# Speed Control of DC Motor using Pid Controller in SIMULINK

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# 1 OBJECTIVE

The main objective of our Project is to design PID controller to supervise and control the speed response of the DC motor in Simulink.

# 2 INTRODUCTION

The speed of a DC motor is given be the relationship, $N = V - IaRa/K$, This Equation show that the speed is dependent on the supply voltage V, the armature circuit resistance Ra, and field flux , which is produced by the field current.Our Project describes the SIMULINK model of the DC motor speed control method namely field resistance, armature voltage, armature resistance control method and feedback control system for DC motor drives.
The parameters of the PID controller kp, ki and kd (or kp, Ti and Td) can be manipulated to produce various response Curves.

# 3 PID CONTROLLER

The combination of proportional, integral and derivative control action is called PID control action. PID controllers are commonly used to regulate the time-domain behavior of many different types of dynamic plants.
Consider the feedback system architecture that is shown in Fig. 1 where it can be assumed that the plant is a DC motor whose speed must be accurately regulated. 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 C (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.

$$u = Kpe + Ki \int edt + Kd\frac{de}{dt}$$

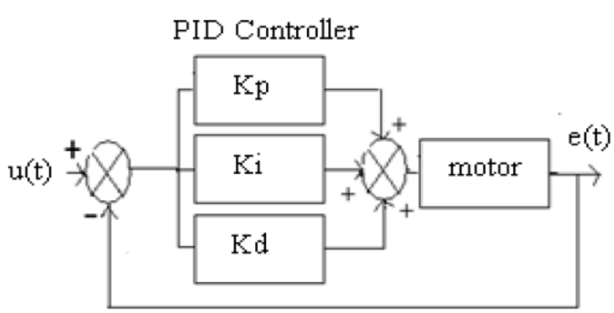



Fig - 1

# 4 DC MOTOR MATHEMATICAL MODELLING AND THE CONTROL THEORY

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 .The electric circuit of the armature and the free body diagram of the rotor are shown in the following fig- 2.

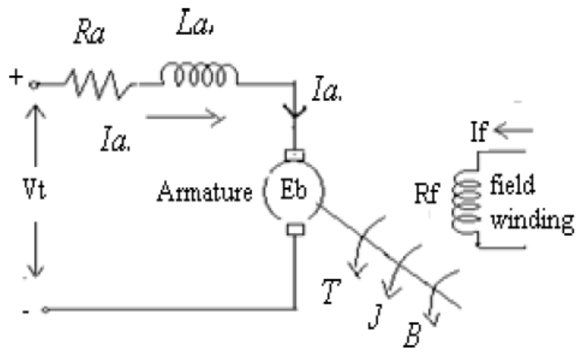



Fig - 2

Let 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,
= Angular displacement of the motor shaft,
=Equivalent moment of inertia of motor shaft and load referred to the motor,
B= Equivalent Coefficient of friction of motor shaft and load referred to the motor.
The DC motors are generally used in the linear range of the magnetization curve. Therefore, air gap flux  is proportional of the field current i.e.

Where Kf is a constant.

The torque T developed by the motor is proportional to the armature current and air gap flux i.e

$$T \propto \Phi \ ia$$

$$T = ka \ \Phi \ ia$$

$$T = kakf \ \Phi \ ia$$

$$T = kia \ .........( \quad 2 \ )$$

Where $K_T$ =motor toque constant

The motor back EMF being proportional to speed is given as

$$Eb \propto \Phi \ \omega$$

$$Eb = kb \ \omega$$

$$Eb = kb \frac{d\theta}{dt} ......( \quad 3 \ )$$

Where Kb= back emf constant

Applying KVL in the armature circuit

$$v = Raia + La \frac{dia}{dt} + Eb ........( \ 4)$$

And thedynamic quation with moment of inertia & coefficient of friction will be

$$T = J \frac{d^2\theta}{dt^2} + B \frac{d\theta}{dt} .......... \ .(5)$$

And with load torque

$$T = J \frac{d^2\theta}{dt^2} + B \frac{d\theta}{dt} + T_L .......( \ 6)$$

Take the laplace transform of equation of (2) ,(3), (4) and (5)

$$T(s) = KIa \ (s)$$

$$Eb \ (s) = KbS \ \theta(s)$$

$$V(s) = Ia(s)(Ra + sLa) + Eb$$
$$V(s) - Eb(s) = Ia(s)(Ra + sLa)$$
$$T(s) = (Js^2 + sB)\theta(s)$$
$$T(s) = (Js + B)s\theta(s)$$
*or*
$$T(s) = (Js + B)\omega(s)$$
$$T(s) = KIa(s)$$

