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

Dr. Ali N. Hamoodi[1], Ibrahim I. Sheet[2], Rasha A. Mohammed[3]

[1]Lect., Engineering Technical College-Mosul, Iraq.

[2]Lect.,Engineering Technical College-Mosul, Iraq.

[3]Asist. Lect., Engineering Technical College-Mosul, Iraq.

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.

LIST OF SYMBOLS:

Symbols	Explanation	Symbols	Explanation
N	speed in (r.p.m).	La	armature inductance
W	speed in (rad/sec).	Tem	electromagnetic torque.
Va	supply voltage (v)	Ta	time constant(La/Ra).
Ia	armature current in (A)	e(k)	Error
Ra	armature resistance in (Ω).	ce(k)	the change of error
Φ	flux in web	I(k)	output of FLC.
Ka	Armature fixed	Ge, Gce & GΔi	scaling factors
P	number of poles.	Tr	rise time
Z	all armature conductor.	Mp	peak overshoot (%).
A	parallel path number	Ts	residing time
EMF	Electromagnet.		
K	flux constant		
TL	load torque.		
ω(s)	output speed		

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 that has a pair of dominant poles, but not recommended to used in more complex system. The use of fuzzy like PI controller is more practical, 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].

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

II. SPEED CONTROL OF DC MOTOR

The equivalent circuit of DC motor (self excited) in figure (1) [3].

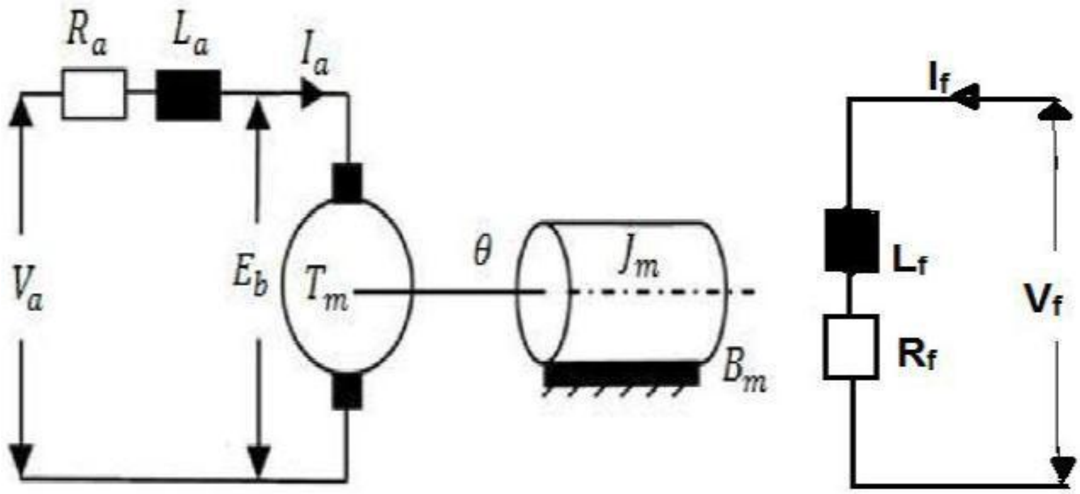


Fig. **1:** DC motor model.

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.

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

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

Three basically method are used for DC motor speed control:

armature circuit resistance variation.

flux alteration.

armature terminal potential.

III. MODELING OF DC MOTOR

Previously [see Fig. 1] The armature potential equation is yived by:

$$Va = Eb + Ia \times Ra + La \times (\frac{di}{dt}) \quad \ldots\ldots\ldots\ldots\ldots\ (2)$$

Balance torque equation:

$$Tm = \frac{Jmd\omega}{dt} + Bm\ \omega + TL \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3)$$

Φ: flux field.

EMF: Electromagnet.

K: flux constant.

The back emf and torque DC motor for are:

$$Eb = K\phi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ (4)$$

$$Tm = K\phi\ Ia \ \ldots\ldots\ldots\ldots\ldots\ (5)$$

Eb: back emf of DC motor.

Tm: mechanical torque.

By taking laplace transformr:

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

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

And,

$$\omega(s) = \frac{(Tm - TL)}{JS} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (8)$$

DC motor closed loop control system is depicted in figure (2).

