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Angular velocity control of a DC motor using the PID method

Akhmad Zulfi Rois Negara
Marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya
zulfi.rois@student.ppns.ac.id

Abstract

The DC motor is widely utilized in industrial and household applications due to its flexibility and relatively simple operation. However, one of its drawbacks is the inconsistency in speed, particularly when the load increases. To address this issue, a controller is required to maintain a constant speed that aligns with the desired set point. PID control is a method designed to minimize the error rate in a system or plant. This type of control incorporates three parameters: Proportional (P), Integral (I), and Derivative (D), which collectively determine the response level of the controller to the plant. Proper tuning of these parameters is essential, and various methods can be employed to adjust them to suit the specific characteristics of the plant. In this study, a PID controller is implemented and simulated using MATLAB and Simulink to evaluate its effectiveness..

Keywords: DC motor, PID, Matlab, Simulink

1. Introduction

In industrial applications, household equipment, air conditioners (AC), robotics, and transportation systems, electric motors are increasingly used as driving mechanisms (Irhas et al., 2020) (Hekimoglu, 2019). Among these, direct current (DC) motors are particularly favored due to their ease of operation (Rahman et al., 2024). However, a notable drawback of DC motors is the decline in speed, leading to inconsistencies caused by varying loads. To address this, PID (Proportional Integral Derivative) control techniques are commonly employed for speed regulation (Nugraha & Eviningsih, 2022) (Sheila et al., 2024).

PID is a widely utilized control technique in engineering that combines three control components: Proportional, Integral, and Derivative (Dermawan et al., 2023) (Ainudin et al., 2022). These parameters collectively influence the quality of a control system's response (Nugraha & Fathin, 2024). Previous studies have demonstrated the effectiveness of PID control in various applications, including speed control designs that achieve stable and specification-compliant PID performance (Kurniawan et al., 2023).

The PID control system operates through a feedback mechanism to correct errors by comparing the measured error value with its deviation (Satrianata et al., 2023). Typically, PID controls can be applied either in combination or separately, as each component offers distinct advantages (Yuniza et al., 2022). For instance, proportional control accelerates rise time, integral control minimizes errors, and derivative control reduces overshoot or undershoot.

2. Material and methods

2.1. Mathods

PID control is a standard method used to correct errors between measured values and their deviations (Borase et al., 2021). By tuning or adjusting control parameters, an optimal response can be achieved in a PID control system. One commonly employed method for parameter tuning is the Ziegler-Nichols method, which is used to determine the Proportional gain (Kp), Integral time (Ki), and Derivative time (Kd) (Latif et al., 2020) (Febriyan & Puriyanto, 2021a). This method is typically implemented and tested first using MATLAB software, where simulations are conducted through block diagrams in MATLAB Simulink to evaluate its performance.

A. Proportional (Kp)
   Proportional control is a control method that can accelerate rise time and reduce the error of a plant. (Ma'arif & Setiawan, 2021) Essentially, this control acts as an adjustable amplifier (Khalifa et al., 2021). This causes the output value to be proportional to the product of the constant gain and the error signal, as shown with the block diagram.

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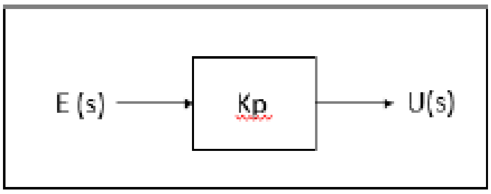

Figure 1. Block diagram of proportional

B. Integral (Ki)

Integral control is a controller that can reduce overshoot and accelerate steady-state response (Aribowo et al., 2022). Integral control is often combined with other controllers because it cannot function independently. Its balancing nature allows a control system, when augmented with an integral compensator, to achieve the desired response. Integral control acts as an amplifier and can be showed with the block diagram.

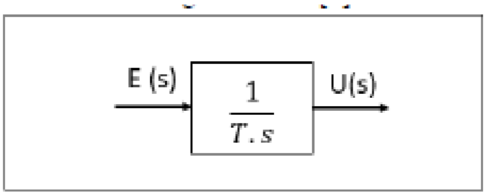

Figure 2. Block diagram of Integral

C. Derivative (Kd)

Derivative control is a type of control that has properties similar to differentiation (Surindra et al., 2020). This control can predict future errors based on the previous error values, resulting in a more stable output (Hekimoğlu et al., 2018). It can be used in combination with both Integral (I) control and Proportional-Integral (PI) control. Essentially, derivative control acts as an amplifier and can be expressed with the block diagram.

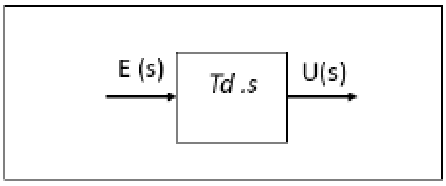

Figure 3. Block diagram of Derivetive

2.2. Material

DC motors are classified into two types: separately excited DC motors and self-excited DC motors. Separately excited DC motors are commonly used for speed regulation through armature voltage control (Febriyan & Puriyanto, 2021b). The equivalent circuit of a DC motor is typically used to illustrate its operational principles and characteristics, as shown in the accompanying diagram.

