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DC Shunt Motor Speed Control and analysis using Ziegler-Nichols Algorithm with PID Controller

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Abstract — In this paper, various speed control techniques for a dc shunt motor namely conventional method Using a PID controller and Ziegler-Nichols controller , speed control analysis of dc shunt by Ziegler-Nichols Controller have been discussed and a comparative analysis have been Without G.A and With G.A between them. The main objective of this paper is to minimize transient response specifications chosen as rise time, settling time and overshoot, for better speed response of DC shunt motor. The MATLAB SIMULINK models have been developed using Control System Toolbox and the comparative analysis is based on the speed responses obtained by simulation of the models. The goal is to determine which control strategy delivers better performance with respect to DC motor's speed.

Keywords— DC shunt motor, speed control, PID controller, and Ziegler-Nichols controller

I. INTRODUCTION

D.C. machine is a highly versatile energy conversion device. It can meet the demand of loads requiring high starting torques, high accelerating and decelerating torques. DC motors are controllable over a wide range with stable and linear characteristics. Therefore, they are the most common choice in the industries for both constant speed and constant load operation [1].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. The electric motors are perhaps the most widely used energy converters in the modern machine tools and robots. These motors require automatic control of their main parameters such as speed, position, acceleration etc. In this paper to control the speed of DC motor, their simplicity, ease of applications such as reliability and favorable cost have long been a backbone of industrial applications and it will 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 [2]. The past decades witnessed many advancing improvements keeping in mind the requirement of the end users. Several approaches have been documented in literatures for determining the PID parameters of such controllers which is first found by Ziegler- Nichols tuning [3,4],Proportional-Integral-Derivative "PID" controller, due to its simplicity, stability, and robustness, is a type of controller that is most widely applied [5], The fuzzy logic, unlike conventional logic system, is able to model inaccurate or imprecise models. The fuzzy logic approach offers a simpler, quicker and more reliable solution that is clear advantages over conventional techniques [6], Genetic algorithm [7], and PSO [8].
This paper presents the most common classical controller tuning method i.e. Ziegler-Nichols technique in short ZN which provides an effective starting point for controller tuning and compared with ZN-PID controller, without GA and with GA Controller. Minimizing of overshoot, minimizing of rise time and minimizing setting time.

II. THE BASIC INTRODUCTION OF DC SHUNT MOTOR

2.1 Introduction of DC Shunt Motor

Shunt DC Motors operate on direct current. As such, the field windings and armature are connected in a parallel combination, and in electrical terminology a parallel combination is known as a shunt. Shunt wound Motors is the most widely used as they have a linear characteristic of Voltage &

Torque. Shunt motor has more constant and controllable speed over various loads. This type of motor runs practically constant speed, regardless of the load. It is the type generally used in commercial practice and is usually recommended where starting conditions are not usually severs. Speed of the shunt-wound motors may be regulated in two ways: first, by inserting resistance in series with the armature, thus decreasing speed: and second, by inserting resistance in the field circuit, the speed will vary with each change in load: in the latter, the speeds are practically constant for any setting of the controller. A high-quality speed control system makes the DC motor suitable for the applications in which changeable speed variation, frequent starting, proper speed regulation, braking and reversing are required. The speed control of DC machines which used to be performed automatically has undergone a revolution as a result of advances in the power electronics area. The process of variable speed drives may be achieved by armature voltage control for speeds under the rated, or by field excitation variation for beyond rated speeds. DC motor speed can be adjusted to a large extent so as to provide simple to control and high performance [9, 10].

2.2 Modeling of DC shunt motor

DC shunt motors have the field coil in parallel (shunt) with the armature show in the fig 1. The current in the field coil and the armature are independent of one another. As a result, these motors have excellent speed control [11]. Hence DC shunt motors are typically used applications that require five or more horse power. The equations describing the dynamic behavior of the DC motor are given by the following equations;