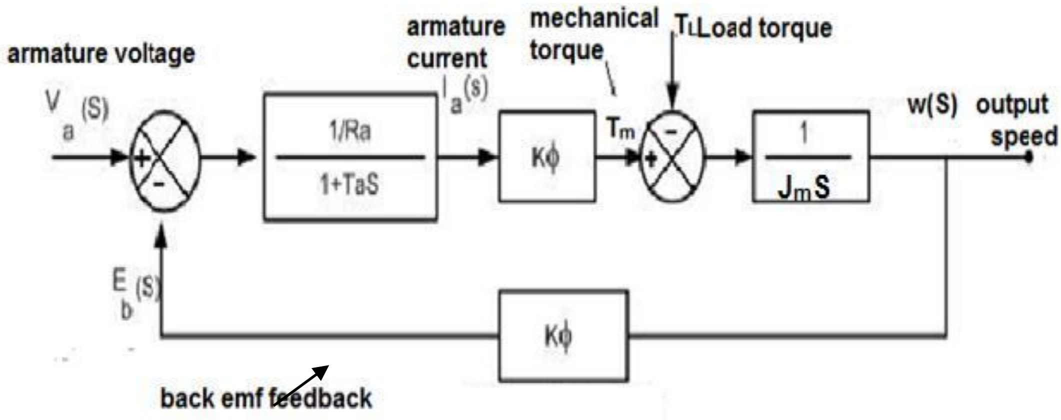


Fig. 2: Modeling of DC motor.

After reduction the above block diagram:

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

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

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

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

Tem >> Ta

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

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

IV. PROPORTIONAL PLUS INTEGRAL PI - CONTROLLER

PI-controllers the better and correct subrogation for industrial application. The corer etiology is its heraldiely simple physique, 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. Block diagram of Dc motor with 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 a set 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)

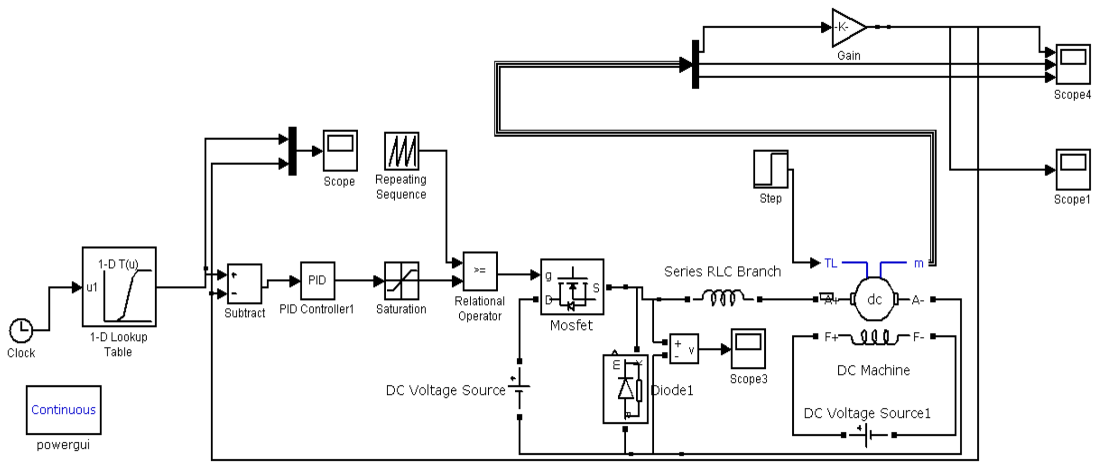


Fig. 3: Modeling of DC motor based PI controller.

