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Speed Control of S.E.D.C. Motor by Using Pi and Fuzzy Logic Controller

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Abstract:- In this paper we proposed PI controller & fuzzy controller design for reducing the sensitivity of the effect of load variations dynamic load changes for the response of the output speed of the system S.E.DC motor which can cause malfunctions in the electronic circuits or the complete failure of the control system. The paper describes the implementations of a PI controller and fuzzy controller which can orate successfully in hostile environments such as an orbiting space vehicle.

Keywords:- SCDC Motor, PI controller & fuzzy controller

I. INTRODUCTION

The DC motors have been popular in the industry control area for a long time, because they have enormous characteristics like, high start torque , high response performance, easier to be linear control etc. The proportional integral (PI) controller is the most common form of feedback in the control systems. PI control is also an important ingredient of a distributed control system and as such these controllers come in different forms. Fuzzy logic offers several unique features that make it a particularly good choice for many control problems. Since the Fuzzy logic controller processes user-defined rules governing the target control system, it can be modified and implement easily to improve or drastically alter system performance.

New sensors can easily be incorporated into the system simply by generating appropriate governing rules. Fuzzy logic is not limited to a few feedback inputs and one or two control outputs, nor is it necessary to measure or compute rate-of-change parameters in order for it to be implemented. Any sensor data that provides some indication of a system's actions and reactions is sufficient. This allows the sensors to be inexpensive and imprecise thus keeping the overall system cost and complexity low. High performance DC motor drives are used extensively in industrial applications. The DC motor drive is a highly controllable electrical motor drive suitable for robotic manipulators, guided vehicles, steel mills and electrical traction [1-5]. Usually, precise, fast, effective speed references tracking with minimum overshoot/undershoot and small steady state error are essential control objectives of such a drive system [6-7]. There have been several conventional control techniques in DC motor drives are presented [8-12]. The conventional control strategies are a fixed structure, fixed parameter design. Hence the tuning and optimization of these controllers is a challenging and difficult task, particularly, under varying load conditions, parameter changes, abnormal modes of operation, etc. Attempts to overcome such limitations using adaptive and variable structure control have had limited success due to complexity, requiring of estimation stages, model structure changes due to discontinuous drive mode of operation, parameter variations, load excursions and noisy feedback speed and current signals [13-17]. In the drive field, fuzzy logic has applied to various problems, such as robust control of DC drive systems. This paper presents**.** In this paper, fuzzy logic controller is used instead of the PI controller to overcome the undesired undershoots coming from load impact at some abnormal conditions. A complete circuit for the system under consideration has constructed. The proposed controller is implemented using a high speed DSP in order to verify the robustness of these controllers.

II. STRUCTURE AND FORMULATION

A S.E.DC motor with armature control is one in which the speed is controlled by the armature voltage V_a. an armature-controlled S.E.DC motor in which the field current If is kept constant is shown in figure1.

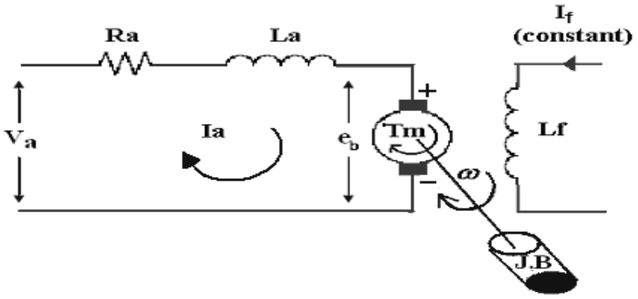

Fig 1: Armature controlled of S.E.DC Motor.

