FUZZY LOGIC CONTROLLER BASED SPEED CONTROL OF THREE PHASE INDUCTION MOTOR

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ABSTRACT

During the past several years, fuzzy control has emerged as one of the most active and fruitful areas for research in the applications of fuzzy set theory, especially in the realm of industrial processes, which do not lend themselves to control by conventional methods because of a lack of quantitative data regarding the input-output relations. Fuzzy control is based on fuzzy logic-a logical system that is much closer in spirit to human thinking and natural language than traditional logical systems. The fuzzy logic controller (FLC) based on fuzzy logic provides a means of converting a linguistic control strategy based on expert knowledge into an automatic control strategy.
This methodology conveying a new method for speed control system for induction motor which is based on fuzzy logic instead of obsolete indirect vector control using PI controller as a speed regulator in outer speed loop. In obsolete method for speed control system of a induction motor drive uses a voltage source pulse width modulation inverter-fed vector controlled indirectly which is having low precision for the speed control giving bad speed regulation characteristics and decreasing the performance of the whole induction motor drive. To prevail over this PI controller by a automatically sensing fuzzy control system which is based on fuzzy set theory. The execution of this automatically sensing fuzzy control system can be inquired through digital simulation which is based on MATLAB-SIMULINK package. By using this digital simulation system the performance of fuzzy control system can be seen by creating variable operating conditions by varying reference speeds and at different load torques. Consequences of this digital/simulation system shows improved performance characteristics of the suggested fuzzy control system over the obsolete PI controller as a speed regulator in outer speed loop.

Keyword: - *Fuzzy logic controller, three phase induction motor*

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1. INTRODUCTION

In recent years the control of high-performance induction motor drives has received widespread research interests. It has been valued more not only because it is the most used motor in industries but also due to their varied modes of operation. Also it has good self-starting capability, simple, rugged structure, low cost and reliability etc. Main property that makes it more useful for industries is its low sensibility to disturbance and maintenance free operation. Despite of many advantages of induction motor there are some disadvantages also. Like it is not true constant speed motor, slip varies from less than 1% to more than 5%. Also it is not capable of providing variable speed operation. But as it is so useful for industries we have to find some solution to solve these limitations and the solution is speed controller, that can take necessary control action to provide the required speed. Not only speed, it can control various parameters of the induction machine such as flux, torque, voltage, stator current. Out of the several methods of speed control of an induction such as changing no of pole, rotor resistance control, stator voltage control, slip power recovery scheme and constant V/f control, the closed loop constant V/f speed control method is most popular method used for controlling speed. In this method, the V/f ratio is kept constant which in turn maintains the magnetizing flux constant that eliminates harmonic problem and also the maximum torque also does not change. So, it‟s a kind of complete utilization of the motor. And the controller used are conventional P-I controller, and fuzzy logic controller.

The use of induction motors has increased tremendously since the day of its invention. They are being used as actuators in various industrial processes, robotics, house appliances (generally single phase) and other similar applications. The reason for its day by day increasing popularity can be primarily attributed to its robust construction, simplicity in design and cost effectiveness.

These have also proved to be more reliable than DC motors. Apart from these advantages, they have some unfavorable features like their time varying and non-linear dynamics. Speed control is one of the various application imposed constraints for the choice of a motor.

The field of power electronics has contributed immensely in the form of voltage-frequency converters which has made it possible to vary the speed over a wide range [11] [13]. However, the highly non-linear nature of the induction motor control dynamics demands strenuous control algorithms for the control of speed. The conventional controller types that are used for the aforementioned purpose are may be numeric or neural or fuzzy. The controller types that are regularly used are: Proportional Integral (PI), Proportional Derivative (PD), Proportional Integral Derivative (PID), Fuzzy Logic Controller (FLC) or a blend between them.

