Comparison Between PID and SMC Controller to Control the Speed of DC Separately Excited Motor

Prakansha Sulakhe, V. P. Rajderkar, and Tushar Guhe

Abstract The purpose of this study is to use an SMC controller to build a speed control scheme for an independently stimulated DC motor. The speed control system is created first, after which it is applied to the model in MATLAB SIMULINK. Following that, we used SMC to gauge the DC motor's speed. The results of the simulation show that a sliding mode controller is the best option for managing the speed of a DC motor as compared when with PID. The SMC's immunity to interruptions allows it to perfectly match the intended pace.

Keywords SMC controller · PI controller · DC separately excited motor · Speed control

1 Introduction

There is a lot of work being put into the control of discontinuous control actions because managing nonlinear systems has always been a significant problem for the study of control systems and automated control theory. In the industrial world, there are quite a few applications for direct current (DC) motors. Changes in armature current are required to alter the variable resistance in the armature circuit or field circuit. A typical speed control system of the motor characteristics is used to regulate the DC motor mentioned above. In order to keep the system stable and create the required system responses, a suitable control should be designed when there are systemic upheavals and uncertainty. So-called "matched uncertainties," as well as other outside uncertainties and disturbances, have no effect on sliding mode control

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R. N. Shaw et al. (eds.), *Innovations in Electrical and Electronic Engineering*, Lecture Notes in Electrical Engineering 1109, https://doi.org/10.1007/978-981-99-8289-9_25

(SMC). Real-time processing capability has improved thanks to quick processor advancements, making it possible to digitally apply cutting-edge control methods that were previously only feasible in principle. Other difficulties include modifying traditional controllers, which in SMC design is not at all difficult. The distinguishing characteristics of SMC enable its practical application in the management of electrical drives. Strong resilience, ease of implementation, order reduction, and disturbance rejection are some of these characteristics. Following is a summary of the main benefits of the SLMC technique: dynamic reaction time simple to implement and simple-to-design resilience, low sensitivity to changes in system characteristics and load obstacles. To ensure the requisite performance, a precise understanding of the motor characteristics is important. While the drive is running, a number of parameters are unknown with certainty and/or are liable to change, which lowers performance. The SMC is an obvious alternative to avoid this design issue. In actuality, it is created from the ground up to regulate system uncertainties, and it may even deliver appropriate performance in the presence of considerable and quick changes in the motor characteristics and a wide range of disturbances.

Since a long time ago, PI controllers are typically utilized for speed control. However, PI controllers cannot completely stabilize the speed when there are problems with modelling uncertainties, parameter fluctuations, load disturbances, or severe nonlinearity. In these circumstances, where speed control is a major issue, SMC can be employed successfully. SMC is utilized in the suggested strategy to develop the controller and ensure reliable functioning.

2 Model of DC Separately Excited DC Motor

Using amplifiers or power modules, commonly known as DC motor drives, a controller and a DC motor are coupled. The controller's step and direction inputs are converted by them into currents and voltages that work with motors. Robotic and electrical machinery typically employ DC motors. In the light of how important it is to control the DC motor's speed.

2.1 Armature Control

The rear emf or E_b has a direct impact on the speed of the DC motor. This demonstrates that speed and armature current I_a are directly related when the supply voltage V and armature resistance R_a are both constant. Figure 1 depicts the DC Motor Correspondence Circuit. Dc motors are frequently employed in the magnetization curve's linear region. One method is to use armature resistance, which involves adding a variable resistance to the armature's circuit. The voltage drop across the armature is lower than the voltage across the line after it has been raised because of the circuit's increased resistance. The armature circuit consists of an inductor (L_a), a resistor (R_a),

