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Speed Control of DC Motor: A Case between PI Controller and Fuzzy Logic Controller

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Abstract

In this paper , A comparison is made between PI- controller and fuzzy logic controller (FLC) in order to controlled the self –excited motor. Matlab simulation package is used to simulate Dc motor and sketched the speed response curve for each type of controller. Final results clearified that the FLC improve Speed response of dc motor rather than PI controller.

Keywords: PI controller, Fuzzy logic, , DC motor, DC motor speed response.

LIST OF SYMBOL :

symbols	**Explanation**
N	speed in (r.p.m).
W	speed in (rad/sec).
Va	supply voltage (v)
Ia	armature current in (A)
Ra	armature resistance in (Ω).
Φ	Field flux per pole in web
Ka	Armature constant = PZ/2πa
P	No. of poles.
Z	Total no. of armature conductor.
a	No. of parallel path
EMF	Electromagnet.
K	flux constant
TL	load torque.
ω(s)	output speed

symbols	**Explanation**
La	armature inductance.
Tem	electromagnetic torque.
Ta	time constant(La/Ra).
e(k)	Error
ce(k)	the change of error
I(k)	output of FLC.
Ge, Gce and GΔi	scaling of factors
Tr	rise time
Mp	Maximum overshoot in percentage.
Ts	settling time

I. INTRODUCTION

The traditional PI- controller is palatial used in Dc motor control system. The general method that used to obtain the PI parameters of Ziegler-Nichols.This method gives a well response for the process which has a pair of dominant poles, but not recommended to used in more complex system. The use of fuzzy PI controller is more practical ,The fuzzy like PI controller has worse response to transtory behaviour of system in which the order pole is higher, Therefore fuzzy logic controller (FLC) is well for non-linear systems and with a wide operation of the variable in a subjective way[1-2].

II. SPEED CONTROL OF DC MOTOR

The equavilent circuit of self excited DC motor is shown in figure (1).

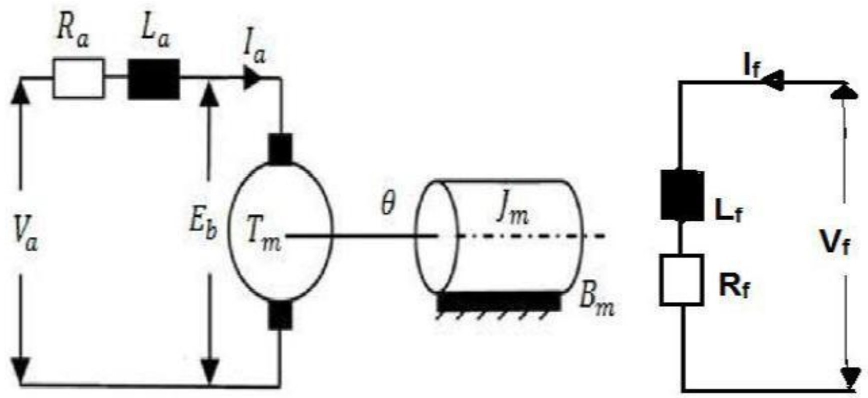


Fig 1: Model of DC Motor [3]

DC motor are congenial for vast speed control and therefore many titration of speed drives. DC motor speed can be controlled by accredited speed variation.

$$N \alpha \frac{(Va - Ia \times Ra)}{\Phi}$$

$$N = \frac{(Va - Ia \times Ra)}{Ka \times \Phi} \quad \text{...}(1)$$

Three basically method are used for DC motor speed control:

- Armature circuit resistance variation.
- Field flux variation.
- Armature terminal voltage variation .

III. MODELING OF DC MOTOR

From previous[see fig.(1)]The armature voltage equation is given by:

Va =Eb+ Ia×Ra+ La ×($\frac{di}{dt}$)……………………………………(2)

Now the torque balance equation will be given by:

Tm = $\frac{Jmd\omega}{dt}$ + Bmω + TL ……………………………………..(3)

Φ: field flux.

EMF: Electromagnet.

K: flux constant.

The back emf and torque DC motor for are:

Eb = Kϕ……………………………………………………(4)

Tm= KϕIa…………………………………………………(5)

Eb: back emf of DC motor.

