Speed Control of PMSM Motor Using Fuzzy and PID Controller

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ABSTRACT

This paper presents the study and analysis of the fuzzy and pid control system applying to permanent-magnet synchronous motor(PMSM).the most commonly used controller for dc motor system is proportional-integral(PI) controller. However, the PI controller has some disadvantages such as, high starting overshoot, sensitivity to controller gains and sluggish response due to sudden load disturbance. Further, fuzzy control is proposed and the performance of fuzzy controller was compared with PID controller and the overall system is modeled and simulated using MATLAB/SIMULINK software. Simulation result are presented and analyzed for both fuzzy and PID controller. It is observed that fuzzy logic and PID based controller gives better responses then traditional PI controller for the speed control of dc motor drives.

Keywords: fuzzy logic controller, Proportional-Integral-Derivative (PID) controller, Speed control, PMSM motor drive.

I.INTRODUCTION

Conventional dc motors are highly efficient and their characteristics make them suitable as servomotor. However, it is need a commutator and brushes which are subject to wear and required maintenance. The function of commutator and brushes were implemented by solid-state switches that can realize more maintenance. These motor are now known as brushless dc motor. To overcome this permanent magnet is employed in stator is called as permanent magnet synchronous motor (PMSM).

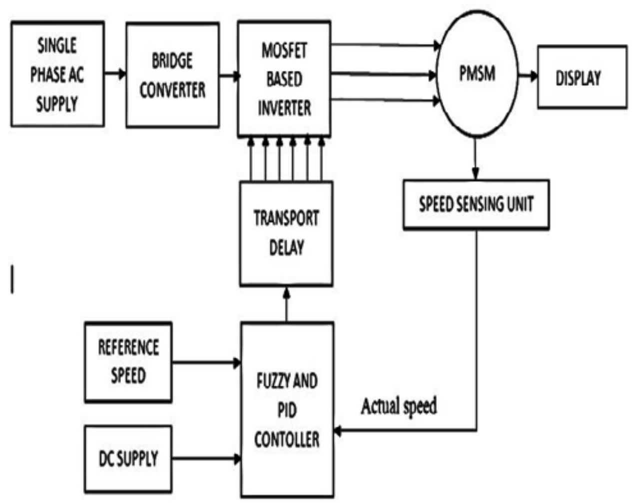


Fig.1.1 Overall Block diagram

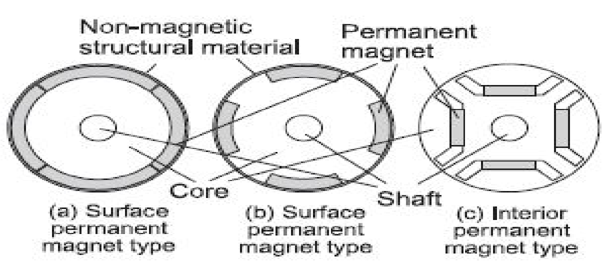
Fuzzy logic controller which is presented by zadeh in 1965 is a new controller [1]. Besides that, fuzzy logic controller is more efficient from the other controller such s proportional –integral (PI) controller. The comparison between them is needed to compare what the controller is efficient [2].the reason why conventional controller low efficiency such as PI controller because the overshoot is too high from the set point and it may takes delay time to get constant and sluggish response due to sudden change in load torque and the sensitivity to controller gains Ki and Kp [3].

To get improved performance of control system, fuzzy logic controller with PID is being introduced. It may reduce the transient at the starting point and make the steady state error will be very less and also the system has shorter rise time, smaller overshoot. Therefore, the system would be more efficient to control the speed of PMSM [2]-[3].

Here we can use the back emf control technique in order to rotate the motor in required speed. Using fuzzy rules, the PID parameters are adjusted. Due to no usage of sensors the system becomes simple and less cost.

