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DC Motor Speed Control Using PID Controller Implementation by Simulink and Practical

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Abstract

In this research, speed control of DC motor (Terco Company) type is implementation by Matlab/Simulation and practical. A comparison is made by Simulink modeling circuit and practical connection. The results obtained from simulation are approximdtly similar to that obtained by practical. Also the dynamic behavior is studied.

Keywords: DC motor, PID controller, DC motor armature, DC motor speed response.

List of Symbols:

R_a:armature resistance (Ω).

L_a: armature self-inductance (H).

i_a: armature current (A).

i_f: field current (A).

E_b: armature back EMF(V).

V: applied voltage (V).

T: total torque developed by the motor (N.m).

θ_m: angular displacement of the motor shaft (rad).

J_m: equivalent moment of inertia of motor shaft & load referred to the motor (kg.m^2).

B_m: coefficient of friction of motor shaft & load referred to the motor (N.m/rad/s).

Φ: air gap flux (web).

K: proportional constant.

K_f: field constant.

K_a: motor armature constant.

K_T: motor torque constant (N. m/A).

K_b: feedback constant (V. s/rad).

K_m: motor gain constant (r. p. m/V).

T_m: motor tourqe(N. m).

ω: angular velocity (rad/s).

τ: motor time constant (sec).

P_t: peak time (sec).

R_t: Rise time (sec).

P. O. S: Maximum overshot (%).

e_{ss}: Steady − state error (sec).

P_m: Peak Amplitude of Velocity (rad/sec).

I. INTRODUCTION

DC motor have high liner control, retort concert and prime lofty torque [1]. The celerity of DC motor is depicated in equation (1).

$$N = \frac{V - I_a R_a}{K\Phi} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

The basal attribute of DC motor is that celerity of it can be adjusted by disparity its terminal voltage. Therefore, it has better than other kinds. A proportional-integral-derivative controller (PID) is broadly wield in industrial control systems. It is a common feedback element [2] .

II. PID CONTROLLER

In PID controller proportional (P) control can´t eliminates steady-state error only, this error can be abolishes by integral (I) control. The dervative (D) control action is to axing the amplitude [3]. The block diagram of control system is depicted in figure 1.

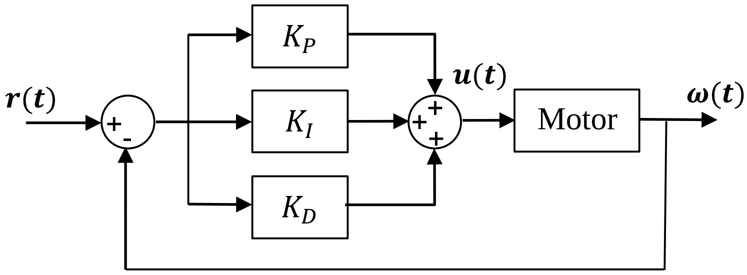

Figure 1. DC motor based PID controller.

$$u = K_p e + K_i \int edt + K_d \frac{de}{dt} \qquad \dots\dots\dots\dots(2)$$

III. DC MOTOR MATHEMATICS MODEL:

The equivalent circuit of separately excited DC motor is illustrated in figure below [4].

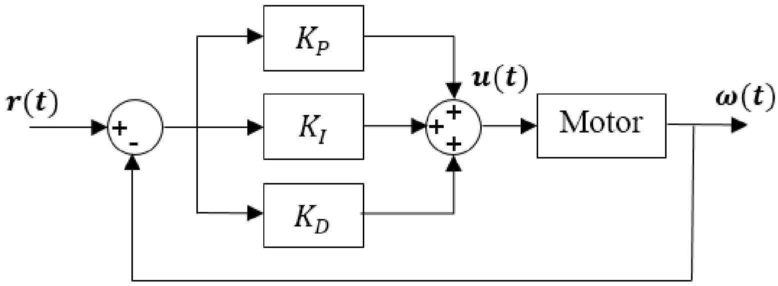

Figure 2. Equivalent circuit of DC motor.