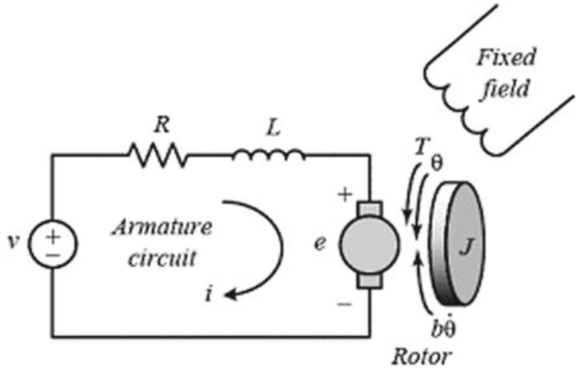

Fig. 1 DC motor circuit diagram

Table 1 Specification of DC motor

Parameters	Values and unit
Resistance (R_a)	00.6 Ω
Inductance (L_a)	00.012 H
Moment of inertia of rotor (J)	1.67 kg m^2/s^2
Electromotive force const. (K_t)	3.0 Nm/A
Back EMF const. (K_b)	3.0 Vs/rad
b	1.67

and a voltage source (e_b). Table 1 displays the nominal rating of the DC motor drive utilized in this.

Consequently, the field current is proportional to the air gap flux.

$$\Phi = f(x) = K_f i_f \tag{1}$$

where K_f is a const. or fixed value.

As a result of the armature current and air gap flux, the motor's torque T_m is proportional to that product.

$$T_m = K_f K_1 i_f i_a \tag{2}$$

where K_1 is a const. or fixed value.

The field current in the armature-controlled DC motor is maintained constant,

$$T_m = K_T i_a \tag{3}$$

K_T, the motor torque const., is used here.

Given as follows, the relationship between the motor back emf and speed is

$$e_b = K_b \frac{\mathrm{d}\dot{\theta}}{\mathrm{d}t} \tag{4}$$

K_b is used here. It follows that the armature circuit's differential equation is

$$L_a \frac{\mathrm{d}_{ia}}{\mathrm{d}_t} + R_a i_a + e_b = e_a \tag{5}$$

Equation for torque is

$$J \frac{\mathrm{d}^2\theta}{\mathrm{d}t^2} + f_0 \frac{\mathrm{d}\theta}{\mathrm{d}t} = T_m = K_T i_a \tag{6}$$

If we apply the Laplace transforms to Eqs. (3) through (5) and assume that the initial conditions are zero, we obtain

$$E_b(s) = E_b s\theta(s) \tag{7}$$

$$(L_a s + R_a)I_a(s) = E_a(s) - E_b(s) \tag{8}$$

$$\left(Js^2 + f_0 s\right)\theta(s) = T_M(s) = K_T I_a(s) \tag{9}$$

From Eqs. (6)–(8) we obtained as following transfer function

$$G(s) = \frac{\theta(s)}{E_a(s)} = \frac{K_T}{s[(R_a + sL_a)(J_s + f_0) + K_T K_b]} \tag{10}$$

2.2 Sliding Mode Control

To adjust a DC motor's speed via sliding mode control, the motor must be constructed in a way that allows us to input the signal deriving from the sliding mode control that was discussed before. Nearly perfect noise rejection and set point tracking are needed for many real-world issues. To accomplish these performances, such systems can use SMC. As a result of the swift switching between a pair or more control limits, this control is referred to as nonlinear. The system's structure can change or switch when the system's state moves over each discontinuity when this control is used as feedback. The state intersects and intersects the surface—also known as the button or sliding surface—and exists continuously on the button such that the error and the rate at which the error changes are both zero. Moving in a sliding motion is the term for this action. The term "sliding mode control" is frequently used to emphasize how crucial sliding motion is (Fig. 2).

$$\dot{x}_1 = x_2 \quad \text{A} = \frac{1}{5}, x_1, x_2 < 0$$
$$X_2 = -Ux_1 \quad = 5, x_1, x_2 > 0t$$

where is the angular velocity expressed in rad/sec. B is a viscous friction coefficient that resists the direction of motion in Nms. and J is the moment of inertia kgm^2/s^2. The armature control's torque, expressed in Nm, is provided.

