PI based techniques are used to overcome this kind of problems.

2.1 Induction Motor Modelling

In the control of any power electronics drive system, a mathematical model of the plant is required. This mathematical model is required further to design any type of controller to control the process of the plant. The induction motor model is established using a rotating (*d*, *q*) field reference (without saturation) concept. The power circuit of the 3-Φ induction motor is shown in the Fig.2.1 the equivalent circuit used for obtaining the mathematical model of the induction motor is shown in the Fig.2.2 an induction motor model is then used to predict the voltage required to drive the flux and torque to the demanded values within a fixed time period. Finally calculated voltage is then synthesized using the space vector modulation.

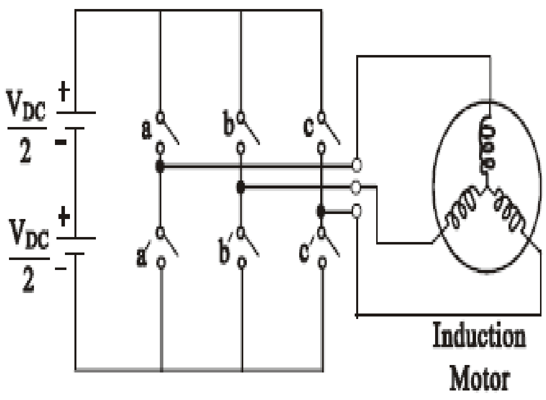

Fig.2.1 Power Circuit of The 3-Φ Induction Motor

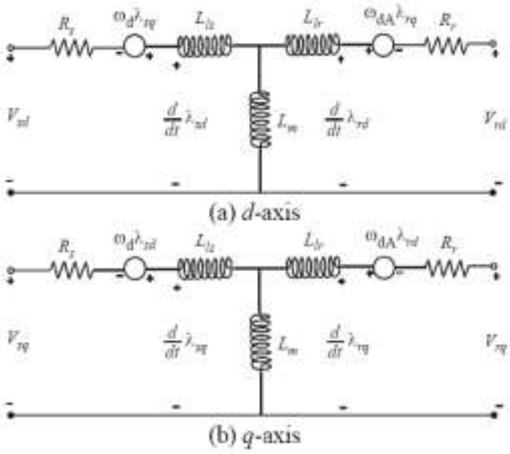

Fig.2.2 Equivalent Circuit of Induction Motor In D-Q Frame

$$V_{sd} = R_s i_{sd} + \frac{d}{dt}\lambda_{sd} - \omega_d \lambda_{sq} \quad (2.1)$$

$$V_{sq} = R_s i_{sq} + \frac{d}{dt}\lambda_{sq} - \omega_d \lambda_{sd} \quad (2.2)$$

$$V_{rd} = R_r i_{rd} + \frac{d}{dt}\lambda_{rd} - \omega_{dA} \lambda_{rq} \quad (2.3)$$

$$V_{rq} = R_r i_{rq} + \frac{d}{dt}\lambda_{rq} - \omega_{dA} \lambda_{rd} \quad (2.4)$$

Where, Vsd and Vsq, Vrd and Vrq are the direct axes & quadrature axes stator and rotor voltages.

The squirrel-cage induction motor considered for the simulation study in this project, has the d and q-axis components of the rotor voltage zero. The flux linkages to the currents are related by the Eq. (2.5) as

$$\begin{bmatrix} \lambda sd \\ \lambda sq \\ \lambda rd \\ \lambda rq \end{bmatrix} = M \begin{bmatrix} isd \\ isq \\ ird \\ irq \end{bmatrix}; \mathrm{M} = \begin{bmatrix} Ls & o & Lm & o \\ o & Ls & o & Lm \\ Lm & o & Lr & o \\ o & Lm & o & Lr \end{bmatrix} \quad (2.5)$$

III. FUZZY LOGIC TOOLBOX SOFTWARE

The Fuzzy Logic graphical user interface (GUI) tools are used to build a Fuzzy Inference System (FIS). The following GUI tools are used to build, edit, and view fuzzy inference systems:

Fuzzy Inference System (FIS) Editor is to handle the high-level issues for the system. Fuzzy Logic Toolbox software does not limit the number of inputs. However, the number of inputs may be limited by the available memory of machine. If the more number of inputs present, or the lengthier membership functions, then it may also be difficult to analyze the FIS using the other GUI tools.