Tm: mechanical torque.

Taking laplace transform of the motor‟s armature voltage equation:

Ia(S) = $\frac{(Va - Eb)}{(Ra + LaS)}$ ……………………………………………...(6)

Now, taking equation (ii) into consideration, we have:

Ia(s) = $\frac{(Va - K\Phi\omega)}{Ra(1+LaS/Ra)}$ …………………………………………..(7)

And,

ω(s) = $\frac{(Tm - TL)}{JS}$ ………………………………………………(8)

The block diagram of DC motor with feedback control system is depicted in figure (2).

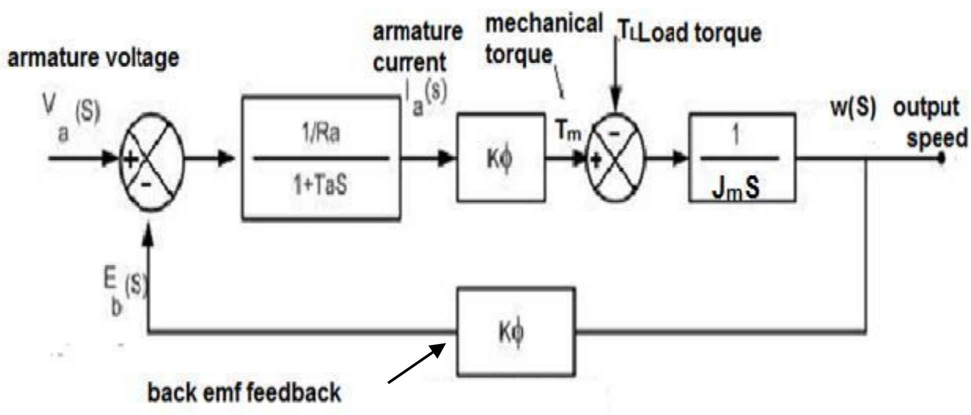


Fig. 2: Modelling Block diagram of DC Motor

After simplifying the above motor model, the overall transfer function will be:

$$\frac{\omega(s)}{Va(s)} = \frac{\frac{K\Phi/Ra}{JmS(1+TaS)}}{1+\frac{K^2\Phi^2/Ra}{JmS(1+TaS)}} \quad \ldots\ldots (9)$$

$$Tm = \frac{Jmd\omega}{dt} = K\Phi Ia \quad \ldots\ldots (10)$$

$$\omega(s) = [(\frac{Ra}{Km})\, Ia(s) - \frac{TL\, Ra}{(Km)^2}] \times (\frac{1}{Tem(s)}) \quad \ldots\ldots (11)$$

$$\frac{\omega(s)}{Va(s)} = \frac{\frac{1}{Km}}{(1+STem+S^2TaTem)}$$

The armature time constant Ta is very much less than the electromechanical time constant Tem, (Ta <<Tem)

The equation can be written as:

$$\frac{\omega(s)}{Va(s)} = \frac{\frac{1}{Km}}{(1+STem)(1+STa)}$$

$$W(s) = \frac{1/km}{(1+STem)(1+STa)} * Va(s) \quad \ldots\ldots (12)$$

IV. PROPORTIONAL PLUS INTEGRAL (PI) CONTROLLER

(PI) controllers the based and correct solution for industrial application. The main etiology is its relatively simple structure, which can be easily understood and implemented in practice that can be facilitly understood and executed in practice, also many sessions of control methods like predictive control are based on it. The block diagram of Dc motor based PI controller is depicted in figure (3). The integral part of this controller is added to the proportional action in order to avoid the offset point and the process work with aset point [4].

Table 1: Parameters of the DC Motor .

