PERFORMANCE COMPARASION OF PID AND FUZZY CONTROL TECHNIQUES IN THREE PHASE INDUCTION MOTOR CONTROL

S.R.Jadhav, S.V.Kulkarni, T.D.Dongale, T.G.Kulkarni, R.R.Mudholkar, M.D.Uplane

ABSTRACT

The demand for control of electric power for electric motor drive system and industrial control exists since many years. Variable-speed drives are designed when a motor is combined with a power electronics converter. By introducing variable speed for the driven load, it is possible to optimize the efficiency of the entire system and this is the area where the maximum efficiency gains are possible. The closed loop control strategies employed are legion and PID is seemed to be superior amongst them. However it further needs to be improved in terms of overshoot and settling time. Hence some other control strategies based on Fuzzy Logic, Artificial Neural Network (ANN), Neuro-Fuzzy etc., can be good alternatives. This paper describes the implementation of controllers based on PID and Fuzzy Logic strategies. A comparative performance analysis demonstrates the clever exploring of Fuzzy Logic control strategies circumventing the demerits of PID control strategies.

Index Term: PID, Fuzzy controller, Three phase inverter, Induction motor

1. INTRODUCTION

AC motors are getting more and more popular with their integration in large number of applications like pumps, conveyors, machine tools, centrifugal machines, presses, elevators, and packaging equipment etc. The major benefits of using AC motor in a system are improved reliability, better performance, higher efficiency, easy scalability and feasibility of speed and torque control by different techniques. The techniques such as Rotor Resistance Control, Stator Voltage Control, Variable f, V/F Control, Slip Energy Recovery Scheme etc. play significant role in precisely controlling the speed of motors. Many researchers have reported the work on speed control of AC machines employing different control strategies [1-3]. The performance comparison of various drives reported in literature [4-10] help the comprehensive understanding drive option targeted for application of interest. The ac drives are electronic devices used to control speed and torque of three-phase induction motors. An induction motor supplied by an ac drive can operate over a good range of frequency, typically from 10Hz to 90Hz. This range of frequencies yields rotor speeds from zero rpm to the rated value. The ac drive can produce the rated torque at any frequency within this range from zero to the rated frequency. In constant torque mode the motor operates up to base speed with constant torque. In constant power mode the motor operates above base speed with varying torque. In constant torque mode the motor is supplied with rated voltage and frequency.

Some advanced techniques are practiced in motor control applications. Among these PID is most popular Algorithm. Some researchers have used Fuzzy, Fuzzy-PID and Neuro Fuzzy technique in many applications. The performance comparison of these methods indicates that some advanced techniques like Fuzzy achieves better performance in certain applications. In the present work the three phase motor drive is proposed, which will be implemented using PIC microcontroller. The PID and Fuzzy algorithms were used to control the three phase induction motor. The performance comparison of the drive with both algorithms will be discussed subsequent sections.

