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PID Controller for Electrical Actuators

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Abstract

This paper concentrate on how to apply PID controller with different options to control the DC and stepper motor of the robot actuator, and MATLAB program is used for calculation and simulation PID controllers are widely used in a industrial plants because of their simplicity and robustness. The difference selections were applied and the result where analyzed to choose performance which was PID controller. The required criteria were fulfilled regarding the some important characteristic such as settling time, rise time and over shoot.

Keywords: *PID, settling time, rise time, Bode diagram.*

Introduction

The main objective of this paper is to having a PID controller that will satisfy the required a control rate for the robot arm. Explaining the ways that used for design PID controller and making sure of its work. Finding the best way to improve the performance of the robotic arm, A DC motor is any of a class of electrical machines that converts direct current electrical power into mechanical power. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic; to periodically change the direction of current flow in part of the motor. Most types produce rotary motion; a linear motor directly produces force and motion in a straight line.

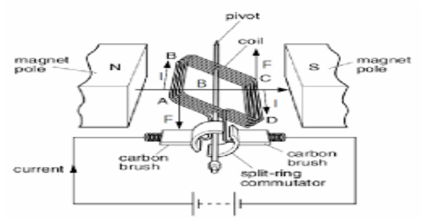


Figure 1: DC Motor

The speed of a DC motor is given be the relationship

$$N = \frac{\mathrm{V} - \mathrm{IaRa}}{\mathrm{k}\varnothing} \;\ldots\ldots\ldots\ldots\ldots\ (1)$$

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 [1].

Mathematics Model: The mathematical model consists of two parts:

a) DC MOTOR: 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 [1]. The electric circuit of the armature and the free body diagram of the rotor are shown in the following

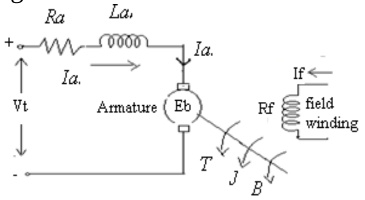


Figure 2: The Electric Circuit of the Armature

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 transfer function of DC motor speed with respect to the input voltage can be written as Follows

$$G(s) = \frac{w(s)}{V(s)} = \frac{K_T}{(Ra+sLa)(Js+b)+K_T K_b} \;\ldots..(2)$$

When we using matlab to find the step response and bode diagram, let that

J=0.01; b=0.1; K=0.01; R=1; L=0.5;
Should get the following step response:

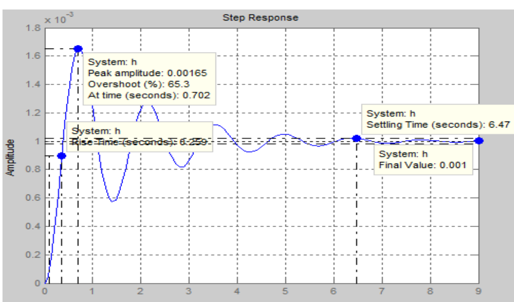


Figure 3: Step Response of DC Motor without PID

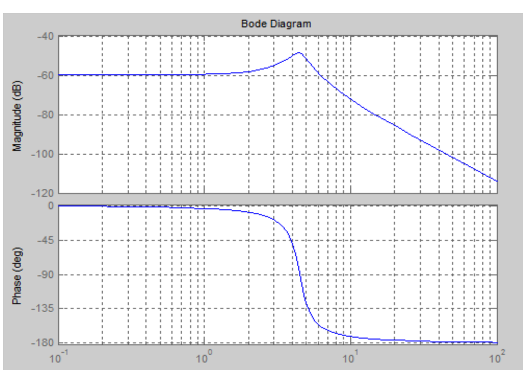
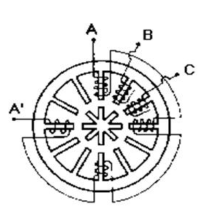


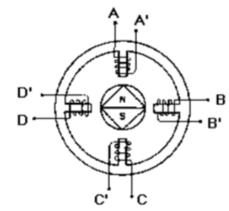
Figure 4: Bode Diagram of DC Motor

b) Stepper Motor: A step motor is a digital device, in that digital information is processed to accomplish an end result, in this case, controlled motion[3]. It is reasonable to assume that a step motor will faithfully follow digital instructions just as a computer is expected to. This is the distinguishing feature of a step motor.

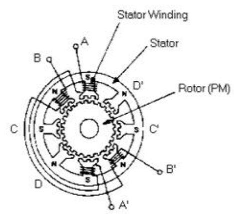
Stepper Motor Types

*Variable-reluctance *Permanent Magnet (PM)





* Hybrid Motor



Stepper Motor Applications

Stepper motors are used in a wide variety of applications in industry, including computer peripherals; business machines, motion control, and robotics, which are included in process control and machine tool applications from the main problem, the dynamic equations in transfer function of stepper motor are the following. [4-6]

$$G(s) = \frac{\theta_o}{\theta_i} = \frac{w_n^2}{s^2 + 2\varepsilon w_n s + w_n^2} * e^{-Ts} \;\ldots\ldots(3)$$

Should get the following step response:

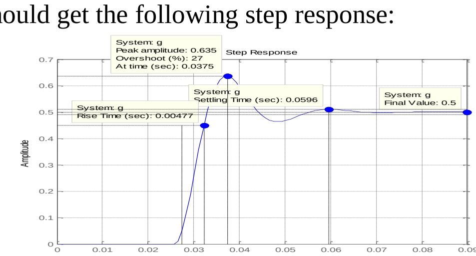


Figure 5: Step Response of Stepper Motor

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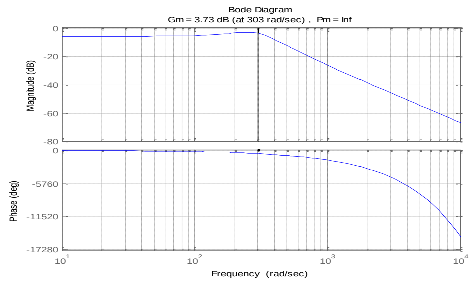

Figure 6: Bode Diagram of Stepper Motor

PID Controller

It is a generic control loop feedback mechanism (controller) widely used in industrial control systems a PID is the most commonly used feedback controller [2].

