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Analysis and Design of Conventional Controller for Speed Control of DC Motor -A MATLAB Approach

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Abstract
The objective of this paper is to control the speed of the motor using conventional controller; compensator is used to improve the steady state error. To evaluate the performance of the controller, time response analysis is carried out. The time response analysis consists of two type of analysis. One is unit step response analysis and other is performance indices analysis.
The paper describes the designing of a closed loop model of the dc motor drive for controlling speed. Accuracy and the dynamic responses are better in a closed loop system. The compensator is used to compensate the parameter of the system in such a way to meet the specification, so that it improves the steady state response of the system and get desired response.

I. Introduction

The development of high performance motor drives is very important in industrial as well as other function applications such as steel rolling mills, electric trains and robotics. Generally, a high performance motor drive system must have good dynamic speed command tracking and load regulating response to perform task. DC drives, because of their simplicity, ease of application, high reliabilities, flexibilities and favorable cost have long been a backbone of industrial applications, robot manipulators and home appliances where speed and position control of motor are required. DC drives are less complex with a single power conversion from AC to DC. A DC motors provide excellent control of speed for acceleration and deceleration. DC drives are normally less expensive for most horsepower ratings. DC motors have a long tradition of use as adjustable speed machines and a wide range of options have evolved for this purpose. In these applications, the motor should be precisely controlled to give the desired performance. DC motor is commonly used in robotic application and industrial machinery. The beauty of this motor is it provide high torque load sustaining properties. Again the speed torque characteristics of DC motors are much more superior to that of AC motors.

The controllers of the speed that are conceived for goal to control the speed of DC motor to execute one variety of tasks, is of several conventional and numeric controller types, the controllers can be: proportional integral (PI), proportional integral derivative (PID), Internal module controller (IMC), Fuzzy Logic Controller (FLC), Neural Network or the combination between them: Fuzzy-Neural Networks, Fuzzy-Genetic Algorithm Fuzzy-Ants Colony, Fuzzy-Swarm. In this project, the used controllers are PID, IMC and FLC to control the speed of DC motor.

II. DC Motor System

A DC motors provide excellent control of speed for acceleration and deceleration. DC drives are normally less expensive for most horsepower ratings. DC motors have a long tradition of use as adjustable speed machines and a wide range of options have evolved for this purpose. In these applications, the motor should be precisely controlled to give the desired performance. DC motor is commonly used in robotic application and industrial machinery. The beauty of this motor is it provide high torque load sustaining properties. Again the speed torque characteristics of DC motors are much more superior to that of AC motors.

III. Lag compensator

A Lag compensator improves the steady-state behavior of a system while nearly preserving its transient response.

The compensator having a transfer function of the form is given by

$$Gc(s) = \frac{(S + Zc)}{(s + pc)} \quad \frac{Zc}{Pc} = \beta > 1$$

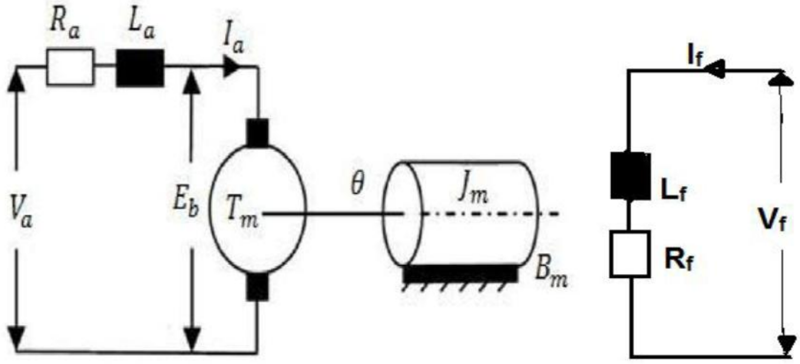
The transfer function of the lag compensator is given by

$$Gc(s) = Kc\beta \quad Ts+1/\beta \quad Ts+1$$

Is ensuring that pole is to the right of zero i.e. nearer the origin than zero. Beta parameter of the Lag compensator is nearly equal to the ratio of the specified error constant of the compensated system to the error of the uncompensated system. The output from a system might be unstable or the response is too slow or there is much overshoot. Systems may have their responses to inputs altered by including compensators. A compensator is a block which is incorporated in the system so that it alters the overall transfer function of the system in such a way to obtain the required characteristics.