2. SYSTEM BLOCK DIAGRAM

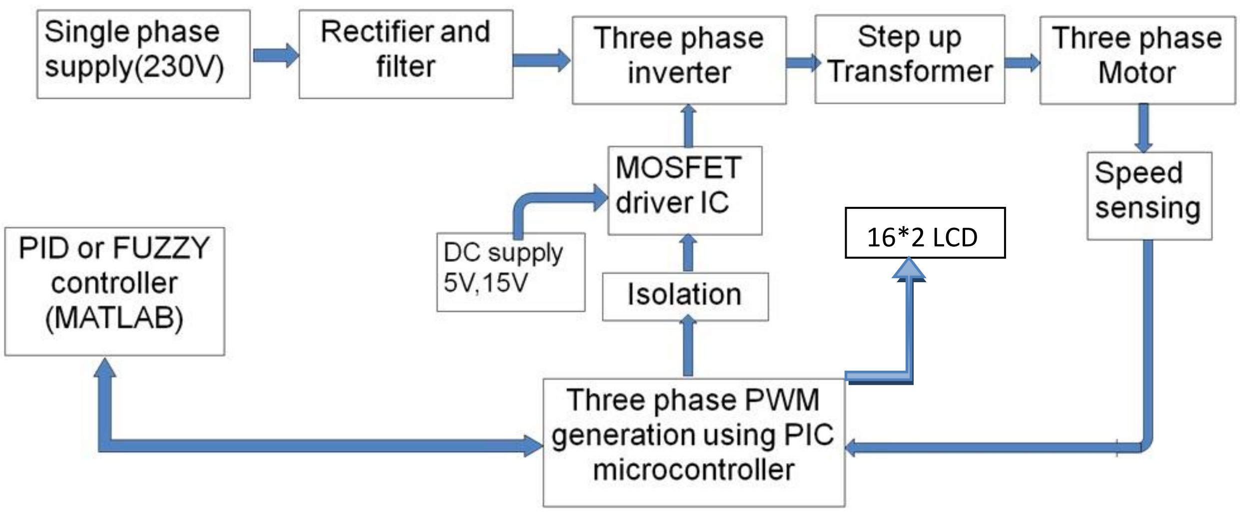

Figure 1: System Block Diagram

The system block diagram is shown in fig.1. It is designed around Peripheral Interface Controller (PIC 16F877A). It includes inverter design, gate drive circuit, isolation and microcontroller for the proposed work. For the operation of variable frequency bridge inverter the required logic pulses are generated by using PIC microcontroller and are applied to gate drive circuit. The frequency for operation is read by microcontroller through Hall Effect speed sensor and current speed is send to Simulink of PID or Fuzzy control technique through USART terminal of microcontroller. The gate drive circuit is consists of opto-isolator to provide isolation for microcontroller and the other gate drive circuitry. The basic three phase voltage source inverter consists of six power MOSFETs with built in anti parallel diodes for freewheeling action. The IRFP–460 N-CHANNEL MOSFET is a semiconductor device operating as a switch. It operates at highest possible turn-ON and turn-OFF rates, extremely high dv/dt capability and ensuring the accurate operation of the inverter. AC voltage from the power grid is rectified using the power bridge and capacitor is used as a filter, the output of filter gives pure DC to the three phase inverter as DC source. Depending upon the frequency generated by microcontroller, the power supplied to the motor is varied. The measured speed is displaying on 16*2 LCD for the purpose of displaying the present speed of motor sensed by Hall Effect sensor.

2.1. Three Phase Inverter Design

Three phase inverter designed using power MOSFETs is as shown in fig.2. The inverse diode associated with the device is sufficient to operate the circuit at higher frequencies. MOSFET technology promises to use much simpler and efficient drive circuits with significant cost benefits compared to bipolar devices. High voltage capacitor is connected across the rectifier out to provide low impedance path for high frequency current at switching of power devices.

