

PI, PID Controllers with Performance Index for Speed Control of DC Motor

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Abstract: DC motor plays an important role in industry and domestic application. Thus, the speed control of DC shunt motor is a prime task. This paper gives a comparison of the performance of conventional proportional integral (PI) and proportional integral derivative (PID) for speed control of DC shunt motor. investigated for speed control of DC motor. At the start PID controller parameters for different tuning techniques are involved and then applied to the DC motor model for motion (speed) control. Simulation results are display, using these controllers, objective of this paper, the performance of a choose dc motor controlled by a proportional-integral-derivative (PID) controller is below the similar transient conditions and performances are compared.

Keywords - DC motor, PID controller, PID tuning, performance index.

I. Introduction

The improvement of great torque performance the motor drives is very essential in built-up and manufacturing used and as well as other purpose applications such as electric trains steel rolling mills, and, automatic manipulators [1]. Purpose of this paper is to control the speed of dc motor for the reason that dc motor has been commonly used in commercially even though its maintenance costs are higher than other motors. Generally, a large torque performance the dc motor drive must have superior dynamic speed control tracking and load variable to perform task. The DC motor drives, because of their effortlessness, ease of application, high stability, good cost and flexibilities have long been a spine of manufacturing applications, and residential appliances where position control and speed control of motor are required. The DC motor drives are less versatile with a single phase transfer from AC to DC. An ahead instance the speed torque characteristics of DC motors drive are preferable to that of AC motors drive. [1]. PID controllers cover numerous significant types. It provides feedback. As PD improves transient response (i.e. it be able to expect the changes during derivative action) and PI improves performance of steady state response (i.e. reduce steady state offset during integral action or law), combination of two may be used to progress overall time response of the system. In addition to this, PID controllers have very uncomplicated control structure and are less high-priced [2]. Objective of this paper different PID controllers are

verified for speed control of DC motor. Integral Time Absolute Error (ITAE) and Integral Time Square Error (ITSE) are determined. Performances of these techniques are compared under same transient levels. The paper is organized as follows. In Section II, model of DC motor is presented. Brief introduction of PID controller is given in Section III. Simulation results are shown as figure and table in Section IV, followed by conclusion in Section V.

II. SPEED CONTROL METHODS FOR DC MOTOR

The motor speed can be controlled by controlling the armature voltage or the field voltage. It is obvious that the speed control is possible by varying the following.

- Flux per pole, ϕ (Flux Control).
- Resistance of armature circuit, R_a (Rheostatic Control).
- Armature applied voltage, (Voltage Control).

The usages of the above methods (with resistance control) have some disadvantages such as a large amount of power is wasted in the controller resistance. Hence, the efficiency is decreased. This needs expensive arrangement for dissipation of heat produced in the controller resistance. It gives speeds below the normal speed. Therefore, these methods are less adaptive. Electronic techniques are used for speed control. These techniques

provide higher efficiency, greater reliability, and quick response.

III. MODELING OF DC MOTOR

The DC motors are highly unfailing and capable because of the some good quality like high starting torque, efficient response and linear controllability. The term speed control stand up for planned speed difference carried out physically or automatically. The DC motor drives are mainly appropriate for broad range of Speed control and adjustable speed drives [3]. Shunt D.C. Machines The field coils of a shunt D.C. machine are connected in parallel to the armature coils. Therefore, the Transient in the armature circuit is simultaneous with the Brief in the field circuit. A circuit model of a Shunt D.C. Motor is shown in Figure.1.below

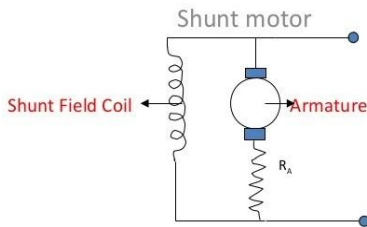


Fig.1. Shunt D.C. Motor

$$V_a(t) = R_a i_a(t) + L_a \frac{di_a(t)}{dt} + e_b(t) \quad (1)$$

$$e_b(t) = K_b \omega(t) \quad (2)$$

$$T_m = K_m i_a(t) \quad (3)$$

$$T_m(t) = J_m \frac{d\omega(t)}{dt} + B_m \omega(t) \quad (4)$$

$$\frac{\omega(s)}{V_a(s)} = \frac{K_m}{L_a J_m s^2 + (R_a J_m + L_a B_m) s^2 + (R_a B_m + K_b K_T) s} \quad (5)$$

Show the transfer functions (5) and overall transfer function dc shunt motor is given below in equation (6).

$$\frac{\theta(s)}{V_a(s)} = \frac{0.5}{0.0077s^3 + 0.09007s^2 + 0.25018s} \quad (6)$$

Where

- R_a = armature resistance (Ω - ohm).
- L_a = armature inductance (H-henry).
- I_a = armature current (A).
- $V_a(t)$ = armature voltage (V).
- E_b = back emf (V).

- ω = angular speed (rad/s).
- T_m = motor torque (N m).
- θ = angular position of rotor shaft (rad).
- J_m = rotor inertia ($kg \cdot m^2$).
- B_m = viscous friction coefficient ($N_m \cdot s/rad$).
- K_m = motor torque constant (Nm/A).
- K_b = back emf constant (V s/rad).

Numerical Values

The DC motor under study has the following specification and parameters for speed control.