2. SIMULATION MODEL

2.1. Simulink model for controlling speed of induction drive using Fuzzy logic controller

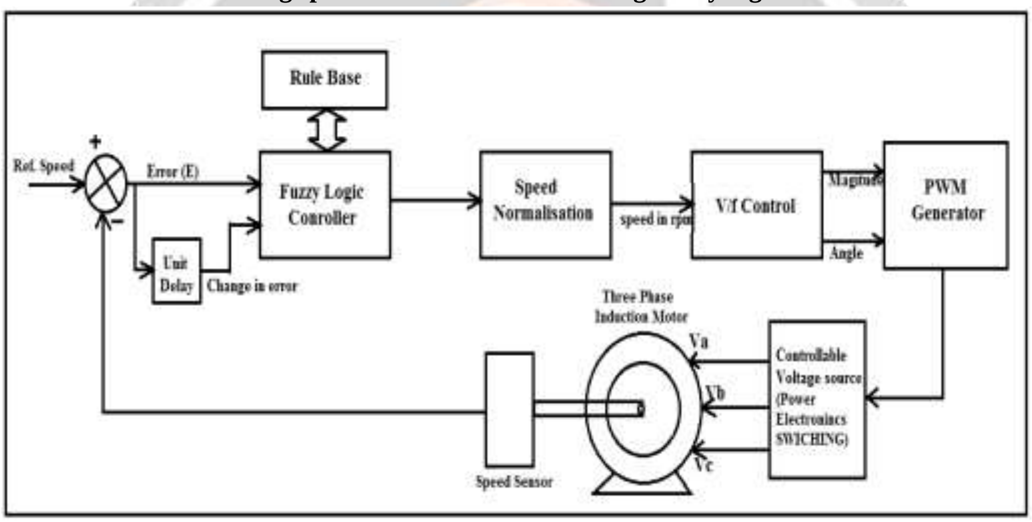

Fig-1: Generalized block diagram of proposed speed control of three phase induction motor using fuzzy logic controller.

Table -1: MATALB simulation model blocks parameter specification fuzzy controller model.

Sr No.	Name of Simulink block	Parameter specification or ratings
1.	Reference speed rad/sec	Step time = 0 sec; Initial value = 0; Final value = 125; sample time = 0.
2.	Fuzzy logic controller	Controller type= Mamadani; And method = Min; Or method = Max; Implication = Min; Aggregation =Max; Defuzzification = Centroid, Input signal = Error speed and change in error of speed.
3.	Saturation	Upper limit = 65; Loser limit = -60
4.	Discrete SV PWM generator	Data type of input reference vector = Magnitude-angle (rad); Switching pattern = Pattern1; Chopping frequency = 1980Hz;

		Sample time = $55*10^{-6}$ Sec.
5.	Universal bridge	Number of bridge arm = 3; Snubber resistance = $1*10^{5}$ Ohm; Power electronics device = GTO/Diode; Ron =1mΩ;
6.	Asynchronous machine (Three phase induction motor)	Mechanical input = Torque (Nm); Rotor type + Squirrel cage type; Mask units = SI; Nominal power = 4391 VA; Voltage line to line =230V; Frequency = 60Hz; Stator resistance Rs = 0.5 Ω; Stator inductance Ls = 1.9894mH; Rotor resistance Rr=0.25 Ω; Rotor inductance Lr=1.3262mH; Mutual Inductance Lm = 0.2655 H;

