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DC Motor Speed Control for a Plant Based On PID Controller

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Abstract: **This paper aims is to design a controller for controlling the speed of DC motor .The effects of the controller on motor speed is analyzed .Automatic tuning of the controller is also introduce for efficient control of the process .The tuning is implemented using Ziegler Nichols method and results are compared with Variation in speed without controller.**

Keywords: **PID, Tuning, Ziegler Nichols, DC Motor.**

1. INTRODUCTION

PID controllers are the most widely-used type of controller for industrial applications. They are structurally simple and exhibit robust performance over a wide range of operating conditions. In the absence of the complete knowledge of the process these types of controllers are the most efficient of choices. The three main parameters involved are Proportional (P), Integral (I) and Derivative (D). The proportional part is responsible for following the desired set-point, while the integral and derivative part account for the accumulation of past errors and the rate of change of error in the process respectively.

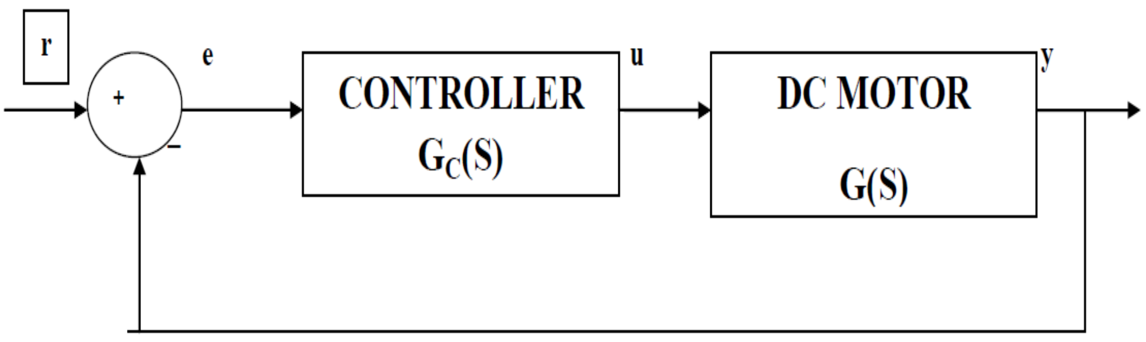

Fig.1 Block diagram

In above fig. the controller is used in a closed loop unity feedback system . the variables r,e,u and y denotes the input signal , error signal, controller signal and output.

The transfer function of closed loop system is given by

$$u = G_C(S) = K_C\left(1+\frac{1}{T_1 S} + T_D S\right) = K_P + \frac{K_I}{S} + K_D S$$

Where K_c is Proportional gain , T_i is Integral time constant and T_d is Derivative time constant.

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Table 1: Effects of K_P, K_I, K_D on plant performance

Closed loop responce	Rise Time	Over shoot	Settling Time	Steady State error
K_P	Decreases	Increases	Increases	Decreases
K_I	Decreases	Increases	Increases	Eliminate
K_D	Small change	Decreases	Decreases	Small change

Tuning Of Pid Controller:

Tuning of a PID controller refers to the tuning of its various parameters (P, I and D) to achieve an optimized value of the desired response. The basic requirements of the output will be the stability, desired rise time, peak time and overshoot. Different processes have different requirements of these parameters which can be achieved by meaningful tuning of the PID parameters. If the system can be taken offline, the tuning method involves analysis of the step input response of the system to obtain different PID parameters. But in most of the industrial applications, the system must be online and tuning is achieved manually which requires very experienced personnel and there is always uncertainty due to human error.

2. PROPOSED METHOD

ZIEGLER NICHOLS: I .ZN Step method: The response of plant to unit step input looks like S shape that characterize two constant delay time L and Time constant T which are determine by drawing tangents at inflection point.

