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Comparative analysis among fuzzy PI controller, fuzzy PID controller and fuzz logic controller for the speed control of induction motor

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Abstract: Comparative analysis among Fuzzy PI, Fuzzy PID and Fuzzy Logic Controller for the speed control of induction motor. 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. FLC can be used as controller for any system without requirement of the system mathematical model unlike that of the conventional electrical drive control, which uses the mathematical model. Like FLC, FUZZY PI and FUZZY PID Controller is also used for high applications in the electric motor drives. But in this paper it is shown that FLC is more reliable, efficient & gives dynamic performance. Due to the usage of the FLC concept, the efficiency, reliability & performance of the AC drives increases The proposed method improves the dynamic performance of the induction machine compared to the conventional speed control of induction motor drives & has got a faster response time. The simulation results presented in this paper show the effectiveness of the proposed method, which has got wide number of advantages.

Keywords: Artificial Intelligence, Fuzzy logic control, Fuzzy PI Control, Fuzzy PID Control, Induction machine, Speed, Simulink model, Torque.

Introduction

Induction motors are being applied today to a wider range of applications requiring variable speed. Generally, variable speed drives for Induction Motor (IM) require both wide operating range of speed and fast torque response, regardless of load variations. This leads to more advanced control methods to meet the real demand. The conventional control methods have the following difficulties:

1. It depends on the accuracy of the mathematical model of the systems
2. The expected performance is not met due to the load disturbance, motor saturation and thermal variations
3. Classical linear control shows good performance only at one operating speed

The coefficients must be chosen properly for acceptable results, whereas choosing the proper coefficient with varying parameters like set point is very difficult to implement conventional control, the model of the controlled system must be known. The usual method of computation of mathematical model of a system is difficult. When there are system parameter variations or environmental disturbance, the behaviour of the system is not satisfactory. Usually classical control is used in electrical motor drives. The classical controller designed for high performance increases the complexity of the design and hence the cost. In recent two decades, soft computation is used widely in electrical drives. They are,

1. Artificial Neural Network (ANN)
2. Fuzzy Logic Set (FLS)
3. Fuzzy-Neural Network (FNN)
4. Genetic Algorithm Based system (GAB)
5. Genetic Algorithm Assisted system (GAA)

Neural networks and fuzzy logic technique are quite different, and yet with unique capabilities useful in information processing by specifying mathematical relationships among numerous variables in a complex system, performing mappings with degree of imprecision, control of nonlinear system to a degree not possible with conventional linear systems. Fuzzy control has been primarily applied to the control of processes through fuzzy linguistic descriptions. Recently, fuzzy logic control has found many applications in the past decades, which overcomes these drawbacks. Hence, fuzzy logic control has the capability to control nonlinear, uncertain systems even in the case where no mathematical model is available for the controlled system.

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Fuzzy Logic Controller and its application for speed control of Induction Motor

Fuzzy controllers have got a lot of advantages compared to the classical controllers such as the simplicity of control, low cost and the possibility to design without knowing the exact mathematical model of the process. Fuzzy logic is one of the successful applications of fuzzy set in which the variables are linguistic rather than the numeric variables. Linguistic variables, defined as variables whose values are sentences in a natural language (such as large or small), may be represented by fuzzy sets. Fuzzy set is an extension of a 'crisp' set where an element can only belong to a set (full membership) or not belong at all (no membership). Fuzzy sets allow partial membership, which means that an element may partially belong to more than one set. A fuzzy set A of a universe of discourse X is represented by a collection of ordered pairs of generic element $x \in X$ and its membership function $\mu : X \rightarrow [0\ 1]$, which associates a number $\mu A(x)$: $X \rightarrow [0\ 1]$, to each element x of X.