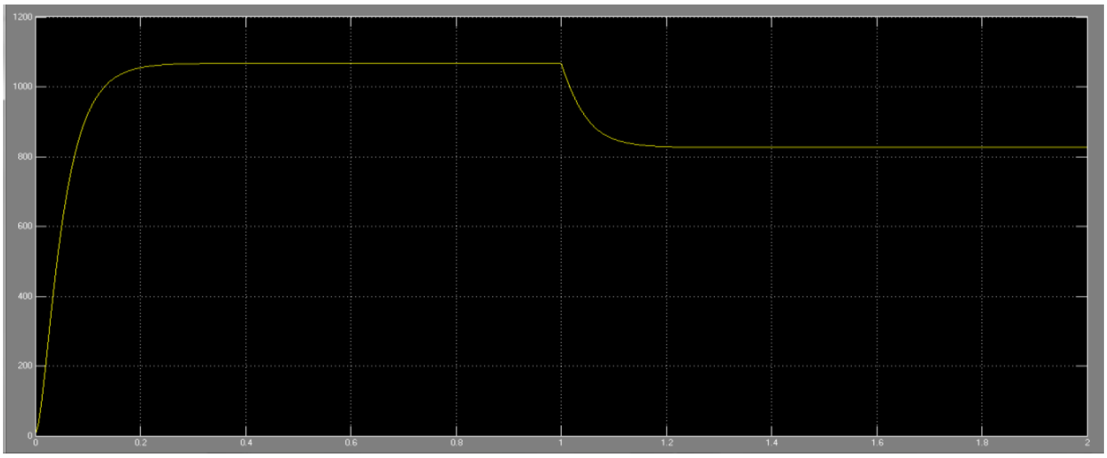


Fig. 4: Speed response of DC motor based PI controller.

The dynamic behavior 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.

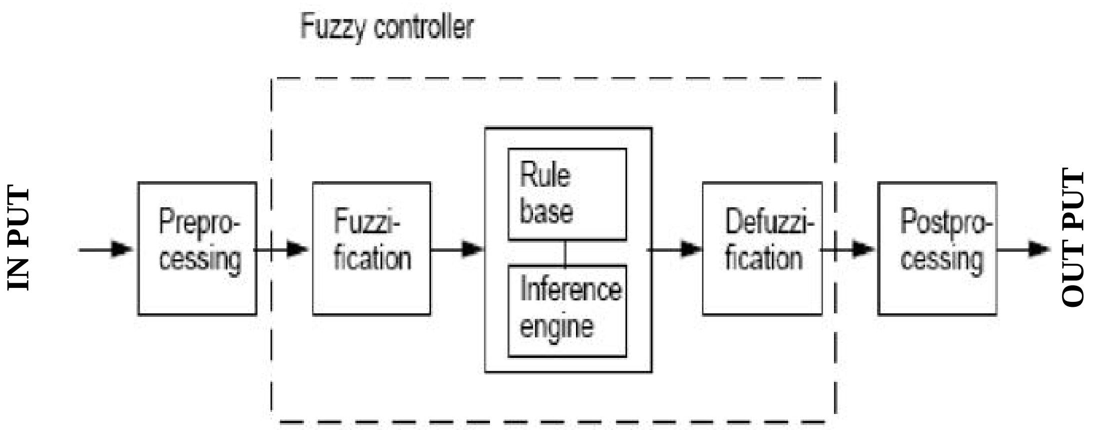


Fig. 5: FLC structure.

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 capable to implement this rules and arithmetic a control signal according to 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 "center of cavity" which gives the role the best crisp value of output control signal.