Recently, fuzzy logic employing the logic of approximate reasoning continues to grow in importance, as it provides an inexpensive solution for controlling ill-known complex systems. Fuzzy controller has already been applied to phase controlled converter dc drive, liner servo drive and induction motor drive [4].

II.CROSS SECTIONAL VIEW OF PMSM



Permanent magnet synchronous motor structure

Fig. 2.1 PMSM cross-sectional view

Fig.2.1 illustrates the structure of a typical permanent magnet synchronous motor.

The permanent magnet synchronous motor (PMSM) can be thought of as a cross between an AC induction motor and a brushless DC motor (BLDC). They have rotor structures similar to BLDC motor which contain permanent magnet. However, their stator structure resembles that of its ACIM cousin, where the windings are constructed in such a way as to produce a sinusoidal flux density in the air gap of the machine.

As a result, they perform best when driven by sinusoidal waveforms. However, unlike their ACIM relatives, PMSM motors perform poorly with open-loop scalar V/Hz control, since there is no rotor coil to provide mechanical damping in transient conditions. Field oriented control is the most popular control technique used with PMSMs. As a result, torque ripple can be extremely low, on par with that of ACIMs. However, PMSM motor provides higher power density for their size compared to ACIMs. This is because with an induction machine, part of the stator current is required to “induce” rotor current in order to produce rotor flux. These additional current generate heat within the motor. However, the rotor flux is already established in a PMSM by the permanent magnets on the rotor. Most PMSMs utilize permanent magnets which are mounted on the surface of the rotor of the rotor. This makes the motor appear magnetically "round", and the motor torque is the result of the reactive force between the magnets on the rotor and the electromagnets of the stator. This results in the optimum torque angle being 90 degrees,

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which is obtained by regulating the d-axis current to zero in a typical FOC application.

III. PID CONTROLLER

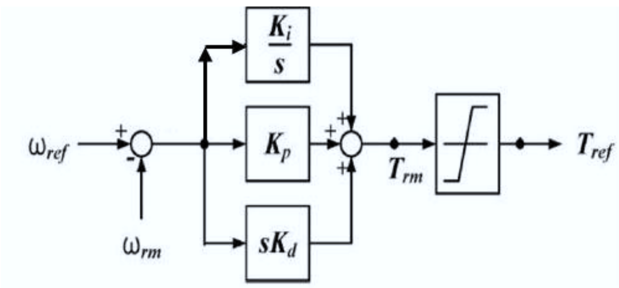

Fig.3.1 PI controller block diagram

Fig3.1 shows the Proportional-Integral-Derivative (PID) controller block diagram. The P-I-D controller has the form,

$u(t)=MV(t)=Kp$
$e(t)+Ki\int e(T)dT+Kdt0ddte(t)\rightarrow(1)$

The speed error EN between the reference speed NR and the actual speed N of the motor is fed to the PID controller, and the Kp, Ki and Kd are the proportional, integral and derivative gains of the PID controller.

IV.FUZZY LOGIC CONTROLLER

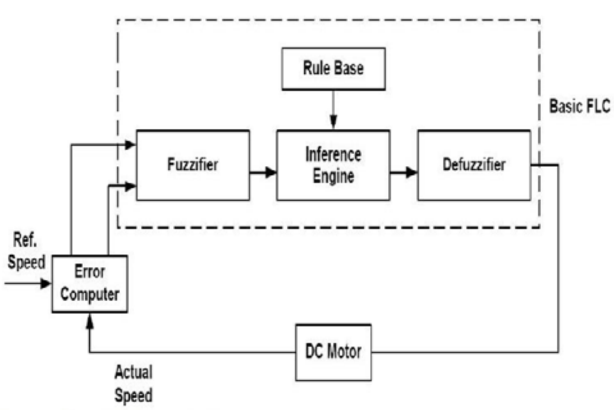

Fig.4.1 shows the basic structure of fuzzy logic controller.

