Speed Control of DC Motor using Pid Controller Based on Matlab

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Abstract: This paper is to design PID controller to supervise and control the speed response of the DC motor and MATLAB program is used for calculation and simulation PID controllers are widely used in a industrial plants because of their simplicity and robustness. Industrial processes are subjected to variation in parameters and parameter perturbations. We are choosing PID parameters and discussed

Key words: DC motor, PID controller, MATLAB representation

I . INTRODUCTION

The DC motors have been popular in the industry control area for a long time, because they have many good characteristics, for example: high start torque characteristic, high response performance, easier to be linear control…etc.

The speed of a DC motor is given be the relationship

$$N = \frac{V - IaRa}{k\phi}$$

This Equation show that the speed is dependent on the supply voltage V, the armature circuit resistance Ra, and field flux Φ, which is produced by the field current. This paper describes the MATLAB/ SIMULINK of the DC motor speed control method namely field resistance, armature voltage, armature resistance control method and feedback control system for DC motor drives [4].

When speed control over a wide range is required, combination of armature voltage control and field flux control is used. This combination permits the ratio of maximum to minimum speed to be 20 to 40. With closed loop control, this range can be extended up to 200.

The parameters of the PID controller kp, ki and kd (or kp, Ti and Td) can be manipulated to produce various response Curves from a given process as we will see later [6].

II. PID CONTROLLER

The combination of proportional, integral and derivative control action is called PID control action. PID controllers are commonly used to regulate the time-domain behavior of many different types of dynamic plants. These controllers are extremely popular because they can usually provide good closed-loop response characteristics.

Consider the feedback system architecture that is shown in Fig. 1 where it can be assumed that the plant is a DC motor whose speed must be accurately regulated [1].
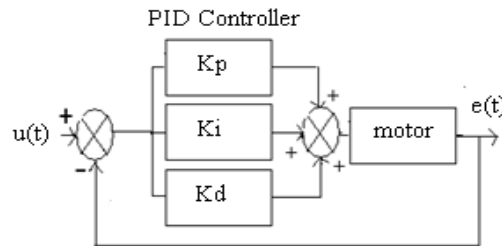
Fig - 1

The PID controller is placed in the forward path, so that its output becomes the voltage applied to the motor's armature the feedback signal is a velocity, measured by a tachometer .the output velocity signal C (t) is summed with a reference or command signal R (t) to form the error signal e (t). Finally, the error signal is the input to the PID controller [5].

$$ u \;=\; kpe \;+\; ki \int edt \;+\; kd \; \frac{de}{dt} $$

III. DC MOTOR MATHEMATICS MODEL AND THE CONTROL THEORY

DC motors have speed-control capability, which means that speed, torque and even direction of rotation can be changed at any time to meet new conditions [3] .The electric circuit of the armature and the free body diagram of the rotor are shown in the following fig- 2, and [2].
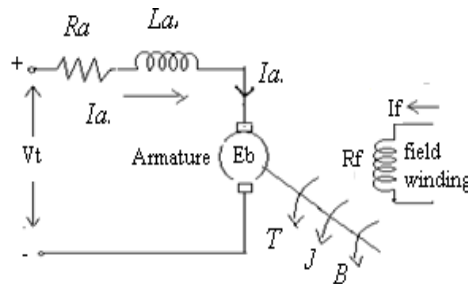

Fig - 2

Let Ra=Armature Resistance,

La=Armature self inductance caused by armature flux,

ia= Armature current,

if= field current,

Eb=Back EMF in armature,

V =Applied voltage,

T=Torque developed by the motor,

θ = Angular displacement of the motor shaft,

J =Equivalent moment of inertia of motor shaft & load referred to the   motor,

B= Equivalent Coefficient of friction of motor shaft & load referred to the motor.