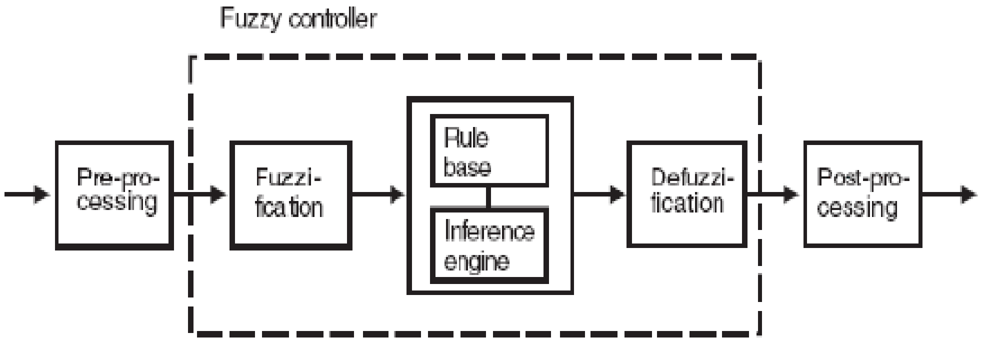

Fig 1. General Fuzzy block diagram

A fuzzy logic controller is based on a set of control rules called as the fuzzy rules among the linguistic variables. These rules are expressed in the form of conditional statements. Our basic structure of the fuzzy logic controller to control the speed of the induction motor consists of 4 important parts, viz., fuzzification, knowledge base, decision making logic and the defuzzification. The necessary inputs to the decision making unit blocks are the rule-based units and the data based block units. The fuzzification unit converts the crisp data into linguistic formats. The decision making unit decides in the linguistic format with the help of logical linguistic rules supplied by the rule base unit and the relevant data supplied by the data base. The error & the change in error is modelled using the equation as

$$e(k) = \omega_{ref} - \omega_r$$

$$\Delta e(k) = e(k) - e(k-1)$$

The output of the decision-making unit is given as input to the de-fuzzification unit and the linguistic format of the signal is converted back into the numeric form of data in the crisp form . The decision-making unit uses the conditional rules of 'IF-THEN-ELSE'. In the first stage, the crisp variables e(k) and Δ e(k) are converted into fuzzy variables. The fuzzification maps the error, and the error changes to linguistic labels of the fuzzy sets. The proposed controller uses following linguistic labels: {NB Negative Big), NM Negative Medium), NS(Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium), and PB (Positive Big)}. Each fuzzy label has an associated membership function.

