Simulation of Speed Control for Separately Excited DC Motor Utilizing Fuzzy Logic Controller

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Abstract

DC motors are considered the most common and widely used, typically of adaptable speed drive operation. There are many researches, DC motor controllers have been implemented but most of them have not reached satisfactory results compared with the use of intelligent systems. Different simulations are performed using the PID and FLC controller for different conditions namely various motor plants having readily changed parameter in order test the robustness of the system , Also three types of input ,i.e. step, ramp, and train of pulses are employed result ,obtained .medicated that the prospered FLC controller are better compared with controllers such as PID,[e.g. for PID, tr= 0.3 sec ,MP=0.1 ts=1.8 ,while for FLC ,tr= 0.008 sec ,MP= 0 ts=0.016 sec .. In this paper presented the concerned with design of the[PID,FLC] controller was achieved through the use of Simulink in MATLAB .The design simulation of all the controllers such as conventional PID controller and intelligent control [namely Fuzzy logic control (FLC)] are compared for different DC motor speed control.

Keywords: speed control, separately excited DC motor, PID controller, and fuzzy logic control.

1. Introduction

Speed controllers are very important in the construction of mechatronic systems where DC motors are referred to as actuators. Separately Excited Direct Current Motor (SEDCM) operated from DC power sources needs speed control for many applications. SEDCM has several advantages, one of the most important one is its ability of speed-control [1]. In the development of intelligent systems, they have been used extensively compared to traditional systems in motor speed control. [2].Because fuzzy logic has a human-like characteristic, but methodology can transform rules based on expert knowledge into an automatic control strategy, it can be well applied to control systems with uncertain dynamics. [3]. Since the early 1950s, PID controller has been widely used in electric drive fields due to its fast and efficient response [4] and PID gains to eliminate and decreasing the overshoot due to load disturbance is difficult[5], but now improved by add FLC .

The project is to simulate a controller of speed for a SEDCM that is different from typical speed controllers.The proposed speed controller utilizes an analogue system. D.C Motor used for multipurpose because easy control it [6,7]. The researcher is taken the SEDCM for speed control by two methods. The first method used PID controller and building of MATLAB program using Simulink technique. this design add to DC Motor model by Simulink style and calculate the results from the output response .The second building Fuzzy Logic controller using MATLAB program by Simulink technique [8] , through simulation style as well as build member ship function ,rule base , Fuzzification , and Defuzzification. The membership function builder based on the error and change in error of a system, the fuzzy set

is drafted from an element which has degree of membership. Some benefits encourage the use of FL system in control application such as, high degree of tolerance, smoother, and fast learning [9] .The fuzzy controller add to DC Motor modeling and run the Simulink model , compute the result (Rise time , Overshoot ,and stilling time) .The third use the controllers of new plant for speed control of DC Motor and change of the parameter plant ,the calculate of result from output response every term .The structure of Speed control consists of the following three major stages involved in which the first one without controller, the second using PID controller and third is FLC [10]. Rule base according to the error and change of error that provides the system with the logic of decision making based on the rule that sets the control strategy.

2. Theory

I- SEDC Motor

The Direct Current Motor (DCM) is the backbone of the industry for several reasons including the good Torque-Speed characteristics. It is the common operator of control systems. DCM provides direct rotary motion and can provide transitional movement, along with wheels or drums and cables. The equivalent circuit of this type of motor is shown in Figure1.
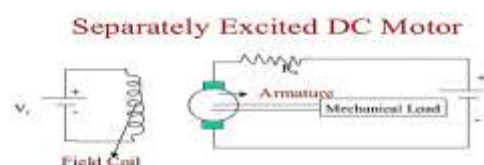

Fig. 1 Schematic diagram of the SEDC Motor

DCM is driving a load with aninertia and damping as shown in figure (1). As the armature rotates it develops an induced voltage (em) which is in a direction to (t). Speed of the motor (ω) depends upon the input and the flux resulted from field current. Since the field current is constant, then the flux must be constant. Therefore the induced armature voltage is only dependent on the speed of rotation.

i.e $em \alpha \omega$ (1)

$$em = ke.\omega = ke.(d\theta_o(t)/dt)$$ (2)

Ke is voltage constant of the SEDCM

The armature voltage equation is:

$$ea(t) = Rm.\text{Im} + Lm(dIa/dt) + em$$ (3)

The developed torque of the SEDCM T(t) is a proportional with flux developed by the current of field, when the current of armature is constant

$$T(t)\alpha Ia = kt.Ia$$ (4)

Kt is torque constant of the SEDCM.