Membership Function Editor to define that the shapes of all the membership functions associated with each variable. ***Rule Editor*** is to edit the rules which are listed that, which defines the behavior of the system. ***Rule Viewer*** to view the fuzzy inference diagram. One can use this viewer as a diagnostic to see, for example, which rules are active, or how the individual membership function shapes influence the results.

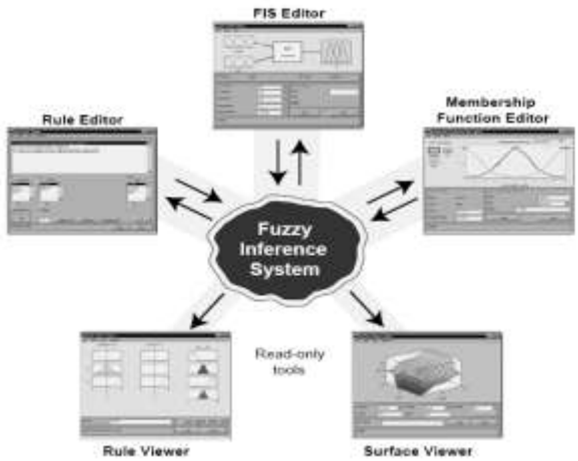

Fig.3.1 Fuzzy Logic Toolbox

IV. SIMULATION CIRCUITS AND RESULTS

Fig. 4.1 shows the Simulink circuit for fuzzy model and Fig. 4.2 Proportional integral block.