IV. Mathematical Modeling of Separately excited Dc Motor

Let us mathematical model the transfer function of the armature controlled DC motor. The electrical equivalent diagram of armature controlled DC motor is given by. The term speed control stand for intentional speed variation carried out manually or automatically DC motors are most suitable for wide range speed control and are there for many adjustable speed drives.



Separately excited Dc Motor

The armature voltage equation is given by:

$$V_a(t) = R_a\ I_a\ (t) + \ L_a.\frac{d\ \ I_a\ (t)}{dt} + \ E_B(t) \quad (1)$$

The back emf equation of motor will be

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

And the torque balance equation will be:

$$T_m(t) = \ \ K_t.\ I_a\ (t) \quad (3)$$

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

In this equation:

K_t = Torque constant (Nm/A)

K_b = back emf constant (Vs/rad)

Let us adding the upper equations together:

$$V_a(t) = R_a.I_a\ (t) + \ L_a.\frac{d\ \ I_a\ (t)}{dt} + K_b\ \omega(t) \quad (5)$$

$$K_t.\ I_a(t) = J\ \frac{d\omega(t)}{dt} + B\omega(t) \quad (6)$$

We have Taking Laplace Transform of (5) & (6), then we get..

$$V_a(s) = R_a.I_a(s) + \ L_a.I_a(s) + K_b\ \omega(s) \quad (7)$$

$$K_t.\ I_a(s) = J\omega(s) + B\ \omega(s) \quad (8)$$

Now the value of current is obtained from (8) and putting in (7) we have…

$$V_a(s) = \omega(s)\frac{1}{K_t}[L_a.Js^2 + R_a.J + L_a.B(s) + K_b.K_t] \quad (9)$$

Then the relation between rotor shaft speed and armature voltage is given by transfer function:

$$\frac{\omega(s)}{V_a(s)} = \frac{K_t}{(JL_as^2+(JR_a+BL_a)s+(K_tK_b+BR_a)} \quad (10)$$

This is the transfer function of the DC motor.

V. Proportional-Integral-Derivative (PID) Controller

The mnemonic PID refers to the first letters of the names of the individual terms that make up the standard three-term controller. These are P for the proportional term, I for the integral term and D for the derivative term in the controller. PID controllers are probably the most widely used industrial controller. Even complex industrial control systems may comprise a control network whose main control building block is a PID control module. In PID controller Proportional (P) control is not able to remove steady state error or offset error in step response. This offset can be eliminated by Integral (I) control action. Output of I controller at any instant is the area under actuating error signal curve up to that instant. I control removes offset, but may lead to oscillatory response of slowly decreasing amplitude or even increasing amplitude, both of which are undesirable. Derivative (D) control action has high sensitivity. It anticipates actuating error initiates an early correction action and tends to increase stability of system.

Ideal PID controller in continuous time is given as

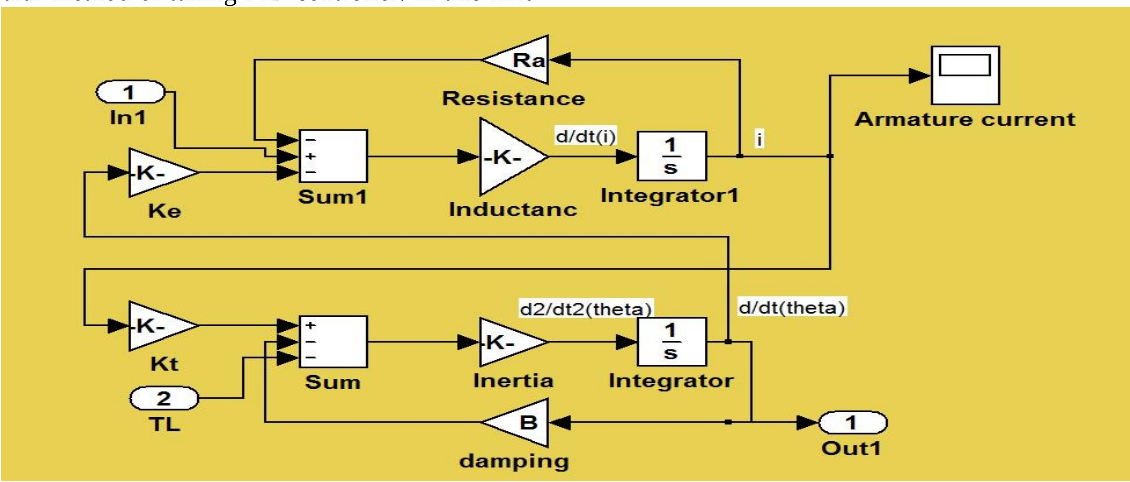
$$y(t) = K_p\left(e(t) + \frac{1}{T_i\int_0^t e(t)dt} + T_d\frac{de(t)}{dt}\right) \quad (10)$$