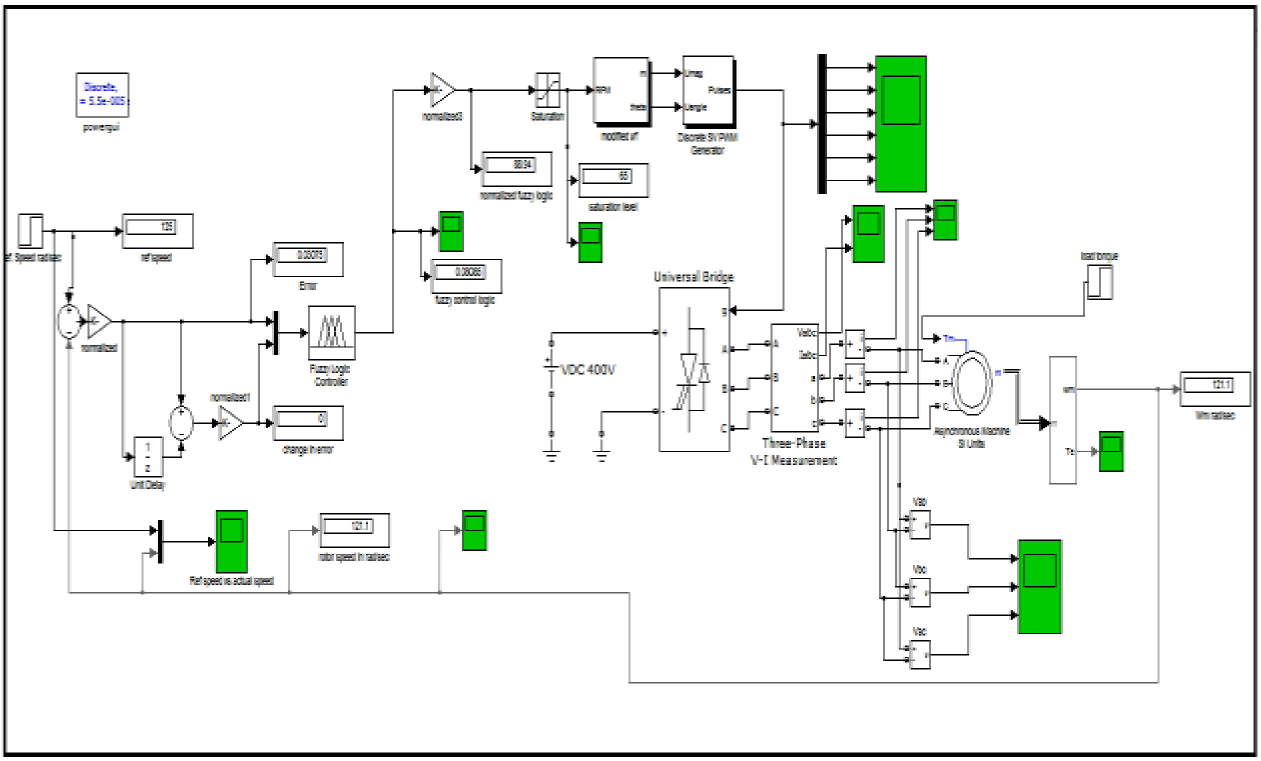

Fig-2: MATLAB simulation model of complete fuzzy logic based speed control of three phase induction motor model using Fuzzy logic controller

Figure 1 shows the generalized block diagram of speed control of three phase induction motor using fuzzy logic controller that generalized model idea was implemented using MATLAB 2009 software in Simulink environment.
Figure 2 of below shows the simulink model to control the speed of the induction motor. The speed controller block used may be PI or PID or Fuzzy depending upon the their performance. The improvement provided by PI, PID and Fuzzy is discussed and compared in the later section.
Figure 3 shows the MATLAB simulation block for modified v/f controller logic. This logic gain control the pulse width modulation generator pulse which drive the inverter circuit that is three phase induction motor input. Based on input to v/f block pulses of inverter bridge rectifier controller this circuit.

