Modelling and simulation of dc drive using PI and PID controller

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Abstract: Many industrial applications require high performance rotating electric drives. A proposed D C drive have a precise speed control, stable operation in complete range of speed and good transient behaviour with smooth and step less control. The purpose of developing a simulation using PI and PID control system is to get steady state and transient response of drive system. Once the type of controller has been decided then the design and analysis are done. This paper focuses modelling of separately excited DC motor for the analysis of machine under any condition and compares the step response of system with and without PI and PID controller.

Keywords: DC Motor, Modelling, Simulation, PI & PID controller.

I. INTRODUCTION

Today, industries are increasingly demanding for process automation in all sectors such as defence, industries, Robotics etc. DC motors have been used in variable speed drives. The versatile control characteristics of dc motors have contributed to their extensive use in industry. DC drives are less complex with a single power conversion from AC to DC. 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. The objective of this paper is modelling of D C motor to get transfer function to form closed loop control system with PI and PID controller with their step response in MATLAB/ Simulink for separately excited D C motor.

II. MODELLING

A .Model of D C separately excited motor

A DC motor can be seen to be comprised of three main parts: current carrying conductors called an armature; a circuit for magnetic field provided by magnets of poles; and a commutator that switches the direction of current in the armature as it passes a fixed point in space.
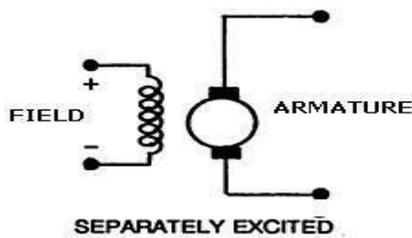
Fif.1 Symbol of DC Separately excited motor

In order to build the DC motors transfer function its simplified mathematical model has been used. The current in the field coil and armature coil independent of one another. As a result these motor have excellent speed and torque control. The equation describing the dynamic behaviour of DC motor is as follows.
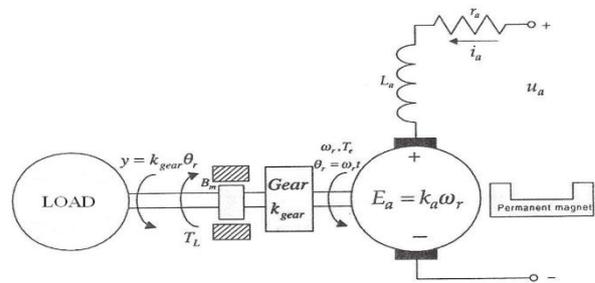
Fig.2 Free Body Diagram of Rotor

Here,

Va= Armature Voltage in volt

Ra= Armature Resistance in Ohm

La=Armature Inductance in Henry

Ia=Armature Current in Amp

Eb= Back EMF in Volt

Tm=Mechanical Torque in N-m

J= Moment of Inertia Kg-m^2

B=Damping Coefficient Nm.Sec

If= Field Current in Amp

Lf= Field Inductance in Henry

Vf= Field Voltage in Volt

The motor torque Tm is related to the armature current, i, by constant factor Kt by constant rotational speed by following equation,

$$T_m = K_t i \qquad \ldots\ldots\ldots(1)$$
$$e_m = K_E \dot{\theta} \qquad \ldots\ldots\ldots(2)$$

As per Newton's Law combined with Kirchhoff's Law:

$$J\,\theta + b\,\dot{\theta} = K_m i - T_L \qquad \ldots\ldots\ldots(3)$$
$$L_m \frac{di}{dt} + R_m i = V - K_M \dot{\theta} \ldots\ldots\ldots(4)$$

Using Laplace Transforms, the above equation can be expressed in terms

$$S(Js + b)\,\theta(s) = K_m I(s) - T_L(s)$$
$$(L_m s + R_m)\, I(s) = V(s) - K_m s\ddot{\theta}$$

By eliminating I(s), the following open –loop transfer function can be obtained, where rotational speed is the output and voltage V in input

In electric drive system, it is desired to describe the appropriate transfer function of motor between motor voltage and its speed.

For this purpose assuming Load torque TL=0,

And friction torque Tf=0, since neither affects the transfer function

Therefore,

$$\frac{\dot{\theta}(s)}{V(s)}\bigg|_{T_L(s)=0} = \frac{K_m}{(Js+b)(L_m s + R_m) + K_m^2}$$

State –Space Representation:

In state space form eqn.3, 4 can be expressed by choosing rotational speed and current as the state variable and voltage is input

$$\frac{d}{dt}\begin{bmatrix} \dot{\theta} \\ i \end{bmatrix} = \begin{bmatrix} -\frac{b}{J} & \frac{K_m}{J} \\ -\frac{K_m}{L_m} & -\frac{R_m}{L_m} \end{bmatrix}\begin{bmatrix} \dot{\theta} \\ i \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{L_m} \end{bmatrix} V$$

$$\dot{\theta} = \begin{bmatrix} 1 & 0 \end{bmatrix}\begin{bmatrix} \dot{\theta} \\ i \end{bmatrix}$$

B. Selection of motor parameters

The DC motor under study has the following specification and parameters.