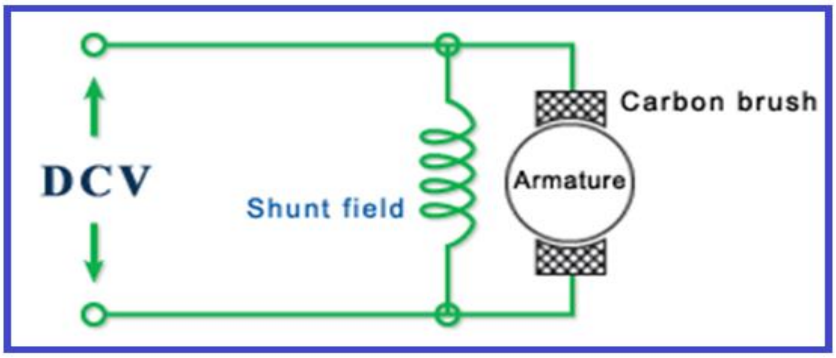

Fig 1. Model Of DC Shunt Motor

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

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

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

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

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

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

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

Where Va=armature voltage (V) ,Ra=armature resistance(ohm),La=armature inductance (H),Ia=armature current (A),Eb=back emf (V), ω= angular speed in rad/s, Bm = friction coefficient of the motor (in Nm/ (rad/sec)) , Jm = moment of inertia (in kg/m²) , Eb = back emf the motor (in volt) and torque constant K (v/rad/sec)

III. CONVENTIONAL PID TUNING CONTROLLER

A Proportional Integral Derivative controller widely used in industrial control system. The Proportional term responds instantaneously to the current error. The integral term responds to the accumulation of error providing a slow response that drives the steady state error towards zero. And derivative term responds to the rate at which the error is changing.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. Without knowing the complete knowledge of the process these types of controllers are the most efficient of choices. The three main parameters used are Proportional (P), Integral (I) and Derivative (D).PID controller show in the fig 2 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 [12-13].

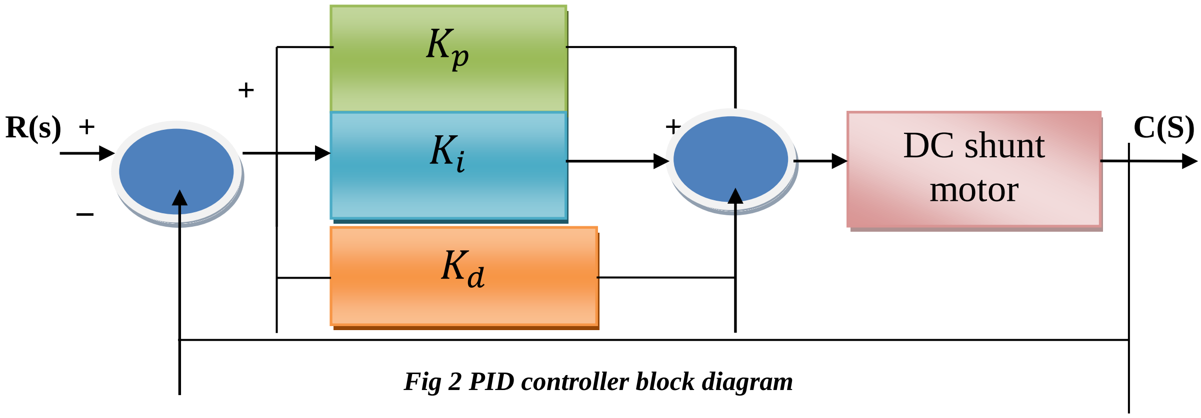

Fig 2 PID controller block diagram

$$P(t) = e(t)\,K_P + K_i \int_0^t e(t)\,dt + K_d \frac{de(t)}{dt} \ldots\ldots\ldots\ldots\ldots(8)$$

Equation (8) shows the output of the PID controller
Where e = Error signal, Kp = Proportional Constant,Ki= Integral Constant,Kd = Derivative Constant

IV. ZIEGLER-NICHOLS TUNING CONTROLLER

4.1 introduction of Ziegler-Nichols method

Over the 1940s, many methods have been developed for obtaining the P, I, D controller parameters. In this work the technical PI controller method is compared with the traditional technique Ziegler-Nichols PID controller. In 1942, Ziegler and Nichols proposed two experimental approaches to quickly adjust the controller parameters without knowing the precise dynamic model of the system to adjust. Both methods are empirical and based on tests. In this paper we use the second method of Ziegler-Nichols, it is a simple technique to tuning P, I, D controller parameters [4]. Ziegler and Nichols presented two methods, a step response method and a frequency response method [14]. The step response method is based on an open-loop step response test of the process, hence requiring the process to be stable.

