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Minimization of Temperature Parameter Variation Effect on DC Motor Using PID controller

Musaab Ali mohammed Sidahmed[1]
PG student
Control Engineering Department, Faculty of Engineering
AL Neelain University
Khartoum – Sudan

Muawia Mohamed Ahmed Mahmoud[2]
Associate Professor
Control Engineering
AL Neelain University
Khartoum – Sudan

Abstract: This paper shows how the temperature effect on DC motor characteristics could be minimized by using PID controller. The effect of adding this controller was proven by plotting the step responses of the plant with and without the PID controller. Results have shown that the PID controller minimizes the effect of the transfer function deviation.

Keywords: DC motor; parameter variation; performance; motor characteristics; PID controller.

I. Introduction

DC motor is used extensively in adjustable-speed drives and position control applications. Their speeds below the base speed can be controlled by armature-voltage control. Speeds above the base speed are obtained by field-flux control. As speed control method for DC motors are preferred where wide speed range control is required.[4] Designing a control system based on the theoretical plant dynamics usually will not satisfy the required performance.

II. Effect of Temperature on DC Motor

Once a motor design is finalized including motor dimensions, magnetic circuit, and motor winding configuration, several characteristics that define motor performance become "theoretically" fixed; the torque constant (K_T), voltage constant (K_E), and motor terminal resistance (R_{mt}). These three values will determine the output torque, motor speed; however this three value will change as temperature change and directly resulting in motor performance[1]. The variation of parameters caused by changing in temperature shown table 1.

TABLE 1 Variation of Parameters Caused by Changing in Temperature

Description	Symbol	@25°C	@125°C
Terminal Resistance	R_{mt}	0.59 Ω	0.83Ω
Voltage Constant	K_E	0.071 V/(rad/s)	0.057 V/(rad/s)
Torque Constant	K_T	0.071 Nm/A	0.057 V/(rad/s)

Evaluating the transfer function for dc motor from input mature voltage$v_a(s)$, to the output rotational speed in (rad/sec)$\omega(s)$,will be easy from Fig 1.

Transfer function of DC motor

$$\frac{\omega(s)}{V_{a(S)}} = \frac{K_t}{L_a*J_m s^2+(R_a*J_m+L_a*B_m)*s+(R_a*B_m+K_{b*K_t})} \quad (1)$$

Where

v_a Armature voltage (V)

R_a	Armature resistance	(Ω)
I_a	Armature current	(A)
L_a	Armature inductance	(H)
e_b	Back emf	(v)
W	angular speed	(rad/s)
T_m	Motor torque	(Nm/A)
J_m	Motor inertia	(kgm^2)
B_m	Viscous fraction constant	(Nms/rad)
K_t	Torque constant	(Nm/A)
K_b	Back emf constant	(vs/rad)

Substitute the parameters from table into transfer function for two different temperature

Transfer function at temperature 25°C

$$gf_1 = \frac{0.071}{0.005s^2+0.0559s+0.064} \quad (2)$$

Transfer function at temperature 125°C

$$gf_2 = \frac{0.057}{0.005s^2+0.0583s+0.086} \quad (3)$$

As the temperature change the performance of DC motor will also change as its shown Fig 2.

