Speed Control of Three Phase Induction Motor Using Fuzzy-PID Controller

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***Abstract*:-The demand for control of electric power for electric motor drive system and industrial control existed for many years. Variable-speed drives are created when a motor is combined with a power electronics converter. By introducing variable speed to the driven load, it is possible to optimize the efficiency of the entire system and it is in this area that the greatest efficiency gains are possible. AC motor drives are widely used to control the speed of conveyor systems, blower speeds, pump speeds, machine tool speeds, and other applications that require variable speed.**

Control deals with the steady state and dynamic characteristics of closed loop system. There are many closed loop control strategy are used such as Proportional control, Derivative control ,Integral control, and some combination of this such as PI, PID in all this PID is mostly used because others has sluggish performance and it is used to avoid oscillations. PID is best one but still it has some limitations such as it require much time to minimize the error and to settle the system at constant speed, hence some other control strategies such as FUZZY, ANN, NEURO-FUZZY etc., can be used. The system described in this paper uses FUZZY -PID controller for implementation.

***Key words*: – PID, FUZZY-PID controller, Three phase inverter, Hall effect speed sensor, Induction motor etc.**

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 Improved reliability, performance , efficiency, scalability, 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 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.

By using conventional speed control i.e. by maintaining constant voltage and frequency ratio we are able to control speed of motor at a constant speed. 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 applicationsFuzzy logic is a broad theory having fuzzy set theory, fuzzy logic, fuzzy reasoning, fuzzy measure etc. fuzzy logic is an extension of conventional logic or binary logic. The fuzzy logic is closely related with human thinking and it is different from probability theory. The use of fuzzy logic in the control field ranges from air conditioner to electric train. This system uses PIC microcontroller for controlling all the modules such as three phase half bridge inverter, speed measurement, serial communication with MATLAB, speed showing on 16*2 LCD Display .All this system uses feedback close loop system in which speed of motor is control using two advanced controller FUZZY-PID controller. There are also some other advantages of this three phase drive incombination with the three phase step-up transformer we can able to control any three phase machine on a single phase supply. The following sections describes PID, FUZZY-PID Simulation and its hardware implementation and finally the conclusion based on comparative study and working of hardware.

2. PID AND FUZZY-PID SIMULINK MODEL DEVELOPMENT.

Simulink model to control speed of AC motor is developed in Matlab. The simulink model for PID and FUZZY-PID controller is designed using various toolbox available in simulink library such as power electronics, control system, signal processing toolbox & from its basic function. The entire system modelled in simulink is closed loop feedback control system consisting of the plant, controller , samplers, feedback system, Mux, transfer function. The two types of Controllers have been developed for real time motor speed control *i.e.* PID and FUZZY-PID Controller.

A. PID Controller Simulink Design in MATLAB

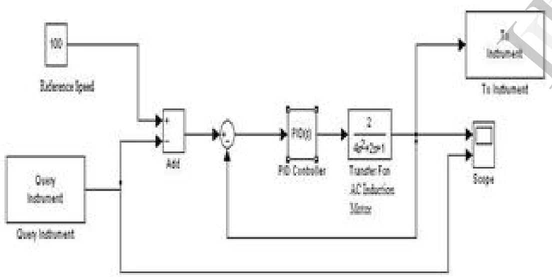

Figure 1. PID simulink model

The actual speed of motor is fed to the controller through Matlab by using instrument control toolbox which has different parameter for configuration such as baud-rate, receiving format as binary, ASCII,etc.

2.1 Tuning of PID Controller:-

The figure.2 shows the tuning of PID controller. Auto-tune PID controller itself tunes for exact values of K_p, K_i and K_d. 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

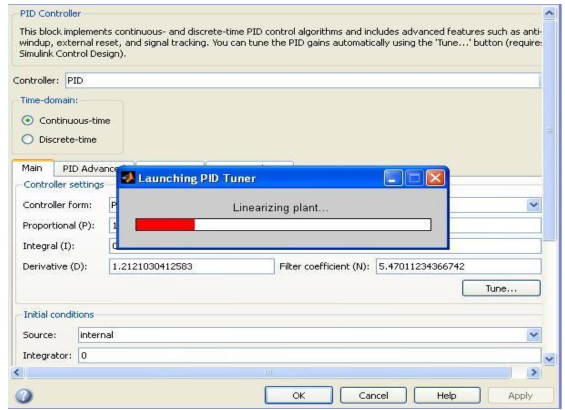

Figure 2.Tuning of Auto-Tune PID Controller

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.1. Because of second order type system it exhibits overshoot and large settling time.