Laplace domain representation of ideal PID controller is

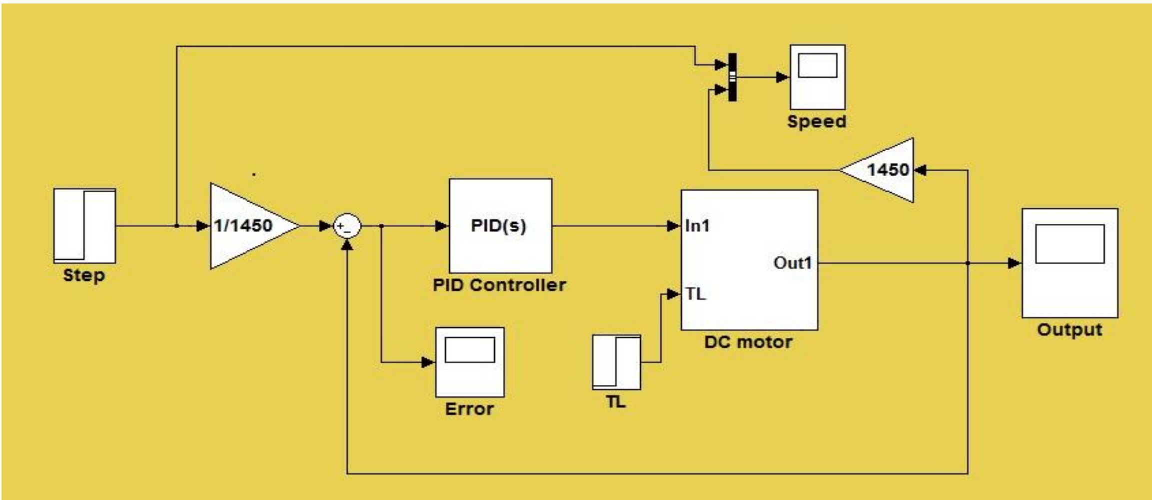
$$Gc(s) = \frac{Y(s)}{E(s)} = K_p(1 + \frac{1}{T_is} + T_ds) \quad (11)$$

VI. There are different Tuning methods of PID Controller

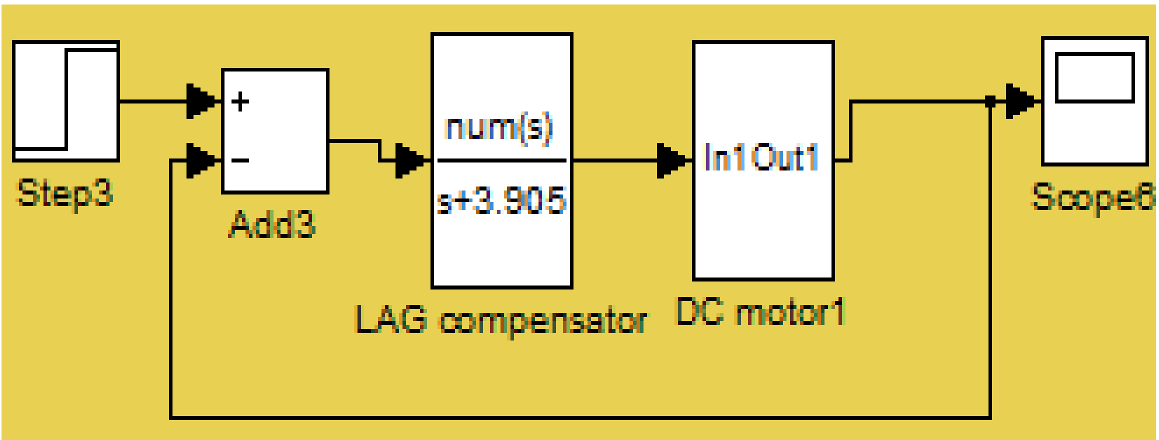
Ziegler and Nichols proposed rules for determining values of K_p, T_i *and* T_d based on the transient response characteristics of a given plant. Closed loop oscillation based PID tuning method is a popular method of tuning PID controller. In this kind of tuning method, a critical gain K_c is induced in the forward path of the control system. The high value of the gain takes the system to the verge of instability. It creates oscillation and from the oscillations, the value of frequency and time are calculated. Table 1 gives experimental tuning rules based on closed loop oscillation method