Where, R_a=Resistance of armature, (ohm), L_a=Inductance of armature winding, (hennery), I_a = Armature current, (ampere),I_f = Field current, (ampere), V_a = Applied armature voltage, e_b = back emf, (volt), T_m=Torque developed by the motor, (N.m), θ =Angular displacement of motor-shaft, (radian), ω = Angular Velocity of motor-shaft, J= Equivalent moment of inertia of motor and load referred to motor shaft, (Kg.m2), B=Equivalent viscous-friction coefficient of the motor and load referred to the motor shaft, (N.m/rad/sec).The armature voltage Va is usually supplied by a generator, which in turn may be supplied by an amplifier. The voltage V_b is the back e.m.f. induced by the rotation of the armature windings in the magnetic field. The transfer function of the S.E.DC motor will be developed for a linear approximation to an actual motor, and second-order effects, such as hysteresis and the voltage drop across the brushes, will be neglected. The input voltage may be applied to the field or armature

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terminals. The air-gap flux of the motor is proportional to the field current.

2.1 Block diagram for S.E.DC motor in terms of Armature Control

The S.E.DC motor transfer function of armature control from the Applied armature voltage $V_a(s)$

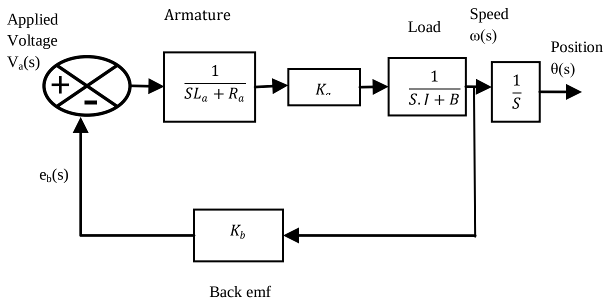

Fig 2: Block diagram of armature controlled of S.E.DC motor without load.

(input voltage), to position (Angular displacement) θ(s) without load which (Td(s)=0) is

$$\frac{\theta(s)}{V_a(s)} = \frac{K_m}{s(Js+B)(L_a s+R_a)+K_m K_b s} \tag{1}$$

From Eq. (1), the S.E.DC motor transfer function of armature control from the Applied armature voltage (input voltage), $V_a(s)$, to speed (the angular velocity) $s\theta(s)=\omega(s)$ without load which (Td(s) =0) is

The S.E.DC motor transfer function without load is shown in the block diagram in figure 2.

$$\frac{\omega(s)}{V_a(s)} = \frac{K_m}{(Js+B)(L_a s+R_a)+K_m K_b} \tag{2}$$

τ_a = La/Ra = time constant of armature circuit, τ_m = J/B = mechanical time constant.S.E.DC motor transfer function of armature control from the Applied armature voltage (input voltage) $V_a(s)$ to speed (the angular velocity) $\omega(s)$ with load Td(s) will become as follow

$$\omega(s) = \frac{K_m}{(Js+b)(L_a s+R_a)+K_m K_b} V_a(s) - \frac{L_a+R_a}{(Js+b)(L_a+R_a)+K_m K_b} T_d s \tag{3}$$

2.2 Block diagram and Transfer Function for S.E.DC motor in terms of Field Control

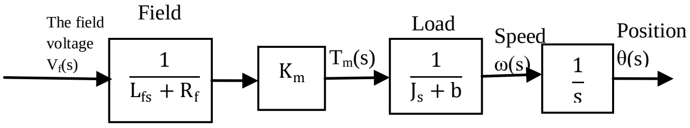

Fig 3: Block diagram of field-controlled S.E.DC motor without load.

The S.E.DC motor transfer function of field controlled from the Field voltage (input voltage) $V_f(s)$, to the position (Angular displacement) θ(s) without load which (Td(s)=0) is

$$\frac{\theta(s)}{V_f(s)} = \frac{K_m}{s(Js+b)(L_f s+R_f)} \tag{4}$$

From Eq. (4), the S.E.DC motor transfer function of field controlled from the Field voltage (input voltage), Vf(s), to speed (the angular velocity), $s\theta(s)=\omega(s)$ without load which (Td(s)=0) is

$$\frac{\omega(s)}{V_f(s)} = \frac{K_m}{(Js+b)(L_f s+R_f)} \tag{5}$$

The block diagram of field controlled of S.E.DC motor obtained from Eq. (5) without load (Td(s)=0) is given in figure 3.The transfer function given by Eq. (5) may be written in terms of the time constants of the motor as follows

$$\frac{\omega(s)}{V_f(s)} = \frac{K_m / b.R_f}{(\tau_f.s+1)(\tau_m.s+1)} \tag{6}$$