Fuzzy logic's linguistic terms are most often expressed in the form of logical implications, such as If-Then rules. These rules define a range of values known as fuzzy membership functions [4]. Fuzzy membership functions may be in the form of triangle, a trapezoid, a bell as shows in figure 4, or another appropriate form.

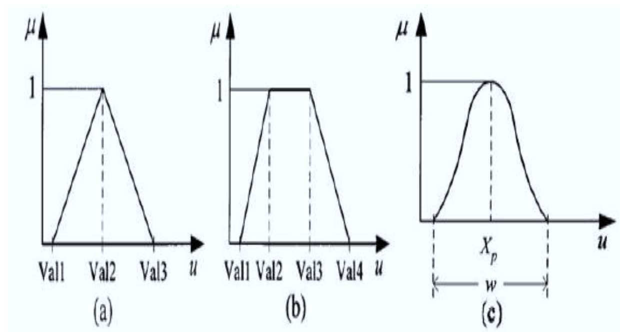

Fig.4.2 Fuzzy logic controller

Fig.4.2 (a) triangular

(b) Trapezoid

(c) Bell membership function

The inputs of the fuzzy controller are expressed in several linguistic levels show in figure 5, these levels can be described as positive big (PB), positive medium (PM), positive small (PS), or in other levels. Each level is described by a fuzzy set. In general, experience and expertise are required for the implementation of fuzzification in complex systems [6].

Fuzzy logic control doesn't need any difficult mathematical calculation; it only use simple mathematical calculation, but is can provide very good performance in a control system [7]. Thus, it can be one of the best available answers today for a board class of

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challenging controls problem. A fuzzy logic control consists of:

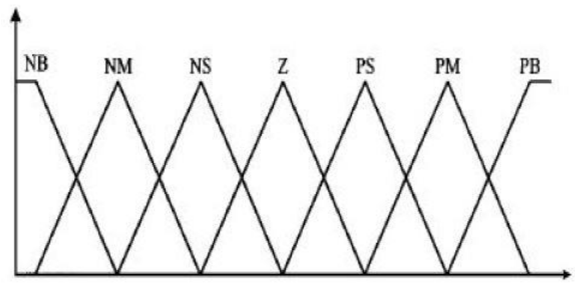

Fig.4.3Seven levels of fuzzy membership function

Fuzzification: This process converts or transforms the measured inputs called crisp values, into the fuzzy linguistic values used by the fuzzy reasoning mechanism.

Knowledge Base: A collection of the expert control rules (knowledge) needed to achieve the control goal.

Fuzzy Reasoning Mechanism: This process will perform fuzzy logic operations and result the control action according to the fuzzy inputs.

Defuzzification unit: This process converts the result of fuzzy reasoning mechanism into the required crisp value.

In the proposed fuzzy speed controller for PMSM, two inputs are defined: current error (three Gaussian membership function i.e. S,Z,L) As shown in fig 4.3 and speed error(seven gaussion membership functions i.e. NB,NM,NS,Z,PS,PM,PB) As shown in fig 4.4.