The developed torque is used to drive the mechanical load. The torque equation is:

$$T(t) = J(d^2\theta_o(t)/dt^2) + B(d\theta_o(t)/dt)$$ (5)

Using Lap lace domain we get:

$$Em = KeS\theta_o(s)$$ (6)

$$Ea(s) - Em(s) = (Rm - Lm(s))Ia$$ (7)

$$T(s) = Kt\,\text{Im}$$ (8)

$$T(s) = Js^2\theta_O(s) + Bs\theta_O(s)$$ (9)

$$T(s) = \frac{G(s)}{1+G(s)H(s)} = \frac{\frac{K}{s(s+1)}}{1+\frac{K}{s(s+1)}} = \frac{K}{s(s+1)+K}$$

(10)

In figure (2), the output (response) from the system may be unstable, very slow, and overshoot. Thus, compensators are used to solve these problems, and it was added into the system to improve the overall transfer function of this model.
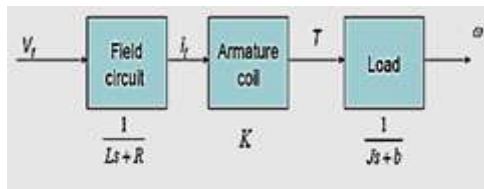

Fig.2 field-controlled DC motor

II- **PID Controller**

The PID controller can realize these notions in the PID (Proportional-Integral Derivative) control algorithm. The PID algorithm is simply a plausible way to do a controller response. The time domain representation of the controller output CO (t) is:

$$co(t) = k_o\left[E(t) + 1/T_I\int_0^t E(t)dt + Td.dE/dt\right]$$ (11)

The definition is written in terms of deviation variables. E is error signal, it represent the difference between reference point and controlled variable, both written as deviation variables.

$$E(t) = Sp(t) - Cv(t)$$ (12)

$$(E(t) - E_s) = (Sp(t) - Sp_s) - (Cv(t) - Cv_s)$$ **(13)**

(Certainly the most likely reference state is one in which the error is zero -the controlled variable CVs is at the set point SPs but this does not require using the equation.

$$E(t) = SP(t) - CV(t)$$ (14)

The three control modes Kc is the proportional gain, or simply gain. Conventionally the gain is applied across the other two modes, as well, as indicated in the definition.

Ti is the integral time. Its reciprocal is often called the reset rate. This reset rate has dimensions of "repeats/time". This is because at constant error input ΔE, the controller output will increase by KcΔE in each time increment Ti. Deactivate integral mode by setting Ti to infinity. Short Ti, or high reset rate, represents more aggressive control response.

Td is the derivative time. Deactivate mode by setting Td to zero. Large Td represents more aggressive control response. Marlin suggests that the derivative mode be applied only to the controlled variable and not the error term as shown in the equation. By this, set point changes would not lead to sudden manipulated variable changes, driven by the derivative mode.

$$co(t) = k_c\left[E(t) + 1/T_I\int_0^t E(t)dt - Td.dcv/dt\right]$$ **(15)**

The transfer function of the PID controller, as in the following equation:

$$G_c(s) = K_d s + K_p + \frac{K_i}{s} = \frac{K_d s^2 + K_p s + K_i}{s}$$ (16)

PID controller operates in a closed- loop system by using equation(16). The tracking error (e) is the difference between the input value (R) and the real output (y). The signal of error (e) will be sent to the PID controller which computes both the derivative and the integral of (e).The signal (u) shown in equation (17), will be sent to the plant, and will get the new output (Y).the new director (Y) will be sent to the sensor again to find the new error signal (e). This controller takes the new signal of error and calculates its derivatives and integrates them again

$$u = K_p e + K_i\int edt + K_d de/dt$$ (17)

