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Comparative Analysis of PI and PID Controllers for Speed Control of DC shunt Motor

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***Abstract*— DC motor plays an important role in industry and domestic application. Thus, the speed control of DC shunt motor is a prime task. This paper gives a comparison of the performance of conventional proportional integral (PI) and proportional integral derivative (PID) for speed control of DC shunt motor.**

***Index Terms*—DC shunt motor, PI controller, PID controller, Speed control.**

I. Introduction

The field of electrical energy will be divided into three areas: Electronics, Power and Control. Electronics basically deals with the study of semiconductor devices and circuits at lower power. Power involves generation, transmission and distribution of electrical energy [1].Many varieties of control schemes such as proportional, integral, derivative, proportional plus integral (PI), proportional plus derivative (PD),proportional plus integral plus derivative(PID),Adaptive control, controller, have been developed for speed control of dc motors. The DC motors have been popular in the industry control area for a long time, because they have enormous characteristics like, high start torque , high response performance, easier to be linear control etc. The proportional integral (PI) controller is the most common form of feedback in the control systems. PI control is also an important ingredient of a distributed control system and as such these controllers come in different forms [2]. Here mainly concentrated on speed control of DC shunt motor. the design of a mathematical model of the DC shunt motor using MATLAB SIMULINK model is used for studying the performance characteristics of dc motor and mainly concentrated on the design of PI and PID controller using MATLAB/ SIMULINK environment.

II. DC shunt Motor Mathematical Model

DC motors are highly reliable and flexible because of the several good characteristics like high starting torque, efficient response and linear controllability. The term speed control stand for intentional speed variation carried out manually or automatically. DC motors are most suitable for wide range of
Speed control and adjustable speed drives [3-4]. Shunt D.C. Machines The field coils of a shunt D.C. machine are connected in parallel to the armature coils. Therefore, the Transient in the armature circuit is simultaneous with the

Transient in the field circuit [5]. A circuit model of a Shunt D.C. Motor is shown in Figure 1below

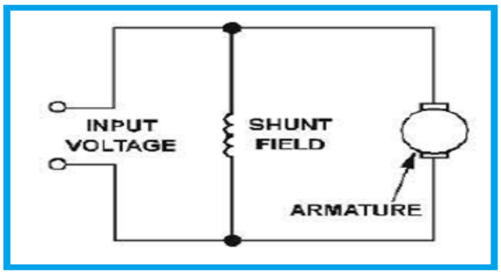

Fig 1 Shunt D.C. Motor

$$V = R\,i + L\frac{di}{dt} + e_b \ldots\ldots\ldots\ldots \quad (1)$$

Because the back EMF eb is proportional to speed ω directly, then

$$E_b = K_b\frac{d\theta}{dt} = K_b\,\omega \ldots\ldots\ldots\ldots \quad (2)$$

$$Tm = K_t\,i \ldots\ldots\ldots\ldots \quad (3)$$

$$Tm = J\frac{d^2\theta}{d\,t^2} + B\frac{d\theta}{dt} \ldots\ldots\ldots\ldots \quad (4)$$

$$\omega = \frac{d\theta}{dt} \ldots\ldots\ldots\ldots \quad (6)$$

$$\frac{\omega(s)}{V_a(s)} = \frac{K_b}{(L_aS+R_a)(JS+B)+K_b^2+RB} \ldots\ldots\ldots\ldots \quad (7)$$

$$G(s) = \frac{\omega(s)}{V_a(s)} = \frac{K_T}{(L_a*j)S^2+S(R_a*j+L_a*B)+(R_a*B+K_b*K_T)} \quad (8)$$

Show the transfer functions 8 and use dc shunt motor data in the equation 9.

$$G(s) = \frac{0.5}{0.0077\,S^2+0.09007S+0.25018} \quad (9)$$

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III. Proportional plus Integral Controller Description