Description of the parameter	Parameter values and units
Armature resistance (Ra)	11.2(Ω)
Armature inductance (La)	0.1215(H)
Armature voltage (Va)	200 (V)
Mechanical inertia (Jm)	0.02215 (Kg.m2)
Friction coefficient (Bm)	0.002953 (N.m/rad/sec)
Back emf constant (k)	1.25 V/rad/sec
Rated speed	1500 (r.p.m)
Motor torque constant	0.5161 (N.m/A)

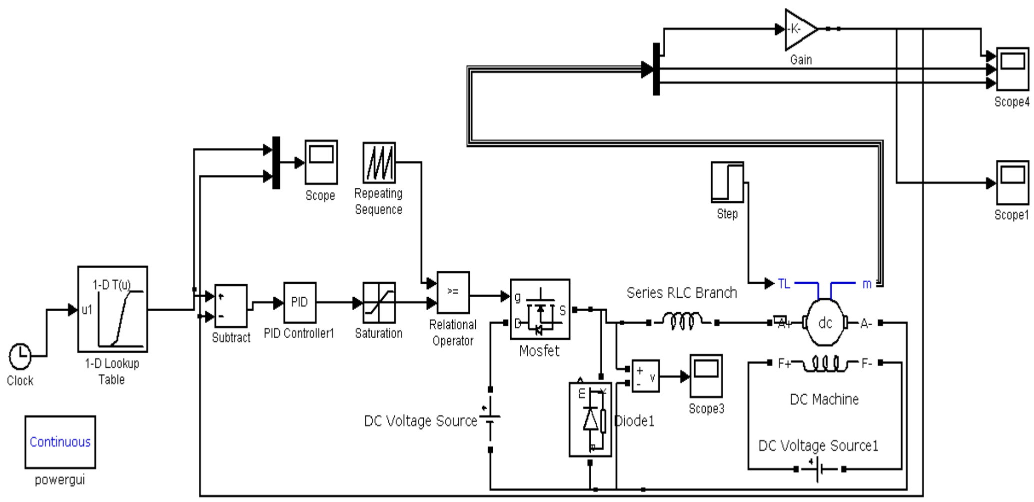


Fig 3. Modling of DC motor based PI controlle

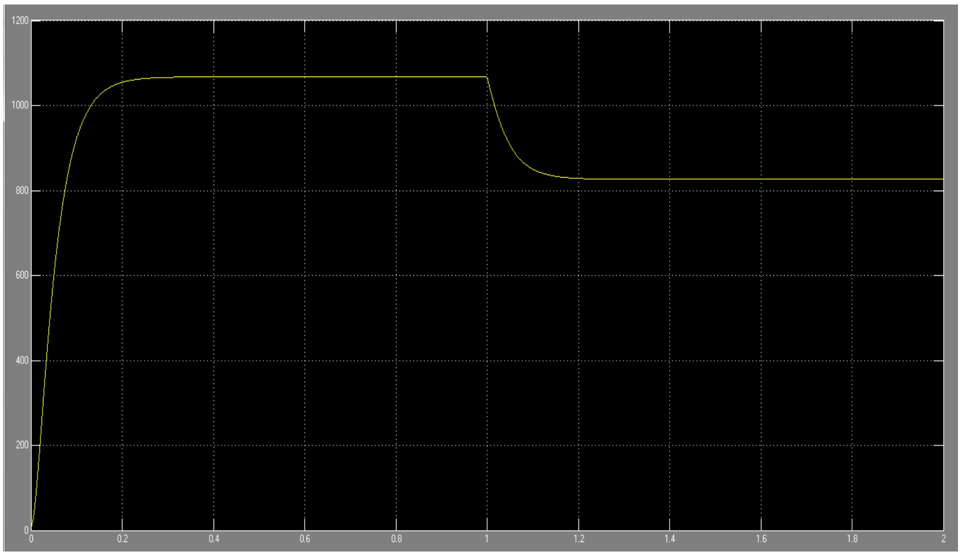


Fig.4 Speed response of DC motor based PI controller.

The dynamic behaviour of above speed response is depicted in table (2)

Table 2 – Dynamic speed response based PI controller.

P.O.S(%)	Peak time(sec)	Rise time(sec)	Setting time(sec)
28.12	0.1	0.03	0.6

V. FUZZY LOGIC CONTROLLER [5-6]

FLC has a specific components characteristic to subsidy a design steps. Fig.5 describes the block diagram of FLC structure.