III-**Fuzzy Logic Controller**

FLC is based on the connection between input data and output data by using control unit which applies a set of unclear rules ("if-then" rules). These rules include linguistic variables rather than a complex mathematical model of the system. The main parts of fuzzy controller are the data rule base, proceeded by the input which used to transform the error and the change of error into the linguistic form. While the succeeded part (defuzzification)

which used to transform the linguistic output to an output signal, as shown in Figure 3.Normalized universe of the input is used by choosing a suitable scaling factor. On other hand, the output is needed to scale up the output of the controller needed for the system. ficzifcation explains the process of language input values that are defined in the knowledge base. Inference uses the rule defined in the Knowledge Base to associate the entered linguistic values with the required action for the resulting linguistic control. Finally, defuzzification rules applicable to the process used to derive the output value of friable or linguistic value of the output.The process of inference is to look for the relationship of inputs and outputs to match the terms of input. [12]
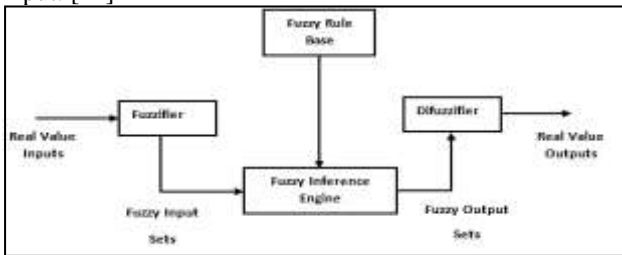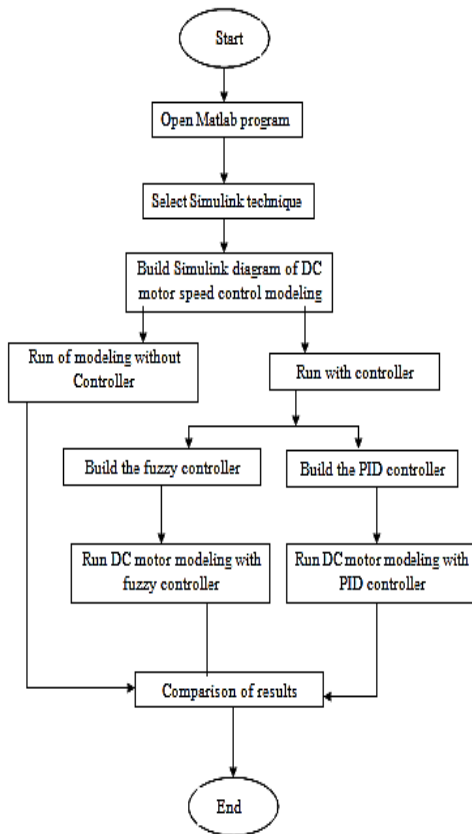

Fig. 3 A fuzzy logic controller architecture

3- **Methodology**

Flow chart of work

The physical parameters of modeling have following values as shown table.1:

Table 1 Physical parameters of model

Physical parameters (symbol)	values	units
moment of inertia(J)	0.01	kg.m^2/s^2
damping ratio(b)	0.1	N.m.s
electromotive constant k=ke=kt	0.01	N.m/Amp
electric resistance (R)	1	ohm
electric inductance(L)	0.5	Hinery

Input (V): source voltage

The rotor and shift are assumed to be rigid

Note that these parameters are chosen to be simple. The motors in real life may be more complex, and most likely will be running at a higher speed.

Simulink diagram of PID controller simulation :

After building the DC Motor in Simulink diagram in PID controller is added by Simulink too. See the Simulink diagram Figure 4.
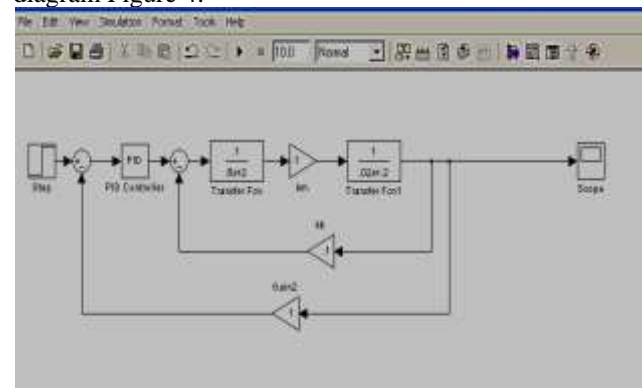

Fig.4 Simulink diagram of SEDCM speed control With PID controller km=kb=constant

PID controller building:

By double click PID controller icon, you view menu. Select the value of KP, KI, KD.