Table 1: Rulebase for controlling the speed

E / ΔE	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

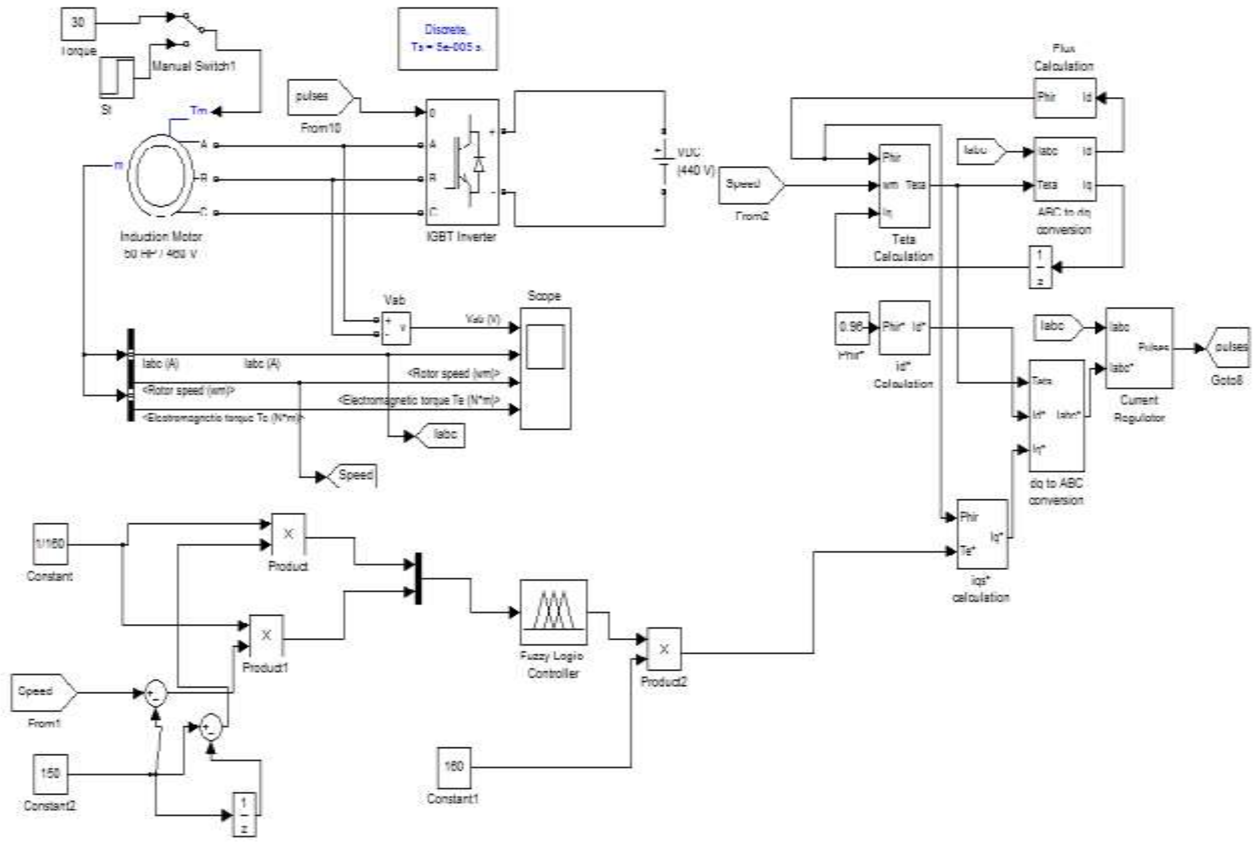

Fig 2: Speed control of IM by Fuzzy Logic Controller

Fuzzy PID Controller and its application for speed control of Induction Motor

It is the combination of fuzzy and PID controller.

PID Controller:

The PID control scheme is named after its three correcting terms, whose sum constitutes the manipulated variable (MV). The proportional, integral, and derivative terms are summed to calculate the output of the PID controller. Defining $u(t)$ as the controller output, the final form of the PID algorithm is:

$$\mathrm{u}(t) = \mathrm{MV}(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{d}{dt} e(t)$$

where

K_p: Proportional gain, a tuning parameter

K_i: Integral gain, a tuning parameter

K_d: Derivative gain, a tuning parameter

e: Error $= SP - PV$

t: Time or instantaneous time (the present)

τ : Variable of integration; takes on values from time 0 to the present t.

Fuzzy PID controller used in this paper is based on two inputs and one output.