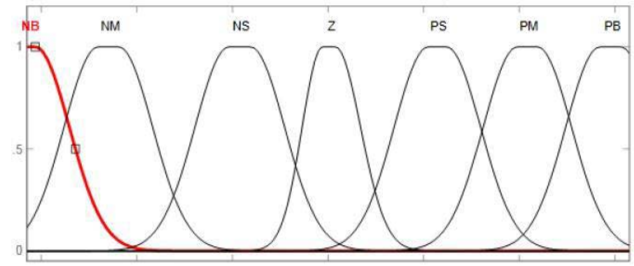

Fig.4.3 Input 1 Speed error membership functions

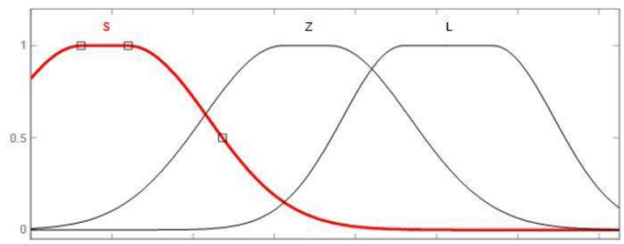

Fig.4.4 Input2 is current error membership functions

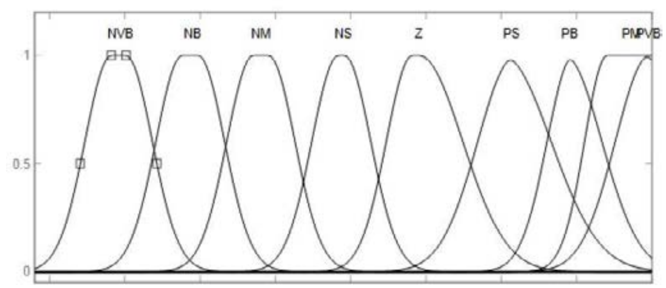

Fig.4.5 Output membership functions

The output of the Mamdani inference model is a Gaussian membership function varying from 0.59 to1 with nine membership functions i.e. NVB, NB, NM, NS, Z, PS, PM, PB and PVB) as shown in Fig. 8.The output is a duty cycle that is compared with a triangular pulse to generate pulse width modulated signal, which is further added with the gate pulses to modulate the inverter voltage and maintain a constant speed. The rule set followed is shown in Table 1,

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FUZZY RULE TABLE

CE/SE	NB	NM	NS	Z	PS	PM	PB
S	NVB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
L	NM	NS	Z	PS	PM	PB	PVB

TABLE 4.1 FUZZY RULE TABLE

V.WORKING PRINCIPLE OF THE PROPOSED SYSTEM

In general, the three phase supply has to been applied to the PMSM only through the controlled inverter with a bridge converter. Fig1.1 shows the overall block diagram of the speed controller drive. In controlled converter the MOSFET's are used as an electronic switching device.

These all are can be turned on and turned off only by means of applying sequence of gate pulse to it, depending upon these switching sequence only the 3phase sinusoidal voltage will be generated and applies to the drive.

Here PID and fuzzy are put together to provide the speed control over a PMSM drive. The PID needs speed feedback that can be getting from PMSM drive; this actual speed can be compared with reference speed to produce an error for further processing of speed control with fuzzy logic control.

Fuzzy controller provide the sequence of pulse depending upon the error from the PID response and compare with the pre-programmed logic in that, logic can be generated and pre-programmed with the help of fuzzy rule table, by this speed could be controlled with the expected range. Also PID provides better gain to overcome the feedback signal system loss.

VI. SIMULATIONS OF THE PROPOSED SYSTEM

To validate the control strategies as described, digital simulation were carried out on a converter dc motor drive system by using MATLAB/SIMULINK.Fig.6.1 shows the simulation model of PID control system. Fig. 11 shows the simulation model of both Fuzzy and PID control system.

Specification of PMSM:-Table 2

No. of phase	3
Rotor type	Round
Voltage	230v
Power rating	100w
Speed (rpm)	4000rpm
Current (amps)	0.4A
Back EMF	Sinusoidal
Stator phase resistance(ohm)	0.18
Armature inductance(L)	0.000835H
Flux linkage(Mh)	0.07145
Torque constant (N.m/A_peak):	0.4278
Voltage constant (Vpeak L-L/krpm	51.8384

a) PID function

The actual speed of the motor speed is given as input to the PID controller and reference speed is given as another input to the speed PID controller. This output of the PI is the dc value that is compared with a continuous triangular pulse of 1 kHz. The output is varying duty cycle that is added with gate pulse to produce a pulse-modulated wave, which triggers the inverter to generate required voltage to maintain the speed at varying load torques and speed reference conditions.

