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Design a Fuzzy Logic Controller for Controlling Position of D.C. Motor

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Abstract: - Fuzzy logic provides an accurate controller for controlling the systems when compared to the classical controllers such as a PID controller. In this work, a fuzzy logic controller (FLC) designed to control the position of a D.C. motor. The motor model is developed and transformed in subsystem by using the Matlab/ Simulink and its parameters taken from a datasheet for a real motor. The control signal adjusted in real time using proper fuzzy membership functions depending upon the armature voltage applied to the D.C. motor. Here tow inputs and one output are used. The fuzzy input variable (error) has seven membership functions, the fuzzy input variable (change of error) has five membership functions, and the fuzzy output variable represented by applied voltage has five membership functions. Important study parameters include input voltage of DC motor and its response for achieving accurate position and high efficiency of the motor. The results of the control achieved a suitable response for applications.

Keywords – D.C. motor, Control, Position, System, Fuzzy, FLC

1. Introduction

D.C. motors have been used for lengthy time because it has high efficiency for converting mechanical energy in manufacturing. As well as energy recovery, machinery in this type of motors is very powerful; it has maximum torque producing quality[1]. Many applications as robot manipulators and home utilizations need a high accurate controllers for achieving the critical processes as determining the position. The FLC has the ability for reaching these required properties in controllers [2]. In this paper, a fuzzy logic controller for position control of a DC motor designed.

In 1973 L.A Zadeh introduced fuzzy logic set and applied (Mamdani 1974) for trying to control system that are fundamentally difficult to model. FLC is one of the most effective applications of fuzzy set theory. FLC has grown as a marginal or corresponding to the classical control schemes in various engineering regions [3]. This paper offers the ability of Fuzzy Logic in planning a control system for position controller of DC Motor.

FLC has three main modules, a fuzzifier, which transform the input signal into fuzzy signal, a fuzzy inference engine which manner the fuzzified signal by decision rules, and a defuzzifier, which change the fuzzy controller output signal to a signal used as the control input signal to the system [4].

Fuzzy set theory differs from usual Boolean set theory in the membership part. Classical Boolean theory is represented by 1 or 0 only. Fuzy theory allows for membership, which may be values from 0 to 1. Membership function exactly determine the degree of membership depending on a stuff such as humidity or density [5].

2. D.C. Motor Mathematical Model

DC motor system often used to the velocity tuning and the position adjustment is a separately excited DC motor [6,7]. An equivalent model as shown in (Figure 1) can represent the separately excited DC motor [8].

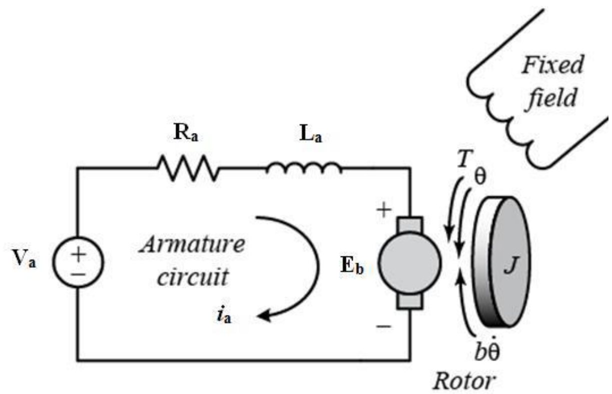

Figure 1: Equivalent model of D.C. motor

Where:

Va = armature voltage (V) (Input)

Ra = armature resistance (Ω)

La = armature inductance (H)

ia = armature current (A)

Eb= back electromotive force (e.m.f.) (V)

T = Torque (Nm)

θ = angular position of rotor shaft (rad) (Output)

Using Kirchhoff's voltage law, the armature voltage equation given by:

$$V_a(t) = R_a i_a(t) + L_a \frac{di(t)}{dt} + Eb(t)$$

The motor torque (T) related to the armature current i, by a factor (K):

$$T = Ki$$

The (e.m.f.) (Eb) related to the angular velocity as:

$$Eb = K\omega = k\frac{d\theta}{dt}$$

According to D.C. motor model and based on the Newton's law combined with the Kirchhoff's law we can obtain:

$$J\frac{d2\theta}{dt} + b\frac{d\theta}{dt} = Ki \quad \text{... (1)}$$

$$L\frac{di(t)}{dt} + Ri = V - K\frac{d\theta}{dt} \quad \text{... (2)}$$

Take Laplace transform for eq. (1) and eq. (2), these equations can be write as:

$$JS^2\theta(s) + bS\theta(s) = KI(s) \quad \text{... (3)}$$

$$LSI(s) + RI(s) = V(s) - KS\theta(s) \quad \text{... (4)}$$

From eq. (3) and eq. (4), we get eq. (5) as following:

$$I(s) = \frac{V(s) - KS\theta(s)}{R + LS}$$

$$JS^2\theta(s) + bS\theta(s) = K\frac{V(s) - KS\theta(s)}{R + LS} \quad \text{... (5)}$$

As these equations, the block diagram of D.C. motor can be develop as shown in (Figure 2).