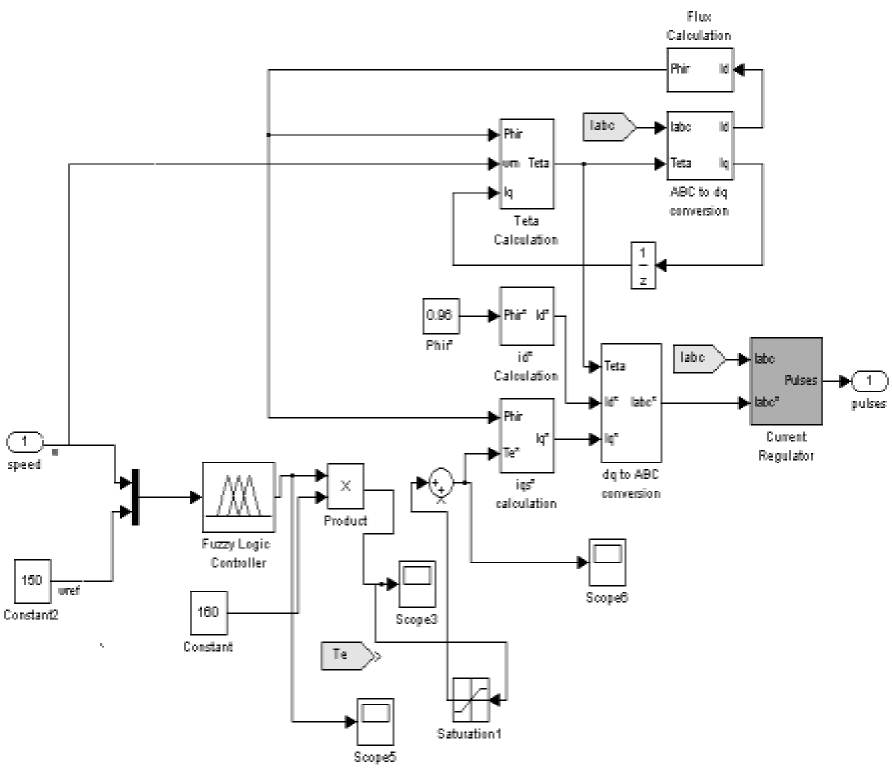

Fig. 4.1 Fuzzy Simulink Block

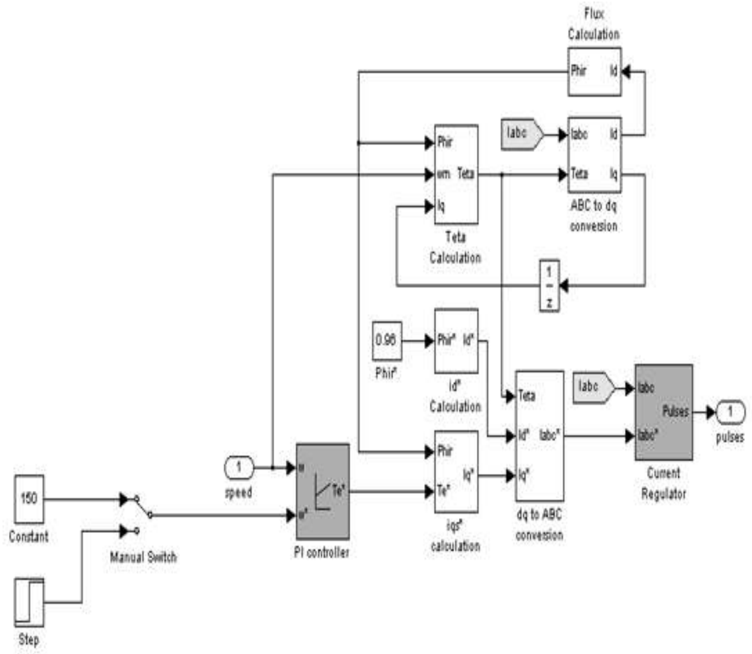

Fig. 4.2 Proportional Integral Block

4.1 Simulation Results of PI controller

The response curves of voltage, stator current, torque & the speed v/s time of PI Controller are shown in the Fig.4.3 respectively. The response of THD is shown in Fig.4.4. From the results, it is observed that the stator current is having more harmonic distortions.

The response curves of voltage, stator current, speed & the torque v/s time of Fuzzy controller are shown in the Fig.4.5 respectively. The response of THD is shown in Fig.4.6. From the results, it is observed that the stator current does not exhibit any overshoots & undershoots & the response of the speed curve takes less time to settle & reach the desired value.