Proportional plus Integral (PI) controllers are widely used in industrial practice for more than 60 years. The development went from pneumatic through analogue to digital controllers, but the control algorithm is in fact the same, The PI controller is standard and proved solution for the most industrial application. The main reason is its relatively simple structure, which can be easily understood and implemented in practice, and that many sophisticated control strategies, such as model predictive control, are based on it. An application with large speed capabilities requires different PI gains than an application which operates at a fixed speed. In addition, industrial equipment that are operating over wide range of speeds, requires different gains at the lower and higher end of the speed range in order to avoid overshoots and oscillations. Generally, tuning the proportional and integral constants for a large speed control process is costly and time consuming. The task is further complicated when incorrect PI constants are sometimes entered due the lack of understanding of the process [5-6]. The control action of a proportional plus integral controller is defined as by following equation:

$$u(t) = K_p\, e(t) + K_i \int_0^t e(t)dt$$

Where: u(t) is actuating signal. , e(t) is error signal. ,Kp is Proportional gain constant. , Ki is Integral gain constant. The Laplace transform of the actuating signal incorporating in proportional plus integral control is

$$U(s) = K_p\, E(s) + K_i\ \frac{E(s)}{s}$$

The block diagram of closed loop control system with PI control of D.C. Motor System is shown in Figure 2. The error signal E(s) is fed into two controllers, i.e. Proportional block and Integral block, called PI controller. The output of PI controller, U(s), is fed to D.C. shunt Motor System [7]. The overall output of D.C. drive, may be speed C(s) is feedback to reference input R(s). Error signal can be remove by increasing the value of Kp, Ki.

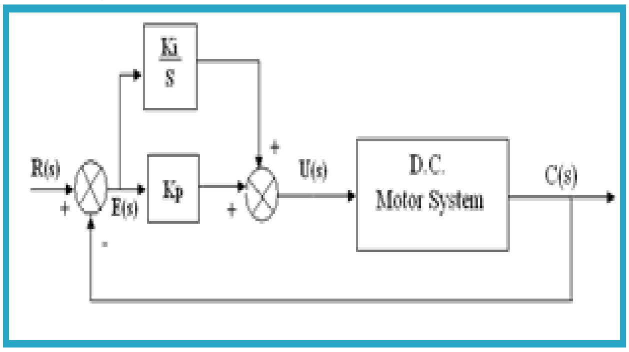


Fig 2 Proportional plus Integral Controller with DC Shunt motor

Since most of the process cannot work with an offset, they must be controlled at their set points and in order to achieve this, extra intelligence must be added to proportional controller and this is achieved by providing an integral action to the original proportional controller. So the controller becomes proportional integral controller.

- Under PI Controller as long as error is present the controller keeps changing its output and once the error is zero or it disappears the controller does not change its output.
- Integration is the mode that removes the offset or the error but sometimes it may make transient response worse.
- In PI Controller the output of the controller is changed proportional to the integral of the error.

PI Controller has the following disadvantages:

- The response is sluggish at the high value of the integral time.
- The control loop may oscillate at the small value of integral time.

IV .PID Description

The PID control is most widely used in industrial applications. It is implemented to control the speed of DC motor which is shown in Fig 3. The error between the reference speed and the actual speed is given as input to a PID controller. The PID controller depending on the error changes its output, to control the process input such that the error is minimized-I-D controller has the optimum control dynamics including zero steady state error, fast response (short rise time), no oscillations and higher stability. The necessity of using a derivative gain component in addition to the PI controller is to eliminate the overshoot and the oscillations occurring in the output response of the system. One of the main advantages of the P-I-D Controller is that it can be used with higher order processes including more than single energy storage. In order to observe the basic impacts, described above, of the proportional, integrative and derivative gain to the system response [8-9].