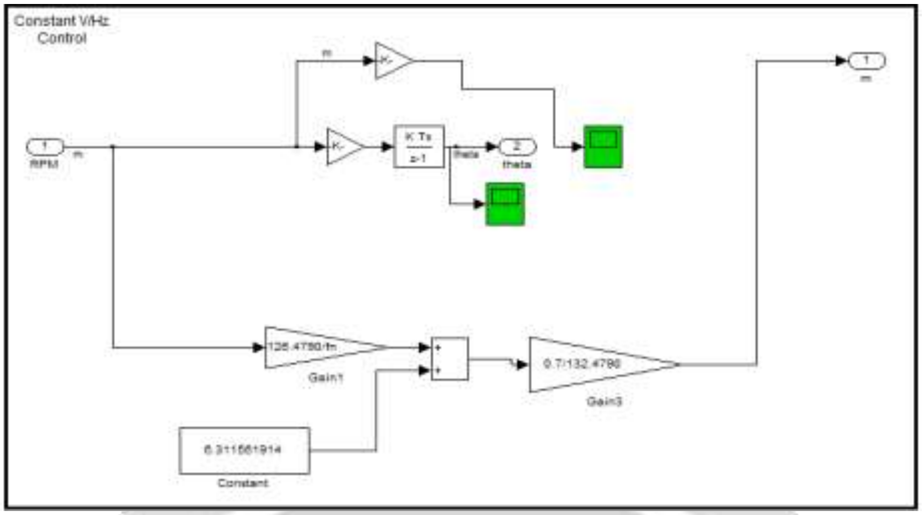

Fig-3: Modified v/f controller for speed control of three phase induction motor

2.2 Simulink model for controlling speed of induction drive using PID controller

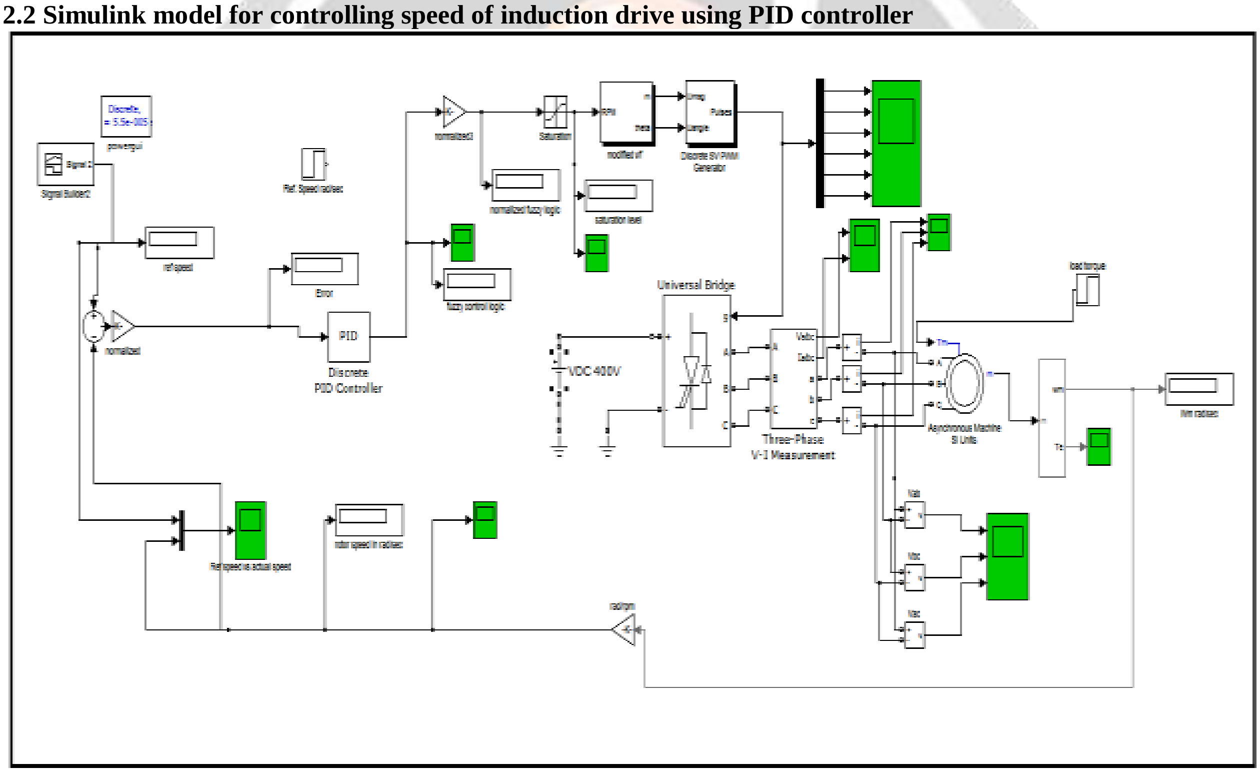

Fig-4: MATLAB simulation model of complete fuzzy logic based speed control of three phase induction motor model using PID controller.

Table-2: MATALB simulation model blocks parameter specification PID controller model.

Sr No.	Name of Simulink block	Parameter specification or ratings
1.	Reference speed rad/sec	Step time = 0 sec; Initial value = 0; Final value = 125; sample time = 0.
2.	PID Controller	Proportional Gain (Kp) =1; Integral gain (Ki) = 1; Derivative gain (Kd) = 1; Time constant for derivation = 1Sec; Output limit:

		Upper=2 & lower =-2; Sample time = 50 µSec.
3.	Saturation	Upper limit = 65; Loser limit = -60
4.	Discrete SV PWM generator	Data type of input reference vector = Magnitude-angle (rad); Switching pattern = Pattern1; Chopping frequency = 1980Hz; Sample time = $55*10^{-6}$ Sec.
5.	Universal bridge	Number of bridge arm = 3; Snubber resistance = $1*10^{5}$ Ohm; Power electronics device = GTO/Diode; Ron =1mΩ;
6.	Asynchronous machine (Three phase induction motor)	Mechanical input = Torque (Nm); Rotor type + Squirrel cage type; Mask units = SI; Nominal power = 4391 VA; Voltage line to line =230V; Frequency = 60Hz; Stator resistance Rs = 0.5 Ω; Stator inductance Ls = 1.9894mH; Rotor resistance Rr=0.25 Ω; Rotor inductance Lr=1.3262mH; Mutual Inductance Lm = 0.2655 H;