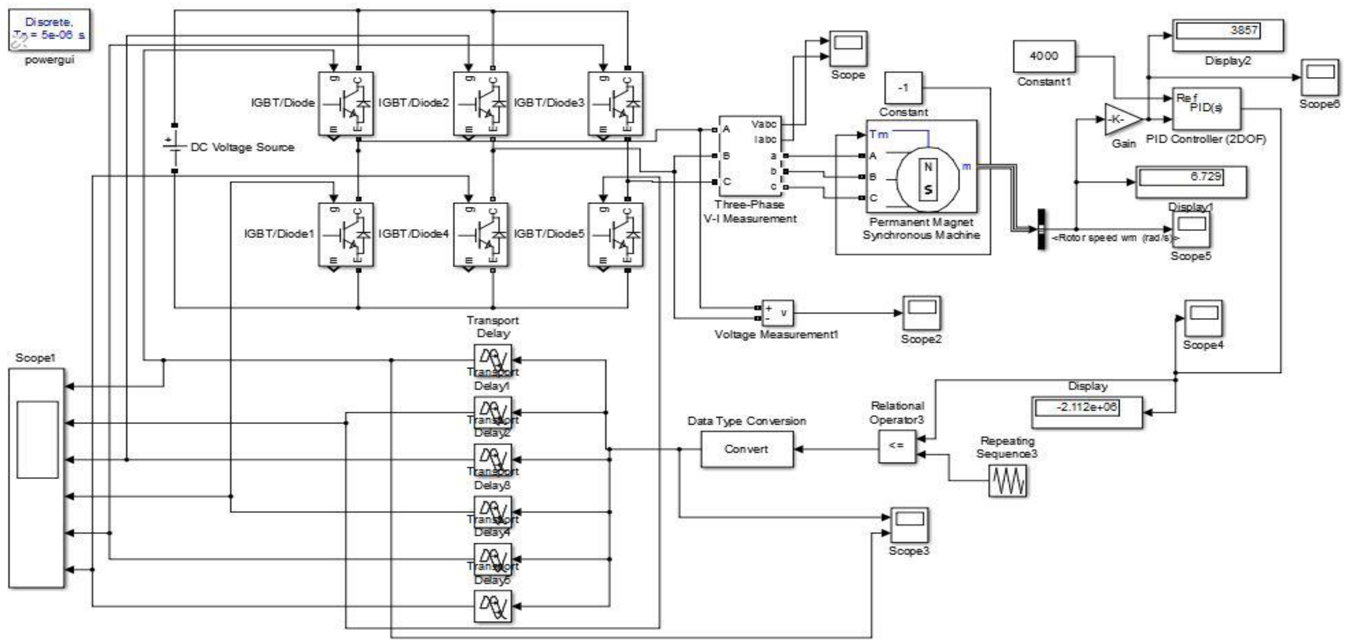

Fig.6.1 SIMULATION OF SPEED CONTROL OF PMSM USING PID

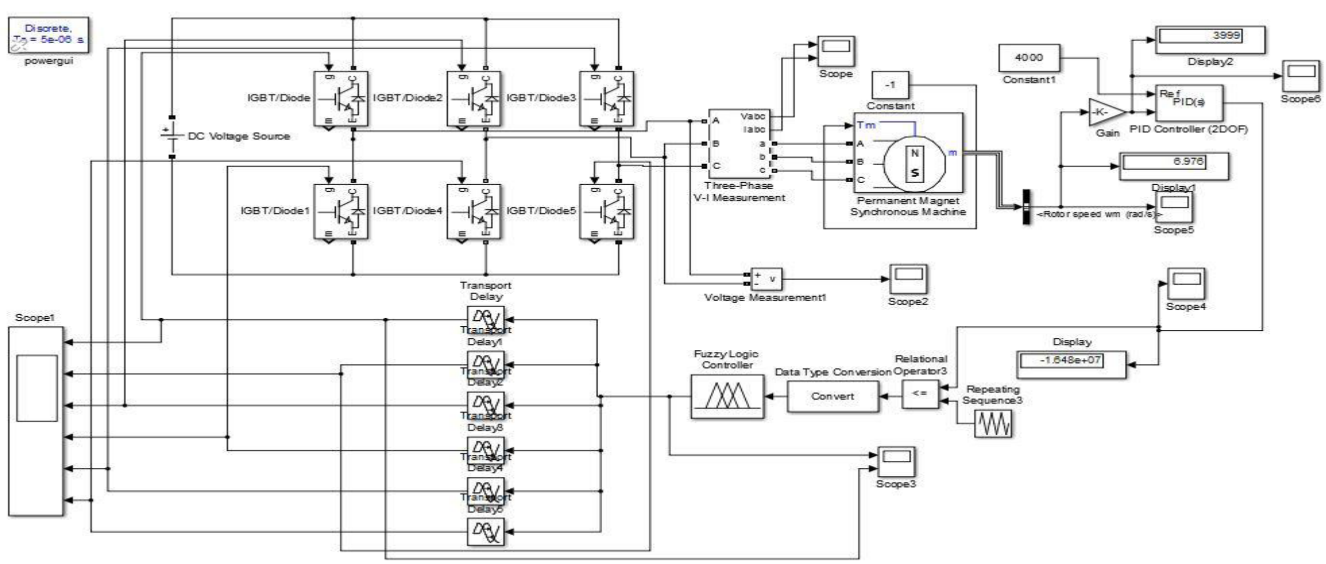

Fig.6.2 SIMULATION OF SPEED CONTROL OF PMSM USING FUZZY AND PID

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The response of the simulation is shown in fig 6.3 and 6.4 respectively.

Fig.6.3 PMSM drive speed control with PID (Speed response curve)

Fig. 13 PMSM drive speed control with Fuzzy and PID (Speed response curve)

SIMULATION RESULTS

Ziegler Nichols Closed Loop PID tuning method was performed for speed control and parameters obtained are shown in Table 2.

The simulation is performed in closed loop when speed reference is constant at 6.977 rad/sec.

Kp	0.318
Ki	20
Kd	0.9
Overshoot (%)	2.5
Setting time(sec)	0.2

$$\frac{2\pi N}{60} = \omega m$$

ωm =6.977 rad/sec π= 3.14

speed N=66.877 rps, rpm=rps*60,so, the reference speed equal to the 6.977 rad/sec is 4000rpm.

B)FUZZY WITH PID

The simulation is performed on closed loop when speed reference is constant at 6.977rad/sec. the parameter are,

Kp	10
Ki	200
Kd	0.9
Overshoot(%)	2.4
Settling time(sec)	0.05

COMPARISON BETWEEN THE SIMULATION PARAMETERS OF PID AND FUZZY-PID CONTROL ON PMSM,

Gain parameters	PID simulation	Fuzzy with PID SIMULATION
Kp	0.318	10
Ki	20	200
Kd	0.9	0.9
Overshoot(%)	2.5	2.4
Settling time(sec)	0.2	0.05

From this observation Overshoot and Settling time of the Fuzzy with PID response is comparatively lesser than the Conventional PID controller.

VII.CONCLUSION

This paper is intended to compare the two controllers namely, proportional-integral-derivative (PID) controller and fuzzy logic controller for the speed control of a phase controlled converter dc excited motor-generator system. It is observed that fuzzy logic controller provide important advantages over the traditional PID controller like limiting the overshoot. This paper also demonstrates the successful application of fuzzy logic control with PID control to a phase controlled converter dc motor drive. Fuzzy logic was used in the design of speed controllers of the drive system and the performance was compared with that of PID controller and the simulation is modeled and simulated using MATLAB/SIMULINK. The advantages of the Fuzzy controller are that it determines the number of rules automatically, reduces computational time, learns faster and produces lower errors than other method. By proper design a fuzzy logic controllers is much better than traditional PID controllers for the speed control of dc motor drives

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