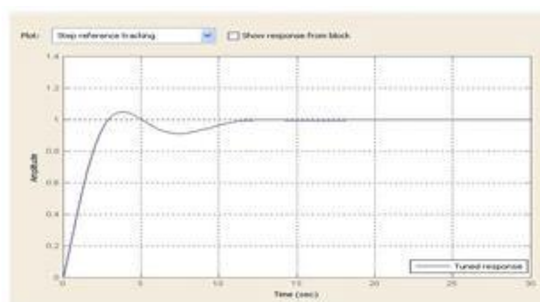

Figure 3. PID Tuning response

Figure 3. 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.

Table-I: System Parameters

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

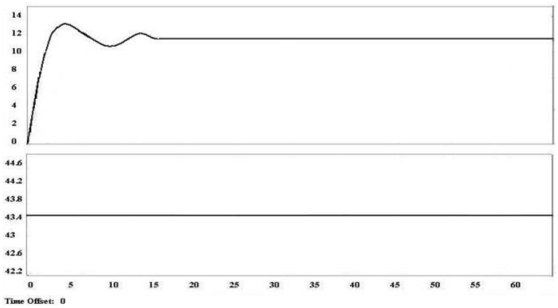

Figure 4.Real time PID response

Figure. 4 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.

B. Fuzzy-PID Controller Simulink Design in MATLAB

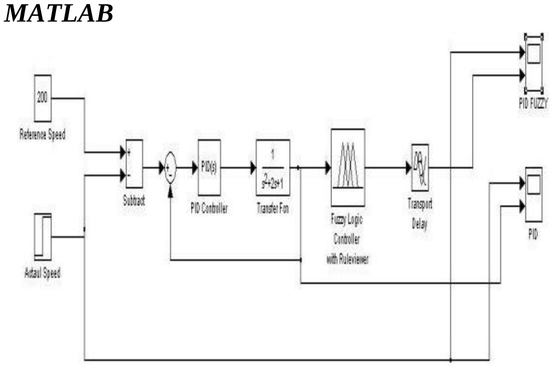

Figure 5. Fuzzy PID Simulink Model

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. Here, we have designed the Fuzzy Inference System for speed control of induction motor as is shown in figure.6

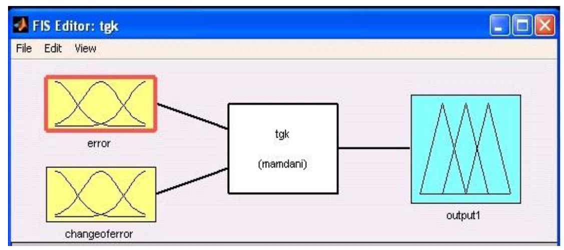

Figure 6. FIS Editor for Fuzzy Controller.

For this particular application, Mamdani controller is used ,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.

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

Table-II:Fuzzy Rule Base Decision Matrix

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.

3. *Hardware Implementation*.

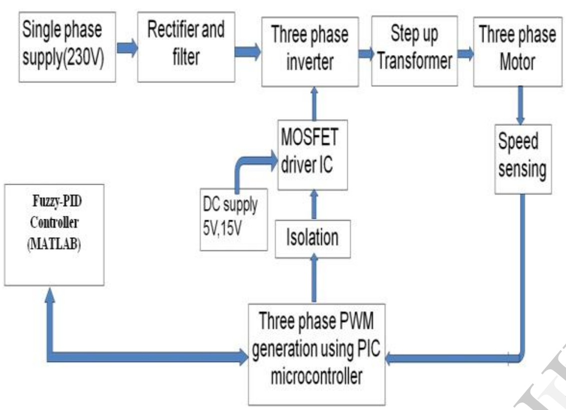

Figure 7. System Block Diagram for Hardware

Figure 7 shows the system block diagram for the hardware implementation. It has following main blocks / components.

3.1 Three Phase Inverter

Three phase inverter designed using power MOSFETs is used. 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; hence MOSFET is selected in this design application. High voltage capacitor is connected across the rectifier out to provide low impedance path for high frequency current at switching of power devices. This gating sequence is generated so that MOSFETs of the same branch cannot be 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 .

3 .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.

3.3 Microcontroller PIC 16F877A.

For control mechanism purpose, PIC16F877A is used. The role of microcontroller is to generate PWM signals 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 Fuzzy-PID 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 Fuzzy-PID Simulink. Microcontroller also displays the current speed in RPS (Rotation per Second) on 16x2 LCD display.