VI. CONTROLLER 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.

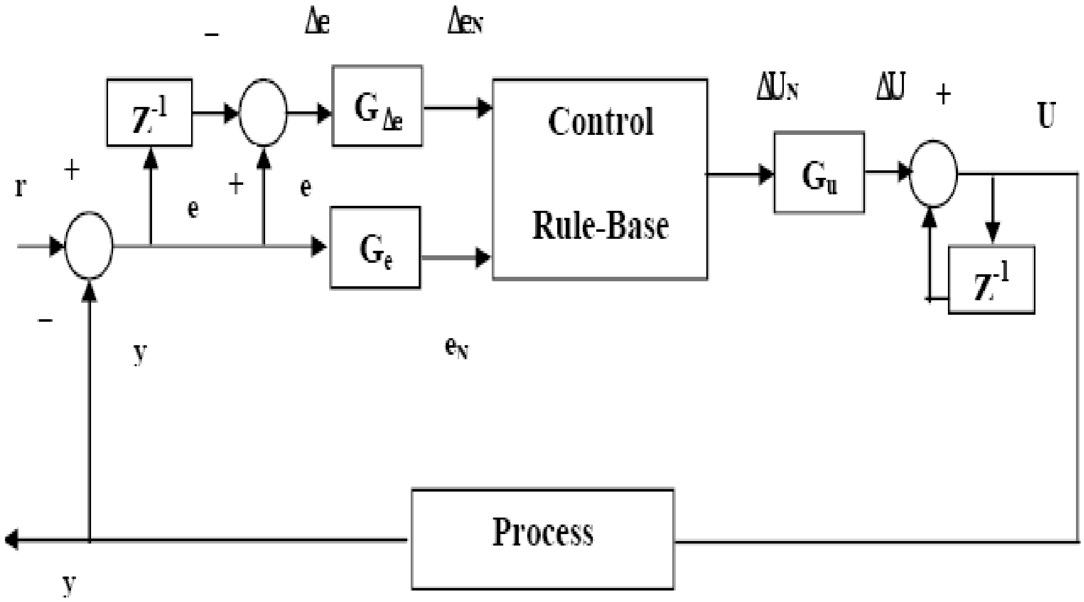


Fig. 6: Block-diagram of control process based FLC.

e(k): error

Δe(k): change of error

$e(k) = r(k)-y(k)$ ………………………………..…………… (13)

$\Delta e(k) = e(k) - e(k-1)$ ………………………………..…………… (14)

Where r & y represent the set point & plant output.

$E(k) = e(k).Ge$ ………………………………..…………… (15)

$CE(k) = ce(k).Gce$ ………………………………..…………… (16)

$\Delta i(k) = \Delta I(k).G\Delta i$ ………………………………..…………… (17)

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

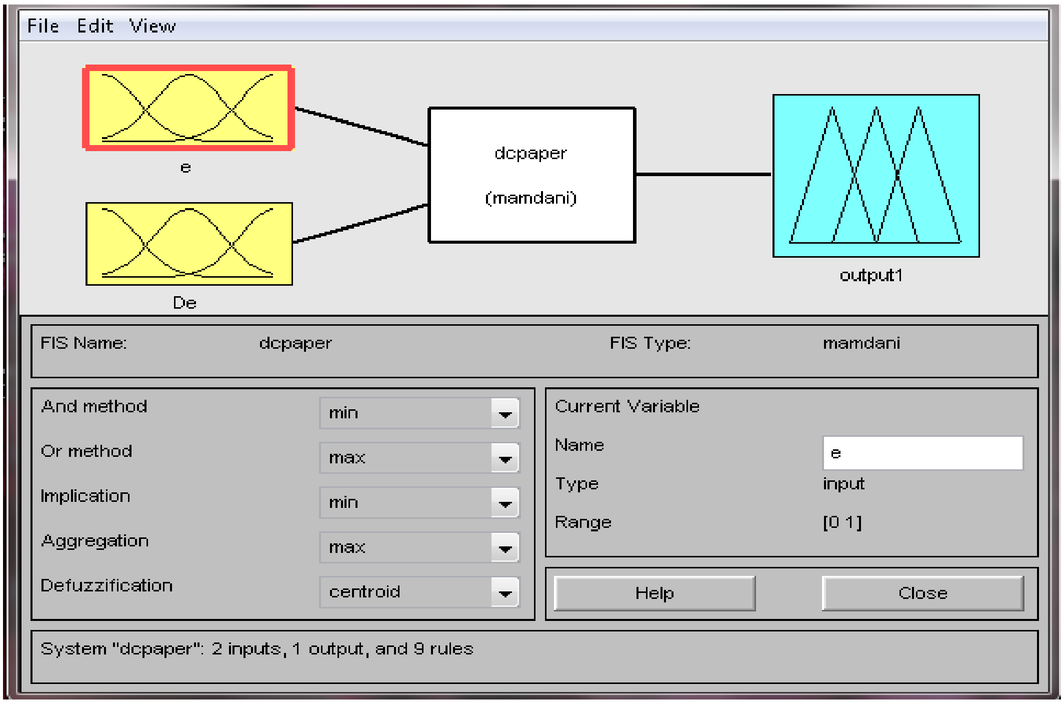


Fig. 7: Internal structure of FLC.