2.3 Simulink model for controlling speed of induction drive using PI controller

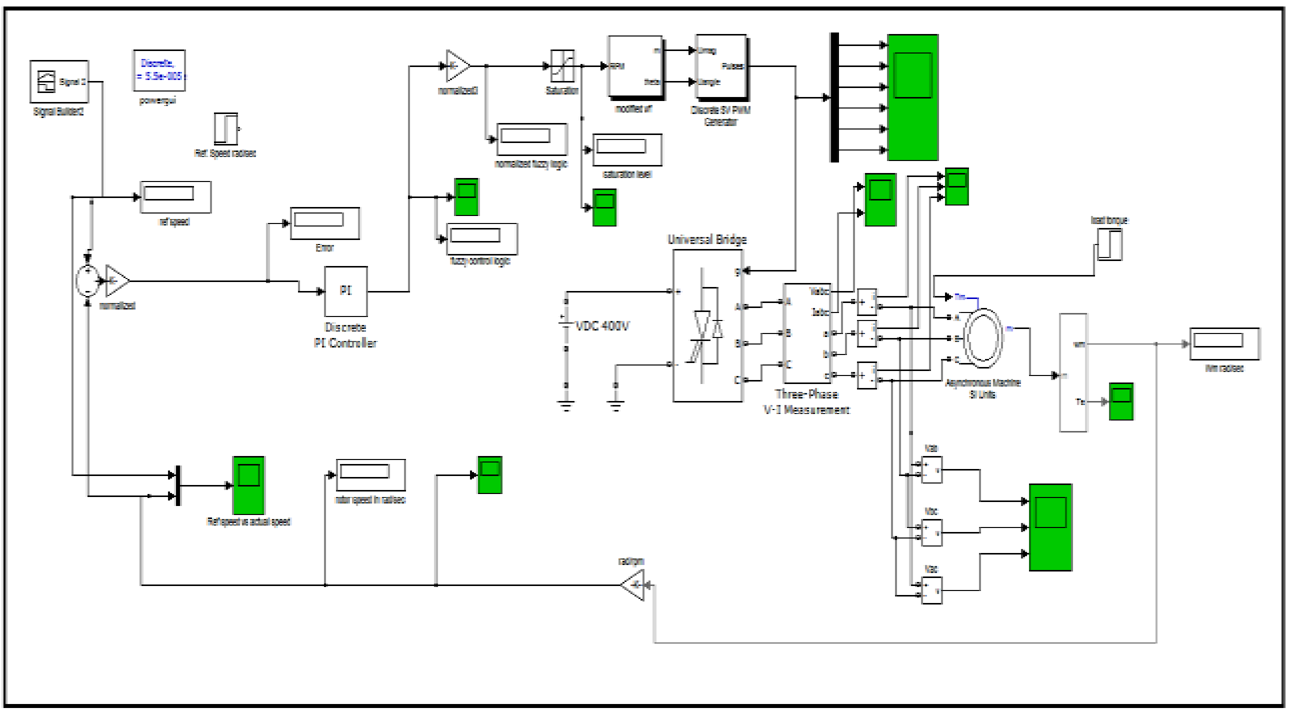

Fig-5: MATLAB simulation model of complete fuzzy logic based speed control of three phase induction motor model using PI controller

Table-3: MATALB simulation model blocks parameter specification PI controller model

Sr No.	Name of Simulink block	Parameter specification or ratings
1.	Reference speed rad/sec	Step time = 0 sec; Initial value = 0; Final value = 125; sample time = 0.
2.	PI Controller	Proportional gain (Kp) = 0.2; Integral gain (Ki) =1; Output

		limit: Upper=2 & lower =-2; Sample time = 50 µSec.
3.	Saturation	Upper limit = 65; Loser limit = -60
4.	Discrete SV PWM generator	Data type of input reference vector = Magnitude-angle (rad); Switching pattern = Pattern1; Chopping frequency = 1980Hz; Sample time = $55*10^{-6}$ Sec.
5.	Universal bridge	Number of bridge arm = 3; Snubber resistance = $1*10^{5}$ Ohm; Power electronics device = GTO/Diode; Ron =1mΩ;
6.	Asynchronous machine (Three phase induction motor)	Mechanical input = Torque (Nm); Rotor type + Squirrel cage type; Mask units = SI; Nominal power = 4391 VA; Voltage line to line =230V; Frequency = 60Hz; Stator resistance Rs = 0.5 Ω; Stator inductance Ls = 1.9894mH; Rotor resistance Rr=0.25 Ω; Rotor inductance Lr=1.3262mH; Mutual Inductance Lm = 0.2655 H;

3. SIMULATION RESULTS

Fig-6: Reference speed verses PID controller speed control response for constant speed control

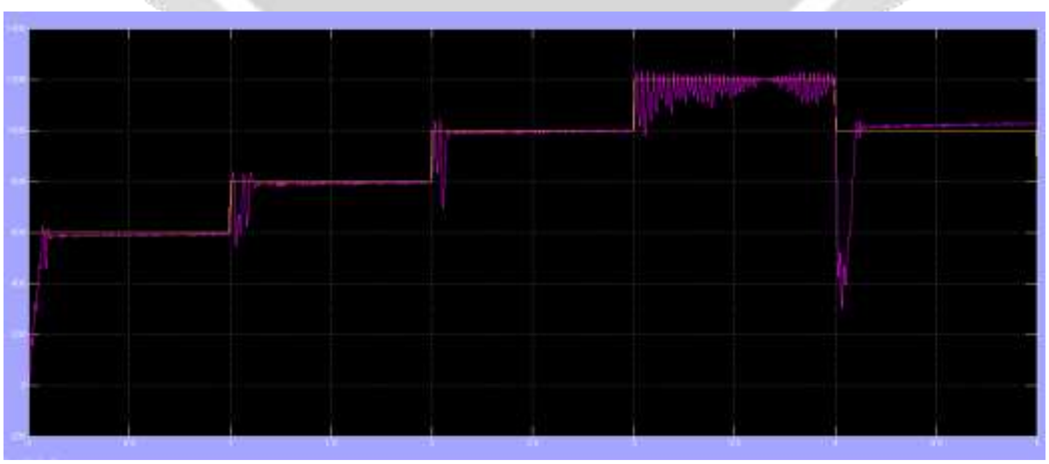

Fig-7: Reference speed verses PID controller speed controlled speed response for variable speed application of three phase induction motor