4.2 Introduction of Control System Toolbox

Control System Toolbox provides industry-standard algorithms and apps for systematically analyzing, designing, and tuning linear control systems. You can specify your system as a transfer function, state-space, zero-pole-gain, or frequency-response model. Apps and functions, such as step response plot and Bode plot, let you visualize system behavior in time domain and frequency domain. You can tune compensator parameters using automatic PID controller tuning, Bode loop shaping, root locus method, LQR/LQG design, and other interactive and automated techniques – optimization based tuning ,PID tuning, internal model control tuning,LQG synthesis tuning and loop shaping tuning. You can validate your design by verifying rise time, overshoot, settling time, gain and phase margins, and other requirements.

In this session dc shunt model is completely designed in Control and Estimation Tools Manager. The test model below shown is completely designed in SISO tool shown in the fig 3 and select the block Simulink compensator design task and select the PID controller [15].

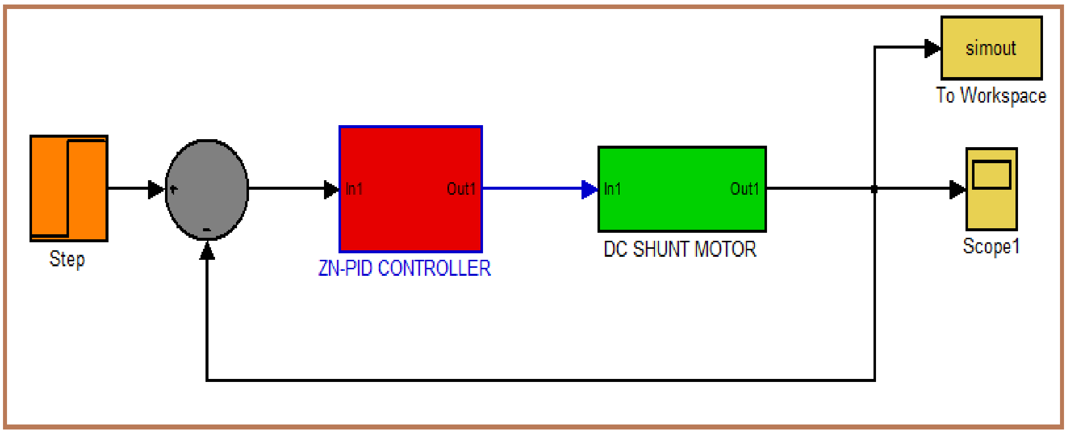

Fig 3 Simulink model of ZN controller with PID controller

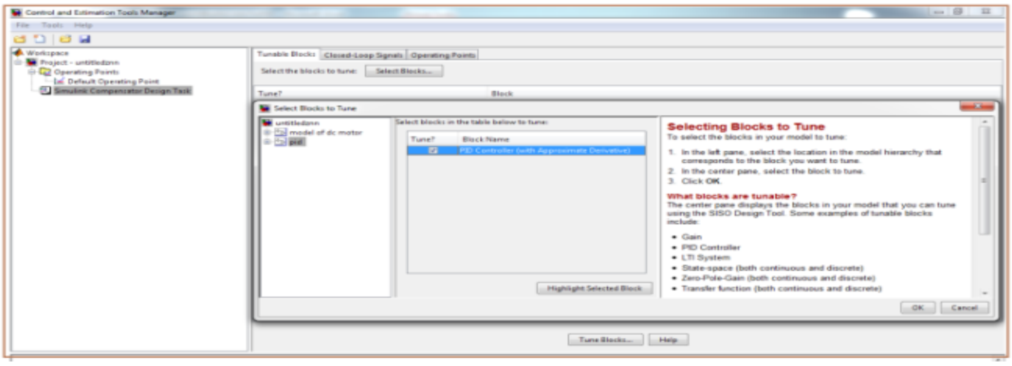

Fig 4 SISO tool

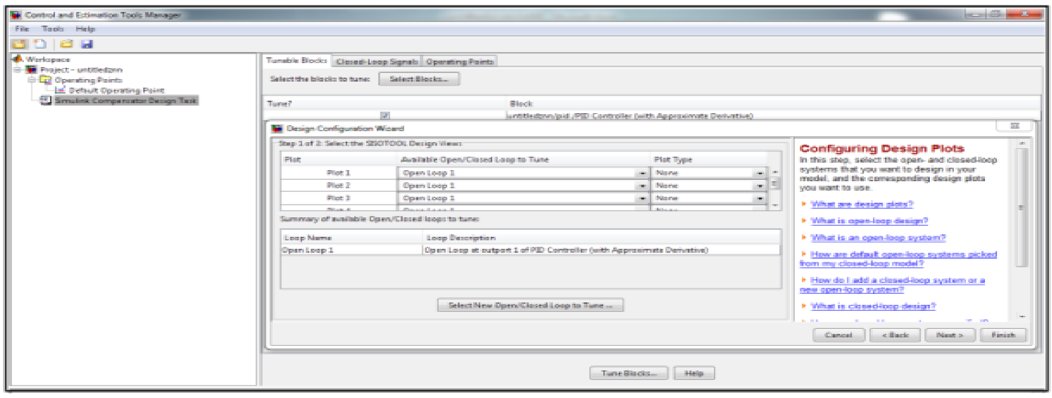

Fig 5 simulink compensator design task

next step show in new window SISO design task and select the automated tuning this is show in the fig 4 and fig 5 select the PID controller and update Ziegler-Nichols open loop show in the fig 6,fig 7vshow the step response of the system.

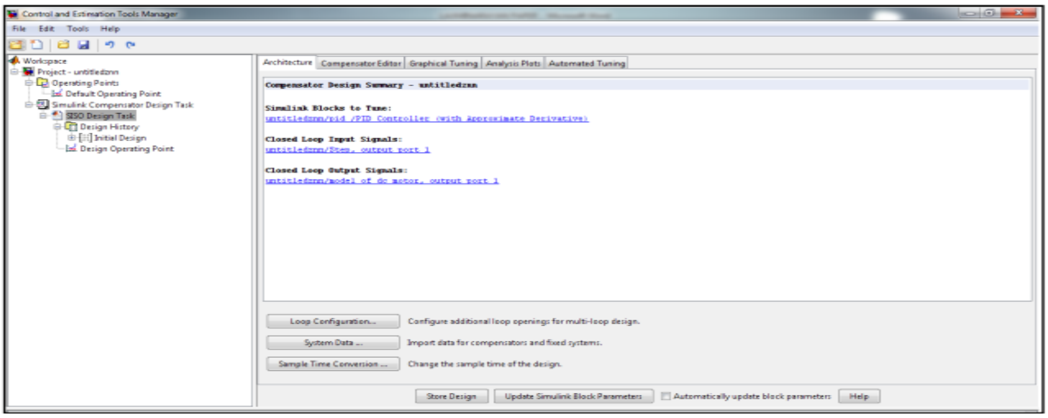

Fig 6 SISO design task windrow

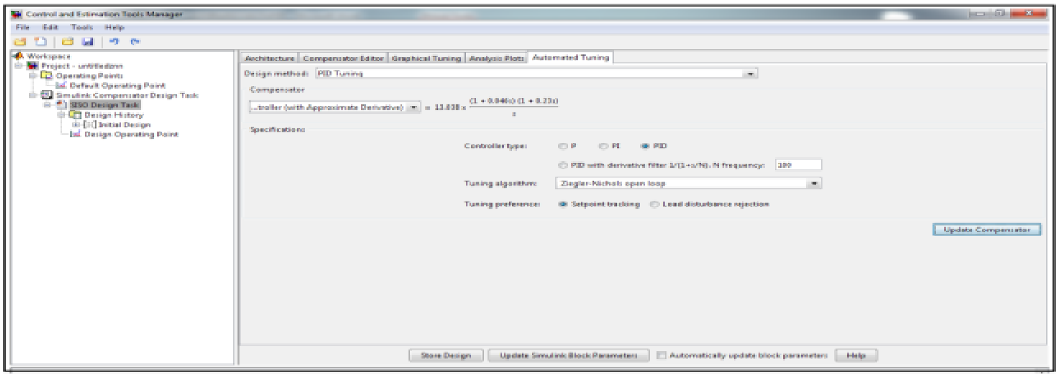

Fig 7 control estimation tools manager

V. SIMULINK RESULTS ANALYSIS

The performance and tuning using the Ziegler-Nichols (ZN) Tuning Controller has been compared with several controllers such as Without G.A and WITH G.A. data of dc shunt motor described below in the table 1 [12]. Ziegler-Nichols (ZN) Controller is also included with which we can see that Ziegler-Nichols (ZN) controller stabilizes the system faster.