Tuning the PID controller:

PID is composed of proportional, integral and derivative this elements changing for every case so that select of the best value. See the Simulink diagram below show Figure 5
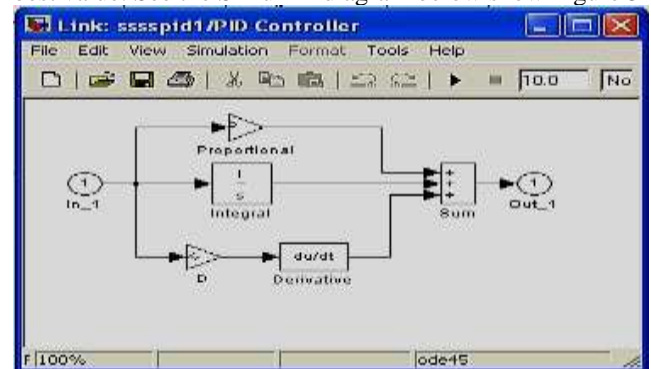

Fig. 5 Simulink diagram of proportional, integral and derivative

The proportional control units (KP) is working to reduce the time to reduce the rise time and will be reduced through trial and error for the selected value of (KP) , but don't remove, the steady –state error. The integrated control units (KI) remove the error stable, but the transient response became worse. The Derivative Control units (KD) will be effect on system stability increasing, overshoot reducing, and the transient response improving. The KP, KD, and KI units strongly controls on the closed loop system.

Fuzzy controller Simulink

FC system design basically amounts to
- select the inputs and outputs of the FC.
- Choose the preprocessing which it necessary for console entries and may be deploying the required processing for outputs.
 - designing the four elements of the FC, will knowledge on these elements and build it by using Simulink technique.

Building of membership function.

A support of the fuzzy is a set of components which have a nonzero membership. Membership function is a relationship connects a number to each element x in the universe. The Membership in Simulink is built $\mu(x)$ shown figure(6 a, b and c).
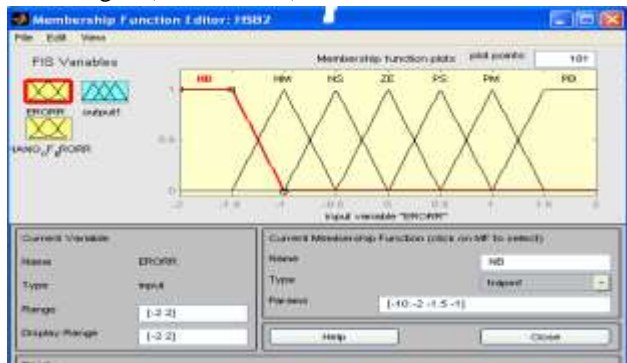