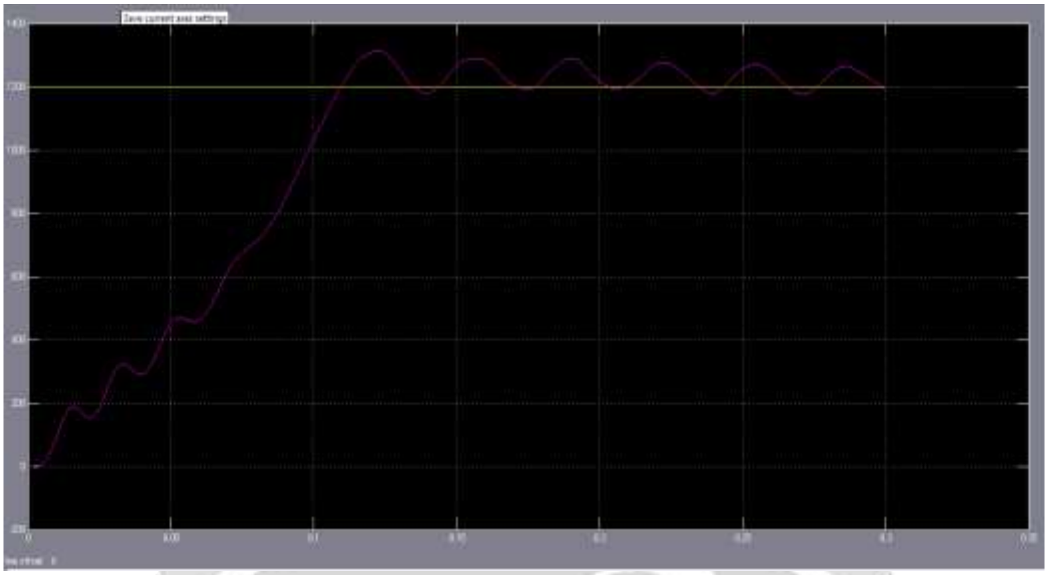

Fig-8: Reference speed verses PI controller speed control response for constant speed control

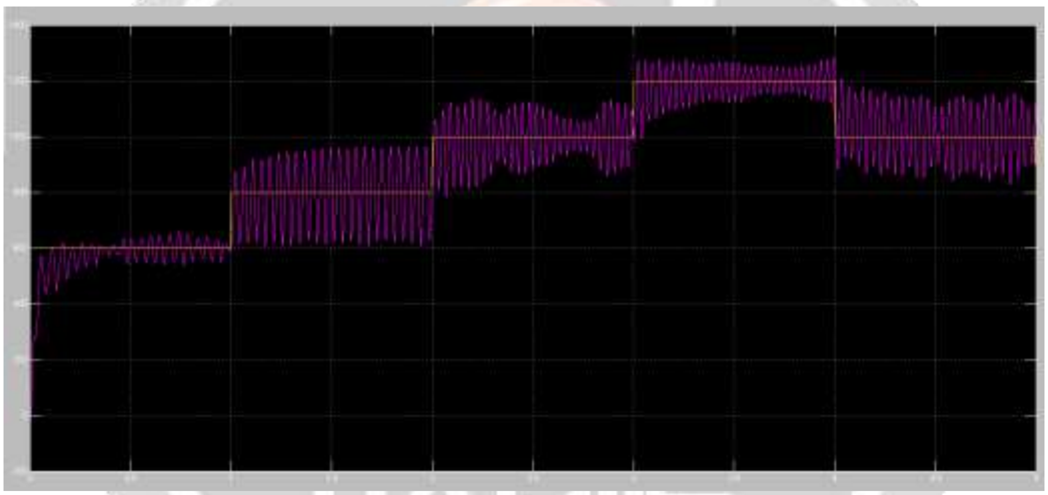

Fig-9: Reference speed verses PI controller speed controlled speed response for variable speed application of three phase induction motor