The modeling of DC motor can be represented by:

$\Phi \propto i_f$

$$\Phi = K_f i_f \qquad \dots\dots\dots\dots(3)$$

Where,

$T \propto \Phi \; i_a$

$T = K_a \Phi \; i_a T = K_a K_f \;\; \Phi \; i_a$

$$T = K i_a \qquad \dots\dots\dots\dots(4)$$

The generated back E.M.F.:

$$E_b \propto \Phi \ \omega$$

$$E_b = K_b \ \omega$$

$$E_b = K_b \frac{d\theta}{dt} \qquad \dots\dots\dots\dots (5)$$

By applying Kirchhoff Law:

$$V = R_a i_a + L_a \frac{di_a}{dt} + E_b \qquad \dots\dots\dots\dots (6)$$

And

$$T = J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt} \qquad \dots\dots\dots\dots (7)$$

Where,

load torque

$$T = J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt} + T_L \qquad \dots\dots\dots\dots (8)$$

Taking Laplace transform:

$$T(s) = K i_a (s)$$

$$E_b(s) = K_b \ S \ \theta(s)$$

$$V(s) = i_a(s)(R_a + sL_a) + E_b$$

$$V(s) - E_b(s) = i_a(s)(R_a + sL_a)$$

$$T(s) = (Js^2 + sB) \ \theta(s)$$

$$T(s) = (Js + B)s \ \theta(s)$$

or

$$T(s) = (Js + B)\omega(s)$$

$$T(s) = K i_a \ I(s)$$

From above equations the block diagram of DC motor armature control is depicated in figure(3) [5].

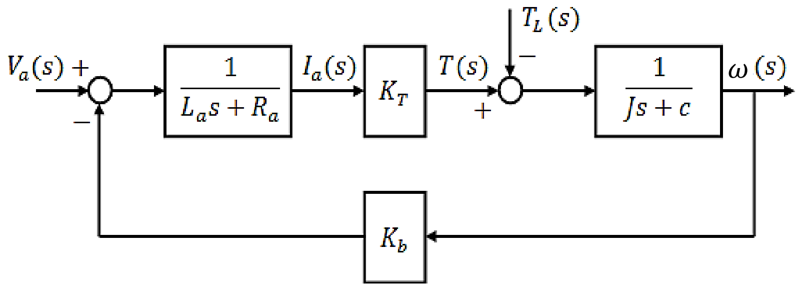

Figure 3. Block diagram of DC motor armature control.

The transfer function of DC motor given by:

$$T(s) = \frac{\omega(s)}{V(s)} = \frac{K_T}{(R_a + sL_a)(Js + B) + K_b K_T} \quad \ldots\ldots\ldots\ldots (9)$$

And

$$\mathrm{T(s)} = \frac{\omega(s)}{V(s)} = \frac{Km}{\tau s + 1} \quad \ldots\ldots\ldots\ldots (10)$$

Where,

$$K_m = \frac{K_T}{R_a B + K_b K_T}$$

and

$$\tau = \frac{R_a J}{R_a B + K_b K_T}$$

IV. MATLAB REPRESENTATION AND SYSTEM RESPONSE:

The circuit diagram of DC motor speed control based PID controller is shown in figure 4.