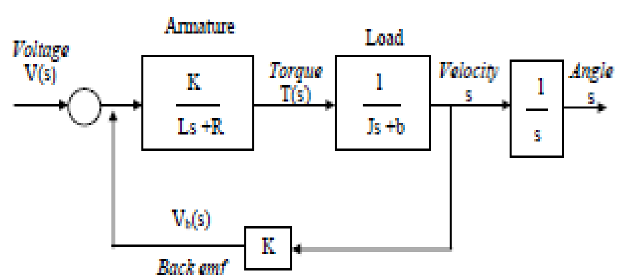

Figure 2: Block diagram of separately excited D.C. motor

From eq. (5), the transfer function of the output angle (θ) to the input voltage (V(s)) can be obtain as in eq. (6).

$$G_a(s) = \frac{\theta(S)}{V(s)} = \frac{K}{S[(R+LS)(JS+b)+K2]} \quad \ldots (6)$$

Depending on D.C. motor block diagram illustrated in (Figure 2), the transfer function of to the angular velocity (ω) to the input voltage (V(s)) given by eq. (7).

$$G_v(s) = \frac{\omega(S)}{V(s)} = \frac{K}{[(R+LS)(JS+b)+K2]} \quad \ldots (7)$$

Now, the D.C. motor can be represented by transfer function shown in eq. (8)

$$\frac{\omega(S)}{V(s)} = \frac{K}{(LJ)S2+(RJ+Lb)S+(Rb+K2)} \quad \ldots (8)$$

3. Fuzzy Logic Controller Design

FLC technology has been widely used and effectively used in manufacturing applications [9]. Fuzzy logic is a method to make technologies more intelligent to mode like humans. A fuzzy logic model is a logical-mathematical technique built on an "If-Then" rule system form [10]. Fuzzy logic controllers designed by using MATLAB – FIS Editor.

The flowing terms (3.1 and 3.2) can achieve the building of FLC and its design, identification of input and output variables, building of control rules, forming the approach for labeling system state in expressions of fuzzy sets, and choice of the compositional rule of the inference. The fuzzy controller designed with two input variables, error and change of error and one output variable, which is the applied voltage to D.C. motor. The FLC based on Mamdani fuzzy inference system uses linear membership function for both inputs and outputs.

3.1 Membership Functions

For the fuzzy logic controller the input variables are error (E) and change of error (CE), and the output variable is applied voltage (V). The membership functions include the linguistic terms in Table 1. Triangular membership functions used for input variables and the output variable. Error has five membership functions as shown in (Figure 3), change of error has seven membership functions as shown in (Figure 4), and output variable has five membership functions as shown in (Figure 5).

Table 1: Linguistic variables

Symbol	Linguistic Variable
NLL	Negative Large Large
NL	Negative Large
NS	Negative Small
Z	Zero
PS	Positive Small
PL	Positive Large
PLL	Positive Large Large

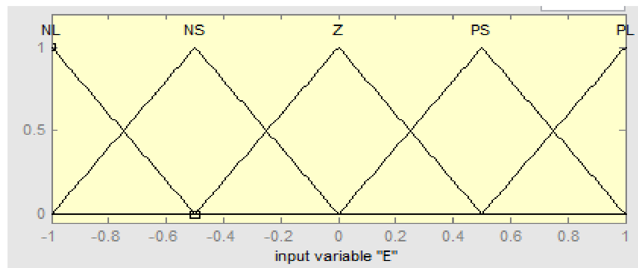

Figure 3: Membership functions of fuzzy input variable (change in error)

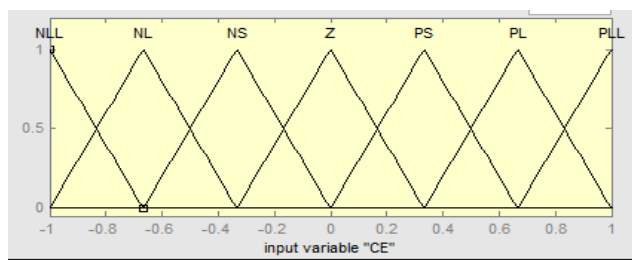

Figure 4: Membership functions of fuzzy input variable (error)

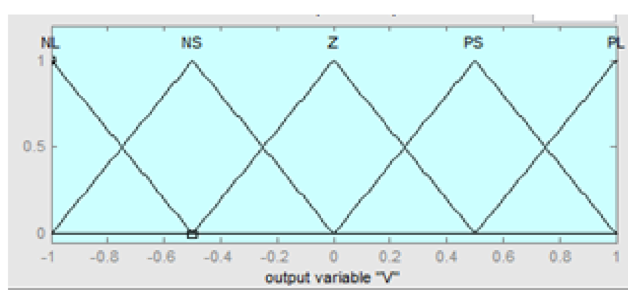

Figure 5: Membership functions of fuzzy output variable (voltage)

3.2 Fuzzy Rule Base

The fuzzy input variable E has seven membership functions and fuzzy input variable CE has five membership functions, and the output variable has five membership functions. Thus, there were total 35 rules generated as shown in Table 2. The rule editor in Matlab used for formatting the rules using different arrangements of input variables.