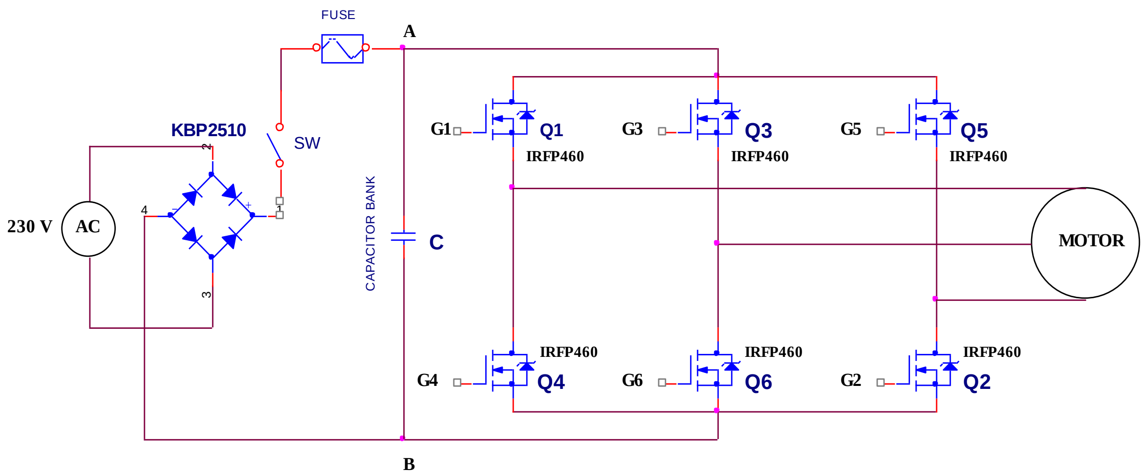

Figure 2: Three Phase Inverter Circuit

Figure 3: Real Time Controlling of 3 Phase Induction Motor

The conduction sequence of MOSFET is 612, 123, 234, 345, 456, 561, and 612. This gating sequence is generated so that MOSFETs of the same branch would not conduct at the same time. There must be some short time delay between turn off MOSFET and turn on MOSFET. This time delay must be greater than or equal to turn-off time of MOSFET (≈20 nS). Each phase to phase contain120^0 phase shift. The Phase to neutral output waveforms are as shown in fig.4.

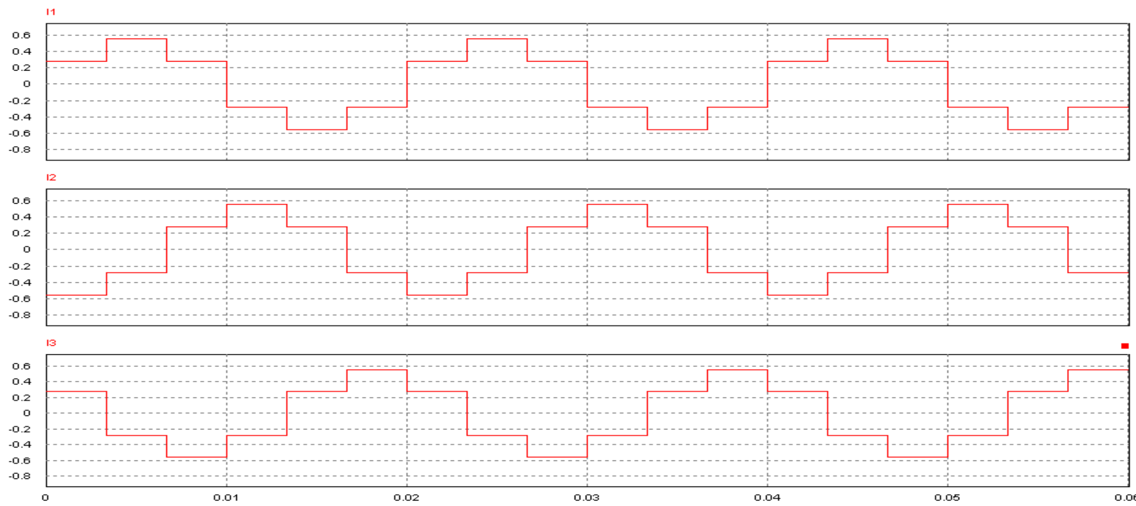

Figure 4: Inverter Output Waveforms (Simulated in PSIM software)

2.2. Gate Drive Using IC- IRS 2110

To protect the control hardware from the high-power hex-inverter dielectric isolation is desired. A single chip, the IRS2110, was found to have the desired functionality. It serves the purpose of implementing gate drives, including the circuitry that takes into account the voltage biasing of the high side MOSFETs [8]. The IR2110 MOS gate driver IC has two channels controlled by TTL or CMOS compatible inputs. IRS2110 have the transition threshold proportional to the supply V_{DD} (3V-20 V). This MGD have two gate drive channels hence independent, input commands or a single input command with complementary drive and predetermined dead time.

2.3. Microcontroller PIC 16F877A

For a control mechanism purpose, PIC16F877A is used. The role of microcontroller is to generate PWM of desired frequency using timer/ counter module. It also monitors the sensed speed by Hall Effect sensor and sends it serially to Simulink designed for PID and Fuzzy control technique. According to speed sensed by Hall Effect speed sensor, the Simulink will generate control signal. This control signal is again provided to microcontroller for PWM variation. In short PWM is varied according to control signal generated by PID or Fuzzy Simulink. Microcontroller also displays the current speed in RPS (Rotation per Second) on 16x2 LCD display.