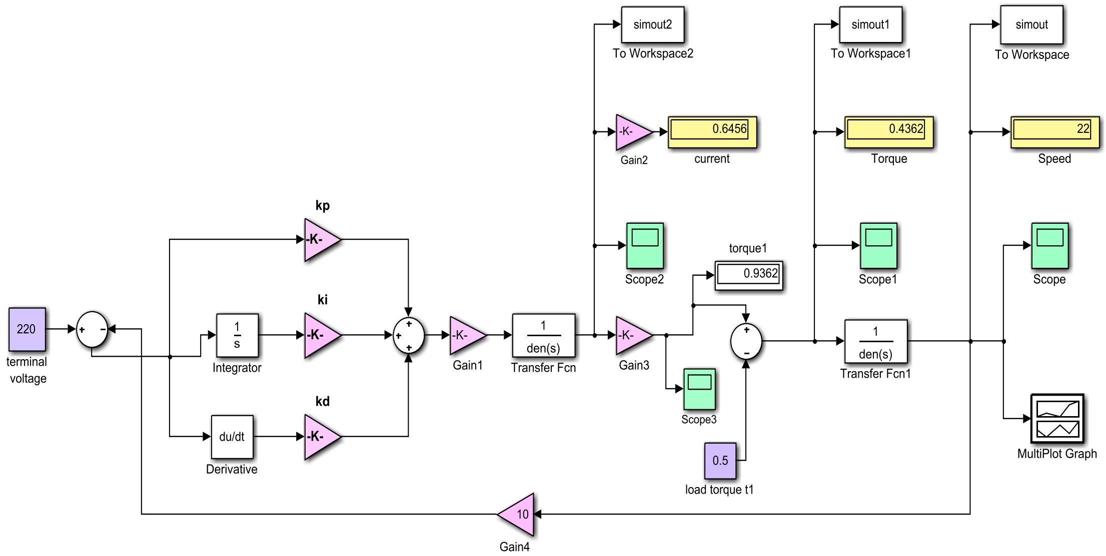

Figure 4. Modeling of DC motor control system.

V. OPEN LOOP CHARACTERISTICS:

The speed response of DC motor is drawn for a bove circuit [see Fig.4] by remove the feedback element and the dynamic behavior of this response is calculated[6].

The specification of Terco DC motor is shown in table 1.

Table 1. Specification of Terco DC motor.

Parameters	Values and units
R_a	0.25 Ω
L_a	60.81 mH
J_m	0.012 Kg.m^2
B_m	0.0204 N.m.s/rad
K_b	10 V.s/rad
Rated speed	1500 r.p.m

The open loop characteristics of voltage-speed and torque-speed relationship are shown in table 2 and 3.

Table 2. Voltage-speed characteristic.

Voltage(V)	Speed(rad/sec)
100	3.92
120	9.60
140	15.29
160	20.98
180	26.67
200	32.35
220	38.04

Table 3. Torque-speed characteristic.

Load Torque (N.m)	Speed(rad/sec)
0.1	57.65
0.2	52.75
0.3	47.84
0.4	42.94
0.5	38.04
0.6	33.14
0.7	28.24

The relationship between voltage-speed and torque-speed is shown in figures 5 and 6 respectively.

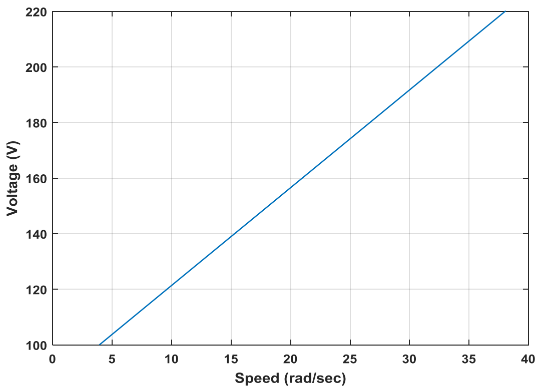

Figure 5. Voltage-speed curve.

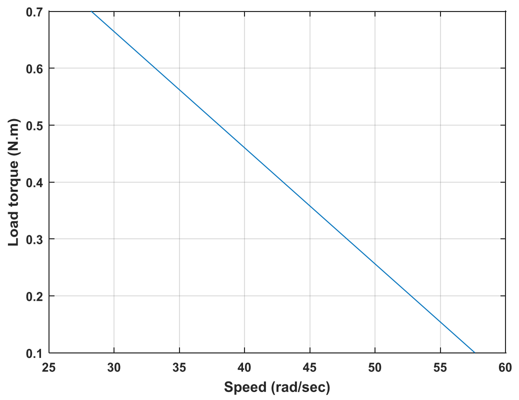

Figure 6. Torque-speed curve.

The speed response with respect to time that achieved by (Ziegler method) is shown in figure.7.