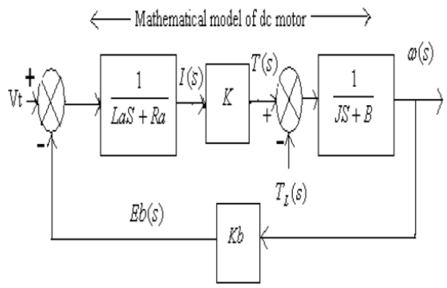



Fig- 3

The transfer function of DC motor speed with respect to the input voltage can be written as follows [2].

$$G(s) = \frac{\omega(s)}{V(s)}$$

$$= \frac{K_T}{(Ra + sLa)(Js + B) + KbK_T} \quad \text{........} (7)$$

From equation (7) the armature inductance is very small in practices, hence, the transfer function of DC motor speed to the input voltage can be simplified as Follows,

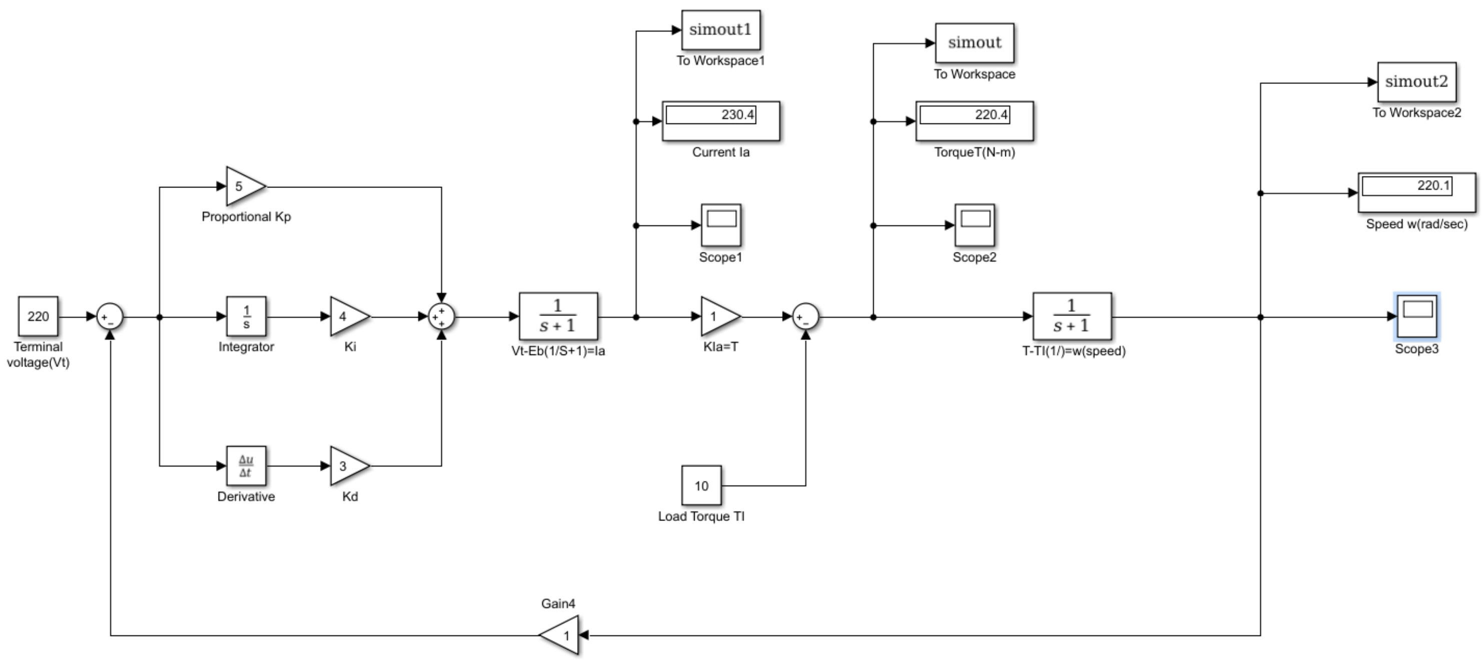
$$G(s) = \frac{\omega(s)}{V(s)} = \frac{Km}{\tau s + 1} \quad \text{..........} \quad (8)$$