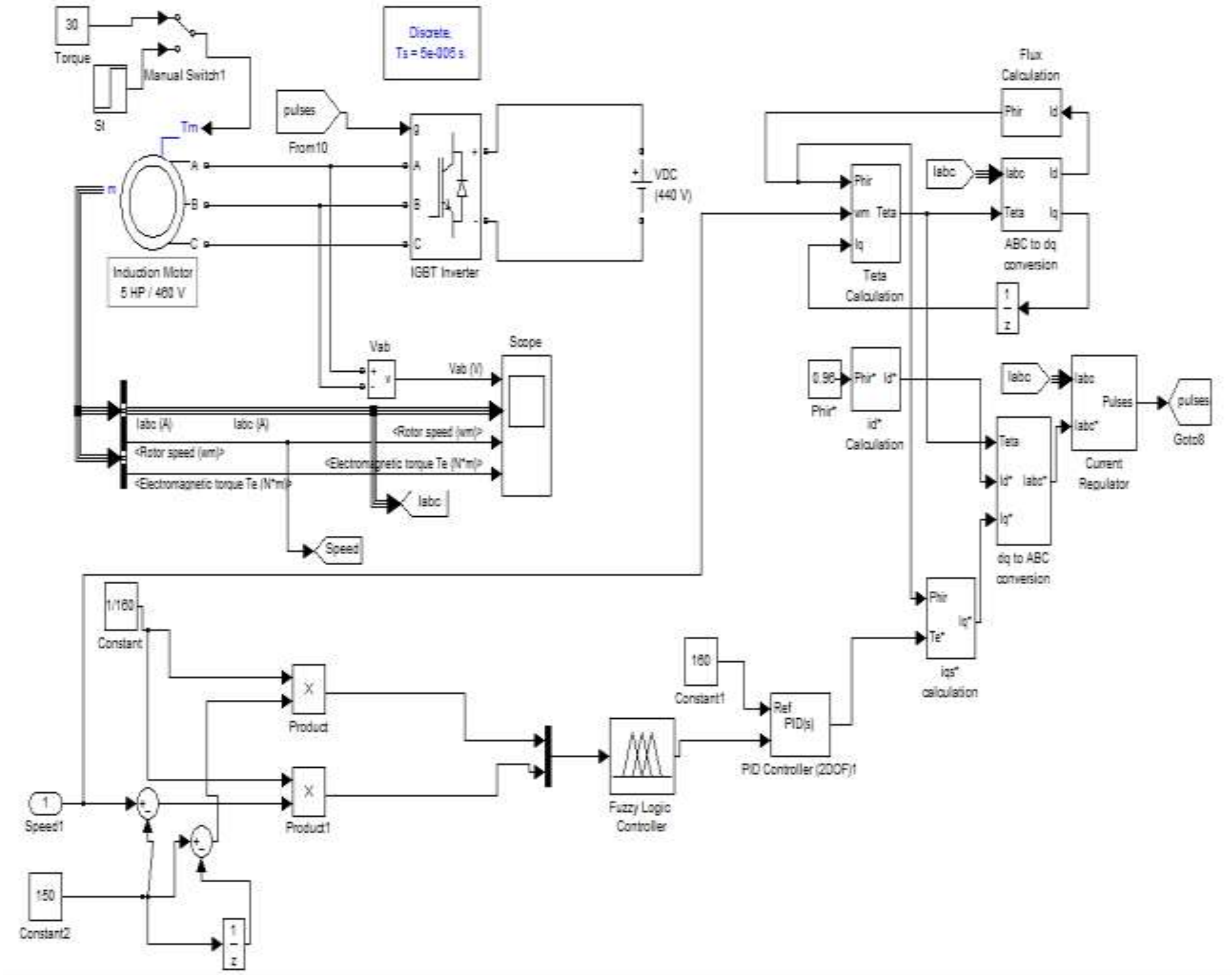

Fig. 3: Speed Control of IM by Fuzzy PID controller

Fuzzy PI Controller and its application for speed control of Induction Motor:

It is the combination of fuzzy and PI controller.

PI Controller:

For integral control action the actuating single consists of proportional error signal added with integral of the error single. Therefore, the actuating signal for integral control action is give by, the following equation:

$$u = K_I \int e \, d\tau$$

In the PI controller we have a combination of P and I control i.e.

