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Design of PLC Based Speed Control of DC Motor Using PI Controller

Masood Nazir

Department of Electrical Engineering, National Institute of Technology, Srinagar, Jammu and Kashmir, 190006, India
Email: masoodnazir111@gmail.com

***Abstract*--**The purpose of this research is to analyze & implement PI control for a simple DC shunt motor. The control algorithm is realized using a Programmable Logic Controller. The complex motor system is composed of a DC motor, driver & a tachogenerator. The main objective is to achieve a satisfactory time response of the system output under external load acting. The PI controller is designed in the programming environment on a previously identified non-linear motor system. Then the PI controller is embedded in the Programmable Logic Controller. Finally the effectiveness of the controller is tested in both simulation mode & experiments.

***Keywords*--**Programmable Logic Controller; tachogenerator; PI controller.

I. INTRODUCTION

PI and PID controllers are the most common types of controllers used in the industry. This is evident from the fact that PI controller comprises of more than 97% of the regulatory controller. This is because PI controller helps in stabilizing the system by reducing the steady state error and peak overshoot. DC motors can be controlled easily as compared to AC motors & hence are preferred generally. Also because of the fact that motors have high power density and large torque to inertia ratio and high efficiency, they don't produce system response. Secondly, any alteration in load torque produces the corresponding change in the rotor speed. The aim of this paper is to regulate the motor speed that is independent of the system parameter using a PI controller based Programmable Logic Controller.

II. SYSTEM DESCRIPTION

The given system comprises of a Simatic S7-1200 PLC, a dc motor, a rectifier circuit & a tachogenerator.

The PLC consists of 2 input modules namely the main supply and feedback from the motor, and one output module namely the PWM output which goes to the Gate terminal of IGBT to control the duty cycle.

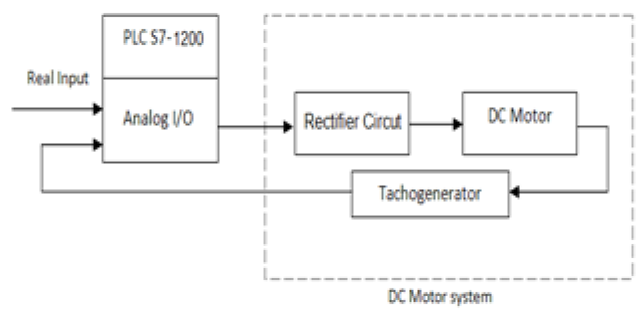

Figure 1: System block diagram.

III. LITERATURE REVIEW

The DC motor of specification 0.37kW, 230V, 1.8A, 1500 rpm is considered here for the experiment.

A) Calculating transfer function of the motor:

1. Calculating field resistance R_f

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TABLE 1: Field resistance & torque calculations.

I_f	V_f	Speed (rpm)	Speed (w)	R_f	$T = \frac{P}{w}$
0.35	110x2	990	103.67	628.57	0.5196
0.30	96x2	1040	109	640	0.4943
0.25	83x2	1130	118.3	664	0.4554
0.22	75x2	1168	122.3	681.8	0.4405

From experimental calculations, we have:

Back EMF, Eb=215.5, Power, Eb*Ia= 53.875.

2. Speed Test

TABLE 2: Speed test calculations.

Speed (rpm)	Speed (w)	Time (sec)
1515	158.65	0
0	0	3.35

$\left|\frac{d\omega}{dt}\right| = 47.35$, $J = \frac{A+f\omega}{\left|\frac{d\omega}{dt}\right|}$

Using the above equations, we get J=2.98. To calculate the transfer function, we use the formula given below:

$$\frac{\omega(s)}{V_f(s)} = \frac{K_{mf}/L_f}{\left(s+\frac{c}{J}\right)\left(s+\frac{R_f}{L_f}\right)} \qquad (1)$$

Thus the calculated transfer function is:

$$T(s) = \frac{8.9}{(4s+1)(0.165s+1)} \qquad (2)$$

B) Power Circuit:

The rectifier circuit is used to convert the AC to DC signal .The output of this circuit is approximately 220V DC. The components that have been used are heat sinks, diodes and 470µF capacitor that act as filter to remove ripples.

C) Programmable Logic Controller:

A Simatic S7-1200 has an impressive cohesive range of the technological functions with the added advantage of a compact design. It consists of the following modules:

a) 13 analog and digital signal modules.
b) 2 communication modules for communication via point to point connection.
c) Ethernet switch with 4 ports.
d) PS 1207 stabilized power supply units with a rated voltage of 24V DC.