Where $K_m = \dfrac{K_T}{R_a B + K_b K_T}$ is a motor gain and $\tau = \dfrac{R_a J}{R_a B + K_b K_T}$ is the motor time constant

From equation (8), the transfer function can be drawn the DC motor system block diagram which is shown in Key point; Field controlled dc motor is open loop while armature controlled is closed loop system. Hence armature controlled dc motor are preferred over field controlled system For small size motor field control is advantageous because only a low power servo amplifier is required while the armature current which is not large can be supplied from an expensive constant current amplifier. For large size motor it is on the whole cheaper to use armature control scheme. Further in armature controlled motor, back emf contributes additional damping over and above that provided by load friction.

# 5 SIMULINK MODEL

This is the simulink model of our project.



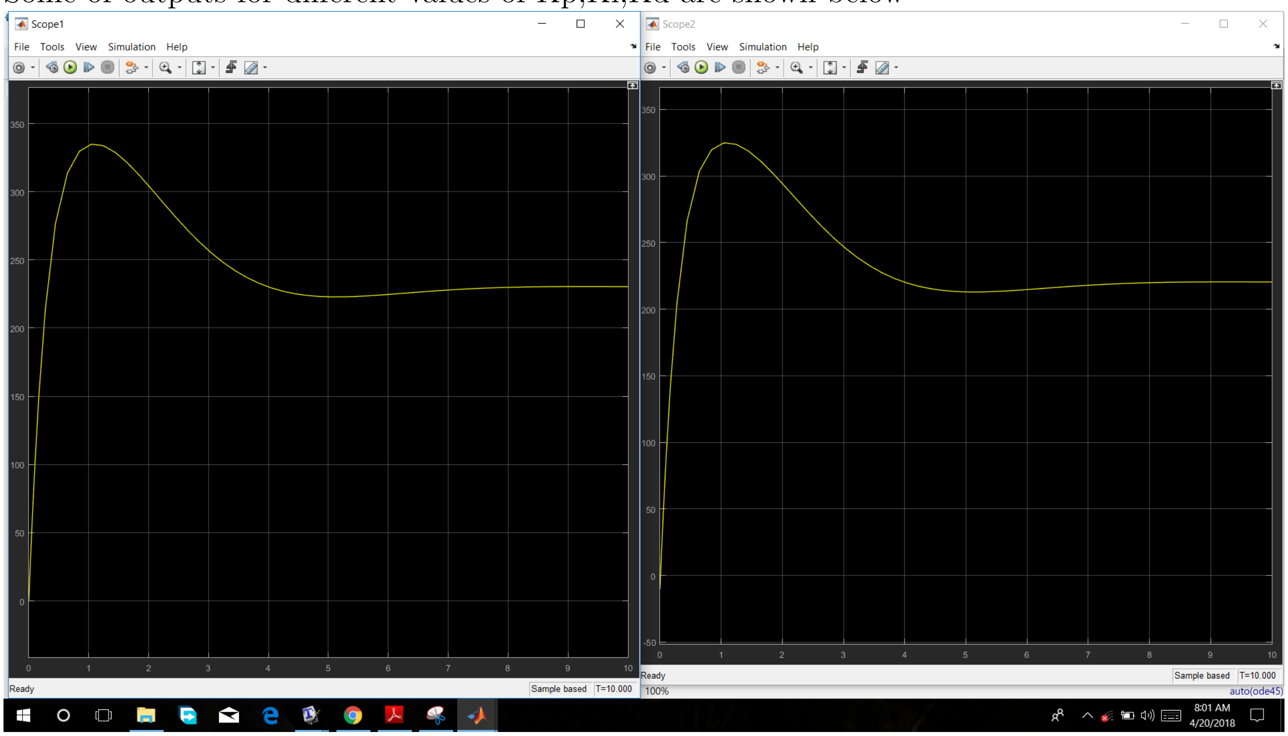
# 6 RESULTS/CONCLUSIONS

Effects of PID controllers parameters kp, ki and kd on a closed loop system are summarized