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

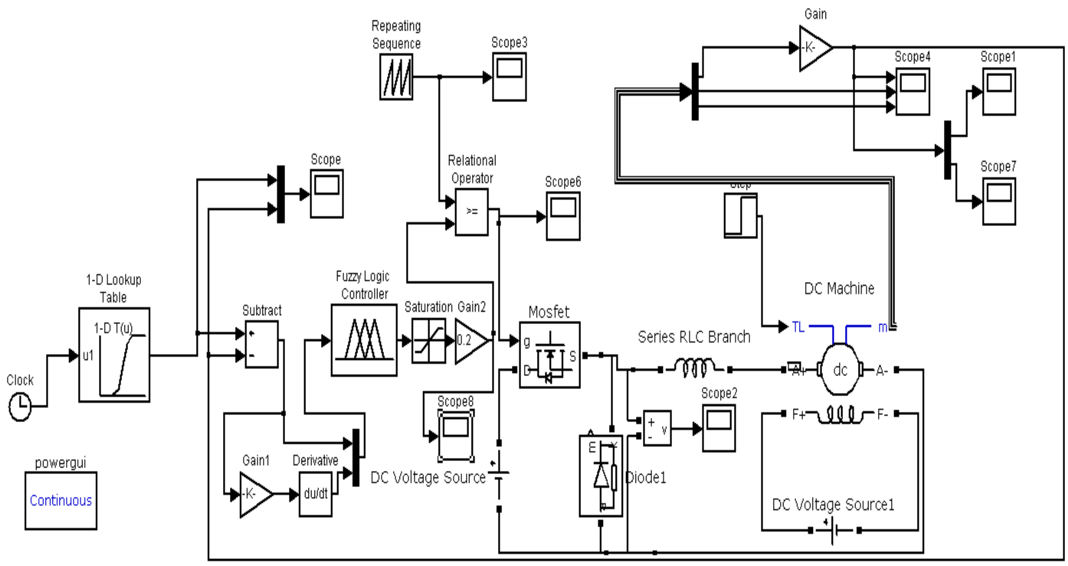


Fig. 8: Modeling of DC motor based FLC.