$$u = K_p e + K_I \int e \, d\tau$$

$$u = K_p e + \frac{1}{\tau_I} \int e \, d\tau$$

$$u = K_p \left(e + \frac{1}{\tau_N} \int e \, d\tau \right)$$

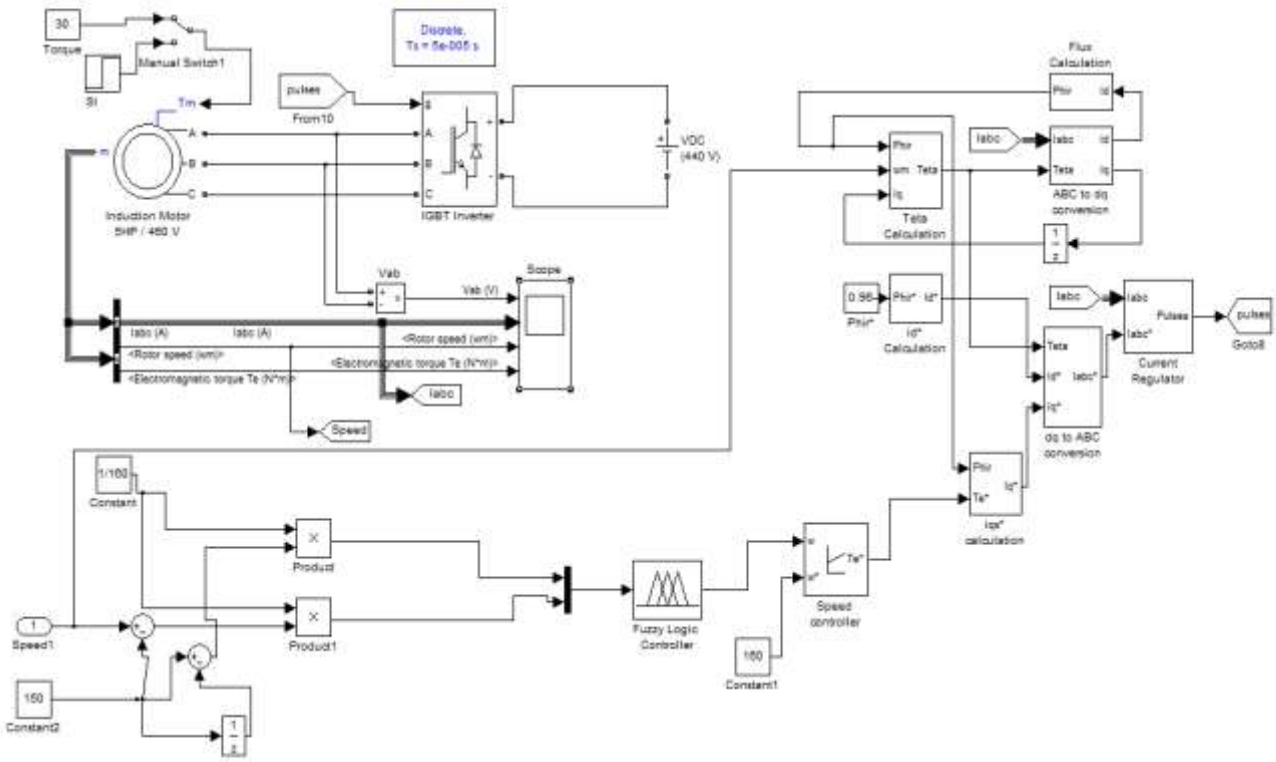

Fig. 4: Speed Control of IM by Fuzzy PI controller

RESULTS

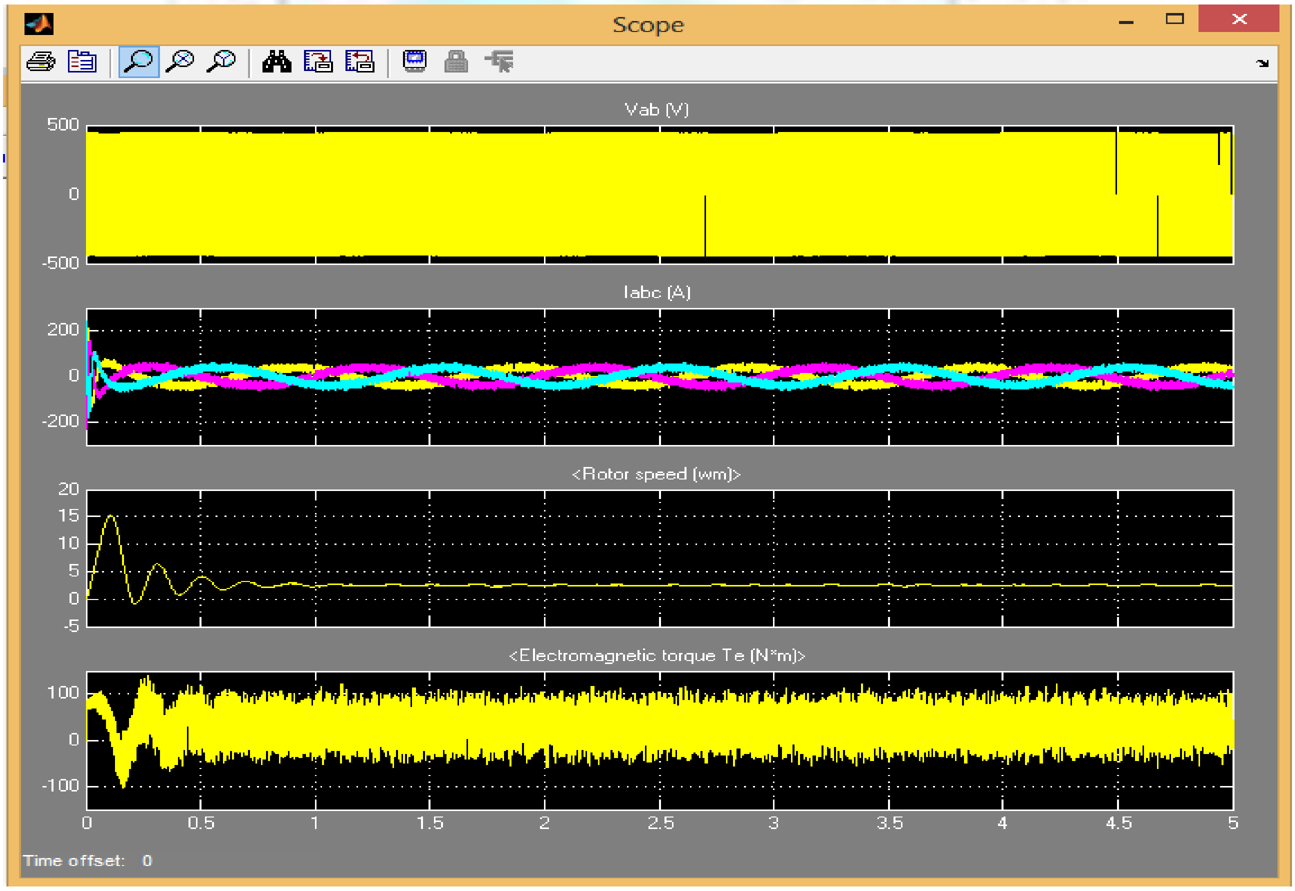

Fig.5: Speed Control of IM by FLC controller

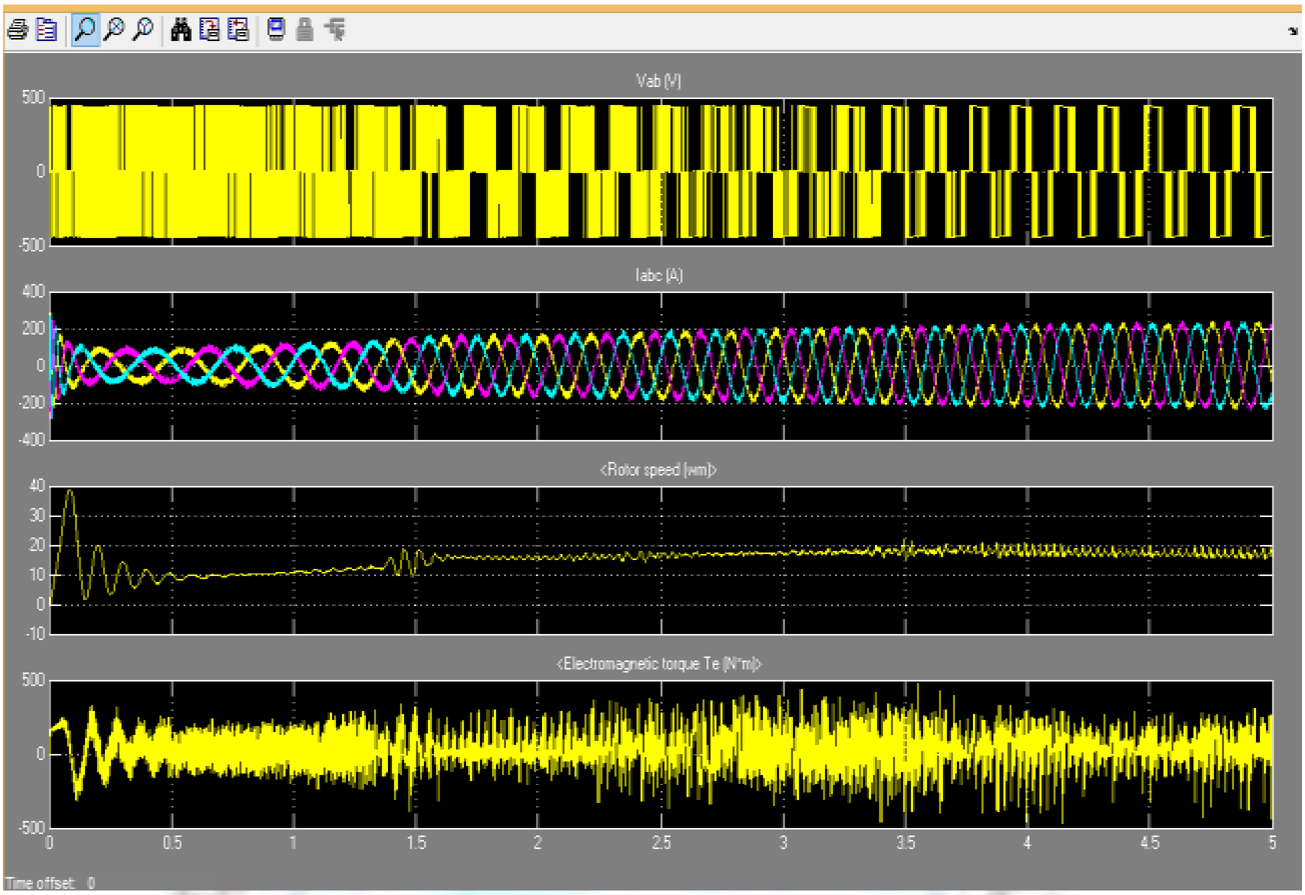

Fig.6: Speed Control of IM by Fuzzy PID controller