3.4 Hall Effect Speed Sensor.

In the present work a unipolar Hall Effect speed sensor MH 183 is used for sensing the speed. 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.

4. Flow Chart For System Development.

From the system development flow chart (figure.8)and system block diagram for hardware (figure.7) the proposed work is designed around Peripheral Interface Controller (PIC 16F877A). It includes inverter design, gate drive circuit, isolation and microcontroller. 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.

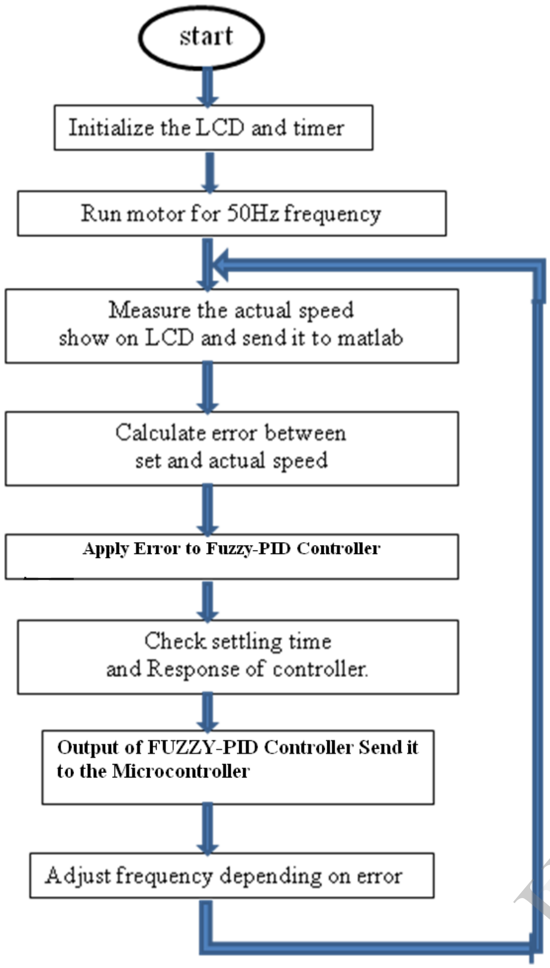

Figure 8. system development Flow Chart.

The frequency for operation is read by microcontroller through Hall Effect speed sensor and current speed is send to Simulink of FUZZY-PID 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.Thus Power supplied to the motor is modulated by frequency generated by microcontroller. The speed sensed by Hall Effect sensor is displayed on LCD.

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. The whole system is in closed loop. The response of FUZZY-PID simulation is shown in fig. from simulation results it seems that the most active recent trends can be formed for hybrid systemof fuzzy logic and PID controller. A PID Controller can be used for fast control while that of fuzzy controller can be used for better performance.

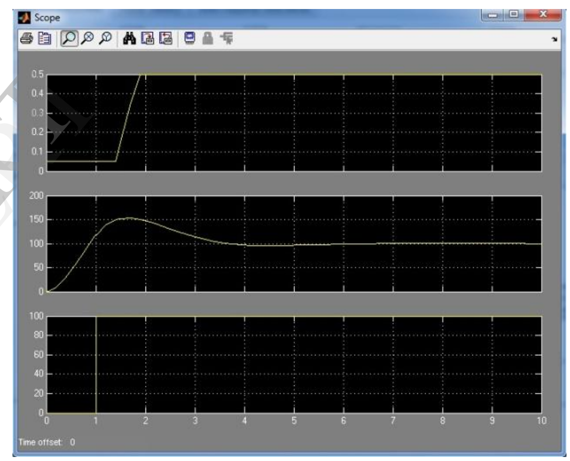

Figure 9, Fuzzy-PID Response for Three Phase Induction Motor Control

5. Conclusion: Instead of all conventional strategies, PID and FUZZY-PID controllers are very different in nature and are efficient for speed controlling of three phase ac induction motor. But 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 suffers from more overshoot and settling time. As evident from response curve (Fig.9) the PID in simulated and real time implemented forms has greater over shoots besides longer settling time. The fig9. also depicts the response of Fuzzy-PID controller intended to drive the three phase induction motor. Fuzzy Controller has offered negligible settling time than PID

controller and with almost no overshoot. The work reveals that that speed controlling of induction motor with Fuzzy-PID controller is smooth and easy than PID controlling method.

6. References.

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