2.4. Hall Effect Speed Sensor

The Hall-effect integrated Sensor in incorporated with a Hall circuit, a linear amplifier, and a CMOS Class A output structure. Integrating the Hall circuit and the amplifier on a single chip minimizes many of the problems normally associated with low voltage level analog signals. In the present work the Hall Effect speed sensor MH 183 is a unipolar Hall Effect sensor is used for speed sensing purpose has been used. It incorporates advanced chopper stabilization technology to provide accurate and stable magnetic switch points. The design, specifications and performance have been optimized for applications of solid state switches. The output transistor will be switched on (BOP) in the presence of a sufficiently strong South Pole magnetic field facing the marked side of the package. Similarly, the output will be switched off (BRP) in the presence of a weaker South field and remain off with “0” field. [10]

3. PID AND FUZZY SIMULINK MODEL DEVELOPMENT

Using Simulink facility of MATLAB the models for following two types of controller have been developed for real-time motor speed control-

1. PID Controller
2. Fuzzy Controller

3.1. PID Controller Simulink Design in MATLAB

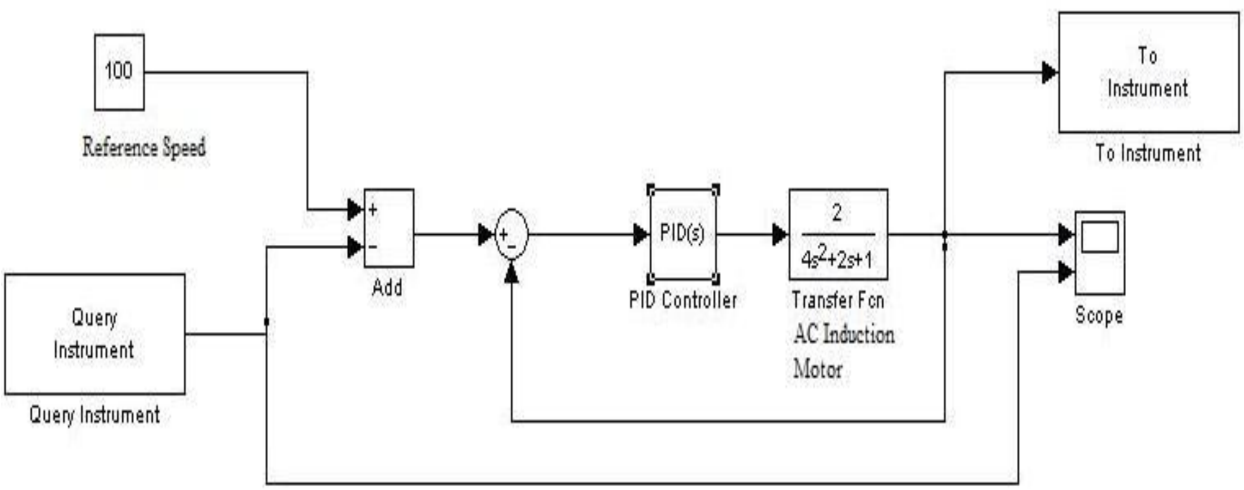

Figure 5: PID Simulink Model

PID Tuner provides a fast and widely applicable single-loop PID tuning method for the Simulink PID Controller blocks. With this method the PID parameters can be easily tuned to achieve a robust design with the desired response time. The actual speed of motor is sensed by speed sensor using PIC controller and it send serially to Simulink. The Simulink block corresponding to *constant* is used to set desired speed. Here auto tune PID is used for tuning plant or system. The transfer function of motor system is a second order type as shown in fig.5.

Because of second order type system it exhibits overshoot and large settling time which forms the metric of performance in the present study.