Where, τ_f = Lf/Rf = time constant of field circuit, τ_m = J/b = mechanical time constant.Typically, find that $\tau_m \rangle \tau_f$ and often the field time constant may be neglected. The S.E.DC motor transfer function of field controlled from the Field voltage (input voltage), Vf(s), to speed (the angular velocity), $s\theta(s)=\omega(s)$ with load which Td(s) is

$$\omega(s) = \frac{K_m}{(Js+b)(L_f s+R_f)} V_f(s) - \frac{1}{(Js+b)} T_L(s) \tag{7}$$

The block diagram of field controlled of S.E.DC motor obtained from Eq. (7) with load Td(s) is given in figure 4.

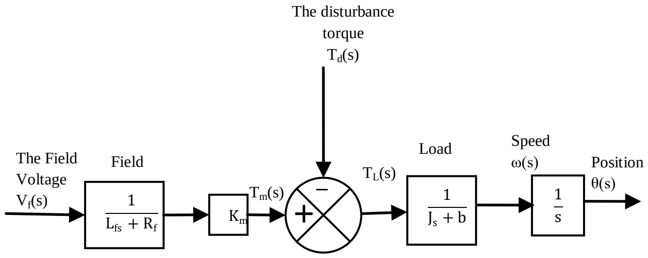

Fig 4: Block diagram of field-controlled S.E.DC motor with load

III. APPROACH & METHOD

Modeling of S.E.DC Motor with Adding PID Controller

First the PID controller works in a closed-loop system using the schematic shown in figure 3.17. The variable (e) represents the tracking error, the difference between the desired input value (R) and the actual output (ω). This error signal (e) will be sent to the PID controller, and the controller computes both the derivative and the integral of this error signal. The signal (u) just past the controller is now equal to the proportional gain (Kp) times the magnitude of the error plus the integral gain (Ki) times the integral of the error plus the derivative gain (Kd) times the derivative of the error where, this signal (u) will be sent to the plant, and the new output (ω) will be obtained. This new output (ω) will be sent back to the sensor again to find the new error signal (e). The controller takes this new error signal and computes its derivative and its integral again. This process goes on and on, this signal (u) is obtained as follow

$$U(t)=K_p e(t)+K_i\int_0^t e(t)dt+K_d\frac{de(t)}{dt} \qquad (8)$$

Using the Laplace transform for Eq. 8 and assuming initial conditions equal zero the transfer function of the PID can be written as

$$G(s)=\frac{U(s)}{E(s)}=K_p+\frac{K_i}{s}+K_d s=\frac{K_d s^2+K_p s+K_i}{s} \qquad (9)$$

Where K_p = Proportional gain, K_I = Integral gain,

K_d = Derivative gain

Rearrange that a little, transfer function of a PID-controller, the three terms can be recognized follows

$$G_s=K_p\left(\frac{\frac{K_d}{K_p}s^2+\frac{K_i}{K_p}+1}{s}\right)=K_p\left(\frac{T_i T_d s^2+T_i s+1}{T_i s}\right) \qquad (10)$$

Where: K_p is the proportional gain , $T_i=K_p/K_i$ is the integral time constant ,$T_d=K_d/K_p$ is the derivative time constant

Such a controller has three different adjustments (K_p, T_i, T_d) which interact with each other. For this reason, it can be very difficult and time consuming to tune these three values in order to get the best performance according to the design specifications of the system.

