MATLAB simulink based Speed Control of SEDC Motor using ZNPID controller

Laxmi narayan lodhi [1], Renu yadav[2], Rameshwar singh [3]

Abstract— **In this paper proposed a new study Ziegler-Nichols tuning based PID controller, it is used for the governing of speed of separately excited DC motor on various load condition. Many industries like paper mill, steel rolling mill etc. required very smooth and constant speed of operation of motor, since classical controller like PI and PID are fail to operate the system when load parameters are changed. Ziegler-Nichols -PID controller is given better speed control solution at such situation. Here we are discussed about PID controller and Ziegler-Nichols -PID controller. The simulation results obtained by Ziegler-Nichols -PID controller are better than the PID controller and fuzzy logic controller. The entire system is modeled using MATLAB 2009 control estimation toolbox.**

Index Terms— **DC motor, speed control, PID controller and Fuzzy logic controller, Ziegler-Nichols controller.**

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].Direct current (DC) motors have been widely used in many industrial applications such as electric vehicles, steel rolling mills, electric cranes, and robotic manipulators due to precise, wide, simple, and continuous control characteristics. Traditionally armature control method was widely used for the speed control of low power dc motors. However the controllability, cheapness, higher efficiency, and higher current carrying capabilities of static power converters brought a major change in the performance of electrical drives [2].Ziegler-Nichols presented a tuning formula, based on time response and experiences. Although it lacks selection of parameters and has an excessive overshoot in time response, still opens the way of tuning parameters. Modified Ziegler-Nichols tuning based on Chien-Hrones- Reswick (CHR) PID tuning formula [3] for set-point regulation accommodate the response speed and overshoot. Many varieties of control schemes such as proportional, integral, derivative, proportional plus integral (PI) [4], proportional plus integral plus derivative(PID) [5-6], Fuzzy Logic controller [7-8],ZN controller [9-10] has been developed for speed control of dc motors. The important aspect of the speed control of a dc motor is the armature voltage control method. By varying voltage to the armature of a dc motor, the speed of the motor can be varied. In this paper to control the speed of DC motor, separately excited DC drive system is used, since 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 given the desired performance. This paper presents the results of the ZN-PID controller using Matlab simulink model for speed control of SEDC Motor through ZN-PID controller for speed control is used to facilitate and efficiency the implementation of controllers [3].

Manuscript received July, 2014.

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II. SEDC Motor Modeling

SEDC Motor is most suitable for wide range speed control and is therefore used in many adjustable speed drives. DC motors are most suitable for wide range speed control and are therefore used in many adjustable speed drives [10-11].The term speed control stand for intentional speed variation carried out manually or automatically SEDC Motor is most suitable for wide range speed control and is there for many adjustable speed drives. In the modeling of SEDC Motor the basic aim is to convert circuit model into transfer function model. This is achieved by taking the Laplace of circuit equations i.e. converting into time domain. Hence both the electrical and mechanical time constants are required.

A. Physical System

Electric circuit of the armature and the free body diagram of the rotor of a SEDC Motor are shown in Figure1. The rotor and the shaft are assumed to be rigid. Consider the following values for the physical parameters show in the table 1 [11].

Table 1 Parameter values of SEDC motor

ISSN: 2278 – 7798

S.No.	Name of Parameter	Value
1	Armature resistance (Ra)	2 ohm
2	Armature inductance (La)	0.5 H
3	moment of inertia (J)	0.02 kg-m^2
4	Back EMF (Kb)	0.01 volts/rad
5	Frictional constant (B)	0.2 N-ms
6	Torque constant (Kt)	0.015 Nm/A

B. SEDC Motor Equivalent Circuit

In the fig 1 model of SEDC Motor, input is the armature voltage, Va, (driven by a voltage source). Measured variables are the angular velocity of the shaft (ω) in radians per second, and the shaft angle (θ) in radians.