The DC motors are generally used in the linear range of the magnetization curve. Therefore, air gap flux Φ is proportional of the field current i.e.

$$ \Phi \;\propto\; if $$
$$ \Phi \;=\; kfif \;\;\ldots\ldots\ldots\; (1) $$

Innovative Systems Design and Engineering
www.iiste.org
ISSN 2222-1727 (Paper) ISSN 2222-2871 (Online)
Vol.4, No.6, 2013 - Selected from International Conference on Recent Trends in Applied Sciences with Engineering Applications

Where K_f is a constant

The torque T developed by the motor is proportional to the armature current and air gap flux i.e.

$$T \propto \Phi ia$$

$$T = ka \Phi ia$$

$$T = kakf \Phi ia$$

$$T = kia \quad ....(\quad 2 \quad)$$

Where K_T =motor toque constant

The motor back EMF being proportional to speed is given as

$$Eb \propto \Phi \omega$$

$$Eb = kb \omega$$

$$Eb = kb \frac{d\theta}{dt} ......(\quad 3 \quad)$$

Where Kb= back emf constant

Applying KVL in the armature circuit

$$v = Raia + La \frac{dia}{dt} + Eb ....(\quad 4)$$

And thedynamic quation with moment of inertia & coefficient of friction will be

$$T = J \frac{d^2\theta}{dt^2} + B \frac{d\theta}{dt} ....(5)$$

And with load torque

$$T = J \frac{d^2\theta}{dt^2} + B \frac{d\theta}{dt} + T_L ....(\quad 6)$$

Take the laplace transform of equation of (2) ,(3), (4) and (5)

$$T(s) = KIa(s)$$

$$Eb(s) = KbS \theta(s)$$

$$V(s) = Ia(s)(Ra + sLa) + Eb$$

$$V(s) - Eb(s) = Ia(s)(Ra + sLa)$$

$$T(s) = (Js^2 + sB)\theta(s)$$

$$T(s) = (Js + B)s \theta(s)$$

or

$$T(s) = (Js + B)\omega(s)$$

$$T(s) = KIa(s)$$

Innovative Systems Design and Engineering   www.iiste.org
ISSN 2222-1727 (Paper) ISSN 2222-2871 (Online)
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A   Block diagram of armature controlled d. c. motor
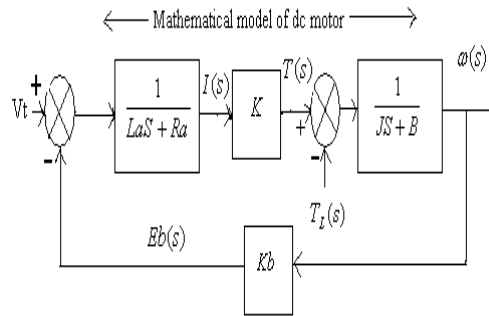

Fig- 3

The transfer function of DC motor speed with respect to the input voltage can be written as follows [2].

$$G(s) = \frac{\omega(s)}{V(s)}$$

From equation (7) the armature inductance is very small in

$$= \frac{K_T}{(Ra + sLa)(Js + B) + KbK_T}........(7)$$

practices, hence, the transfer function of DC motor speed to the input voltage can be simplified as Follows,

$$G(s) = \frac{\omega(s)}{V(s)} = \frac{Km}{\tau s + 1}..........(8)$$

Where $K_m = \dfrac{K_T}{R_a B + K_b K_T}$ is a motor gain and $\tau = \dfrac{R_a J}{R_a B + K_b K_T}$ is the

motor time constant

From equation (8), the transfer function can be drawn the DC motor system block diagram which is shown in

Key point;   Field controlled dc motor is open loop while armature controlled is closed loop system. Hence armature controlled dc motor are preferred over field controlled system

For small size motor field control is advantageous because only a low power servo amplifier is required while the armature current which is not large can be supplied from an expensive constant current amplifier.

For large size motor it is on the whole cheaper to use armature control scheme. Further in armature controlled motor, back emf contributes additional damping over and above that provided by load friction.
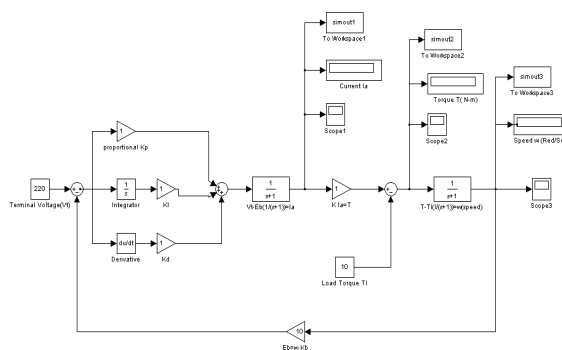
IV. MATLAB REPRESENTATION AND SYSTEM RESPONSE

Fig- 4

A. PROPORTIONAL-INTEGRAL-DERIVATIVE CONTROL (PID)

The combination of proportional, integral and derivative control action is called PID action control and the controller is called three action controllers.