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

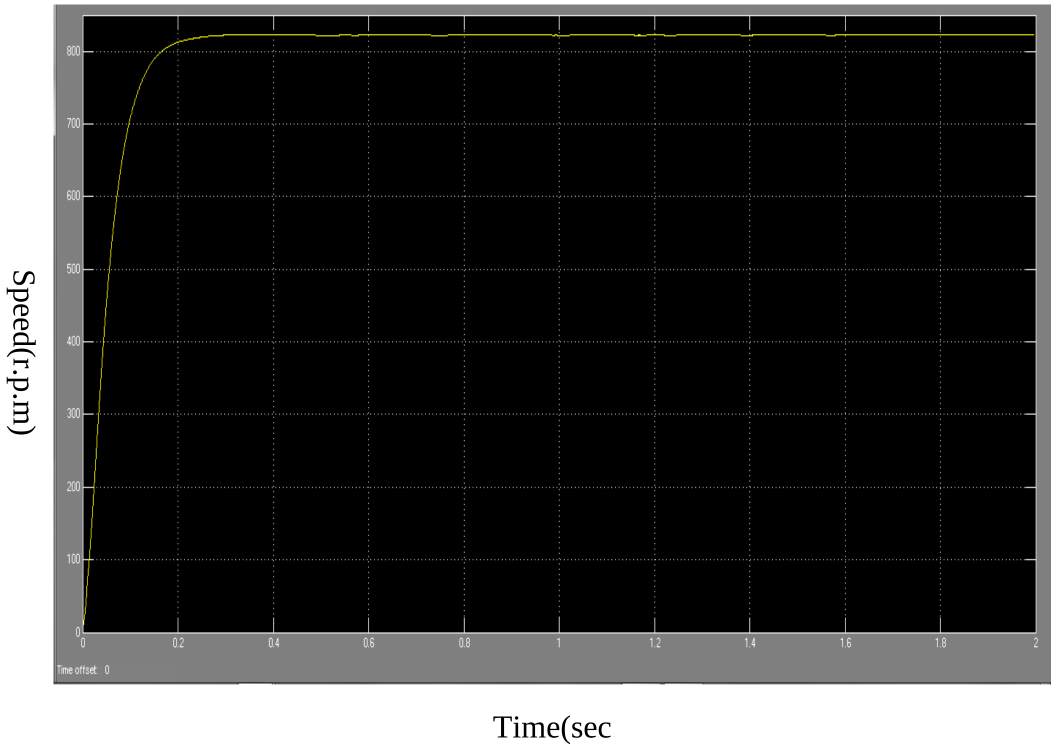


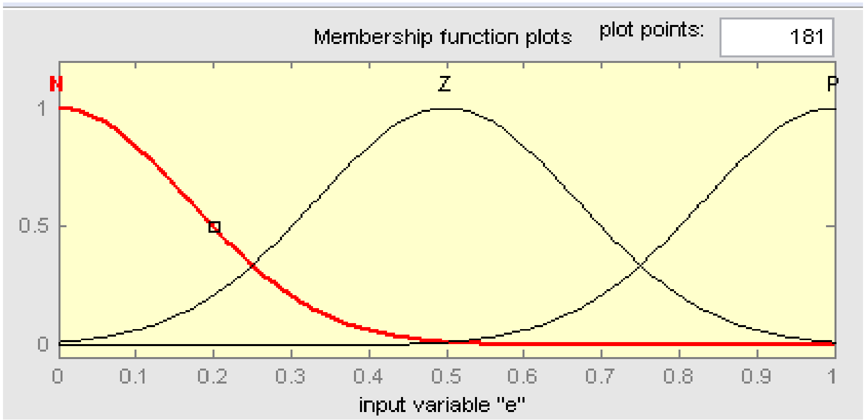
Fig. 9: Speed response of DC motor based FLC.

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

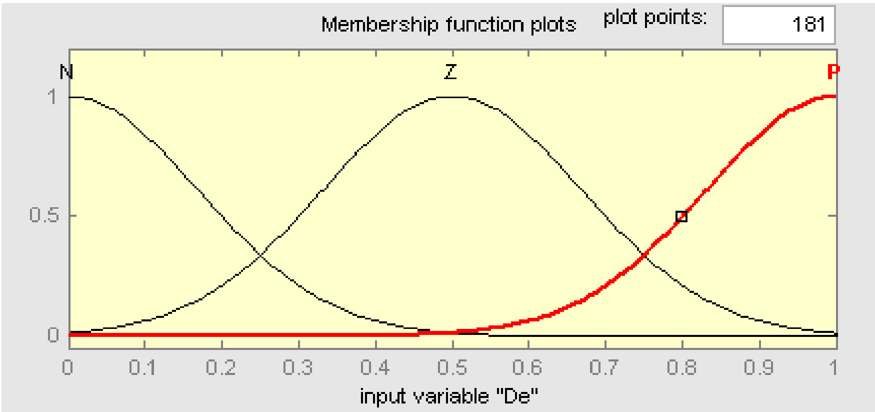
Table 3: Dynamic speed response based fuzzy.

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

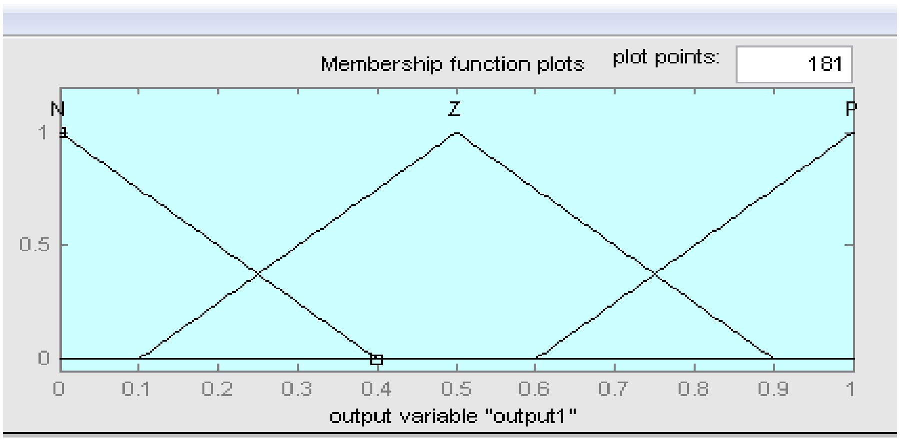
The membership functions that depended in input and output of FLC is illustrated in figure (10).



(A)



(B)



(C)

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).