A. Specifications

2hp, 230 volts, 8.5 amperes, 1500rpm

B. Parameters

$R_a = 0.45 \text{ ohm}$, $L_a = 0.035 \text{ H}$, $K_b = 0.5 \text{ volt/(rad/sec)}$,
 $J = 0.022 \text{ Kg-m}^2/\text{rad}$, $B = 0.2 \times 10^{-3} \text{ N-/(rad/sec)}$.

III. PID CONTROLLER

PID Controller is a basic control loop of feedback mechanism and is widely used in control system. The disparate symptoms of a the DC motor such as diffusion and invention can degrade the performance of traditional controllers [4]. PID Controllers use three basic types of parameter or modes: Proportional (P), Integral (I) and Derivative (D). While proportional and integral control is used as single control approach, a derivative control used is that it improves the transient response of the system. In this paper it is implemented a technique to control the speed of DC motor drive which above is shown in Figure.3. The speed error between the references speed and the actual speed is given as input to a PID controller. The PID controller working on the changes in error its productiveness, to control the process input such that the error is reduce. PID controller is also known as the three-term of main controller parameter, whose transfer function is commonly written in the parallel form given by equation (12) or the ideal form is given by equation (2)[5].

General form of the Transfer function of a PID controller is given as,

$$G(S) = K_p + K_I \frac{1}{s} + K_D S \quad (7)$$

$$K_p \frac{K_I}{s} + K_D S = \frac{K_D s^2 + K_p s + K_I}{s} \quad (8)$$

$$= K_p \left(1 + \frac{1}{T_I s} + T_D s \right) \quad (9)$$

A. Proportional control action

It is simplest class of continuous control law. The controller output $u(t)$ is made proportional to the actuating error signal $e(t)$. The proportional gain is also called proportionality constant, it is denoted by K_p and the control action is written by

$$u(t) = K_p e(t) \tag{10}$$

Where $e(t) = r(t) - y(t)$ for unity response system(t) is the error signal, $r(t)$ is reference input of the system, and $y(t)$ is the output of the system.

B. Integral control action

In this a controller with integral control action, the value of the controller productivity is changed at a rate proportional to the actuating error signal. If there zero steady state error is desirable, this means a control mode that is a function of error will be build-up.

$$\frac{du(t)}{dt} = K_I e(t) \tag{11}$$

$$U(t) = K_I \int_0^t e(t) \tag{12}$$

Where is K_I an integral gain constant.

C. Derivative control action

The used of integral law is sufficient to reduce the steady error to zero however, the dynamic or the transient response may still be broke because of large oscillations, overshoots etc. The derivative control law, sometimes called rate control, is therefore, the magnitude of the controller output is proportional to the rate of change of the actuating error signal.

$$U(t) = K_D \frac{de(t)}{dt} \tag{13}$$

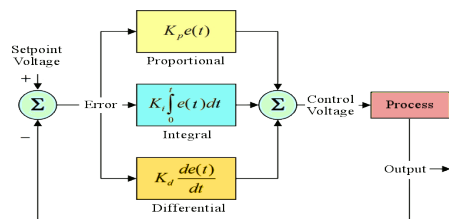


Figure.2 .PID Controller with System

Where e = Error signal
 K_p = Proportional Constant
 K_i = Integral Constant
 K_d = Derivative Constant

$$u(t) = K_p e(t) + K_I \int_0^t e(t) + K_D \frac{de(t)}{dt}$$

We would like that the PID controller to propitiate the follow criteria:

- Settling time less than 2 sec
- Overshoot less than 5%

- Steady state error less than 1%

IV. FIGURES AND TABLES

Table. I. Tuning PID Parameters of the Controllers

Tuning Method	Controllers	K_c	t_D	t_c
ZNOP-SP	PI	10.14	11.32	-
	PID	9.10	13.14 0	-0.12
ZNOP-DR	PI	6.815	190	-
	PID	14.24 0	131	-0.21
ITAE	PD	4.12	54	-
	PID	-0.52	4.60	4.52
ITSE	PI	3.88	58	-
	PID	1.42	5.15	3.91 2

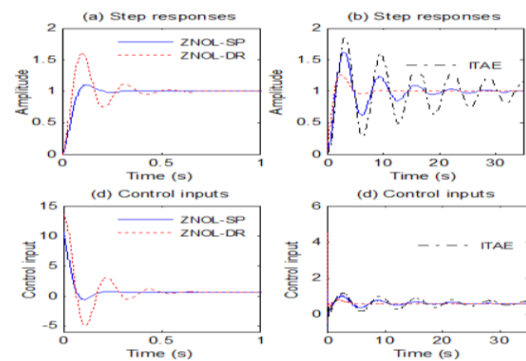


TABLE II RESULT OF STEP RESPONSES

Tuning Method	Controllers	%M _p	Tr(sec)	Ts(sec)
ZNOP-SP	PI	23.30	1.32	1.20
	PID	17.5	.50	2.40
ZNOP-DR	PI	79.85	2.10	2.470
	PID	43.20	1.25	0.187
ITAE	PI	3.12	0.54	1.354
	PID	0.82	0.60	0.246
ITSE	PI	34.58	0.82	0.254
	PID	6.12	0.24	11.01

V. CONCLUSION

In this paper, we have discus different type of PID fine-tuning techniques are established for speed control of DC motor. Two different transient conditions are tested for all the controllers are responses are compared. From simulation result it is observed that the performance of PI controller is satisfactory compared to other controllers. It is

believed that the study carried out in this paper is useful to control engineer to recognize the effect of different PID tuning techniques.

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