Table -2: Ziegler –Nichols tuning rule based on step response of plant (first Method)

Type of controller	K_P	T_i	T_d
P	$\frac{T}{L}$	∞	0
PI	$0.9\frac{T}{L}$	$\frac{L}{0.3}$	0
PID	$1.2\frac{T}{L}$	2L	0.5 L

II .ZN Frequency Method: $T_i = \infty$ and $T_d = 0$ is set using Proportional controller only and K_p is increased to critical values K_{cr} at which output exhibit sustain oscillations Thus critical gain K_{cr} and Corresponding period P_{cr} is experimentally determined.

Table3: ZN tuning rule based on critical gain and critical period

Types of controller	K_P	T_i	T_d
P	$0.5K_{cr}$	∞	0
PI	$0.45K_{cr}$	$0.833P_{cr}$	0
PID	$0.6K_{cr}$	$0.5P_{cr}$	$0.125P_{cr}$

3. SPEED CONTROLLER OF DC MOTOR

DC motor Provide excellent Speed control for both acceleration and deceleration with effective and simple torque control. When speed control over a wide range is required, combination of armature voltage control and field flux control is used. This combination permits the ratio of maximum to minimum speed to be 20 to 40. With closed loop control, this range can be extended up to 200.

The parameters of the PID controller kp, ki and kd (or kp, Ti and Td) can be manipulated to produce various response Curves. The electric circuit of armature is Shown below.

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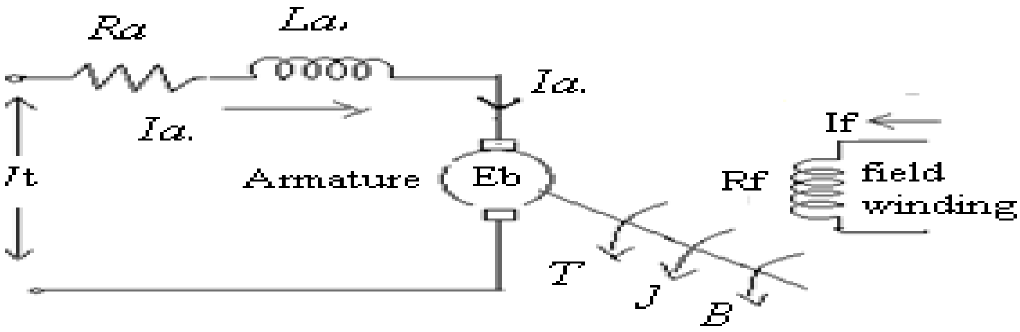

Fig.2. Armature circuit

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,

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

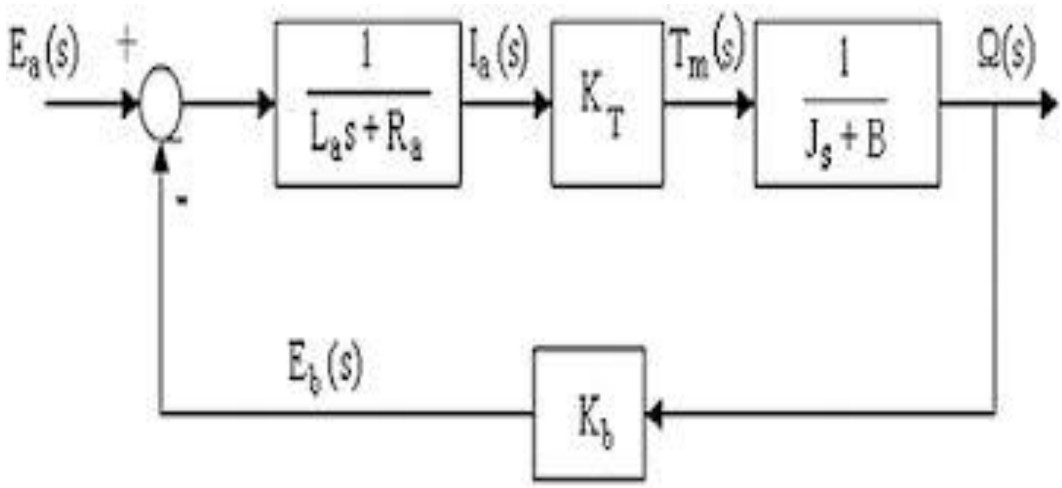

Fig 3. Mathematical model of DC Motor

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

$$G(S) = \frac{Q(S)}{E_a(S)} = \frac{K_T}{(R_a + SL_a)(JS + B) + K_T K_b}$$

$= \frac{K_m}{\tau s+1}$ Where $K_m = \frac{K_T}{R_a B + K_T K_b}$ is motor gain and