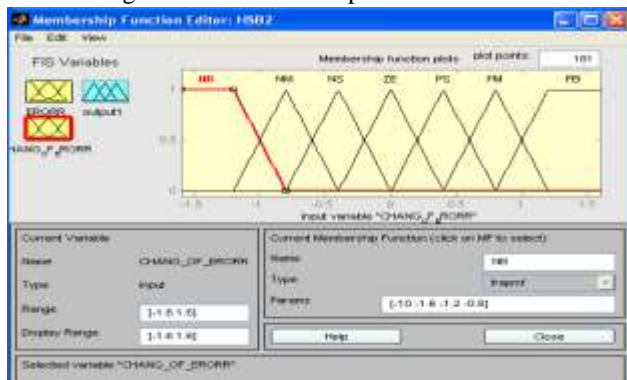Fig. 6a The membership function of error

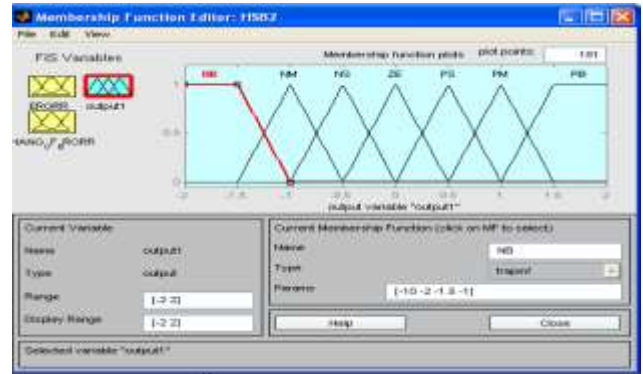Fig. 6bThe membership function of change of error

Fig. 6c The membership function of output

Building the rule base:

Basically, the console contains language rules (if-then format) but can be expressed by different ways. Table 2 and figure 7show the formats similar to rules are presented to the end user in many systems. The table contains 49 bases divided into two parts (NB, NM, NS, Z, PS,PM, PB) which are made by these rules to reduce the error ratio. This paper uses a base table that displays the Toeplitz structure, where the output member functionality is the same in a diagonal line. Table 1 shows the rules table that displays the Toeplitz structure where the country line with the ZERO membership function is the main country line**.**

Table 2 represent rules in the if-then format

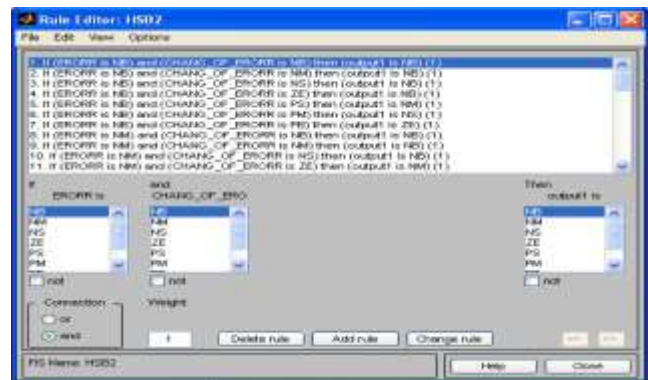| ce\e	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

Fig.7 Windows of rule base

Defuzzification:

The control signal becomes. Thus, the resulting fuzzy set is detected in a clear control signal. Many types of defuzzification are used the researcher from trial and error found maim of maximum (MOM), gives good result. Therefore selected (mom) from Simulink menu.

Fuzzy Simulink diagram:

The building of fuzzy Simulink diagram uses the block fuzzy controller and connects it to DC motor Simulink diagram. The block fuzzy controller must be known by its elements (membership, rule base, and defuzzification) after building it and connecting to Simulink diagram shown Figure 8.
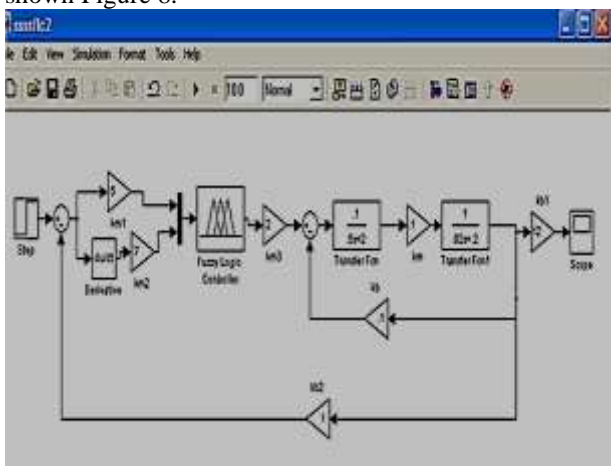

Fig.8 The Simulink diagram of DC motor speed control with fuzzy logic controller

Results:

The result taken from all cases are revealed in output response curve. In case the DC motor speed is controlled without controller you see the overshoot is high, the rise time is high ,and steady-state error high. Because the motor is un controlled but when the PID controller is used in DC motor gives improved the output response where you see changes in the time salient through use PI controller ,PD controller and PID controller from tuning the gain (KI,KP and KD) ,so this method improves the output response and is classic. The intelligent control use fuzzy controller, which is used in this research gives good accuracy, reliability, ease of control ,and the result of unit step input approximates of ideal case see the Table 3.The fuzzy controller uses improvement in output response where you see the fuzzy controllers better than of PID controller shown figures(9 a ,b and c)