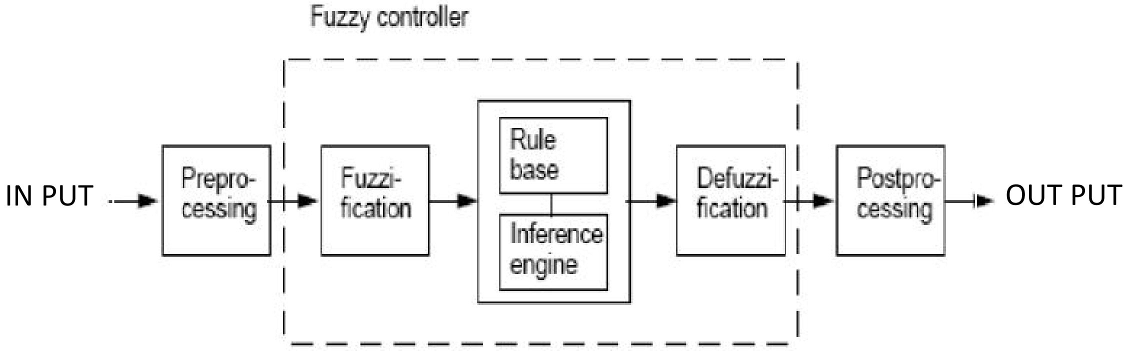


Fig 5. Structure of fuzzy logic controller.

Fuzzy Logic Preprocessing

From previous figure 5 shows that the condition of measurement are given before controller. The inputs of measurements are hard or crisp value rather than linguistic value.

* *Fuzzification*

The first block of FLC represents the fuzzification which convert the input values to degree of membership. This block make a match between input data and the rules condition.

* *Rule Base*

FLC rules are represent in "If-Then" conditions or format and this rules collections are called a (rule- base). Matlab toolbox able to execute this rules and compute a control signal depending on error and change in error, Δ (e).

**Defuzzification*

Defuzzification action represent the conversion from fuzzy output to the crisp value again that represents the output control signal of the system . the best method that used to for this conversion is "centre of cavity" which gives the role the best crisp value of output control signal.

VI . CONTROLLR PROCESS BASED FUZZY LOGIC:[7]

The inputs and output control signal of FLC depending on rule-base are represent in the following block-diagram as shown in figure 6.

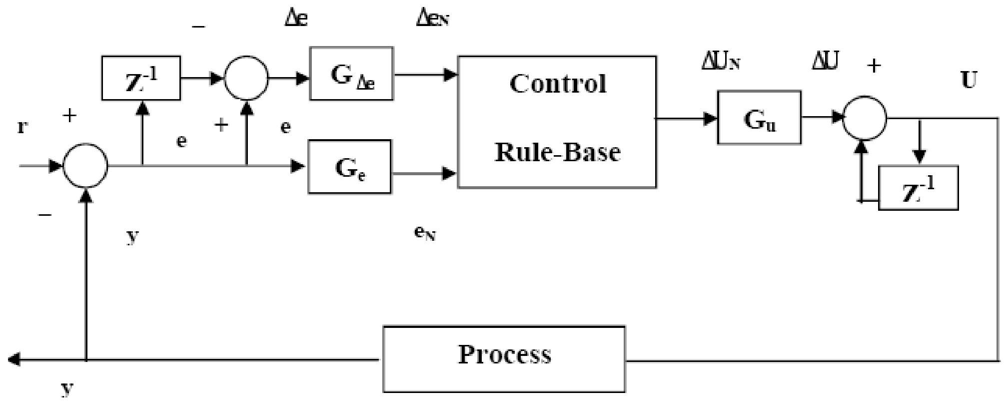


Fig.6 Input and output block diagram signals used with FLC.

The FLC has two inputs, the error e(k) and change of error Δe(k), which are defined by:

$e(k) = r(k)-y(k)$……………………………………..…(12)

$\Delta e(k) = e(k) - e(k-1)$ ………………………………(13)

where r and y

denote the applied set point input and plant output, respectively. Indices k and k−1 indicate the present stateand the previous state of the system, respectively. The output of the FLC is the incremental change in the control signal Δu(k).The controller has two input variables and one

output variable.