3.2. Fuzzy Controller Simulink Design in MATLAB

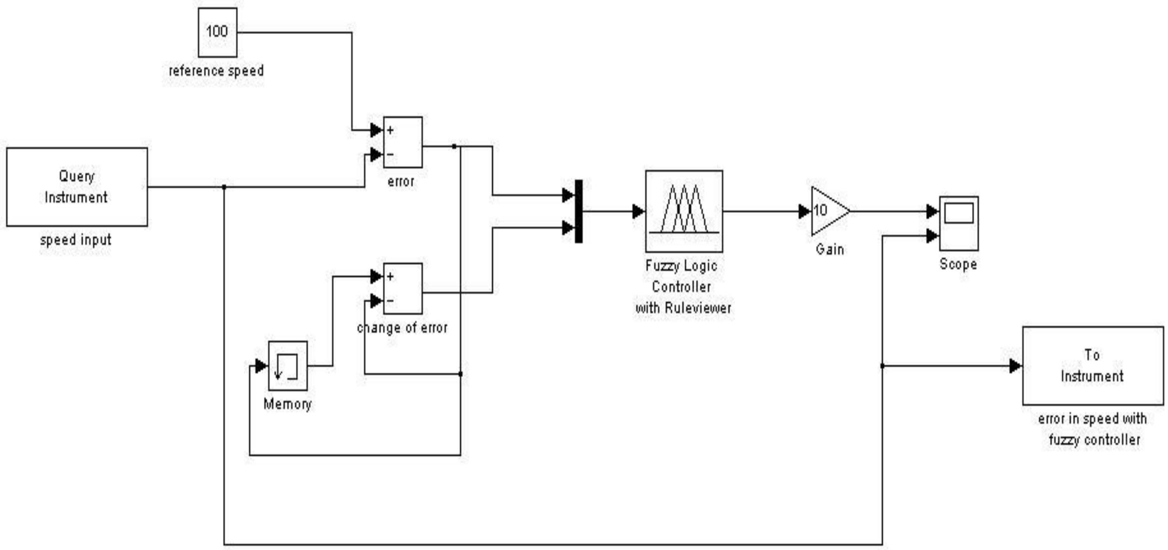

Figure 6: Fuzzy Simulink Model

Fig.6 shows Simulink design model for Fuzzy Controller. It contain query instrument for accepting the real time present speed of motor through serial port of PIC. The *constant* is set to a reference speed. *Error* block generates the output which is the error between actual speed and set speed. This is error applied to one input of Fuzzy controller and other to store the error in memory to provide it to *change of error block* which gives error between previous error output and actual error at present state. Multiplexer combine both input and gives it to Fuzzy controller. Real time scope is used to observe actual behavioral of a system. To *instrument block* is used to send output of Fuzzy Controller to PIC microcontroller. The Fuzzy Inference Scheme (FIS) for Fuzzy controller is design using Mamdani method. It contains structure of minimum and maximum operation [11]. Direct method operates on an inference rule such as-

"IF x is A and y is B THEN z is C"

Where A, B and C are fuzzy sets. In this rule there are two main parts, the part following IF called premise and part following THEN is called consequence. Hence x and y are called premise variables and z is the consequence variable.

3.3. PID Simulation Model

The fig.7 shows the tuning of PID controller. Auto-tune PID controller itself tunes for exact values of K_p, K_i and K_d.