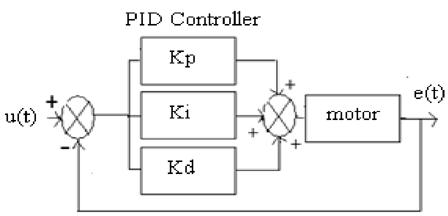

Figure 7: A Block Diagram of a PID Controller

The transfer function of the PID controller looks like the following:

$$K_p + \frac{K_I}{s} + K_D s = \frac{K_D S^2 + K_p s + K_I}{s} \quad ...(4)$$

KP = Proportional gain KI = Integral gain
KD = Derivative gain

Table 1: Characteristics of P, I, D Controller

CL response	Rise time	Over shoot	Settling time	s-s error
Kp	Decrease	Increase	Small change	Decrease
Ki	Decrease	Increase	increase	Eliminate
Kd	Small change	Decrease	Decrease	Small change

PID Design and Application

a) The transfer function of DC motor speed with respect to the input voltage can be written as follows [3]

$$G(s) = \frac{K_T}{(Ra+sLa)(Js+b)+K_T K_b} \quad ...(5)$$

Kp=1.7, kd= .15 ki=200.

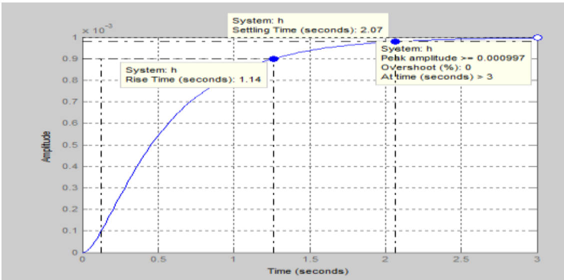

Figure 8: Step Response of DC Motor without PID

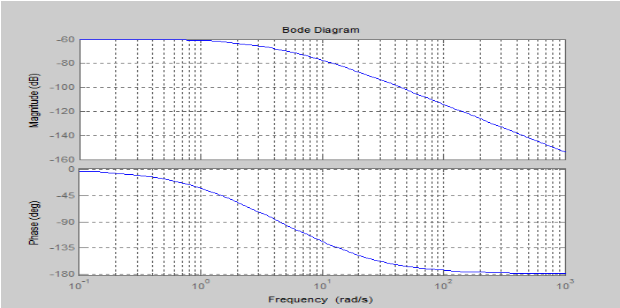

Figure 9: Bode Diagram of PID Control of DC Motor PID Control for Stepper Motor

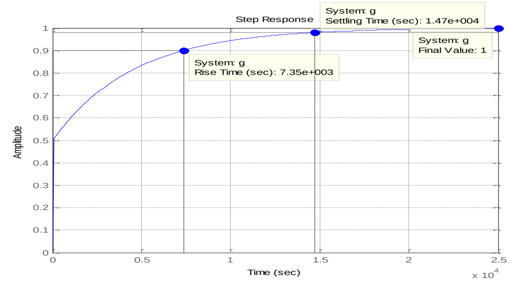

Figure 10: Step Response of PID Control of Stepper Motor

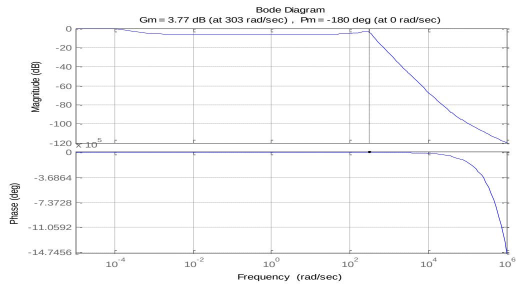

Figure 11: Bode Diagram of PID Control of Stepper Motor

Results

The steps of the design can be summarized in the following points:

1. The response of Dc and stepper motor was quite good after PID controller
2. In general the analysis of current circuit of the Dc and stepper motor so important before implementation so that to check the transfer function of Dc and stepper motor response without PID controller.
3. The studied characteristic of system found before the PID controller had poor transient response (i.e. rise time, settling time, and steady state error, over shoot).
4. To solve Dc and stepper motor problem which represent poor transient response, the controller transfer function must be added to Dc and stepper motor response to improve the response.

Conclusion

1. This paper studies the DC and stepper motor robot arm actuator using PID controller.
2. The robot applications are very sensitive and should be accurate.
3. Using the DC and stepper motor as an actuator for the robot without control will not give the required results hence the robot operation may be deviated from targets which
4. When the PID controller was added, the results obtained are relatively good compared to the response before adding it.
5. In addition to the transient response and steady state error of the DC and stepper motor with the designed PID controller were significantly improved.

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