The input and output variables of fuzzy PI controller can

be defined as:

$E(k) = e(k).Ge$ ………………………………………(14)

$CE(k) = ce(k).Gce$ …………………………………...(15)

$\Delta i(k) = \Delta I(k).G\Delta i$ ……………………………………(16)

The type of FLC that used in this work is mamdani as shown in figure (7)

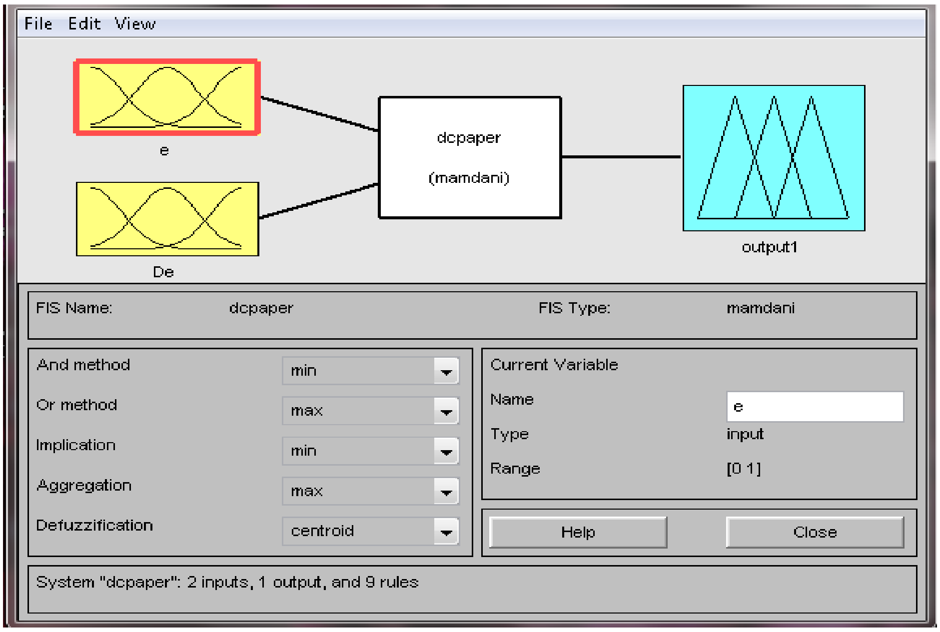


Fig (7) Internal Structure of FLC.

Dc motor based FLC is simulated by matlab simulink as shown in figure (8)

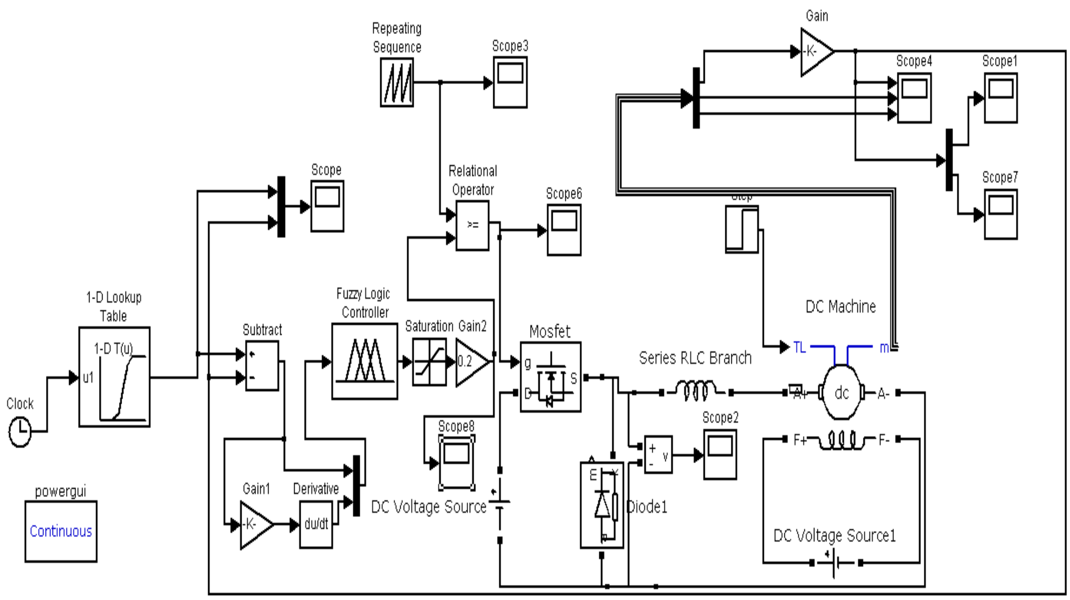


Fig.8 Modeling of DC motor based FLC.

