SPEED CONTROL OF DC MOTOR USING PID CONTROLLER BASED ON MATLAB

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Abstract: DC motors are widely used in industrial variable speed applications due to their more demanding speed and torque characteristics and easy control aspects. This article introduces a method to control the speed of a DC motor using a PID controller to control the speed of a DC motor, and also uses MATLAB software for calculations and simulation. The choice of PID parameters has been elucidated as a result of several variation experiments.

Introduction

DC motor is a power actuator which transforms electrical energy into mechanical energy. DC motors are most suitable for wide range speed control and are therefore used in many adjustable speed drives. The advantage of dc motors may be speed control. Since speed is directly proportional to armature voltage and inversely proportional to magnetic flux produced by the poles and adjusting the armature voltage and the field current will change the rotor speed. DC motors have been widely used in many industrial applications such as electric cranes, electric vehicles, and robotic manipulators due to wide, simple, and continuous control characteristics [1, 2].

DC motors are highly versatile and flexible in aspects of speed control. High performance DC motor drives are popular in industrial applications for its enormous good characteristics such as high starting, accelerating and retard torque, high response performance, rapid braking and easier to be linear control etc. DC motor is a highly controllable electrical actuator and is widely used for robotic manipulators, guided vehicles, steel rolling mills, cutting tool, overhead cranes, electrical traction and other application etc. In comparison to AC drive, DC motor drives are simple and less expensive [1, 3].

The design of such a controller requires specification of three parameters: proportional gain, integral time constant and derivative time constant .so far, great effort has been devoted to develop methods to reduce the time spent on optimizing the choice of controller parameters [1].

PID controller

The best-known controllers used in industrial control processes are proportional-integral-derivative (PID) controllers because of their simple structure and robust performance in a wide range of operating conditions. PID controller is a generic control loop feedback mechanism (controller) widely used in industrial control system [3].

The PID controller calculation (algorithm) involves three constant parameters called the proportional (P), integral (I) and derivative (D) values, these values can be interpreted in terms of time. P depends on the present error, I on the accumulation of past error, and D is a prediction of future error, based on current rate of change [4].

These controllers are extremely popular because they can usually provide good closed-loop response characteristics, can be tuned using relatively simple design rules, and are easy to construct using either analog or digital components [5] (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 $y(t)$ 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 (Fig. 2).

At the same time PID controller has some disadvantages, namely, the undesirable speed overshoot and the sluggish response due to sudden change in load torque and the sensitivity to controller gains K_I and K_P . The performance of this controller depends on the accuracy of system models and parameters. There for there is need of a controller which can overcome disadvantages of PID controller. The PID controller output shows the following equation:

$$U(t) = K_P e(t) + K_I \int_0^t e(\tau) d\tau + K_D \frac{de(t)}{dt}, \quad (1)$$

where K_P , K_I , K_D are proportional, integral and derivative constants respectively; e is error signal.

Taking the Laplace transform of this equation gives the transfer function $G(s)$:

$$G(s) = \frac{U(s)}{e(s)} = \left(K_P + \frac{K_I}{s} + K_D s \right). \quad (2)$$

Fig. 1. Feedback system architecture

Fig. 2. Block diagram of PID controller

Fig. 3. Block diagram of open (a) and closed (b) loop control system

Before examining the input-output relationships and design methods for the PID controller, it is advisable to review typical characteristics observed for the velocity response of a DC motor to a step voltage input. Different characteristics of the motor response (steady-state error, peak overshoot, rise time, settling time, etc) are controlled by selection of the three gains that modify the PID controller dynamically [6].

In open loop control system, it cannot correct the variation in output automatically. In these systems the output remains constant for a constant input signal. By approximately changing input output may change to desired value and variations in external Conditions may cause the output to change [6, 7] (Fig. 3, a).

In closed loop control system, it can correct the variation in output automatically. In these systems the output remains constant for a changing input signal. The measured response of the system is compared with a desired response of the system. The difference between two response gives the actual response of the system [7] (Fig. 3, b).

DC Motor Model

This in this section, the entire system is described. This section is divided into two sub-parts. In the first part, the dynamic model of DC motor speed control is presented (Fig. 4).