$\tau = \frac{J R_a}{R_a B + K_T K_b}$ Is motor time constant the following block diagram shows a closed loop system with PID controller analysis of this system is done by considering the values of K_p, K_I,K_D.

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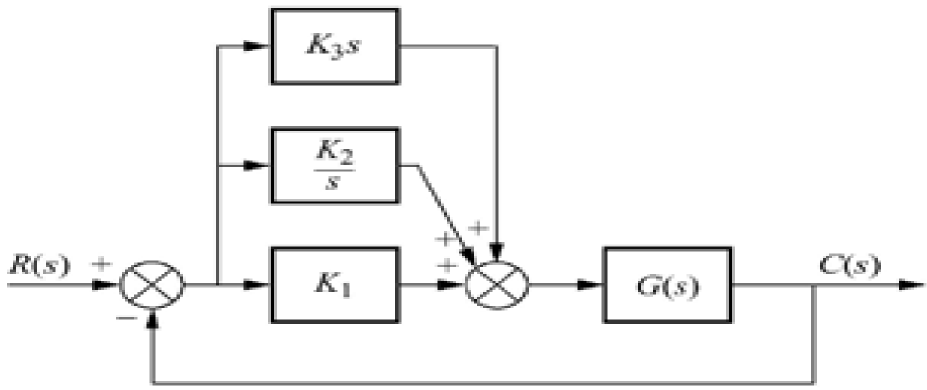