Table 2: Rule base of FLC

CE/E	NL	NS	Z	PS	PL
NLL	NL	NL	NL	NS	NS
NL	NL	NL	NS	NS	Z
NS	NL	NS	NS	Z	Z
Z	NS	Z	Z	Z	PS
PS	Z	Z	PS	PS	PL
PL	Z	PS	PS	PL	PL
PLL	PS	PS	PL	PL	PL

Analysis of the two inputs (error and change in error) and output in Matlab rule viewer shown in (Figure 6).

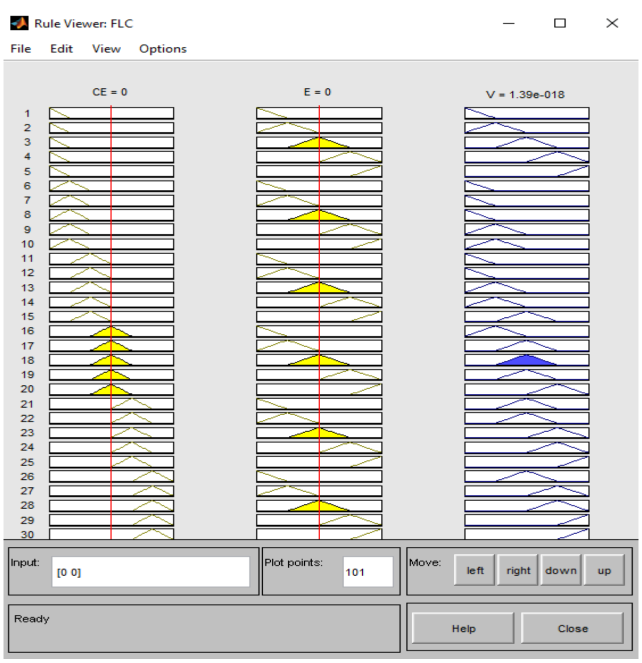

Figure 6: FLC Rule Viewer

4. Simulink Implementation and Results

In this paper, the separately excited D.C. motor represented by a transfer function and its parameters ashown in Table 3. Here the overall model of DC motor with FLC realized by using MATLAB/SIMULINK. FLC control system with D.C. motor designed in MATLAB/SIMULINK illustrated in (Figure 7). The output response of the system determined by applying the step function as an input.

Table 3: D.C. motor parameters

Parameter	**Value**
Armature Voltage	200 V
Armature Resistance	0.4 Ohm
Armature Inductance	0.05 H
Rotor Inertia	0.5 kg.m2
Back E.M.F. Constant	1.25 V.S./Rad
Friction Coefficient	0.01 N.m./Rad
Rated Speed	1500 r.p.m
Torque Constant	1 N.m/A

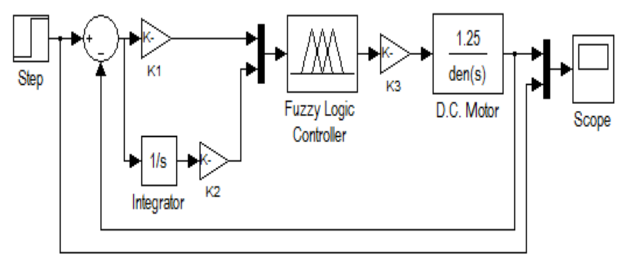

Figure 7: System model of D.C. motor with fuzzy FLC

The output signal of FLC for system illustrated in (Figure 8).

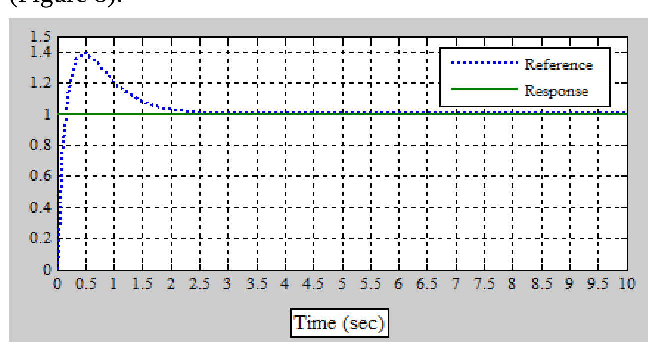

Figure 8: Step response of system based on FLC

From the output response of the system FLC, there are an appearance improvement in the response, there is a reduction in the overshoot of the system, rise time, peak time, settling time, and delay time of the system. These parameters calculated from the step response of the system with FLC as shown in Table 4.

Table 4: Performance specifications for FLC

Parameter	Value
Overshot Percentage	40%
Rise Time (sec.)	0.0921
Peak Time (sec.)	0.5
Settling Time (sec.)	2.373
Delay Time (sec.)	0.0563

5. Conclusions

The design aims to apply a smooth control of position in D.C. for minimizing the position error. In this paper, FLC designed for controlling the position of separately exited DC motor. The results display that the overshoot of the system, rise time, peak time, settling time, and delay time of the system has been improved actually by using FLC. FLC has a better dynamic response from the system; it shows best performance in following the reference input signal. FLC has a higher flexibility. Hence, FLC design was proposed and implemented for controlling D.C. motor position.

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