The out speed response that obtained from above figure is given in figure (9).

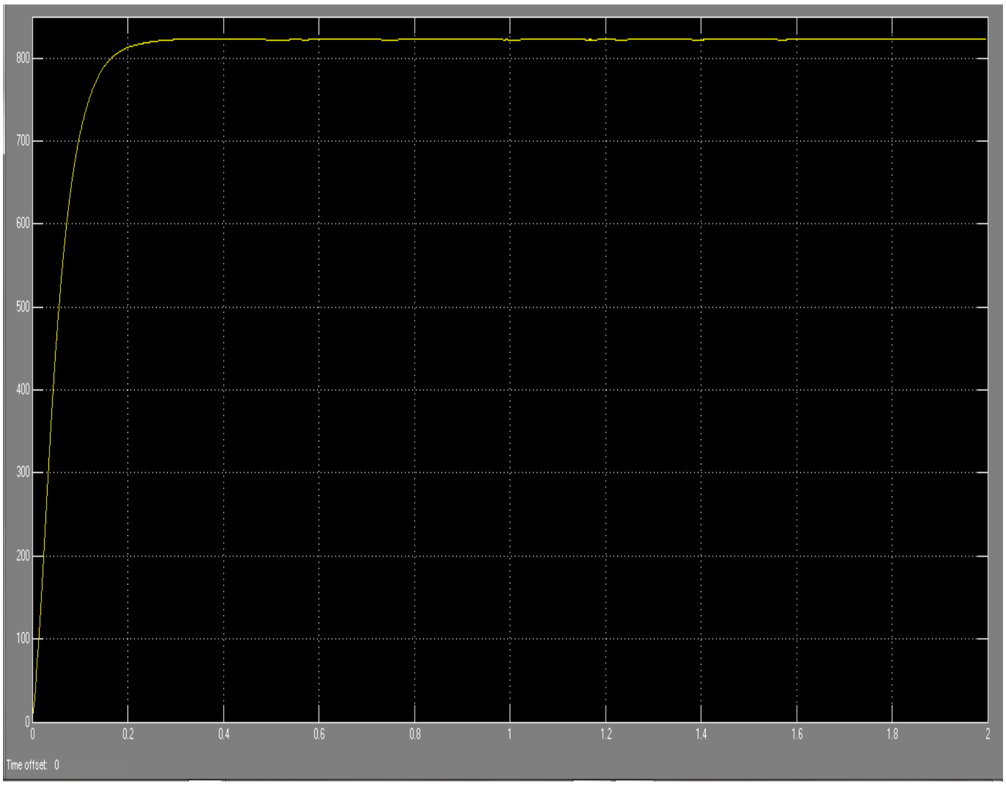


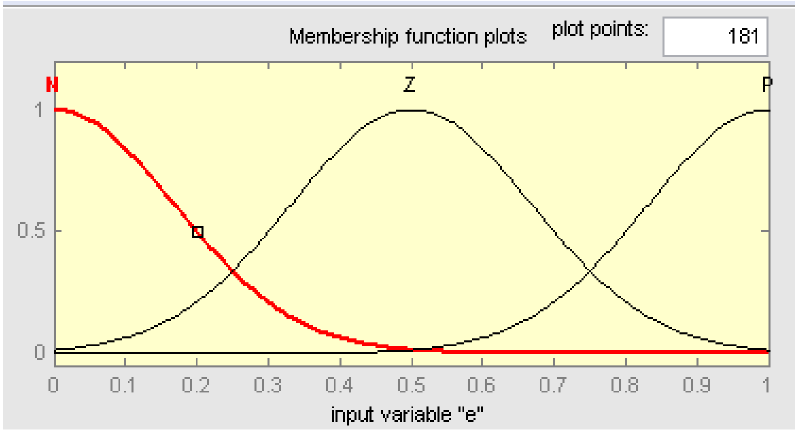
Fig.9 speed response of DC motor based FLC.