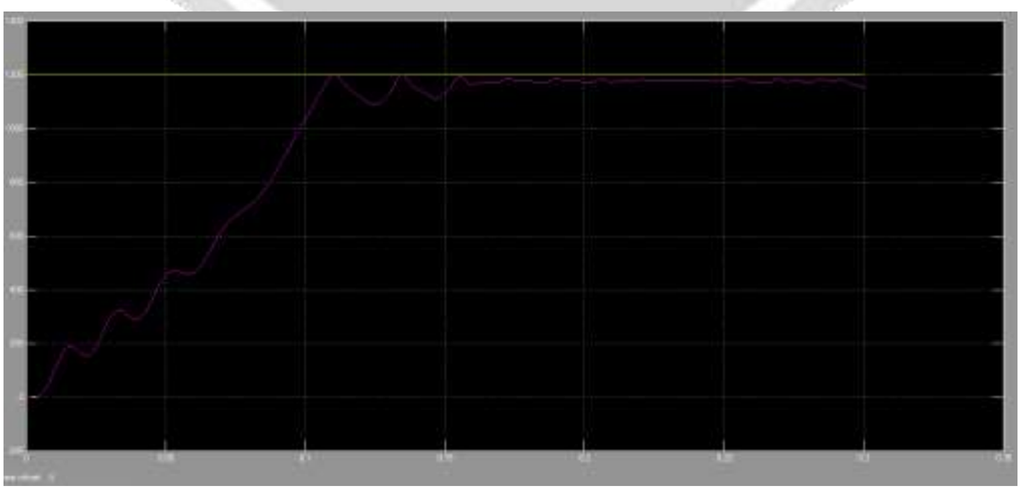

Fig-10: Reference speed verses Fuzzy logic controller speed control response for constant speed control

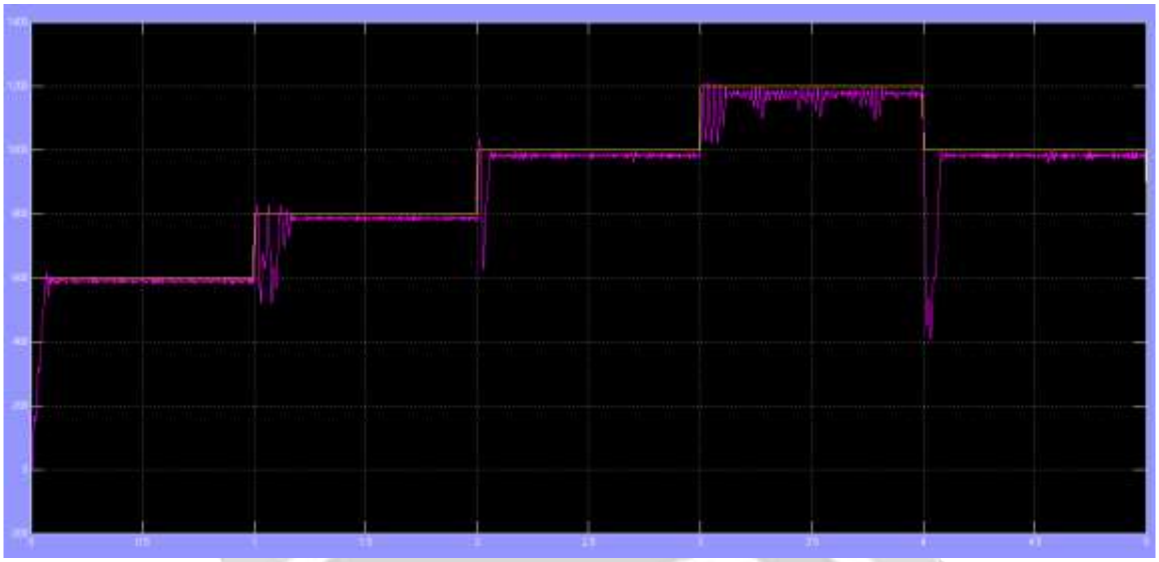

Fig-11: Reference speed verses Fuzzy logic controlled speed response for variable speed application of three phase induction motor