The output voltage of the tachometer, e_t, is related to the angular velocity of the motor through the tachometer constant K_t :

$$e_t(t)=K_t\omega(t) \qquad (11)$$

Using the Laplace transform for Eq. (11) the output voltage of the tachometer can be written as

$$E_t(s)=K_t\omega(s) \qquad (12)$$

$$G_{(s)}=\frac{\omega(s)}{R(s)}=\frac{\left(\frac{K_d s^2+K_p s+K_i}{s}\right)\left(\frac{K_m}{(Js+B)(L_a s+R_a)+K_m K_b}\right)}{1+K_t*\left(\frac{K_d s^2+K_p s+K_i}{s}\right)\left(\frac{K_m}{(Js+B)(L_a s+R_a)+K_m K_b}\right)} \qquad (13)$$

$$G_s=\frac{\omega(s)}{R(s)}=\frac{K_m\left(K_d s^2+K_p s+K_i\right)}{\left((Js+B)(L_a s+R_a)+K_m K_b\right)s+(K_t*K_m)\left(K_d s^2+K_p s+K_i\right)} \qquad (14)$$

On other hand, transfer function for S.E.DC Motor and PID Controller under the effect of the load (Td) is shown in the block diagram in figure 5.

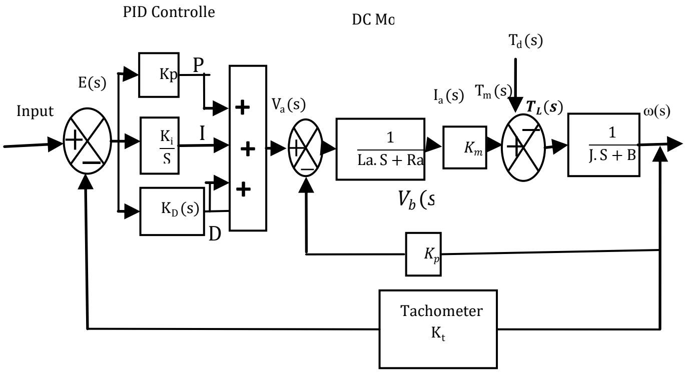

Fig 5: Block diagram of PID Controller connected with armature controlled of S.E.DC motor under the effect of the load.

IV. RESULT & DISCUSSION

A) The system under the effect of load with adding PI controller

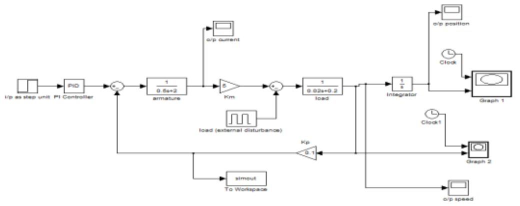

Fig 6: Simulink model of armature-controlled S.E.DC motor with load and PI controller

For the standard value of P=200 and I=0.1, the response between current (mA) and time (s) will be observed as follows:

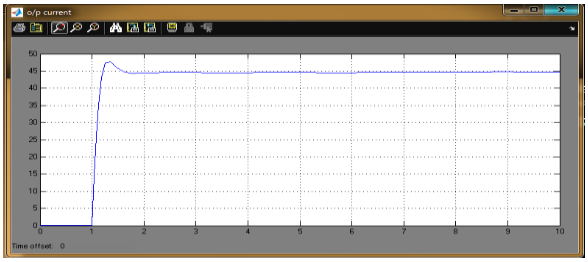

Fig 6.a: Step response of armature current (I_a ampere) of the system SEDC motor with load and PI controller (between current and time)

For the same standard value of P=200 and I=0.1, the graph between Speed (m/s) and time (s) will be plotted as follows:

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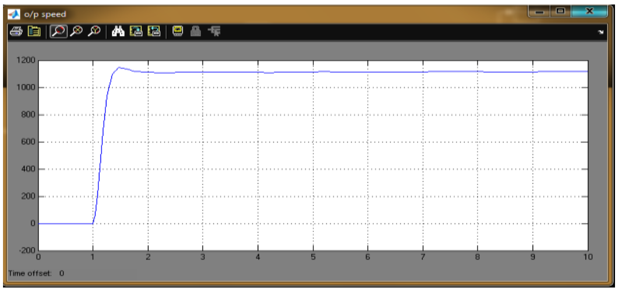