The DC motor specifications are as follows:

Shaft power of the motor = 1 kw

V_a is armature voltage applied to the motor, V; $V_a = 110$;

R_a is armature-winding resistance, Ohm; $R_a = 0.378$;

L_a is armature-winding inductance, mH; $L_a = 5.9$;

I_a is armature-winding current, A;

I_f is field current, A;

Fig. 4. DC motor model

E_a is applied armature voltage, V;
 E_b is back emf, V;
 θ is angular displacement of the motor shaft, rad;
 T is torque delivered by the motor, N·m;
 J is moment of inertia of the motor and load referred to the motorshaft, $\text{kg}\cdot\text{m}^2$;
 $J = 0.018$;
 B is equivalent viscous-friction coefficient; $B = 0.02$;
 In the second part, the proposed controlled system is presented and simulations have been done with MATLAB on Simulink platform.
 Modeling DC motor with load (Fig. 5). Output signals Without PID (Fig. 6).

Fig. 5. Simulink model of armature-controlled DC motor with load

Fig. 6. Uncontrolled DC Motor Speed Response:
 a – Speed; b – Torque motor

DC Motor with PID controller

The transfer function block diagram of armature controlled separately Excited DC motor with the speed an angular velocity $\omega(s)$ to the applied armature voltage with load. (Fig. 7).

Output signals with PID (Fig. 8).

Characteristics of P, I, and D controllers are as follows:

- a proportional controller K_P reduces the rise time but it will never eliminate the steady-state error;
- an integral control K_I eliminates the steady-state error, but it makes the transient response worse;
- a derivative control K_D increases stability of the system, by reducing the overshoot, and it improves the transient response of the system [2] (Table 1, Fig. 9).

Fig. 7. Block diagram of armature-controlled DC motor with PID controller under the effect of load

Fig. 8. PID Controlled Response of DC Motor:
1 – Step; 2 – Speed

Table 1

Effects of each of controllers K_P , K_I and K_D on a closed-loop system

CL Response	Rise time	Overshoot	Settling time	S-S error
K_P	Decrease	Increase	Small change	Decrease
K_I			Increase	Eliminate
K_D	Small change	Decrease	Decrease	Small change

Fig. 9. Properties of response

Conclusion

This paper presented the separately excited DC motor speed control strategy using PID controller under varying load. The DC motor model was designed with PID controller to control the speed of the motor under the effect of load. The speed of the motor is kept constant and the load torque is varying.

As far as results of the experiment are concerned, it can be concluded that PID controller is very effective and powerful controller that is capable of controlling the open-loop speed control of DC motor under varying load condition. Simulation results of the proposed system proved that PID controller has a better control approach to control and sustain the speed of the motor under varying load condition.

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Управление скоростью двигателя постоянного тока с применением ПИД-регулятора на основе MATLAB

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Ключевые слова: блок-схема; двигатель постоянного тока; интегральный контроль; представление MATLAB; производный контроль; пропорциональное управление; сигнал ошибки.

Аннотация: Приведена математическая модель двигателя постоянного тока, широко используемого в промышленных приложениях. Разработана модель замкнутой системы, состоящей из двигателя постоянного тока и ПИД-регулятора скорости вращения его вала, реализованная в Simulink. Осуществлен выбор параметров ПИД – регулятора и построены графики переходного процесса в замкнутой системе, настроенной на технический оптимум.

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Drehzahlregelung des Gleichstrommotors mit Anwendung des PID-Reglers auf MATLAB

Zusammenfassung: Es ist ein mathematisches Modell des in industriellen Anwendungen weit verbreiteten Gleichstrommotors vorgestellt. Entwickelt ist ein geschlossenes Systemmodell, das aus einem Gleichstrommotor und einem PID-Regler seiner Wellendrehzahl besteht und in Simulink implementiert ist. Die Wahl der Parameter des PID-Reglers ist erfüllt und die auf das technische Optimum abgestimmten Kurven des Einschwingvorgangs im geschlossenen System sind erstellt.

Commande de la vitesse du moteur à courant continu avec l'application du régulateur PID à MATLAB

Résumé: Est présenté un modèle mathématique du moteur à courant continu largement utilisé dans les applications industrielles. Est élaboré un système en circuit fermé composé d'un moteur à courant continu et d'un régulateur PID de la vitesse de rotation de son arbre, mis en œuvre à Simulink. Est effectuée la sélection des paramètres du régulateur PID et sont construits des graphiques de transition dans un système en boucle fermée réglé en optimum technique.

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