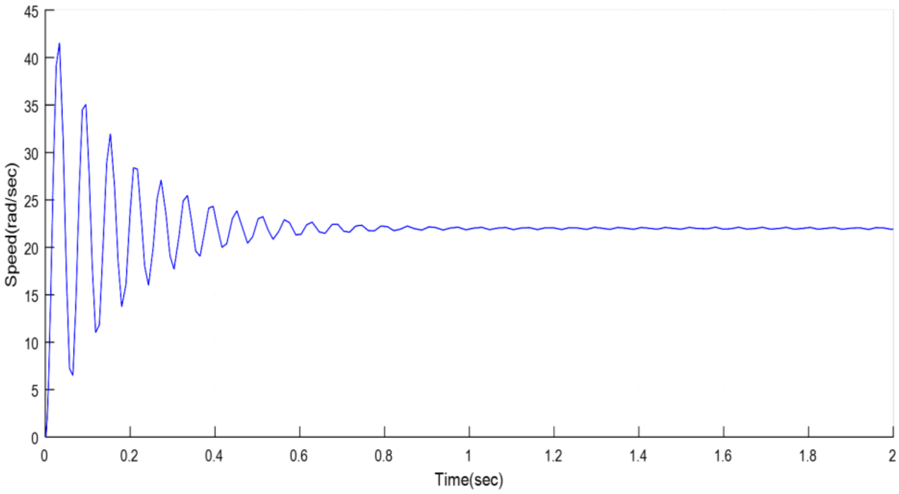

Figure 7. Speed response with time based Ziegler method.

The transient performance of speed response is shown in table 4.

Table 4. Dynamic behavior of speed response.

P_t (sec)	t_r (sec)	P.O.S (%)	e_{ss} (sec)	P_m (rad/sec)
0.0338	0.00188	84.72	0.4598	41.5642

VI. CLOSED LOOP CHARACTERISTICS:

PID constants make an improvement on the speed reponse curves. This ameliorate can be seen it as depicated in figure 8.

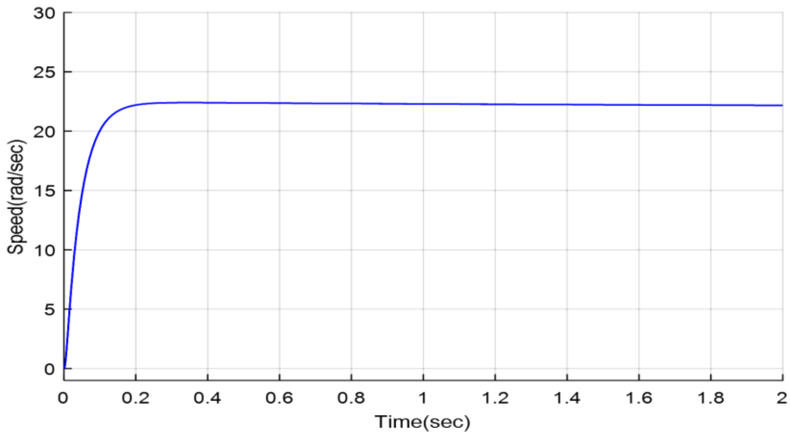

Figure 8. Improvement speed response with time

$(K_p = 0.23, K_i = 0.12, K_D = 0.01)$.

The transient performance of speed response of above figure is shown in table 5.

Table 5. Improvement dynamic behavior of speed response.

P_t (sec)	t_r (sec)	P.O.S (%)	e_{ss} (sec)	P_m (rad/sec)
0.323	0.093	1.818	0.131	22.4

VII. PRACTICAL RESULTS

The experiment voltage – speed and torque – speed relationship is implementation practically on Terco DC motor as shown in figure 9.