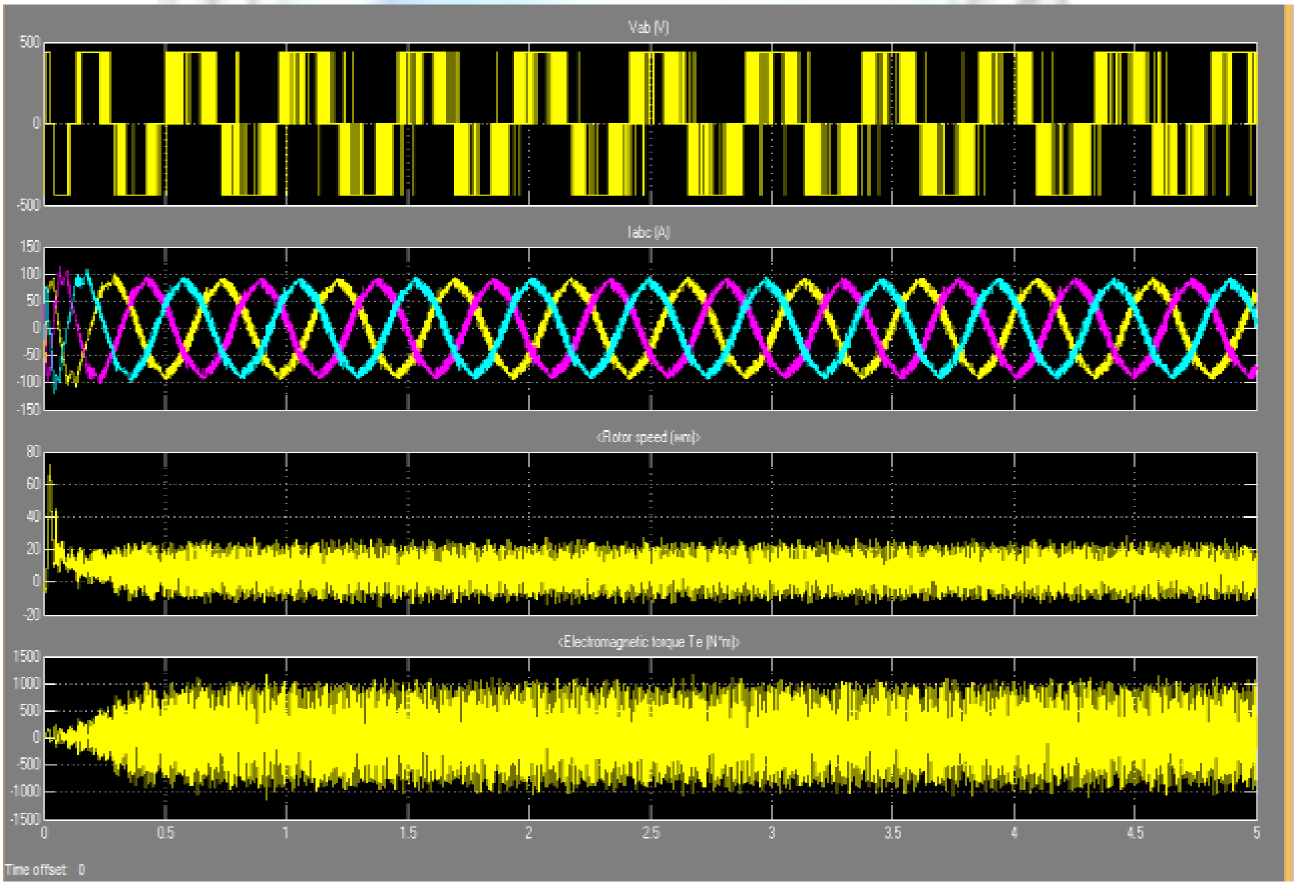

Fig.7: Speed Control of IM by Fuzzy PI controller

CONCLUSION

The speed control of an induction motor drive by means of the fuzzy, fuzzy PID and fuzzy PI technique has been investigated in this paper. By considering the speed comparison of all three controllers, the fuzzy controller has shown good performances and also settling time of the speed matched with the desired values that were taken during the simulations. By the method presented in this paper, the efficiency, performance and reliability of induction motor drive increases by the use of FLC rather than that of using PI and PID Controller. Based on this FLC is more efficient and reliable than that of FLC with PI and FLC with PID Controller for this speed control of induction motor.

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