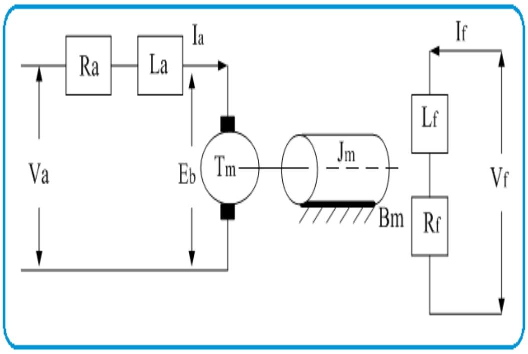

Fig 1model of SEDC Motor

C. *System Equations*

A linear model of a simple SEDC Motor consists of an electrical equation and mechanical equation. Using Kirchhoff's Voltage Law (KVL) and Newton's second law, the following equation is obtained:

$$\frac{d\,i_a}{dt} = -\frac{R_a}{L_a} i_a - \frac{K_b}{L_a}\omega + \frac{Va}{L_a} \qquad \textbf{(1)}$$

$$\frac{d\omega}{dt} = \frac{K_T}{J} i_a - \frac{Bm}{J}\omega \qquad \textbf{(2)}$$

Assuming the above equations, the steady state representation can be obtained as, fig 2 show the SEDC Motor armature control system.

$$\begin{bmatrix} \frac{di_a}{dt} \\ \frac{d\omega}{dt} \end{bmatrix} = \begin{bmatrix} \frac{-R_a}{L_a} & \frac{-K_b}{L_a} \\ \frac{K_T}{J} & \frac{-Bm}{J} \end{bmatrix} \begin{bmatrix} i_a \\ \omega \end{bmatrix} = \begin{bmatrix} \frac{1}{L_a} \\ 0 \end{bmatrix} [V_a] \qquad (3)$$

$$y = [0 \quad 1] \begin{bmatrix} i_a \\ \omega \end{bmatrix} \qquad \textbf{(4)}$$

The transfer function of the motor using the state space model by formula

$G(s) = C\,(s\,I - A)^{-1}\,B$

in the equation (3) and (4) and obtain the equation 5.

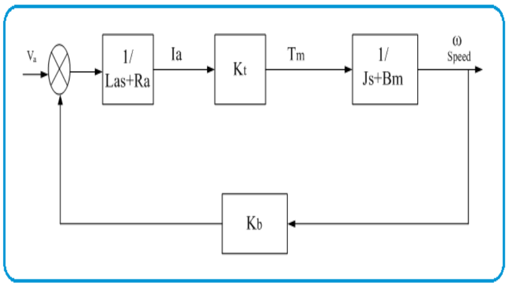

Fig 2- Block Diagram of SEDC Motor

$$G(s) = \frac{K_T}{(L_a * J)S^2 + S(R_a * J + L_a * B) + (R_a * B + K_b * K_T)} \qquad \textbf{(5)}$$

Show the transfer functions 5 and use SEDC Motor data in the equation 6.

$$G(s) = \frac{0.5}{0.0077\; S^2 + 0.09007S + 0.25018} \qquad (6)$$

III 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 motor 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.

A standard test model as considered is taken for study of DC motor with Z-N tuning controller. The test model below shown is completely designed in SISO tool. Fig. 3 shows the block diagram of SEDC motor driving an inertial load. The test model below shown is completely designed in SISO tool.

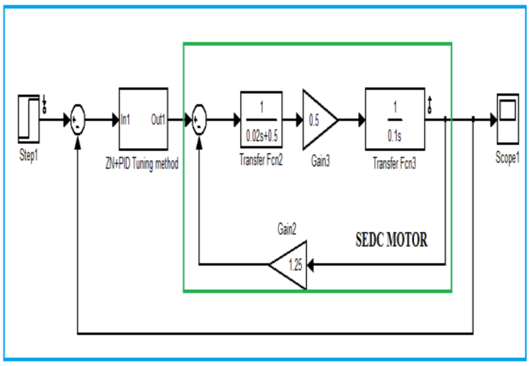

Fig 3 Simulink model of ZN –PID controller

ISSN: 2278 – 7798

IV. SIMULINK RESULTS

The results of the system with using different type of controllers are shown here. Such as PID, Fuzzy Logic Controller and Ziegler-Nichols (ZN) controller are being applied.

Test Case A: Proportional Integral Derivative (PID) Controller

PID-MATLAB simulink model show in the fig 4. Tuning of different values of PID controller such as KP, KI and KD, best results of (PID) controller show in the fig 5 and table 2, the PID controlled response of the system has considerably high overshoot and larger settling time values. Hence, an attempt is made to further improve the response of the system using Ziegler-Nichols controller.