The dynamic behaviour of above speed response with FLC is depicted in table (3)

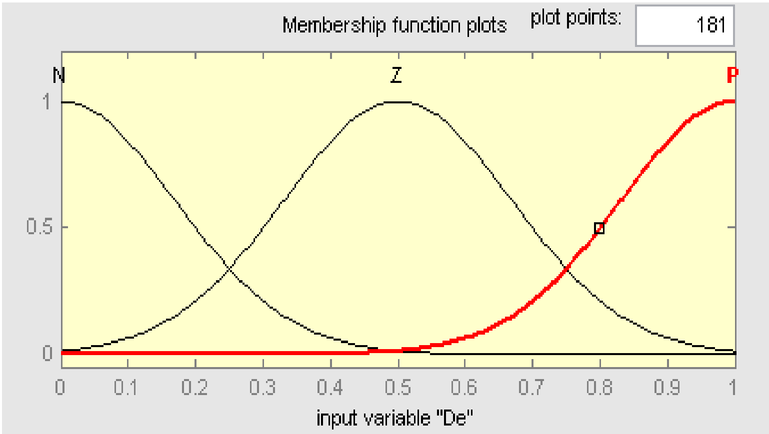
Table 3 – Dynamic speed response based fuzzy.

P.O.S(%)	Peak time(sec)	Rise time(sec)	Setting time(sec)
2.5	0.2	0.1	0.18

The membership functions that depended in input and output of FLC is illustrated in figure (10).



(a)



(b)

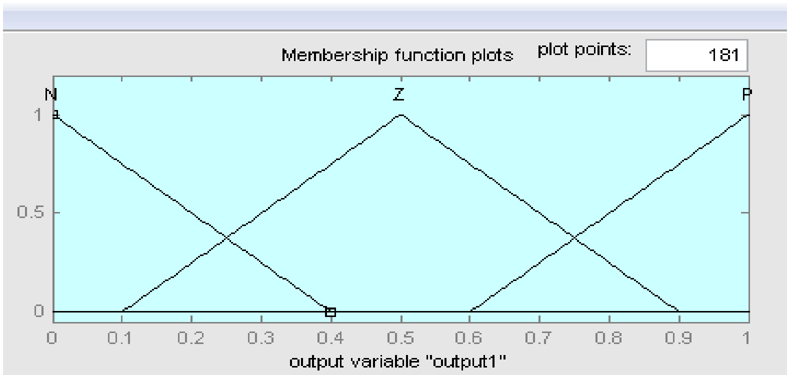


Fig.10. Membership functions of FLC.

a- error(e) b-change of error(Δe). c-output

The rules that performed from previous membership functions , the waves which obtained from these rules and the 3D FLC output surface are given in figures (11,12,13).

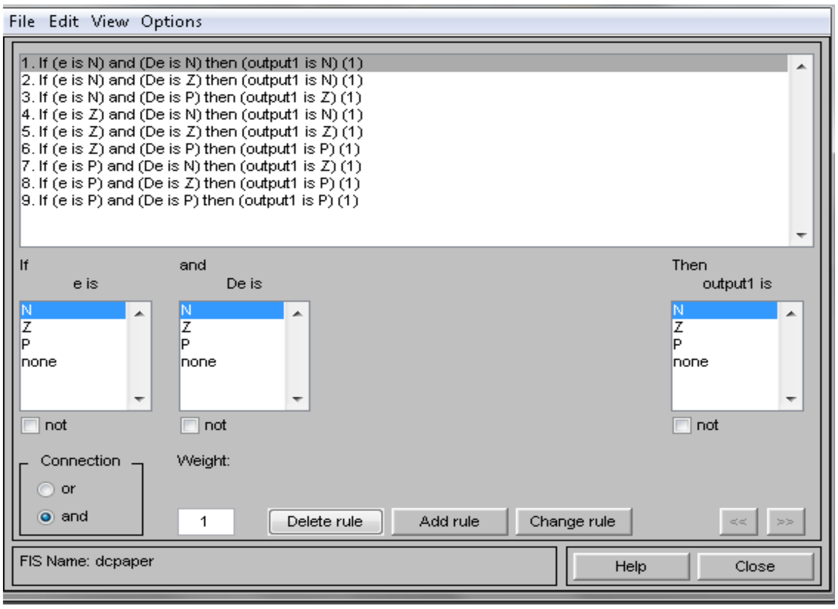


Fig. 11. FLC DC motor rules.