Fig 6. b: Step response of output (speed) of the system SECD motor with load and PI controller (between speed and time)

B) The system under the effect of load with adding Fuzzy controller

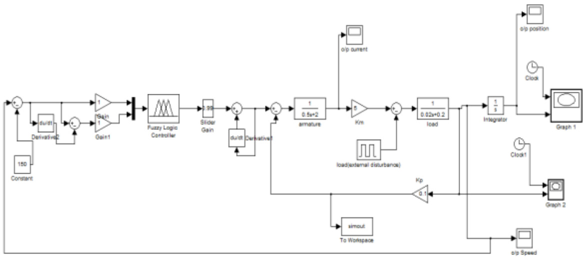

Fig 7: Simulink model of armature-controlled S.E.DC motor with load and Fuzzy controller

For the same standard value i.e. P=200 and I=0.1, the responses will be observed as follows:

Fig 7 (a) : Step response of output (speed) of the system SECD motor with load and Fuzzy controller (between speed and time)

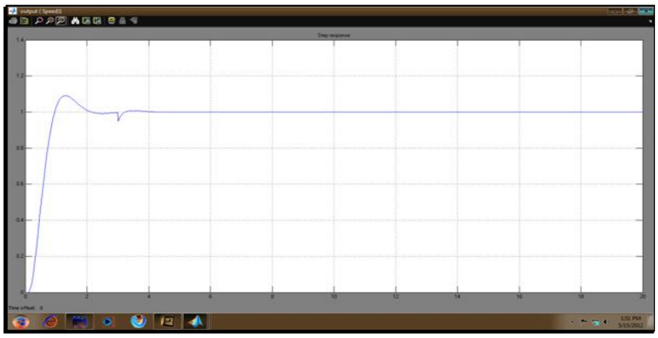

Fig 7.(b): Step response of output (speed) of the system SECD motor with load and PI controller (between speed and time)

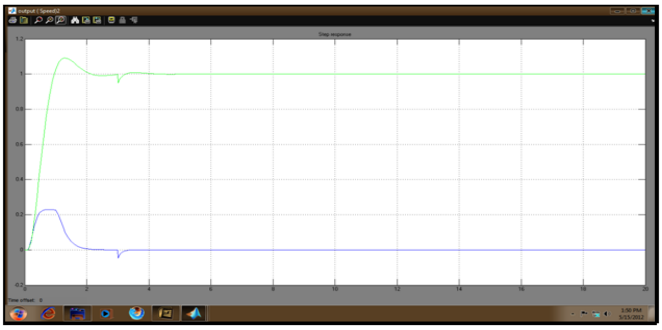

Fig 7(c): Step response of output (speed) of the system SECD motor with load and PI and Fuzzy controller (between speed and time)

It can be seen from Fig. 7 that regardless of motor running at high speed or low speed, compared with PID control, fuzzy network controller has not only a fast responding, but also small overshoot. From Fig. 7(a), 7(b) and Fig.7(c), we can see that when the system is greatly disturbed, motor can regulate itself quickly under the control of the proposed method, and the entire system has good adaptability and strong robustness.

V. CONCLUSION

On the above responses concluded that after a period of time from operating the S.E.D.C. motor, by using feed forward controller, P, PI, PID and Fuzzy controller, where by comparing the results of the response of the output (speed) of the system (S.E.D.C. motor), it is evident that, feed forward, P, PI, and PID controllers that have been used for getting the desired design requirements for the system (S.E.D.C. motor) that some of desired results for system design requirements are not satisfied for improving the performance of the response of the output (speed) of the system (S.E.D.C. motor). After using Fuzzy controller all of desired design requirements for the system (S.E.D.C. motor) are satisfied for improving the performance of the response of output (speed) of the system (S.E.D.C. motor). Therefore fuzzy controller gives much more improved dynamic responses

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