Here the proportional part of the control action repeats the change of error and derivative part of the control action adds an increment of output so that proportional plus derivative action is shifted ahead in time.

The integral part ads a further increment of output proportional to the area under the deviation line. The combination of proportional, integral an derivative action may be made in any sequence as shown.

Now, we increase the gain Kd, with Kp=5; Ki=10. All results are illustrated in the Table 3 and the corresponding plots are shown in Fig .

From the results we see that the rise time increase from (0.50 sec to 0.82sec) for (Kd=1 to Kd=4) and the overshoot from (23% to 12%) and there is small change in the settling time. Hence the steady state error is completely zero.

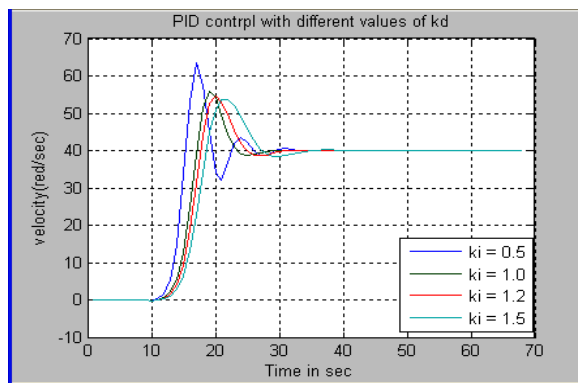| Kd	Rise Time(sec)	Maximum Overshoot (%)	Steady State Error	Peak Amplitude of Velocity (red/sec)
1	0.50	23.39	0	40
2	0.65	15.95	0	40
3	0.71	14.52	0	40
4	0.82	12.58	0	40

Table – 1   PID control

Fig- 5

So now we know that if we use a PID controller with: Kp=4,ki=1 and Kd=1; all our design requirements will be satisfied and the response looks like
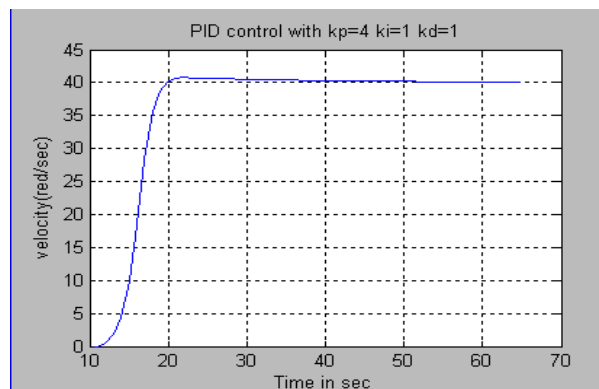
Fig- 6

PID controller with: Kp=4,Ki=1 and Kd=1

Effects of PID controllers parameters kp, ki and kd on a closed loop system are summarized in the table below.

Closed loop Response	Rise Time(sec)	Maximum Overshoot(%)	Settling Time(sec)	Steady State Error
As increase of K_P	Decrease	Increase	Small change	Decrease
As increase of K_I	Decrease	Increase	Increase	Eliminate
As increase of K_D	Small change	Decrease	Decrease	Small change

Table- 2

V. CONCLUSION

Accurate performance of a motor is desired feature for any industrial application.

As the age of motor increases its performance also deceases with aging, so it is desired to evaluate the performance of motor from time to time for efficient operation

The conventional method for calculating output performance indices are quite time consuming.

The PID based approach algorithm worked satisfactory for the test system.

The important observations made during the studies are

1) The solution time for proposed PID approach is only a fraction of time taken by conventional algorithm.

2) A proportional controller Kp will have the effect of reducing the rise time and reduce but never eliminate the steady state error.

3) An internal controller Ki will have the effect of eliminate the steady state error but it may make the transient response worse.

4) A derivative controller Kd will have the effect of increasing the stability of the system and reducing the overshoot and improve the transient response.

5) The output performance obtained by normalized value in PID is very close and near to accuracy.

6) MATLAB used for simulation of entire project is sophisticated and user friendly software.

It must be mentioned that the efficiency of the speed algorithm can be improved by using more efficient learning techniques and dynamic weight selection algorithm

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