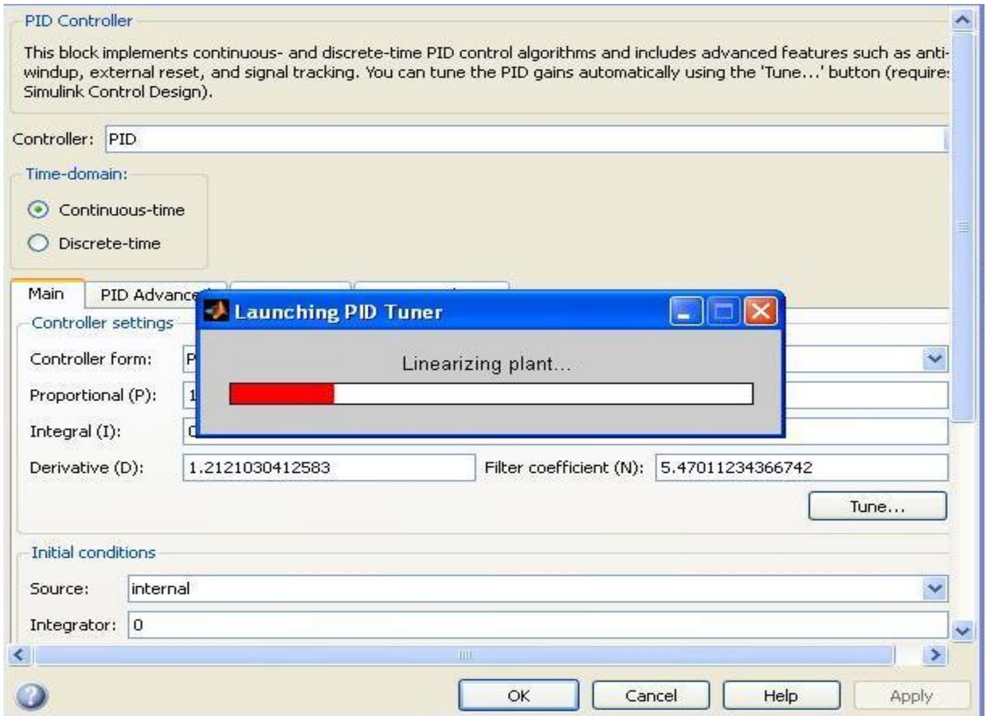

Figure 7: Tuning of Auto-Tune PID Controller

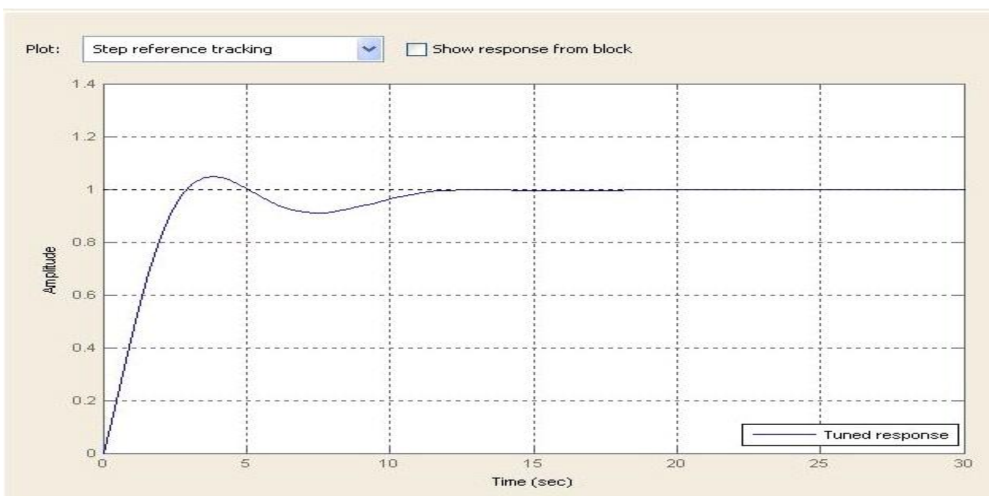

Figure 8: Auto-Tune PID Tuning Response

Fig.8 shows the response of auto-tune PID controller. It depicts the transient response, steady state response, pick rise time, pick overshoot and most important parameter is the settling time. By changing response time we were able to set all this parameter to desired value. Auto-tune PID tuning response and all the parameter shows a settling time of 10.8 s which is quite large. It means that system exhibits little sluggish response in tracking the set point. The various performance metric parameters are shown in below table-I.