Table 1 Parameters of DC shunt

S.NO	Parameters of DC Shunt motor	Symbol of DC shunt motor	Motor
1	Armature resistance	Ra	0.45 ohm
3	Armature inductance	La	0.035 (H)
4	Moment of inertia of motor	J	0.022Kg-m2/rad
5	Back emf constant	Kb	0.5 volt/(rad/sec),
6	Frictional constant of motor	B	0.2*10^-3N-/(rad/sec).

Case 1 Tuning of Proportional Integral Derivative (PID) Controller for DC shunt motor

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 and 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 other controller.

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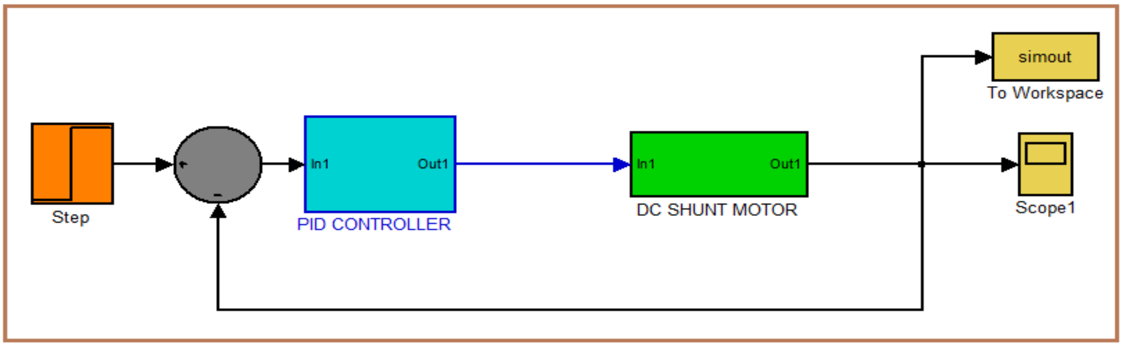

Fig 8 PID-MATLAB Simulink Model

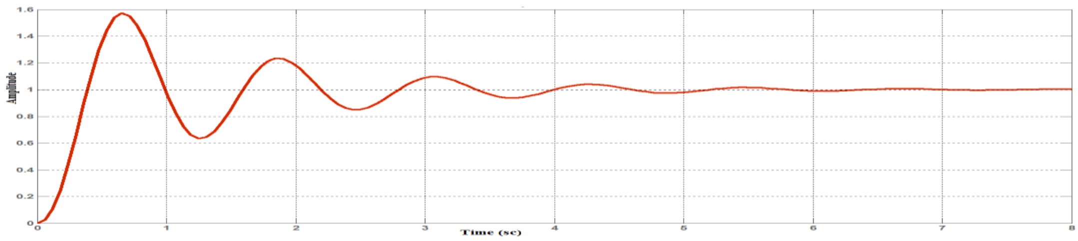

Fig 9 step response of PID controller

Table 2

PID parameters			Setting time (Ts)	Rise time (Tr)	Maximum Overshoot (%)
kp	**ki**	**kd**			
0.1603	4.384	**0.0004708**	5.01	0.246	57.3

Case 2 Tuning of ZN-PID controller for DC shunt motor

In this case tuning of Ziegler-Nichols Proportional Integral Derivative (ZN-PID) controller, MATLAB simulink model of DC shunt motor show in the fig 10. response of ZN-PID controller best response then other controller .It can be observed, that rise time, settling time and overshoots with the Tuning controller PID-Controller and Ziegler-Nichols Proportional Integral (ZN-PID) Tuning controller are much shorter time, the Ziegler-Nichols Proportional Integral Derivative controller provides better performance and better results than conventional PID controller, its show in the comparative table 3 and best graph show in the fig 11.