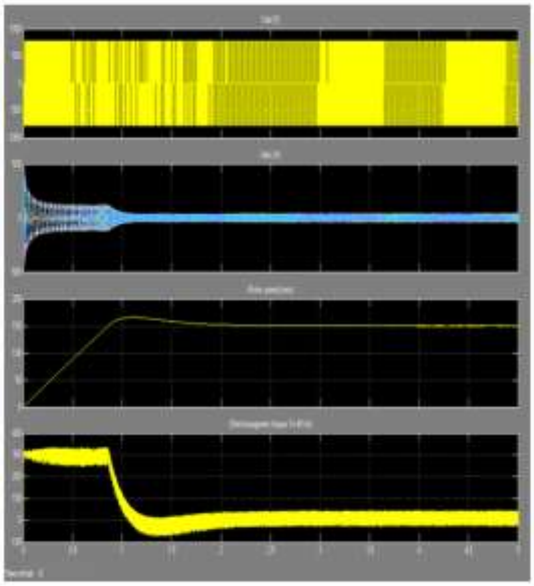

Fig. 4.3 Voltage, Currents, Speed & Torque of PI Controller

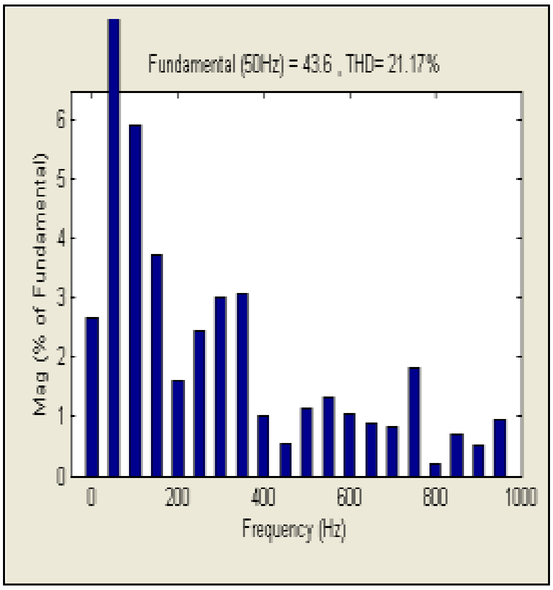

Fig. 4.4 T.H.D at 0.5 Second & 50 Hz Freq. of PI Controller

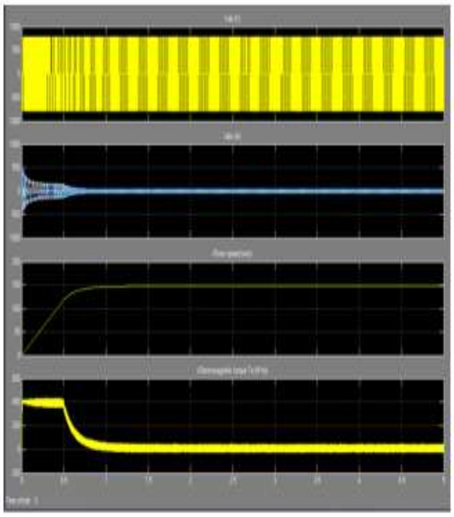

Fig. 4.5 Voltages, Currents, Speed & Torque v/s Time of FLC

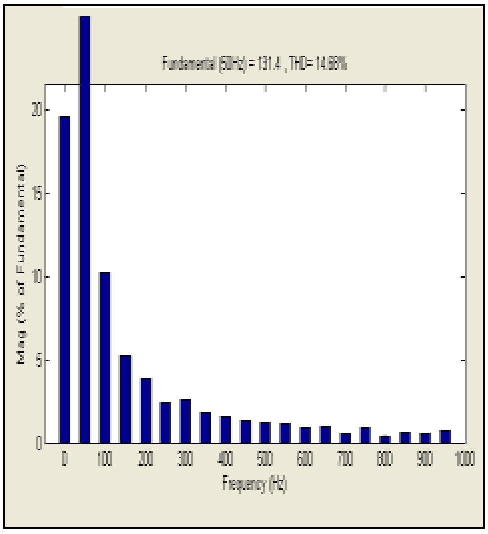

Fig.4.6 T.H.D at 0.5 second & 50 Hz Freq. of Fuzzy Controller

4.2 Observations

From the simulation results it is observed that the settling time taken by the FLC is less compared to that of PI controller and also from the T.H.D analysis carried out for different start time, it is observed that the percentage T.H.D associated with Fuzzy logic controller is less compared to PI as shown in table 4.1. From this we would come to know that fuzzy method is better than PI controller. In the Fig.4.7 pink line represents PI & yellow line represents fuzzy which settled early than that of PI controller.

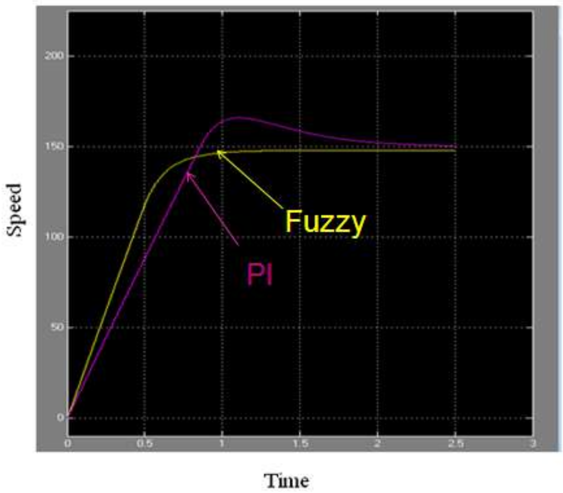

Fig.4.7 Speed Comparison of FLC and PI

Table 4.1 T.H.D Analysis of PI & Fuzzy Logic Controllers

Sl. no.	Start time	PI		Fuzzy	
		Freq. (Hz)	T.H.D	Freq. (Hz)	T.H.D
1	0.08	78.33	64.88%	125.8	59.68%
2	0.18	89.3	73.26%	66.52	34.79%
3	0.28	81.15	67.16%	88.77	34.20%

4	0.38	56.29	37.37%	150.0	43.21%
5	0.48	77.23	36.07%	131.4	14.68%
6	0.58	102.6	35.33%	73.25	20.12%
7	0.68	110.8	23.73%	45.41	23.33%
8	0.98	43.6	21.17%	29.84	29.84%

V. CONCLUSION

The speed control of an induction motor drive by means of the fuzzy and PI controller technique using SVPWM concept has been investigated in this project. A new FLC that improve the performance of scalar IM speed drives has been proposed. The method uses a new linguistic rule table in FKBC to adjust the motor control speed and FLC can achieve a good system performance of the IM scalar drive. The performance, reliability and efficiency of the induction motor drives are more in the case of FLC rather than that of PI Controller.

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