fig4. Model of DC motor with PID Controller

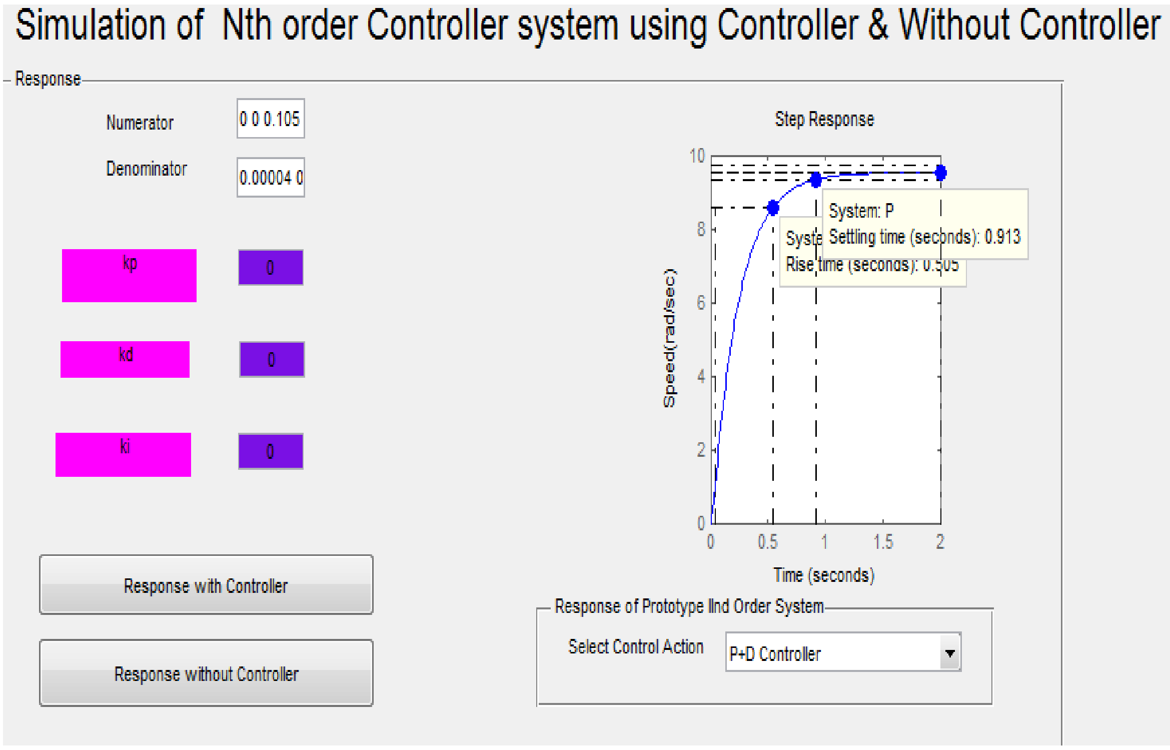

Fig5. Performance characteristics of motor without controller

Now Tuning of the controller is done to find out suitable values of K_P, K_I, K_D

I. ZN STEP METHOD: Tuning of controller is done by taking delay time L=1 and Time constant T= 5

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The Controller formulation : Gc(S)=Kp+ Ki/s + Kd*s)
---------------------------------------------------------
 Controller Type  |    Kp    |    Ki    |    Kd    |
---------------------------------------------------------
     P            | 5    0    0
     PI           | 4.500000e+00     1.350000e+00     0
     PID          | 6    3    3
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Fig.6. Values of K_P , K_i , K_d obtain from ZN method.

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Table. 3. Comparision of performance parameter with different controller and without controller

	RISE TIME	SETTLING TIME	%OVERSHOOT
WITHOUT CONTROLLER	0.505 sec	0.913sec	0%
P	0.0139sec	0.097sec	37.7%
P+I	0.0148sec	0.245sec	33.6%
P+I+D	0.00807sec	0.0098sec	0%

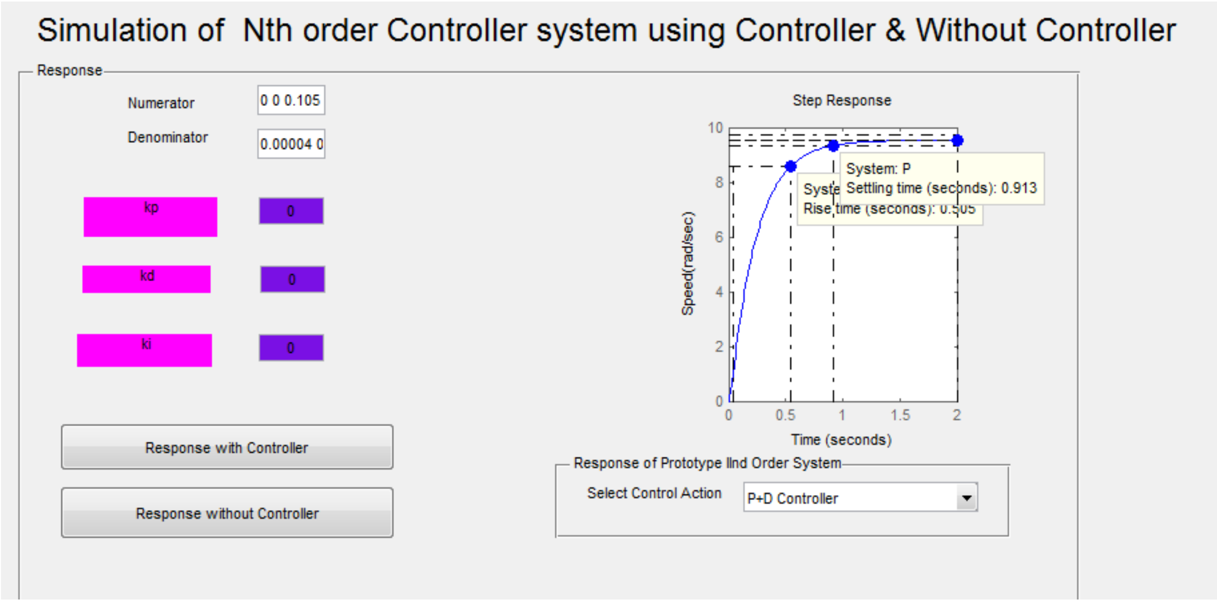

Fig .7. Variation of speed without controller

Above figure shows that the motor is having high rise time and settling time which is not required .our approach is to reduce this value so controllers are employed.