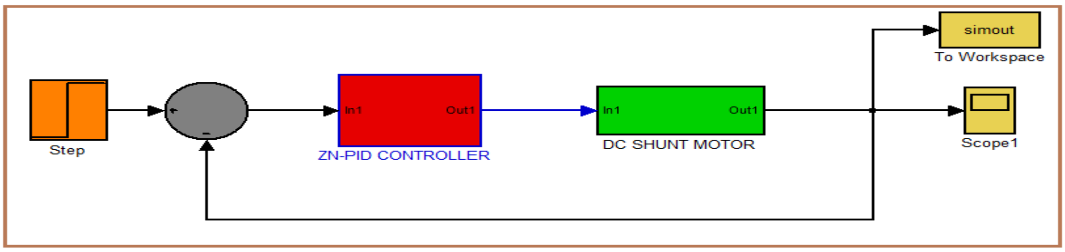

Fig 10 MATLAB simulink model of dc shunt motor

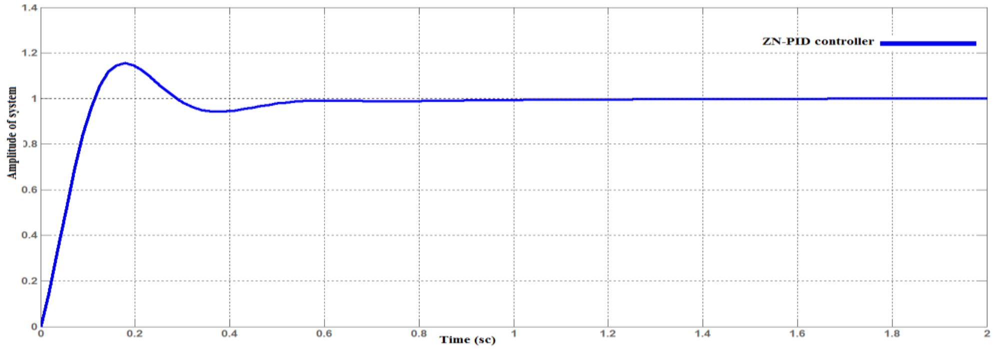

Fig 11 best graph of ZN-PID Controller

Table 3 result of ZN-PID Controller for DC Shunt motor

Technique	Rise time (Tr)	Setting time (Ts)	Maximum Overshoot (%)
ZN-PID Controller	0.086	0.509	15.4

CASE 3 Compare of ZN-PID Controller with Different controller

In this case Comparison of different techniques without Genetic Algorithm, with Genetic Algorithm, and Ziegler-Nichols Proportional Integral Derivative (ZN-PID) controller for speed control of dc shunt motor Hence a Ziegler-Nichols tuning techniques is better results, minimum rise time and minimum setting time, ZN based tuning methods have proved their excellence or better results by improving the steady state characteristics and performance indices. The output response shown in Fig. 12 and Table 4.

Table 4 comparison of without GA, with GA, and ZN-PID technique.

Different Techniques	Rise time (Tr)	Settling time (Ts)
Without GA	1.0603	8.66
With GA	0.3773	0.9433
ZN-PID Controller	**0.086**	**0.509**

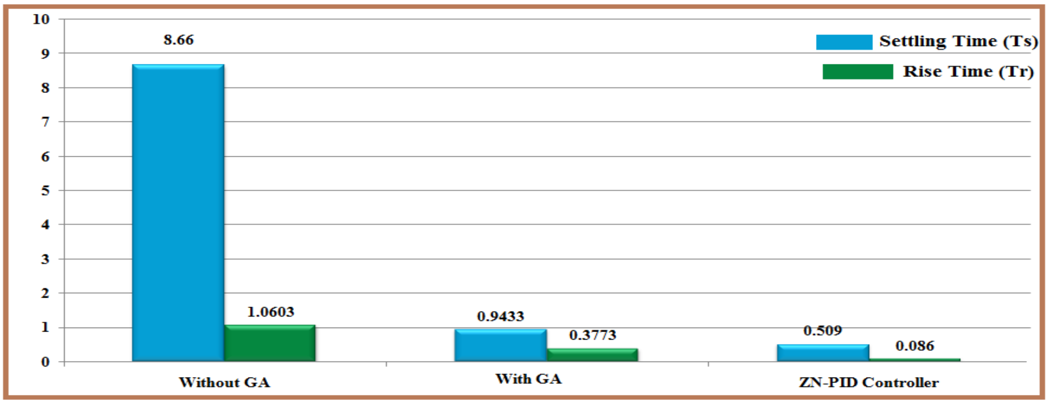

Fig 12 comparison of results without GA, with

VI. CONCLUSION

In this paper PID controller is tuned using Ziegler and Nichols technique to control the speed control of dc shunt motor. Our aim is to increase the dynamic performance of the system output like settling time, rise time and maximum overshoot. The simulation results are obtained using

MATLAB/SIMULINK. ZN-PID Controller response is compared with that of without Genetic Algorithm, with Genetic Algorithm controller. The results show that the overshoot, settling time, rise time and control performance has been improved greatly by using Ziegler-Nichols Proportional Integral Derivative (ZN-PID) controller.

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