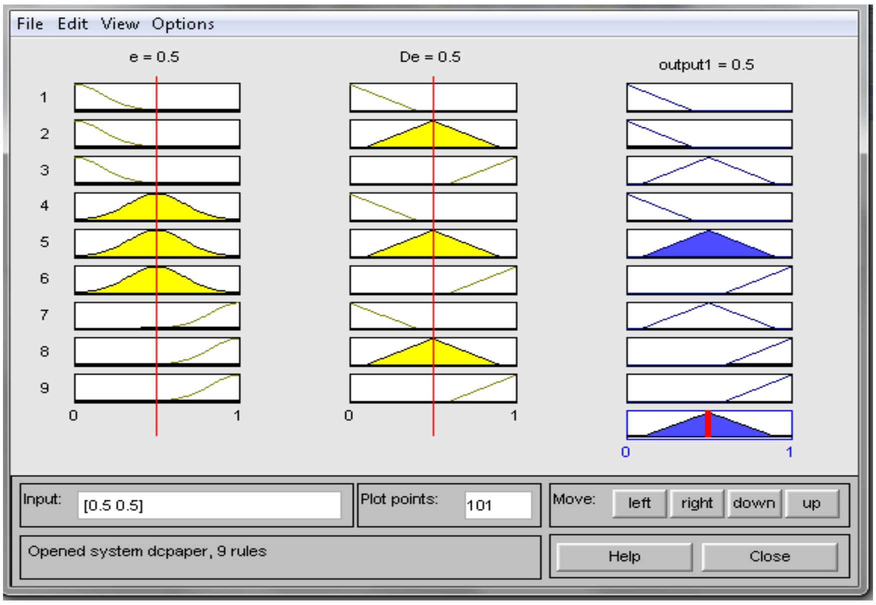


Fig. 12. Waves of DC motor rules.

The 3D surface of inputs and output of FLC is given in figure (13)

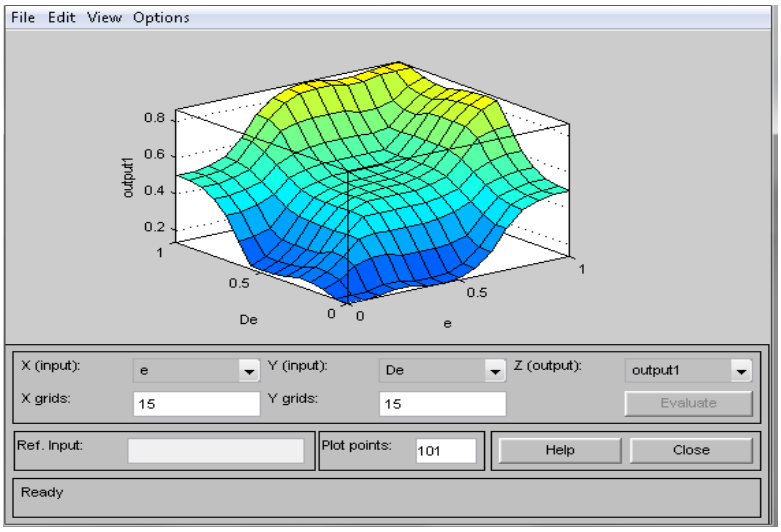


Fig 13. 3D **FLC** output surface of DC motor.

VI. CONCLUSION

The speed response curve based fuzzy logic controller is improved the P.O.S and setting time (stability) for DC motor dynamic behavior but it has slightly bigger values of peak time and rise time as compared with the response that obtained from same DC motor based PI- controller.

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