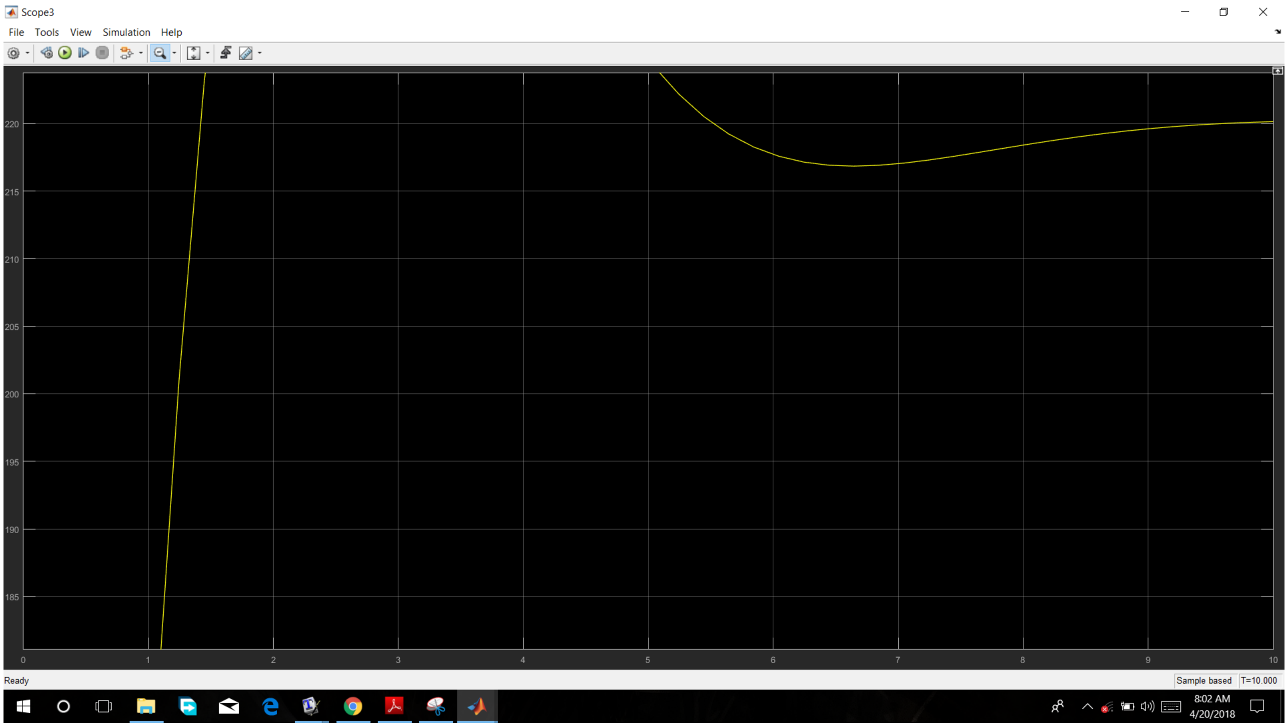
| Closed loop Response | Rise Time(sec) | Maximum Overshoot(%) | Settling Time(sec) |
|---|---|---|---|
| As increase of $K_P$ | Decrease | Increase | Small change |
| As increase of $K_I$ | Decrease | Increase | Increase |
| As increase of $K_D$ | Small change | Decrease | Decrease |

Hence the speed of DC Motor is Controlled using different values of Kp,Ki,Kd.The accuracy and precision in control depends on suitable and normalised values of Kp,Ki,Kd.

Some of outputs for different values of Kp,Ki,Kd are shown below




Kp=5,Ki=4,Kd=3,Current and Torque responses




Kp=5,Ki=4,Kd=3,Speed control response