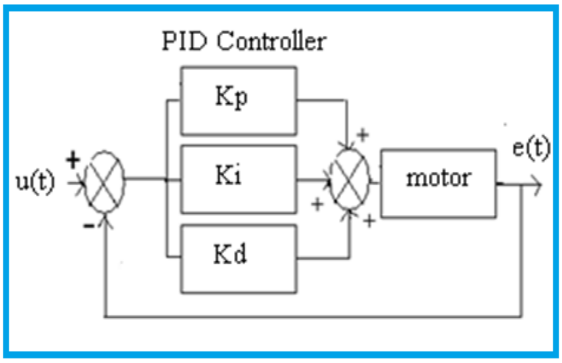


Fig 3 PID Controller with DC Shunt motor

PID parameter values directly from the transfer function model of the process, without doing any experiment. Still, you should verify that the PID tuning is proper by simulating. What is the aim of the controller tuning? If it was possible to obtain, we would like to obtain both of the following for the control system:

- Fast responses.
- Good stability.

Unfortunately, for practical systems these two wishes cannot be achieved simultaneously. In other words

- The faster response.

- The worse stability.
- The better stability.
- The slower response.

V Results Analysis with MATLAB Simulink

Case 1 Tuning of Proportional Integral (PI) Controller for DC motor

In this case study of different tuning parameter of integral (PI) controller, PI-MATLAB simulink model show in the fig 4, best tuning parameter of PI controller are 3.344, 2.062 and1.072 in this case, best results of (PI) controller show in the fig 5, 6 and 7 and comparative different tuning result of (PI) controller show in the table 1 .