Table-I: System Parameter for Three Phase Induction Motor Control

Parameter	**Observed Value**
Rise Time	2.09 second
Overshoot in %	4.91%
Peak Time	1.05 second
Settling Time	10.08 second

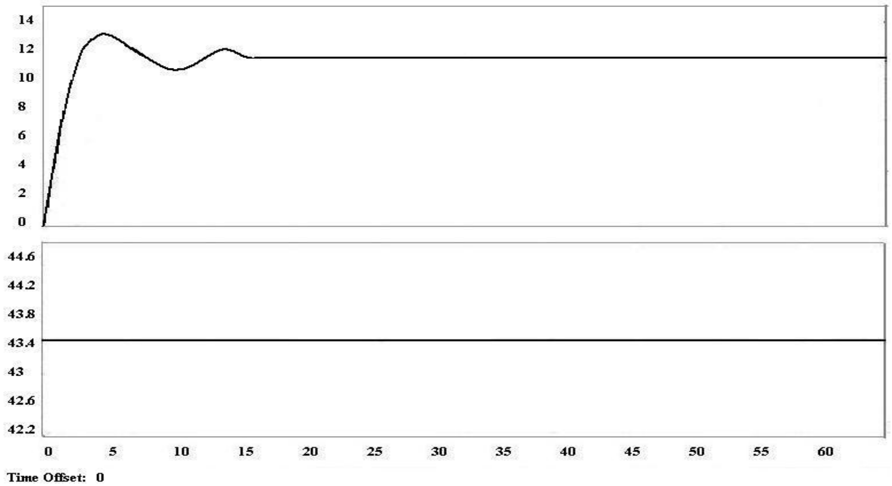

Figure 9: Real Time PID Response for Three Phase Induction Motor Control

Fig.9 shows the actual tuned PID output response and real-time speed of induction motor. Depending upon set speed and error in speed is generated which is applied to the PID controller and depending on this error PID gives the output which is passed over to PIC microcontroller to maintain the speed. Program in microcontroller develops a decision signal such that if speed of motor is increasing the PID Algorithm gives large error output and depending upon error the three phase half-bridge inverter frequency is accordingly decreased to slow down the motor speed. In the same way, if speed is found to be decreasing then frequency for inverter is increased. This whole program is developed using MPLAB environment with hitch c-compiler.

3.4. Fuzzy Simulation Model

In order to control speed of induction motor using Fuzzy Controller, it is necessary to develop Fuzzy Inference System (FIS) in MATLAB environment. PID is one of the popular methods for many applications but it has certain limitations. Although, it is well suited for certain applications, Fuzzy control is another simplest method for control applications. It basically closely associated with the human's decision making. Also it is rule based approach providing more smooth control strategy [11-12]. Here, we have designed the Fuzzy Inference System for speed control of induction motor as is shown in fig.10.

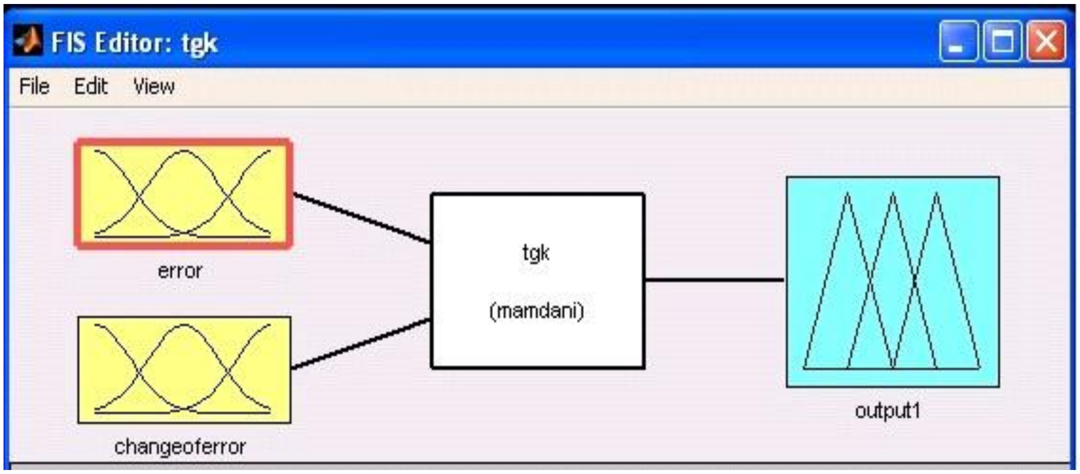

Figure 10: FIS Editor for FUZZY Controller by Mamdani Method

For this particular application, Mamdani controller is used [11], which has two inputs namely 'error' and 'change *of error*' and single output. Input and output contains seven triangular membership functions. These seven membership functions are labeled as 'NL, NM, NS, Z, PS, PM, PL' which are same for inputs and output variables. The ranges for these inputs are dependent on the speed of motor. The error input is nothing but difference between the speed sensed using Hall Effect sensor and set point speed, and change of error is nothing but the difference between current speed and previous speed. The previous speed is stored in memory block which holds the data for particular time. According to these inputs and control policy the rules are defined using decision matrix table shown in table-II.