1. Specifications:
 3hp, 230V,11Amp,1500 rpm
2. Parameters:
Ra=2.45ohm,La=0.2145 H,Kb=1.05volt/rad/sec, J=5kg-m2,B=0.0859 N/rad/sec.

III. CONTROL SYSTEM DESIGN

Types of controller

A-Proportional Control:

In proportional controller it examines the magnitude of the error and it reacts proportionally. A large error receives a large response. For example, if there is a large temperature error, the fuel valve would be opened a lot. On the other hand, a small error receives a small response. In mathematical term, the proportional term (Pout) is expressed as:

Pout = Kp*e
Where:
Pout: Proportional portion of controller output
Kp : Proportional gain
e : Error signal,
e = Set-point – Process Variable

2- Integral Control:

The integral type of controller overcomes the offset, integral control attempts to correct small error (offset). Integral examines the error over time and increases the importance of even a small error over time. Integral is equal to error multiplied by the time the error has persisted. A small error at time zero has zero importance.

A small error at time 10 has an importance of 10 times error. In this manner, integral increases the response of the system to a given error over time until it is corrected. Integral can also be adjusted and the adjustment is called the reset rate. Reset rate is a time factor. The shorter the reset rate the quicker the correction of an error. However, too short a reset rate can cause erratic performance. In hardware-based systems, the adjustment can be done by a potentiometer changing the time constant of a RC circuit. Most of today's applications use software based control such as

$$I_{out} = \frac{1}{T_i}\int edt = K_i\int edt$$

Where:
Iout: Integral portion of controller output
Ti: Integral time, or reset time
Ki: Integral gain
e : Error signal, e = Set-point – Process Variable

3-Derivative Control:

The derivative controller gives the control output with the rate of change in the error signal. Derivative will cause a greater system response to a rapid rate of change than to a small rate of change. In other words, if a system's error continues to rise, the controller must not be responding with sufficient correction. Derivative senses this rate of change in the error and provides a greater response. Derivative is adjusted as a time factor and therefore is also called rate time. It is essential that too much derivative should not be applied or it can cause overshoot or erratic control. In mathematical term, the derivative term (Dout) is expressed as:

$$D_{out} = T_d\frac{d}{dt}e = K_d\frac{d}{dt}e$$

Where:
Dout: Derivative portion of controller output
Td: Derivative time
Kd: Derivative gain
e : Error signal, e = Set-point – Process Variable

4- PID controller:

PID controllers typically use control loop feedback in industrial and control systems applications. The controller first computes a value of error as the difference between a measured process variable and preferred set-point. It then tries to minimize the error by increasing or decreasing the control inputs to the process, so that process variable moves closer to the set point. This method is most useful when a mathematical model of the process or control is too complicated or unknown.
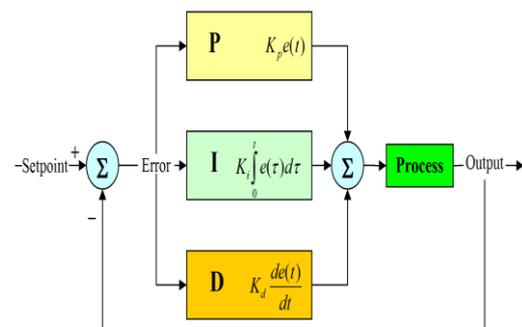
Fig.3 PID controller block diagram

.To design steady state system and improve step response of PID controller proper tuning constant have to done. Obtaining any open loop response and determining what need to be improved.

➤ Kp to improve the rise time.
➤ Kd to improve the overshoot.
➤ Ki to eliminate the steady state error.

tune each of Kp,Kd,Ki constant until obtaining a desired response.

IV. SELECTION OF CONTROLLER

The control system be analyzed and suitable controller be selected and design Listed below are the most important properties of the widely used P, PI, PID

a. Whether the system is based on integral or proportional control action.
b. Process lag.
c. Speed of the error correction.
d. Acceptability of steady-state error.

According to the above table, controllers and systems can be assigned to each other as:

➤ For easy-to-control systems where steady-state errors are acceptable, P controllers are used.
➤ In systems with great lag where offset is tolerable PD controllers are used
➤ For applications with low requirement to control dynamics and where the system does not exhibits great lags, I controllers are used
➤ For a dynamic control response without exhibiting the steady state error, PI controllers are used
➤ If it is required that the speed of the response is as high as possible, regardless of the
Greater lag, PID controllers are used.

V. SIMULATION

By implementing simulating model in MATLAB/simulink the response of the open and close loop system with and without controller can study and compare the performance.