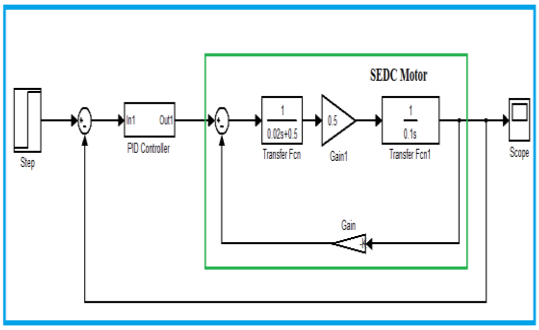

Fig 4 SEDC Motor with PID controller

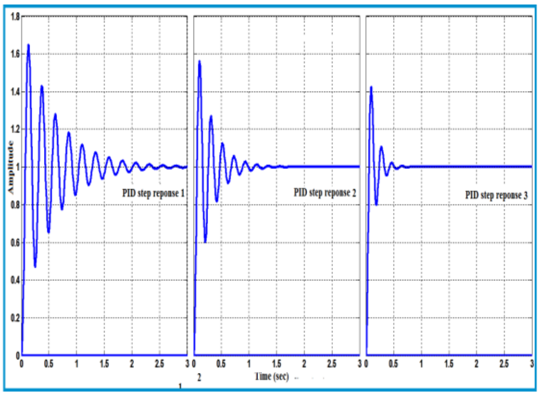

Fig 5 step response of PID controller

Table 2 Different tuning response of PID controller

PID Response	PID Step Response 1	PID Step Response 2	PID Step Response 3
overshoot	64.9	55.6	42.4
Rise time	0.0482	0.0412	0.0379
Settling time	2.08	0.96	0.481

Test Case B: Proposed Ziegler-Nichols PID controller

In this case tuning of Ziegler-Nichols Proportional Integral Derivative (ZN-PID) controller, MATLAB simulink model of DC shunt motor show in the fig 5.It can be observed, that rise time, settling time and overshoots with the Tuning controller 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 fig 7.

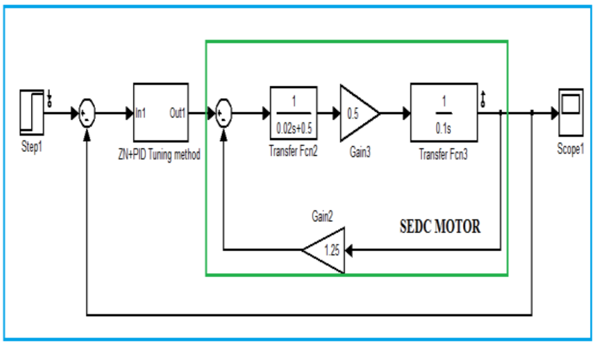

Fig 5 SEDC Motor with ZN-PID controller

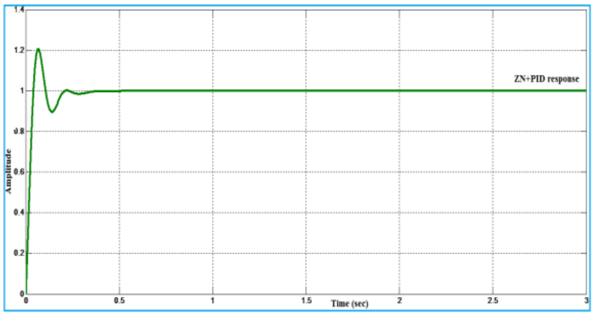

Fig 6 Step response of ZN-PID controller

Test Case C Compare of ZN-PID Controller with Different controller

In this case Comparison of different techniques PID Controller, Fuzzy logic controller and Ziegler-Nichols Proportional Integral Derivative (ZN-PID) controller for speed control of SEDC 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 Table 3.

Table 3 comparison of without GA, with GA, and ZN-PID technique

Controllers	PID tuning	Fuzzy logic	ZN-PID
Overshoot	34.51	4.1997	**20.5**
Rise time	0.0286	0.1240	**0.0413**
Settling time	1.3950	0.3405	**0.191**

CONCLUSION

In this paper, the tuning parameters of PID controller are designed using Ziegler-Nichols tuning controller. The results of all the three methods are checked by MATLAB simulink as well as coding. According to the results of the computer simulation, tuned controller Ziegler-Nichols efficiently is better than the PID and Fuzzy logic controller.

ISSN: 2278 – 7798

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ISSN: 2278 – 7798