Simulink representation of DC motor

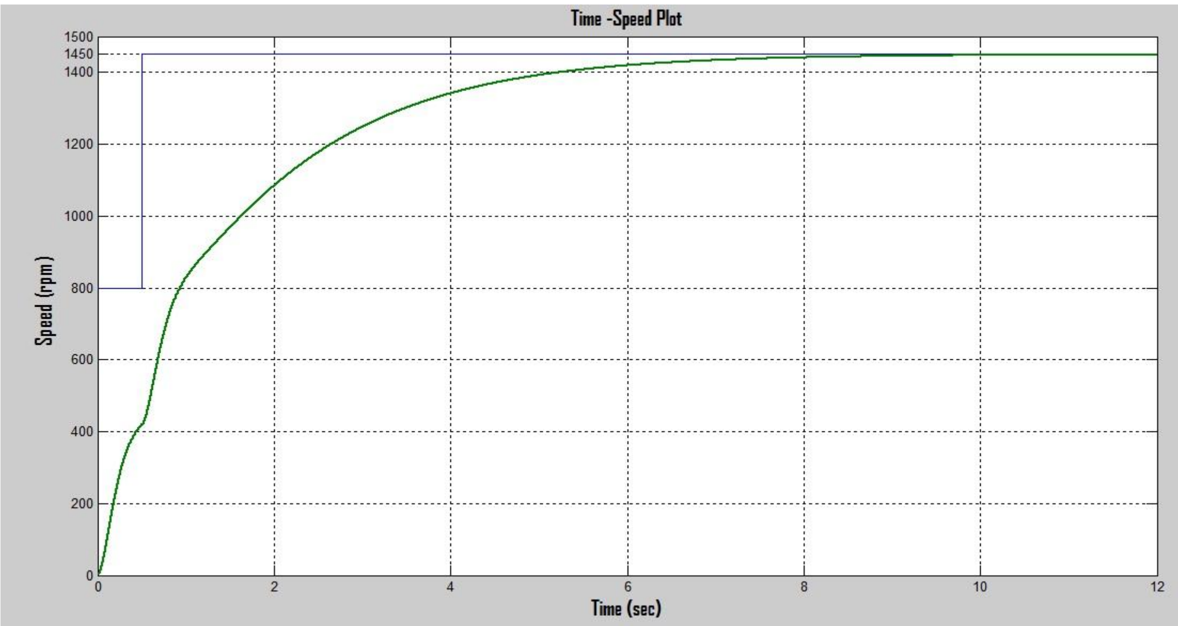


Simulink representation of PID Controller