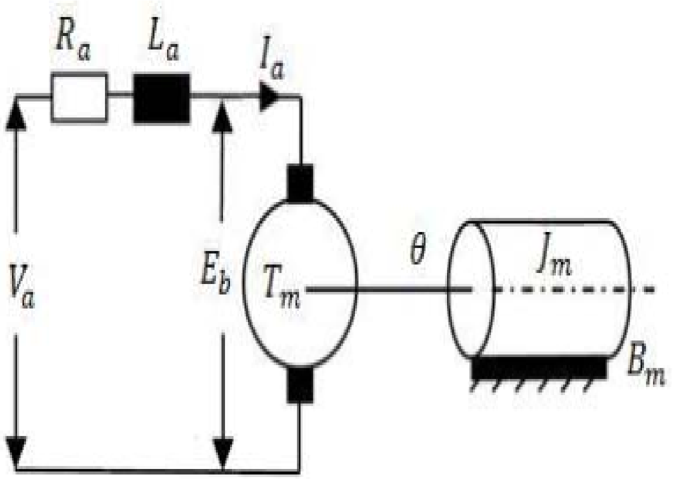

Fig 1. DC motor modeling

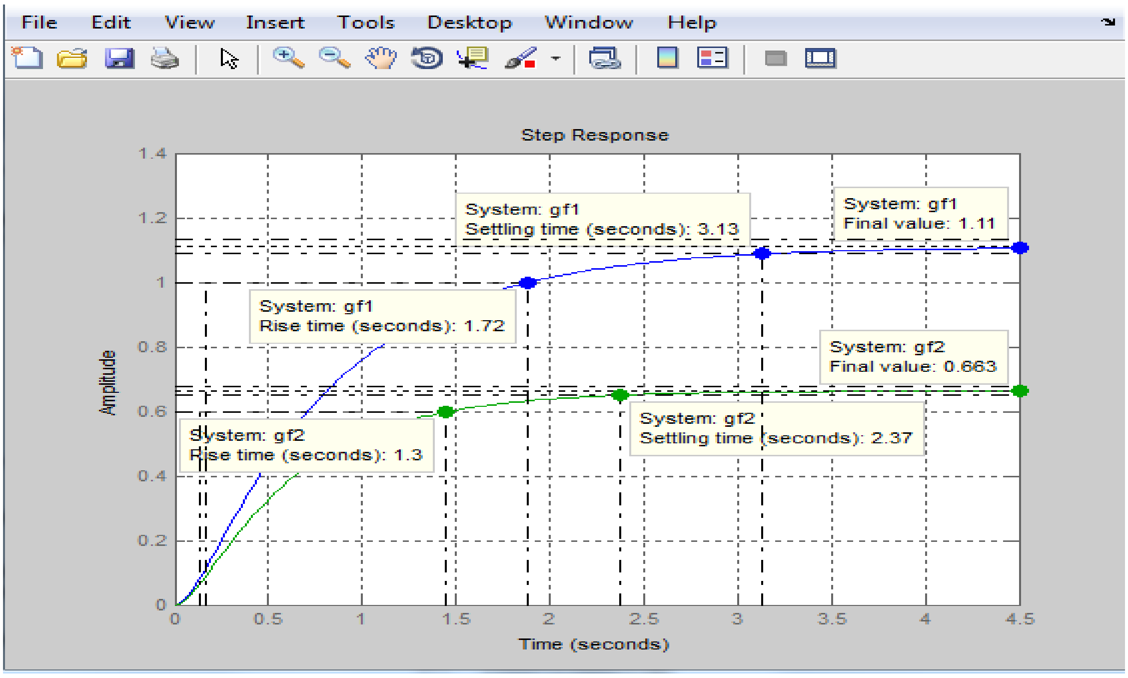

Fig 2. Step response for two transfer function gf_1&gf_2

III. Minimize of the Effect of Temperature using PID Controller

Introducing PID controller to minimize the effect of temperature on DC motor is acceptable. PID controller tracks the error, the difference between the desired input value and the output actual output value . PID controller receives the error signal, and then computes the derivative and the integral of this error signal. The control signal to the plant is equal to the proportional gain times the magnitude of the error plus the integral gain times the integral of the error plus the derivative gain times the derivative of the error. [2]

Taking Laplace transform of equation (4) to find the transfer function for PID controller

$$K_P + \frac{K_s}{s} + K_d \text{ s} = \frac{K_d S^2 + K_p s + k_i}{s} \quad (4)$$

Estimated parameter for PID controller

$K_I = 11$

$K_p = 8$

$K_d = 0.5$

Transfer function for PID controller as

$$Tf_{PID} = \frac{0.5S^2 + 8s + 11}{s} \quad (5)$$

PID controlled system for both systems at temperature 25°C & 125°C

At temperature 25 the transfer function controlled system will be as

$$\frac{\omega(s)}{V_{a(S)}} = \frac{0.0355s^2 + 0.568s + 0.781}{0.005s^3 + 0.0914s^2 + 0.632s + 0.781} \quad (6)$$

At temperature 125 the transfer function controlled system will be as

$$\frac{\omega(s)}{V_{a(S)}} = \frac{0.0285s^2+0.456s+0.627}{0.005s^3+0.0868s^2+0.542s+0.627} \quad (7)$$