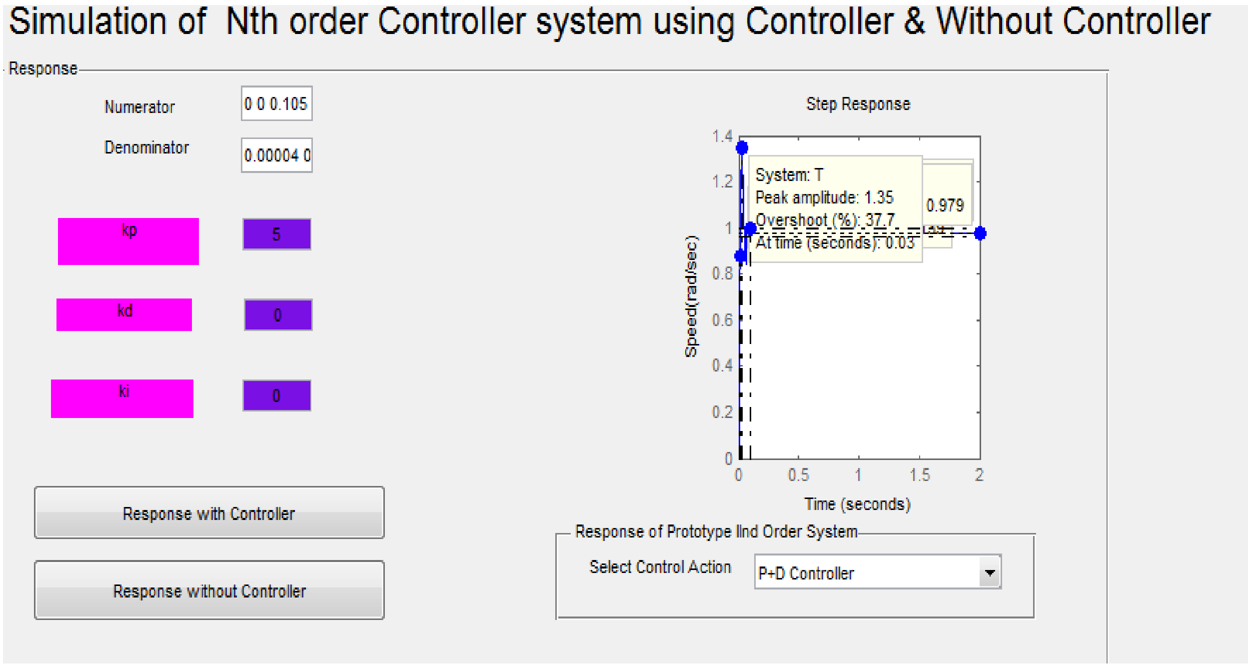

Fig. 8. Variation in speed with Proportional controller

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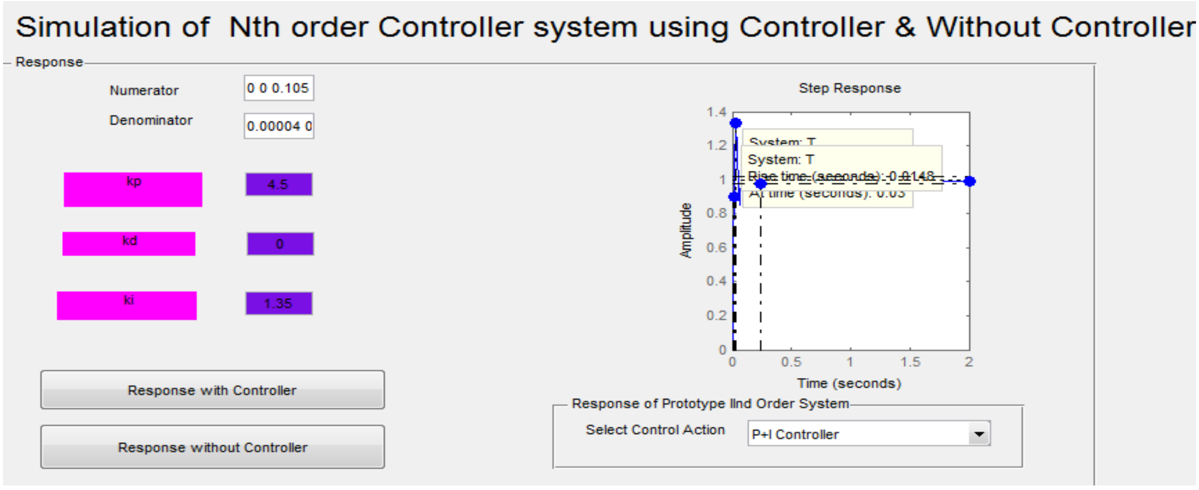

Fig.9 Variation in speed with Proportional and Integral controller

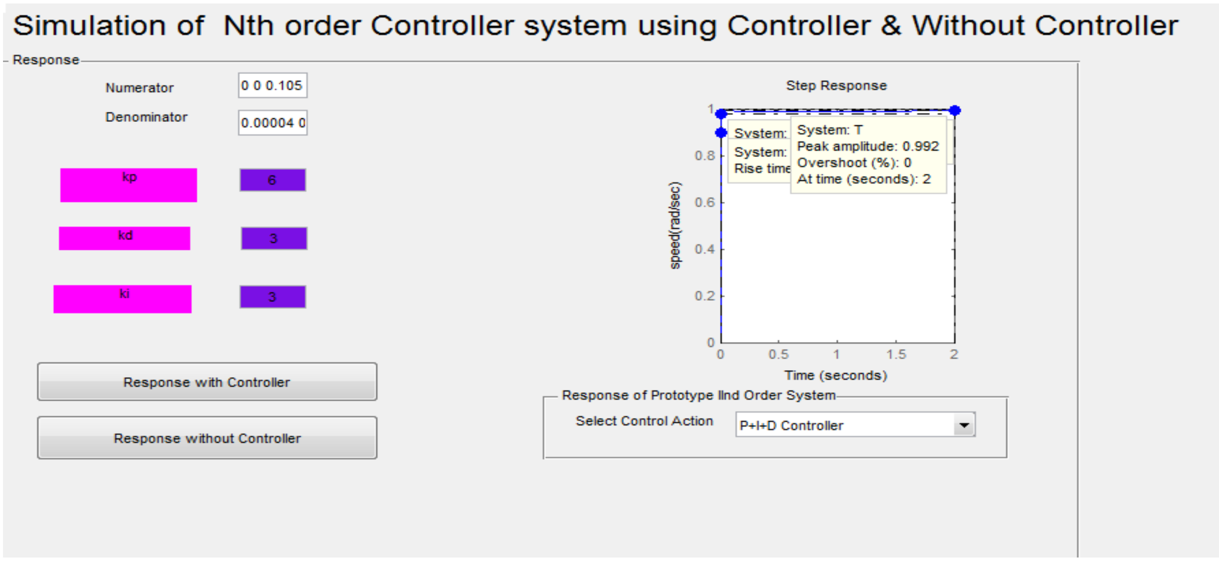

Fig.10 Variation in speed with PID controller

4. CONCLUSION

In this paper different controllers are design for motor. Response of motor with and without controller are compared. Tuning of controller are done by using ZN method and values of Proportional gain ,integral gain and derivative gain are derived from tuning method and response is studied using MATLAB.

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