1. D C drive without controller

In first simulation all parameters of motor refer and connect the system in open loop i.e without feedback and on scope we get the step response for open loop controller.
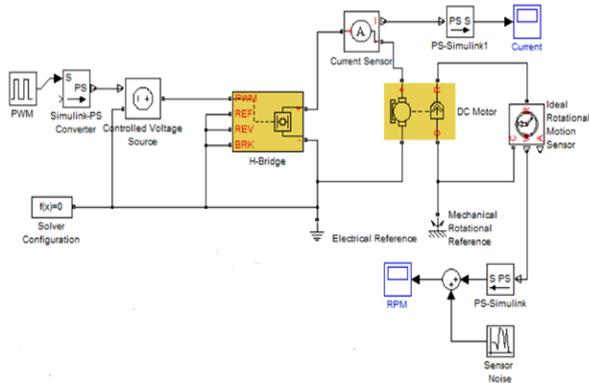
Fig.4 Block Diagram of open loop system
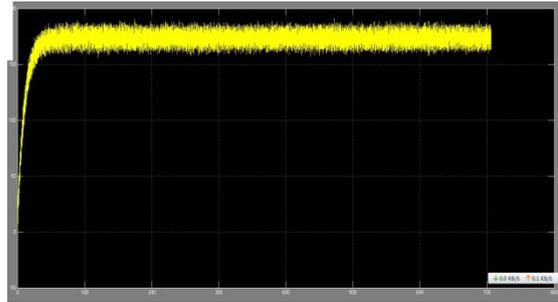
Fig.5 Step response of system without controller

2. D.C drive with PI controller

In second simulation PI controller to control the d c motor. We form closed loop system by adding the speed sensor and converting analog to digital using A to D conversion block. Basically we implement the Phase lock loop for d c motor as follows.
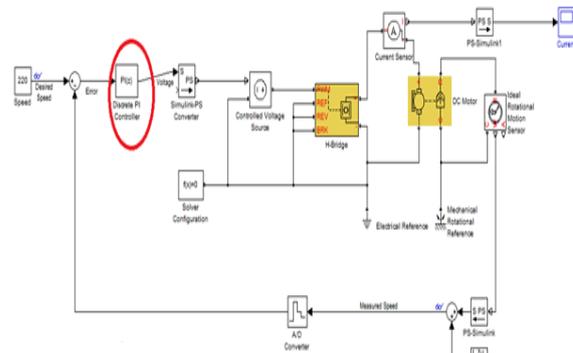
Fig.6 Block Diagram of closed loop system with PI controller
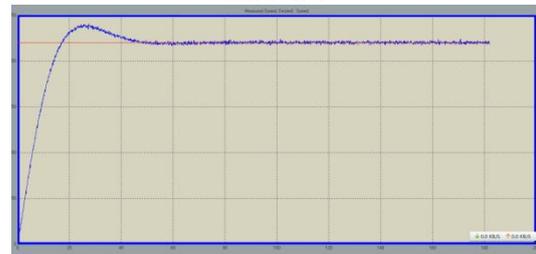
Fig.7 Step response of system with PI controller

3 .D.C drive with PID controller:

In third simulation we replace PI controller by discrete type PID controller. And get the step response for d c drive
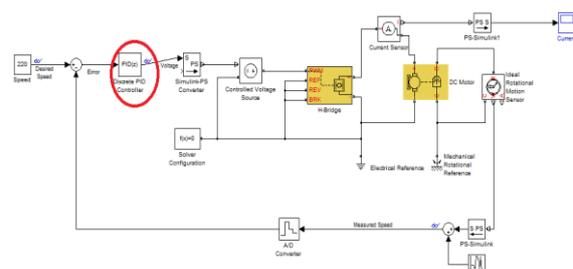
Fig.8 Block Diagram of closed loop system with PID
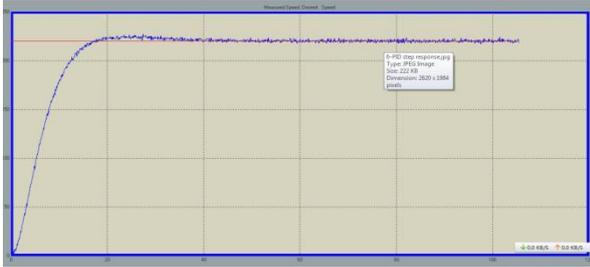
Fig.7   Step response of system with PID controller

PARAMETER	PI	PID
STEADY STATE ERROR	LESS	LESS
SETTELING TIME	25 sec	20 sec
OVERSHOOT	HIGH	LESS
RISE TIME	15.4 sec	13.2 sec
STEP RESPONSE	STABLE	MORE STABLE

Table.1 Comparisons of step response PI and PID

VI. CONCLUSION

The proportional – integral – derivative (PID) controller operates the majority of the control system in the world. It has been reported that more than 95% of the controllers in the industrial process control applications are of PID type as no other controller match the simplicity, clear functionality, applicability and ease of use offered by the PID controller. PID controllers provide robust and reliable performance for most systems if the PID parameters are tuned properly.

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