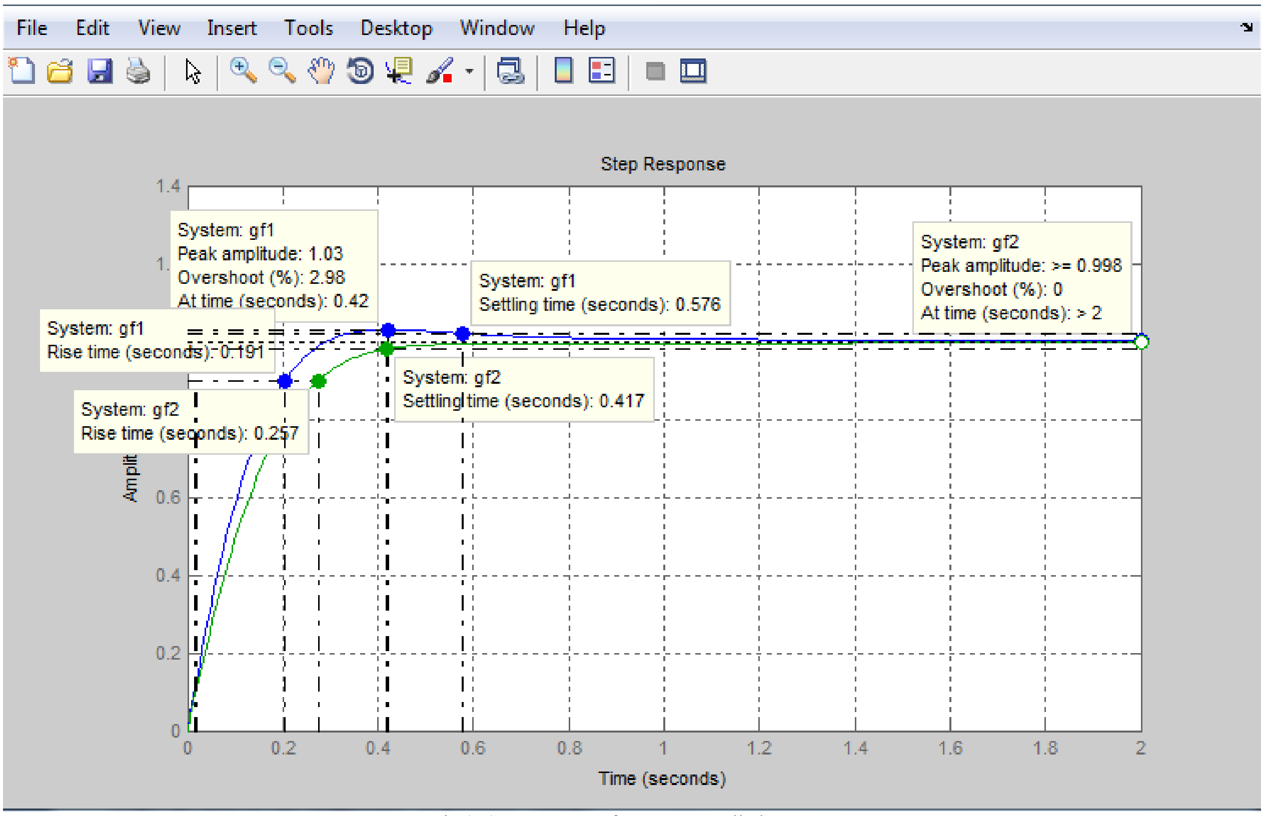

Fig 3. Step response for two controlled system

IV. RESULTS

Due to change in temperature a deviation in the transfer function occurs. When temperature increases the value of rise time, settling time, and peak amplitude decrease. After introducing PID controller to minimize the effect of temperature it become clear that as it shown on table1 the deviation tends to be small.

TABLE 2. Characteristics of step response before and after adding the PID controller

Controlled System at Temperature (°C)	**Rise Time (s)**		**Settling Time (s)**		**Peak AMP& Overshoot**	
	Without PID	**With PID**	**Without PID**	**With PID**	**Without PID**	**With PID**
25	1.72	0.191	3.13	0.579	1.11	Peak amp>= 1.03 Overshoot(%):2.98
125	1.3	0.257	2.37	0.417	0.663	Peak amp> 0.998 Overshoot(%):0

V. CONCLUSION

At an elevated DC motor temperature, characteristics of motor would no longer be fixed, which lead to variation in parameters and directly effect on DC motor performance PID controller used to minimize this variation on parameters has shown that the error produced by the deviation was minimized effectively.

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