3.1. comparison between FLC and PI Controller Results

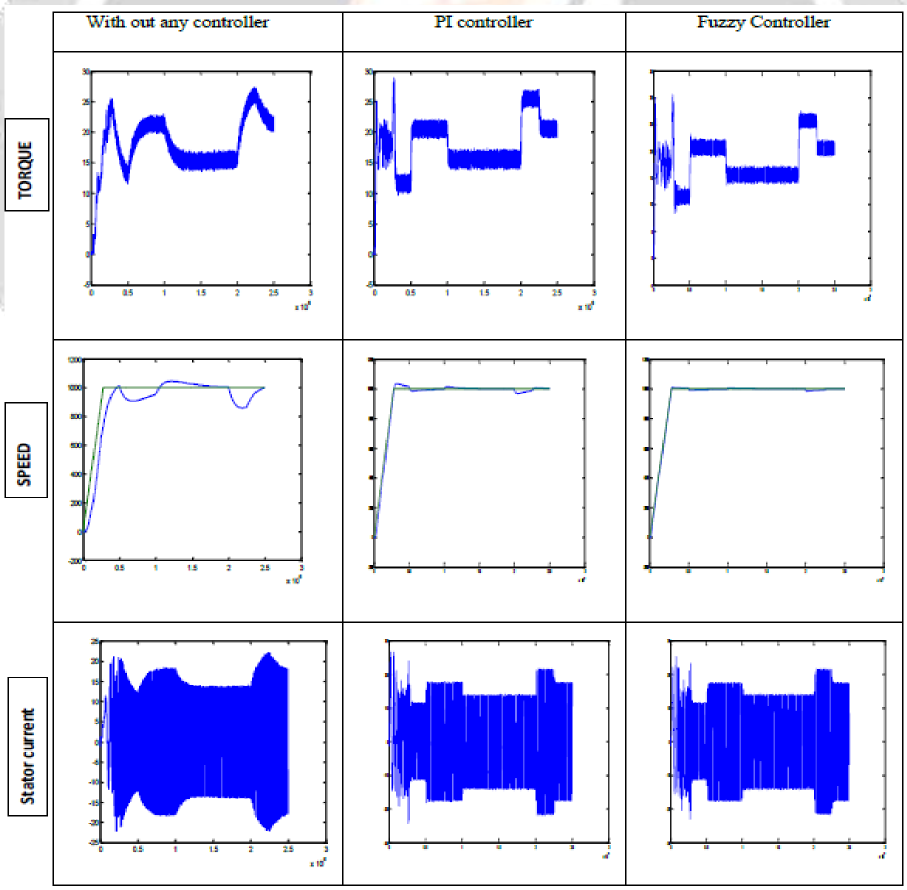

Fig-12: comparison table between PID, PI and Fuzzy logic controller

The Fuzzy Logic Controller, however, portraits a better response when the reference speed is changed (either decreased or increased with respect to the base speed). It tends to approach the new reference speed faster and has,

comparatively, a very low overshoot. It can be observed from figure 9 and figure 11 that the PI controller diverges from the new reference speed and does not attend a steady state when it is very less as compared to the base speed or greater than the base speed. The Fuzzy Logic Controller on the other hand attains a steady state. Even though this attained speed is not exactly equal to the new reference speed, it is very much close to it.
The torque plots show that while using the Fuzzy Logic Controller oscillations occur during starting while the PI controller doesn't show any such characteristic. This is because the Fuzzy
Logic Controller is based on random knowledge of data. The machine provides a desirable response after some time as the controller first has to learn from or adjust according to the data provided by the user.
From the current plots, the same inferences can be achieved. We can see that in all the current plots the current is sinusoidal. But there is a distortion in the envelope before the machine attains steady state. The reason for this is that during starting the machine passes through the unstable region.
The simplification or linearization of the non-linear system under consideration has to be performed by the conventional control methodologies like PI, PD and PID since their construction is based on linear system theory. Hence, these controllers do not provide any guarantee for good performance [14]. They require complex calculations for evaluating the gain coefficients. These controllers however are not recommended for higher order and complex systems as they can cause the system to become unstable. Hence, a more heuristic approach is required [12] for choice of the controller parameters which can be provided with the help of fuzzy logic, where we can define variables in a subjective way.
Thus we can avoid the numerical complicacy involved in higher order systems. Fuzzy logic provides a certain level of artificial intelligence to the controllers since they try to imitate the human thought process. This facility is not available in the conventional controllers.

4. CONCLUSION

After the simulation of the of the block diagram in MATLAB/SIMULINK®, it was found that the fuzzy logic controller used in the simulation worked quite effectively. The advantages of the Fuzzy Logic Controller used in the simulation were as follows:

- The overshoots in the system was very less as compared to conventional PI controller.
- The settling time was less.
- The speed tended to approach the reference speed even when it was higher than the base speed or very low as compared to the same, unlike the PI Controller.
- The designing of the control mechanism was not very cumbersome.
- The disadvantages of the Fuzzy Logic Controller used were:
- The rise time was little higher as compared to the conventional PI controller.
- After the change in reference speed from base speed, the actual speed did not exactly follow it, but was found to be almost equal to it.
- The Fuzzy Controller was then tuned and the some simulations were run. It was found that now the motor speed exactly follows the reference speed even after the speed changes.
- The modified Fuzzy Logic Controller also works fine when the reference speed is a ramp function. Hence, this modified controller is superior to that of the prior controller.

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