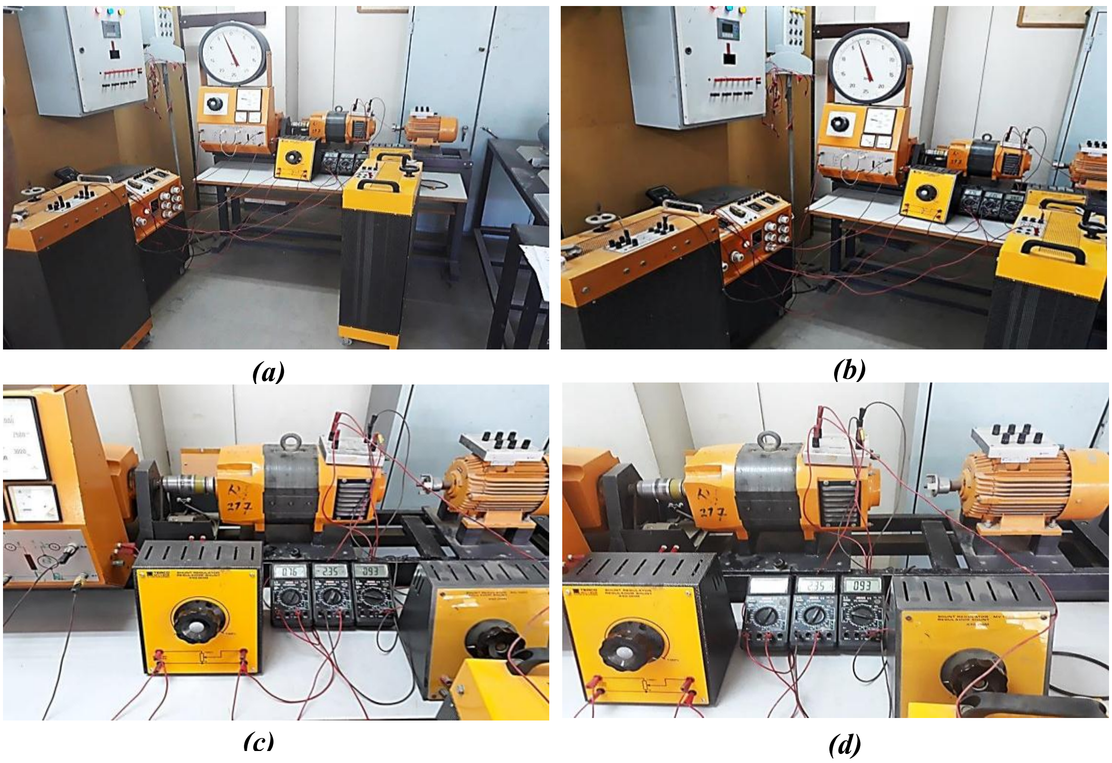

Figure 9 (*a, b, c, d*). Terco set connection.

The practical readings of voltage-speed and torque-speed are shown in table 6 and 7 respectively.

Table 6. Voltage-speed.

Voltage (V)	Speed (rad/sec)
100	3.6
120	9.1
140	14.8
160	19.5
180	26.1
190	30.3
200	37.21

Table 7. Torque-speed.

Load Torque (N.m)	Speed (rad/sec)
0.1	57.21
0.2	51
0.3	46.8
0.4	40.8
0.5	37.23
0.6	31.1
0.7	27.21

The experimental relationship between voltage-speed and torque-speed characteristics is shown in figures 10 and 11.

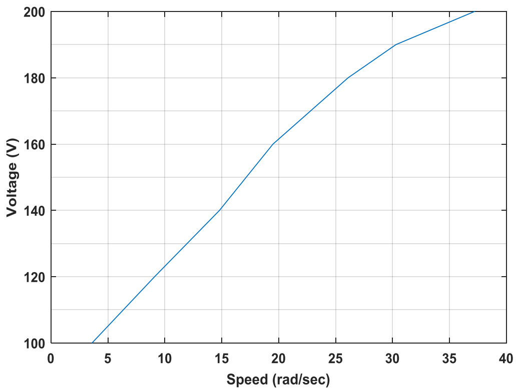

Figure 10. Experiment voltage-speed curve.

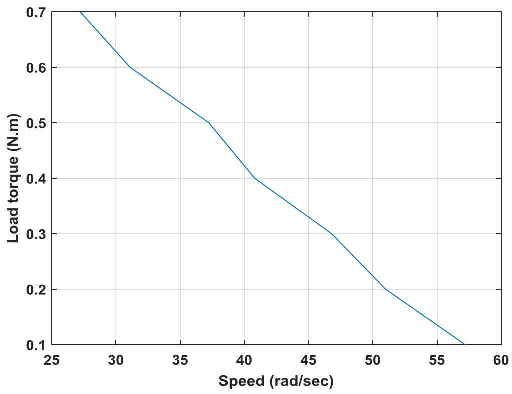

Figure 11. Experiment torque-speed curve.

VIII. CONCLUSION

- The output performance that obtained by normalized value in PID is very close and near to accuracy.
- The affect of (K_P, K_I, K_D) constants on speed response is appears verged as mentioned in PID controller paragraph.

- The dynamic behavior of speed response is more enhancements as compared with that of Ziegler method.
- The results that obtained from practical are approximately similar to that obtained from Simulation.

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