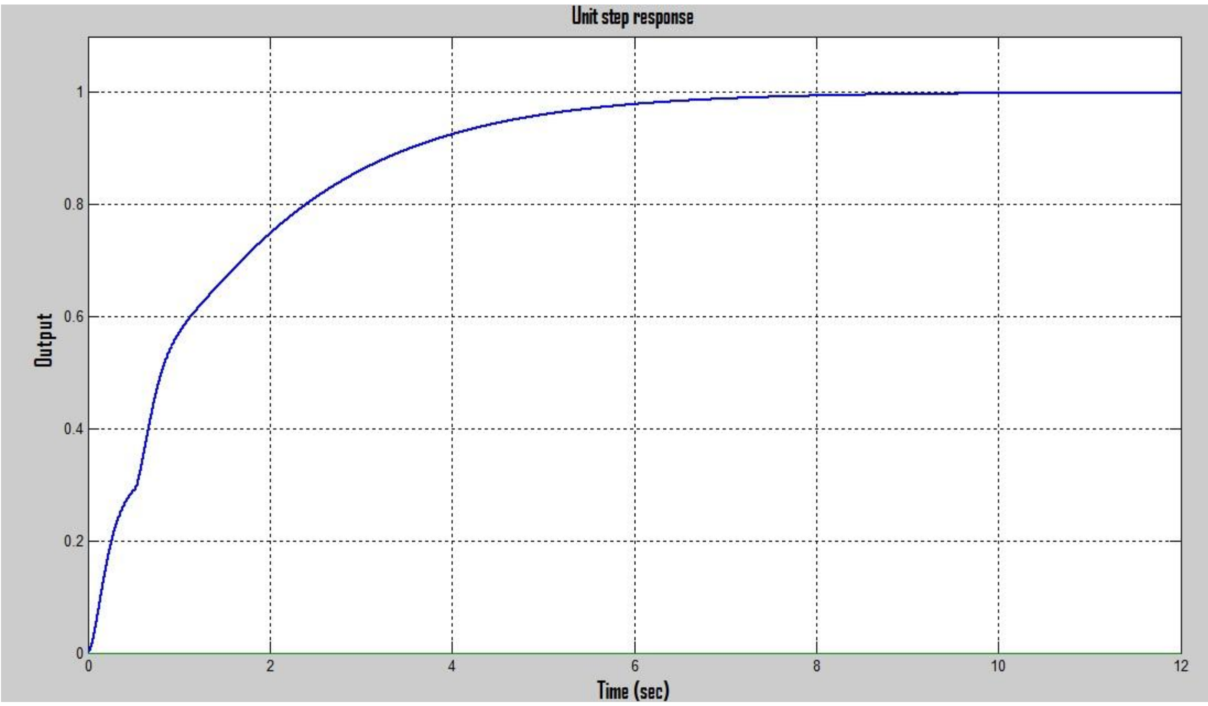


DC Motor with Lag compensator

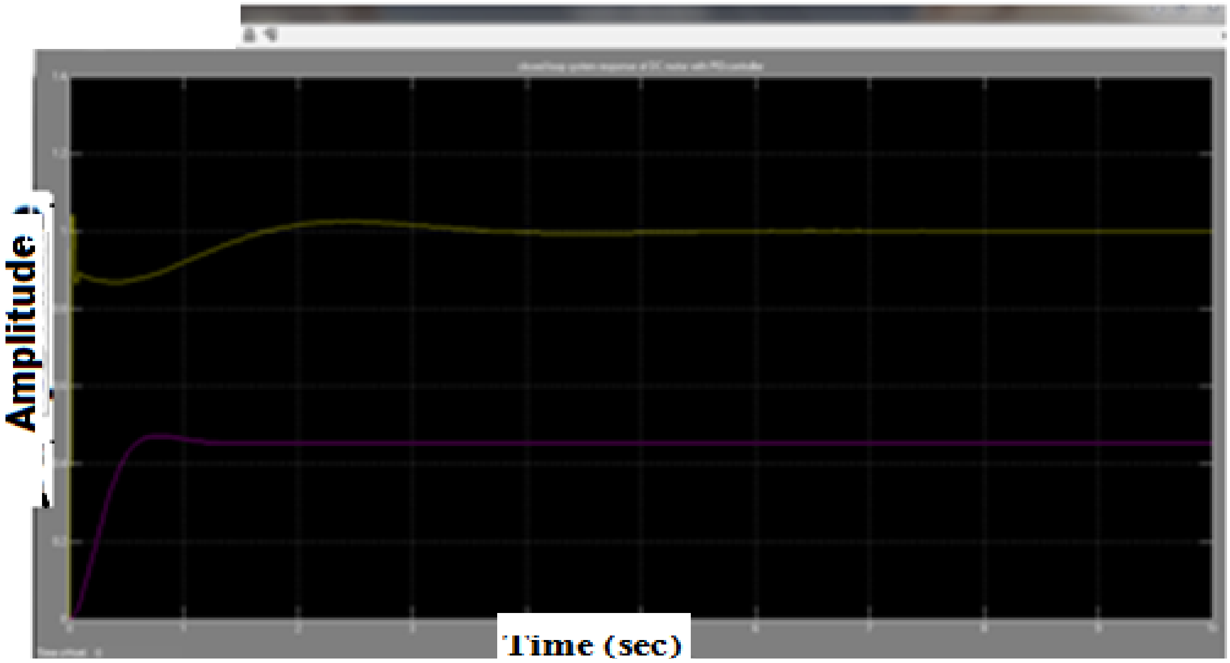
Simulation effect:



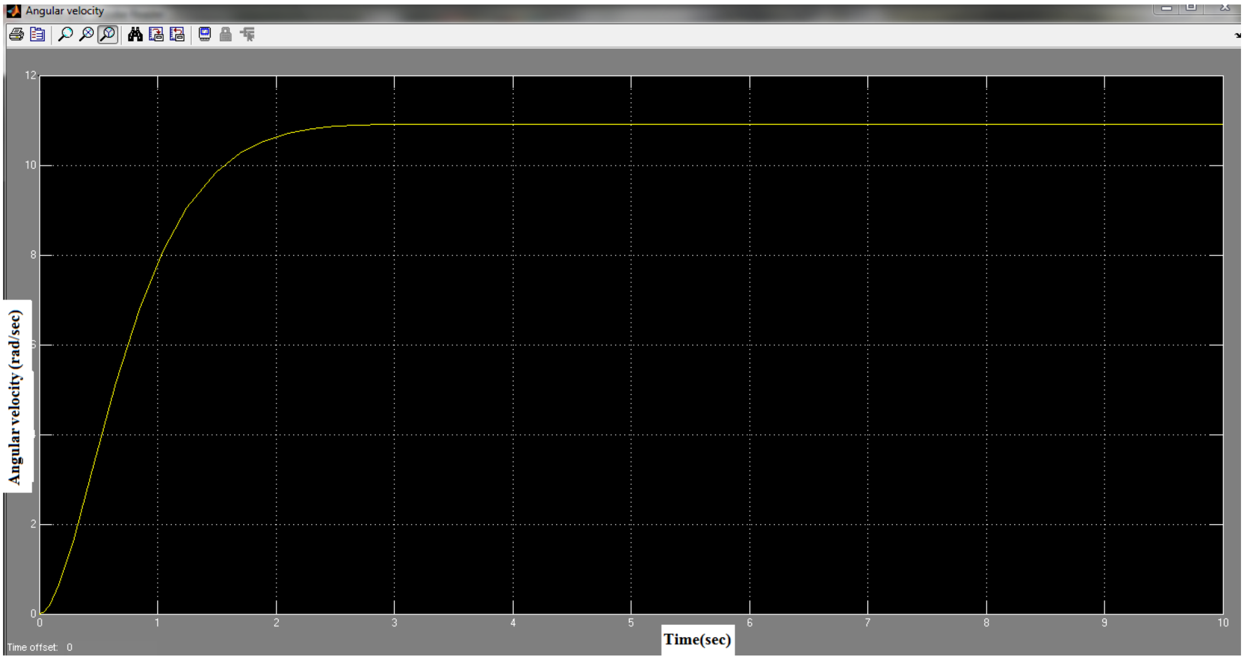
Time vs. Speed graph



Unit step response of PID controller



System response with lag compensator



Angular velocity vs. Time graph

Table 1 Ziegler-Nichols Closed loop oscillation based tuning methods.

Type of Controller	K_p	T_i	T_d
P	$0.5K_c$	∞	0
PI	$0.45K_c$	0.83T	0
PID	$0.6K_c$	0.5T	0.125T

VII. Conclusion

In this paper study of performance of conventional controller and Lag compensator has been studied. Lag compensator has been included into the system in to improve the response of the dc motor without affecting the other parameters. There are some design constraints like settling time, rise time, maximum overshoot, damping ratio; steady state error under which the compensator are designed .Steady state parameter is the primary key which has to be taken into under consideration. We have to use conventional controller to control the speed of motor.

By appropriate parameter of the dc motor transfer function closed loop system are constructed and response of the closed loop response has been observed The mathematical formulation of the transfer function has been done and location of the poles and zero has been plotted. The stability of the system has been analyzed by plotting poles and zeros on the root loci plot. The closed loop response of the dc motor with PID controller has also been studied. In order to calculate gain margin phase margin, bode plot has been drawn.

Specification of the separately excited DC Motor which is given below:-

Consider the following values for the physical parameters
Armature inductance (L_a) = 0.5 H
Armature resistance (R_a) = 1Ω
Armature voltage (V_a) = 200 V
Mechanical inertia (J) = 0.01 Kg. m
Friction coefficient (B) = 0.1 N. m /rad/sec
Back emf constant K_b = 0.01 V/rad/sec
Motor torque constant
K_t= 0.01N.m/A
Rated speed = 1450 rpm

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