Table-II: Fuzzy Rule Base Decision Matrix for Speed Control

ce \ **e** / **u**	**NL**	**NM**	**NS**	**Z**	**PS**	**PM**	**PL**
NL	NL	NL	NL	NL	NM	NS	Z
NM	NL	NL	NL	NM	NS	Z	PS
NS	NL	NL	NM	NS	Z	PS	PM
Z	NL	NM	NS	Z	PS	PM	PL
PS	NM	NS	Z	PS	PM	PL	PL
PM	NS	Z	PS	PM	PL	PL	PL
PL	Z	PS	PM	PL	PL	PL	PL

The rules have the following format-

IF *error is NL* AND *change of error is NL* THEN *output is NL*

IF *error is NM* AND *change of error is PS* THEN *output is NS*

Likewise, all forty nine rules are designed as control demand needs the action. This system is of MISO (Many Input-Single Output) structure. Here inputs are two and each input has seven partitions, thus there are 7x7 = 49 rules. The rules are fired according to the inputs and output conditions and decisions pertaining to output control signal are generated. This output is again sent back to the PIC microcontroller. It detects the output and accordingly it generates a particular PWM sequence for increasing or decreasing the speed. The fuzzy controller provides more smooth response and also less settling time [11, 12]. The whole system is in closed loop. The response of fuzzy simulation is shown in fig.11. It shows the settling time required and also the settled output for given input.

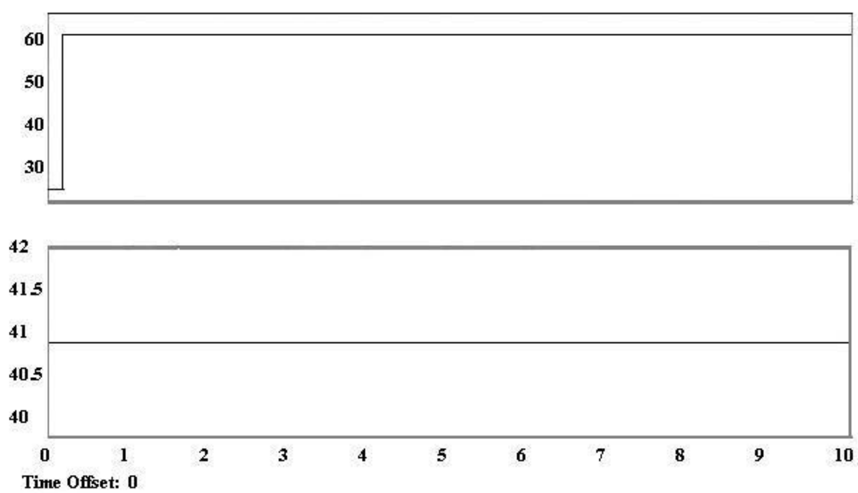

Figure 11: Real Time Fuzzy Response for Three Phase Induction Motor Control

4. RESULTS AND DISCUSSION

PID and FUZZY controllers are very efficient for speed controlling of three phase ac induction motor. They provide precise controlling action within their limits. PID controller is very much useful because it uses auto tuning. Once it is tuned it tracks the output according to the provided input. But it has a limitation that it has more settling time and overshoot. Fuzzy controlling is another means for this application. Its advantage is that it provides minimum settling time than PID controller and also less overshoot. The experimental results of both the controller are compared and analyzed. It is found that speed controlling of AC induction motor with Fuzzy controllers is better than PID controlling method.

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