IV. TUNING OF PI CONTROLLER

Direct Synthesis Method: This method is based on the process model and the desired closed loop transfer function. The advantage is that performance requirements are incorporated directly through the specification of closed loop transfer function. The closed loop transfer function is calculated from the below model.

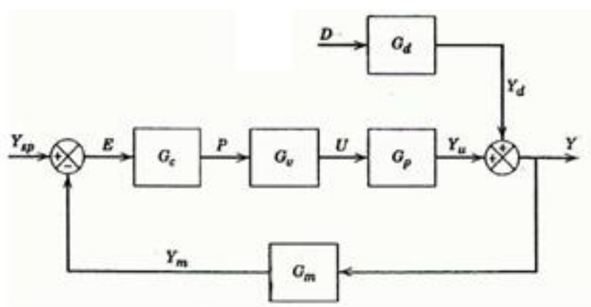

Figure 2: Standard feedback control system representation.

The closed loop transfer function is given as

$$\frac{Y}{Y_{sp}} = \frac{G_c G_v G_p}{1 + G_c G_v G_p G_m}$$

Put $G_V G_P = G$ Assume $G_m = 1$

Incorporating the above assumptions & using Taylor series expansion, we have

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$$G_c = \frac{1}{\tilde{G}} \frac{e^{-\theta s}}{(\tau_c + \theta) s}$$

For a Second Order Plus time Delay Model, We have

$$K_c = \frac{1}{K} \frac{\tau_1 + \tau_2}{\tau_c + \theta}, \quad \tau_I = \tau_1 + \tau_2, \quad \tau_D = \frac{\tau_1 \tau_2}{\tau_1 + \tau_2}$$

This gives,

K_C=0.936, T_I=4.165, T_D=0.158.

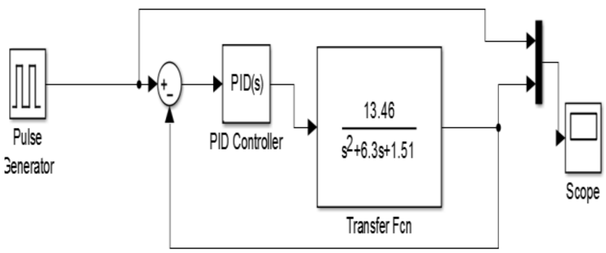

Figure 3: Simulation model in programming environment.

V. RESULTS

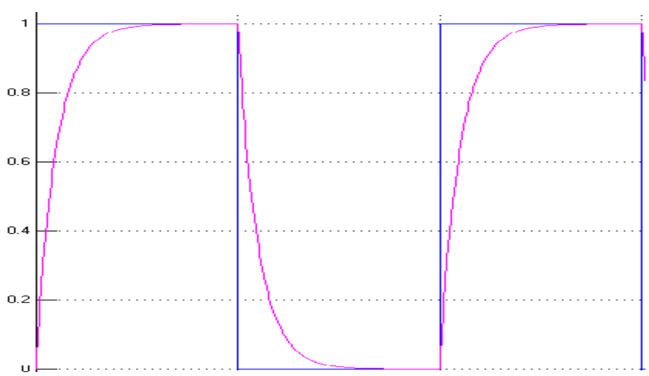

Figure 4: Time response to pulse signal simulation mode.

The tuning parameters of the PI controller computed from the direct synthesis method act as input to the PLC, which, in turn, gives a PWM signal to the gate terminal of the IGBT. From the experimental results, we know that the tacho generator reads 11V when the motor is running at 1200rpm. Consequently, when a set point of 11V (that acts as a feedback from the motor) is input to the PLC, the tachometer reads 1200rpm which vindicates our results.

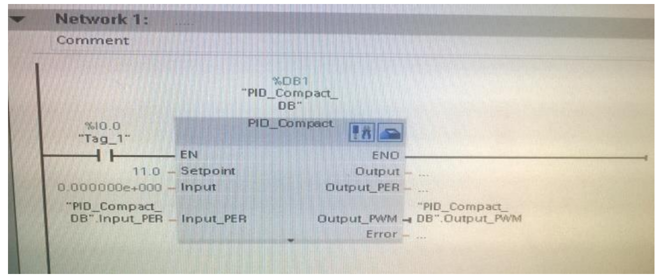

Figure 5: Ladder logic diagram.

VI. CONCLUSION

In this paper, a classical PI controller based Programmable Logic Controller is designed for regulating the speed of the dc motor. The system comprises of a dc motor, a tachogenerator and a power amplifier circuit. The performance of the PI controller is checked in simulation mode. In experiments, the PLC based PI controller is used which demonstrates the effectiveness for speed control of the DC motor.

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