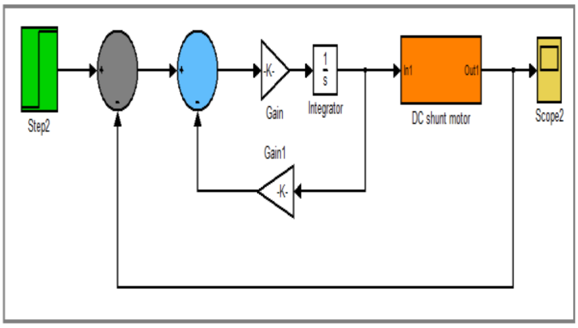


Fig 4 PI-MATLAB simulink model of DC shunt Motor

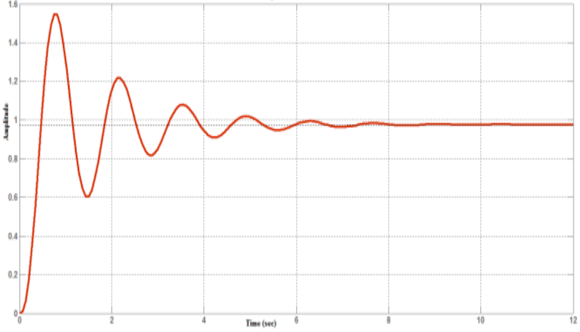


Fig 5 step response of PI controller

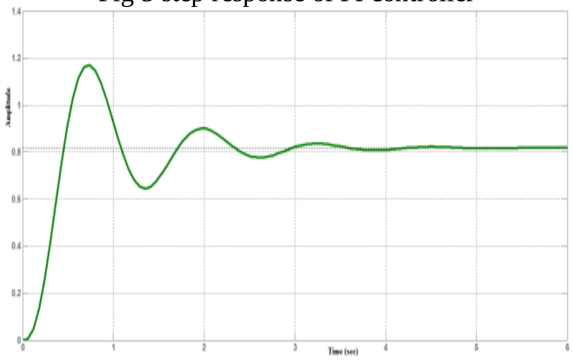


Fig 6 step response of PI controller

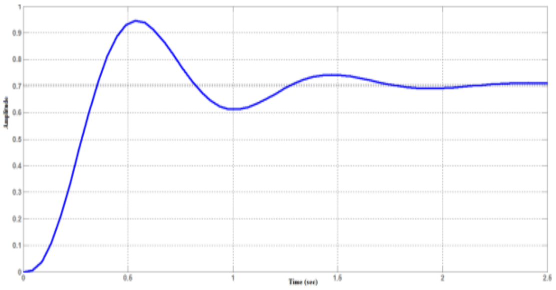


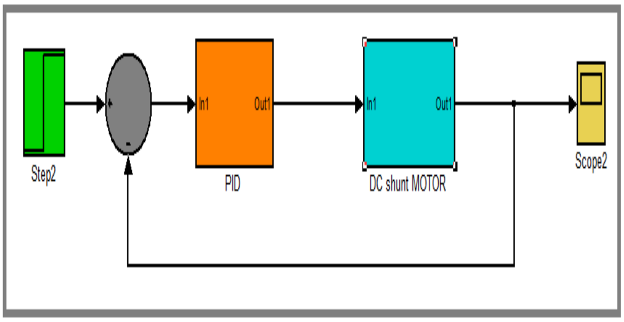
Fig 7 step response of PI controller

Table 1 Compare of different tuning Parameter of PI cintroller

Response of PI controller			
Tuning of PI cintroler (K)	Setting time (Ts)	Rise time (Tr)	Maximum Overshoot (%)
3.385	5.78	0.282	58.6
3.646	3.36	0.276	43.4
7.498	1.97	0.217	34.1

Test case 2 Tuning of Proportional Integral Derivative (PID) Controller

In this case study of different tuning parameter of Proportional integral derivative (PID) controller, PID-MATLAB simulink model show in the fig 8. Tuning of different values of PID controller such as KP, KI and KD, best results of (PID) controller show in the fig 9 ,10and 11 and comparative result of (PID) controller show in the table 2, the minimum rise time, minimum settling time and minimum overshoot achieve by PID controller. It's clear response of PID controller good response then PI controller.



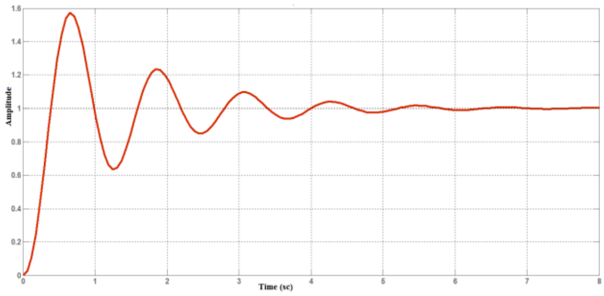


Fig 9 step response of PID controller

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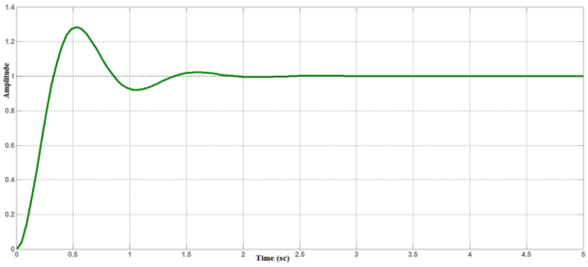

Fig 10 step response of PID controller

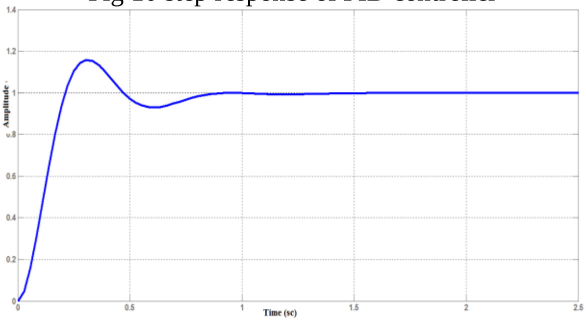

Fig 11 step response of PID controller

Table 2 Compare of different tuning Parameter of PID cintroller

Response of PID Controller controller		
Setting time (Ts)	Rise time (Tr)	Maximum Overshoot (%)
5.01	0.246	57.3
1.67	0.225	28.4
0.79	0.146	15.9

VI.CONCLUSION

Speed control of the DC motor system using both PI control and PID control system has been presented in this paper. Table 3 compare of PI and PID controller, PID control system is better than PI control system. Therefore, PID control system is easy to implementation, easy to control of DC motor. PID controller is Fast responses and Good stability

Table 3 Compare of PI controller and PID cintroller

Controller	**Rise time of system**	**Setting time of system**	**Maximum overshoot**
PI controller	0.217	1.97	34.1
PID controller	0.146	0.79	15.9

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