Table 3 result of unit step input approximates of ideal case

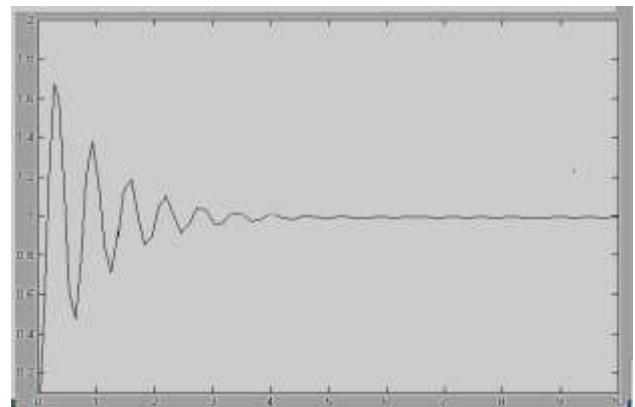| Item	With fuzzy controller	With PID controller	Without controller
rise time	0.008 sec	0.3sec	0.5 sec
overshoot	0.0sec	0.1	0.35
Settling time	0.016 sec	1.8 sec	4.5 sec

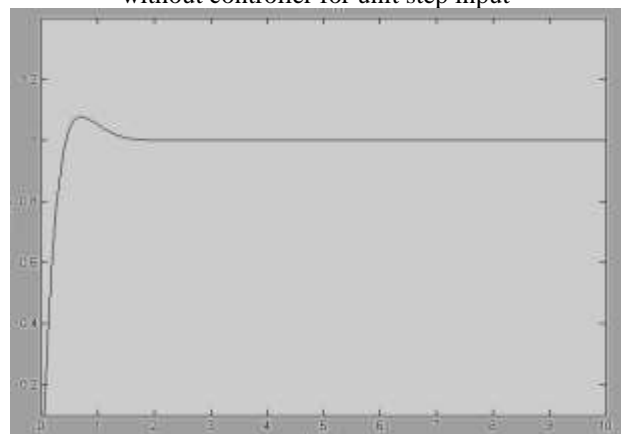Fig.9a The output response of DC motor speed control without controller for unit step input

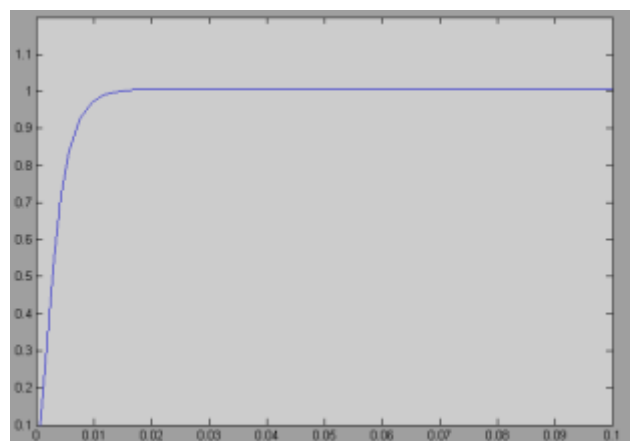Fig. 9b Output response of Simulink diagram using PID

Fig. 9c Output response to unit step input using fuzzy logic controller.

Conclusions

The DC motor speed control needs the accuracy, because the overshooting state and steady-state error affect motor operation and response, so that the researcher has depended on three cases in work. The first DC motor runs without controller. The second DC motor works with the PID controller in which case the output response is improved. The third case uses fuzzy logic controller. In this case the output response is very good and output result is very accuracies. The use of MATLAB program and Simulink enables the user to have flexibility in choosing different elements and diagrams. They also provide good and easy means of obtaining and inspecting output at various points of the diagrams concerned. The use of fuzzy logic simplifies the design of controllers, because it relies on fixed fuzzy rules, the rule base is built based on input information. comparison of the results obtained from using fuzzy logic controller with those based on PID controller indicate .The fuzzy logic control gives better results.

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