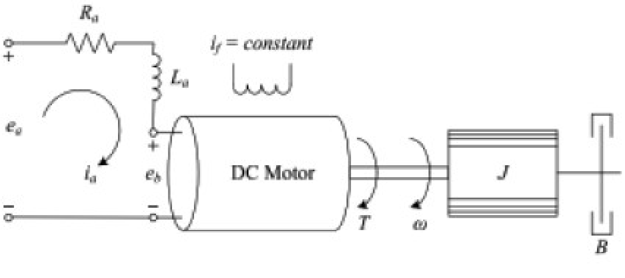

Figure 1. The equivalent circuit of a DC motor.

Parameter:

Ra: armature resistance, Ω

La: armature induction, H

ia: armature current, A

if : field current, A

ea: applied armature voltage, V

eb: back electromotive force, V

T : motor torque, N.m

ω: angular velocity, rad/s

A: moment of inertia, kg.m2

Kb: electromotive force constant, V.s/rad

K : motor torque constant, N.m/A

B: motor friction constant, N.m.s/rad

Table 1. DC motor parameter

Parameter	Value
Ra	0.4 Ω
La	2.7 H
J	0.0004 kg.m2
B	0.0022 N.m.s/rad
K	0.015 N.m/A
Kb	0.05 V.s

Block diagram illustration of a DC motor. which uses an open loop system input from the DC motor to the output the motor speed is written in this equation

$$G(s)=\frac{w(s)}{Ea(s)}=\frac{K}{(Las+Ra)(Js+B)+KbK}$$

3. Results and discussion

3.1. Matlab Simulation

The following is a program for simulate in Matlab software.

```
clc
Ra = 0.4;
La = 2.7;
J = 0.0004;
B = 0.0022;
K = 0.015;
Kb = 0.05;
num = K;
den = [La*J (La*B + Ra*J)
(Ra*B+Kb*K)];
Gs = tf(num,den);
Kp = 0.8
Ki = 0.4
```

Kd = 0.2

After the program is successful operated, then create block diagram circuit like this figure.

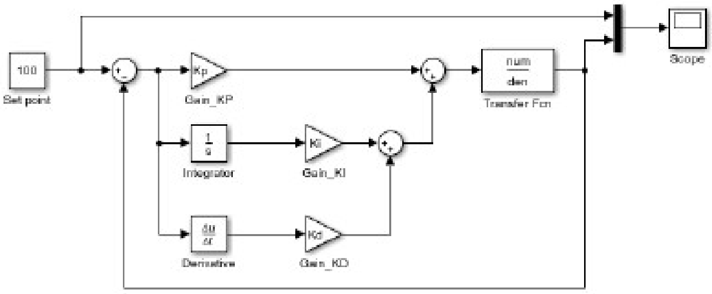

Figure 2. Ilustration of block diagram DC motor

To determine the values of (Kp), (Ki), and (Kd), a manual method is employed using the PID Tuning feature available in MATLAB software. Through repeated simulations, the most suitable response for controlling the angular speed of the DC motor is identified. From the simulations, the appropriate parameter values are as follows:

Kp = 0.8

Ki = 0.4

Kd = 0.2

The resulting parameters Kp, Ki, and Kd produce a graph as shown below.

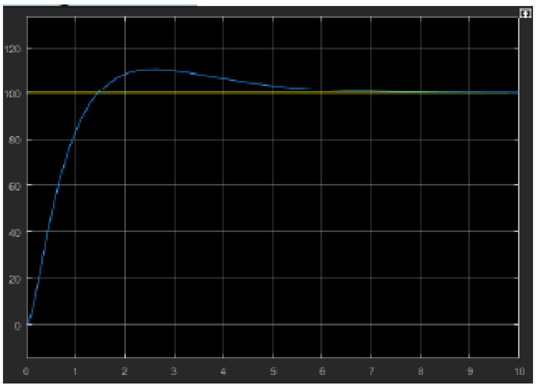

Figure 2. Graphic of block diagram DC motor

From the simulation results, an overshoot value of 110 was obtained. This value is higher than the setpoint value of 100. Additionally, the time required to reach the steady-state condition is 6.2 seconds. These results indicate the system's response to the changes that occurred.

4. Conclusion

Based on the research conducted, it can be concluded that the appropriate values for KpK_pKp, KiK_iKi, and KdK_dKd for the specified DC motor parameters are Kp=0.8K_p = 0.8Kp=0.8, Ki=0.4K_i = 0.4Ki=0.4, and Kd=0.2K_d = 0.2Kd=0.2. These PID parameters resulted in low overshoot and steady-state values, allowing the angular speed of the DC motor to be adjusted according to the motor's requirements.

Credit authorship contribution statement

Author Name: Conceptualization, Writing – review & editing. **Author Name**: Supervision, Writing – review & editing. **Author Name**: Conceptualization, Supervision, Writing – review & editing.

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