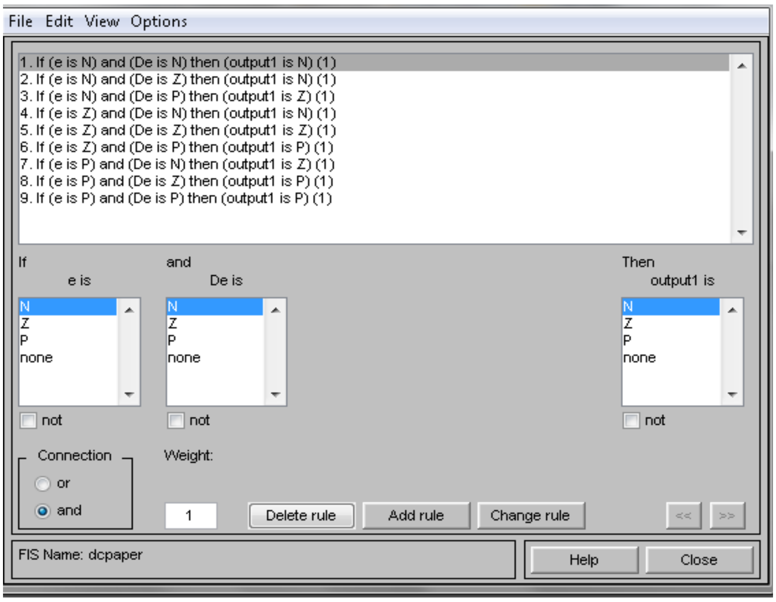


Fig. 11: FLC DC motor rules.

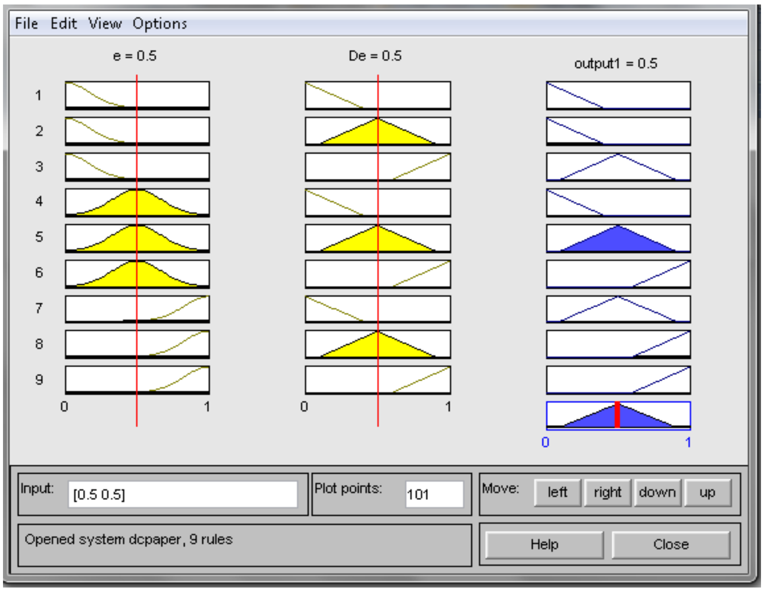


Fig. 12: Waves of DC motor rules.

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

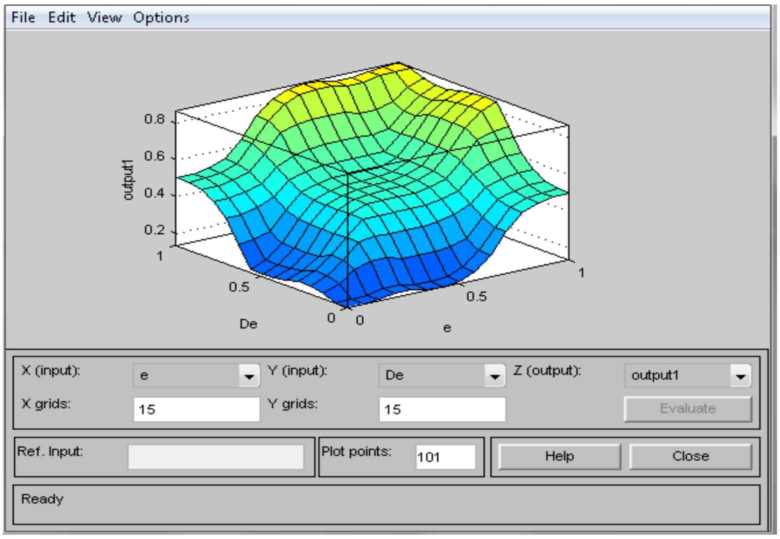


Fig. 13: 3D FLC output surface of DC motor.

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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