$$\tau(t) = J\frac{\mathrm{d}w}{\mathrm{d}t} + B\omega(t) \tag{11}$$

$$\tau(t) = K_t i_a(t) \tag{12}$$

$$V_a(t) - E_b(t) = R_a i_a(t) + L_a\frac{\mathrm{d}i_a}{\mathrm{d}t} \tag{13}$$

where E_b represents electromagnetic force in V and R_a and L_a, respectively, show the resistance and inductance of the armature in ohms and H, respectively.

$$E_b(t) = K_b(t)\omega(t) \tag{14}$$

One may create a state model using the preceding equation and the variables and as illustrated below, i_a serve as state variables while V_a serves as a manipulating variable.

$$\begin{bmatrix} \frac{\mathrm{d}w(t)}{\mathrm{d}t} \\ \frac{\mathrm{d}i_a(t)}{\mathrm{d}t} \end{bmatrix} = \begin{bmatrix} \frac{-b}{J} & \frac{K_t}{J} \\ \frac{-K_b}{L_a} & \frac{-R_a}{L_a} \end{bmatrix} \begin{bmatrix} \omega(t) \\ i_a(t) \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{L_a} \end{bmatrix} V_a(t) \tag{15}$$

$$\frac{\omega(s)}{V_a(s)} = \frac{3992.015}{s^2 + 51s + 51.39} \tag{16}$$

The aforementioned equation solved in time domain as

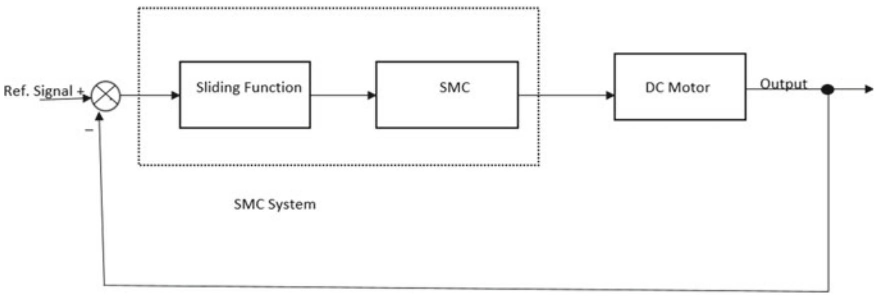

Fig. 2 DC motor schematic with SMC

$$(t) + 51.39\dot{\omega}(t) = 3992.015 V_a(t) \quad (17)$$

Now consider, $x_1 = \omega(t)$ and $u = V_a(t)$ once transformed, the system can then take the canonical form shown below.

$$x_1 = x_2 \quad (18)$$

$$x_2 = -51.39x_1 - 51x_2 + 3992.015U \quad (19)$$

$$y = x_1 \quad (20)$$

Next, choose the sliding surface.

$$\sigma = c(r - x_1) + x_2 \quad (21)$$

c being the sliding matrix's constant $C\sigma\varepsilon R^{m+n}$ such that $c < 0$ total control legislation is stipulated by

$$U = U_1 + U_{nl} \quad (22)$$

where $K > 0$ is picked where it is large enough the trajectory converges to the sliding surface more quickly, the higher the value of K.

3 PID Controller

PID control is a tried-and-true technique for moving a system towards a desired location or level. It is used in numerous chemical and scientific processes, as well as automation, and is essentially omnipresent as a technique of managing temperature. To keep a process's real output as close as feasible to the target or set point output, PID control employs closed-loop control feedback.

4 Result

The control system is designed by using MATLAB/Simulink. The maximum voltage is 100 V. Both the driving parameters and the load is changed. Figure 3 shows the DC motor drive with load with SMC. We must design the motor based on the designed parameters in order to regulate the DC motor speed using a SMC controller.

Figure 4 says that changing PID constants as the DC motor parameters are changed. It is seen that the output speed of DC motor increases due to SMC from 30 to 32 rpm and tend to adapt as the DC motor parameters are changed.

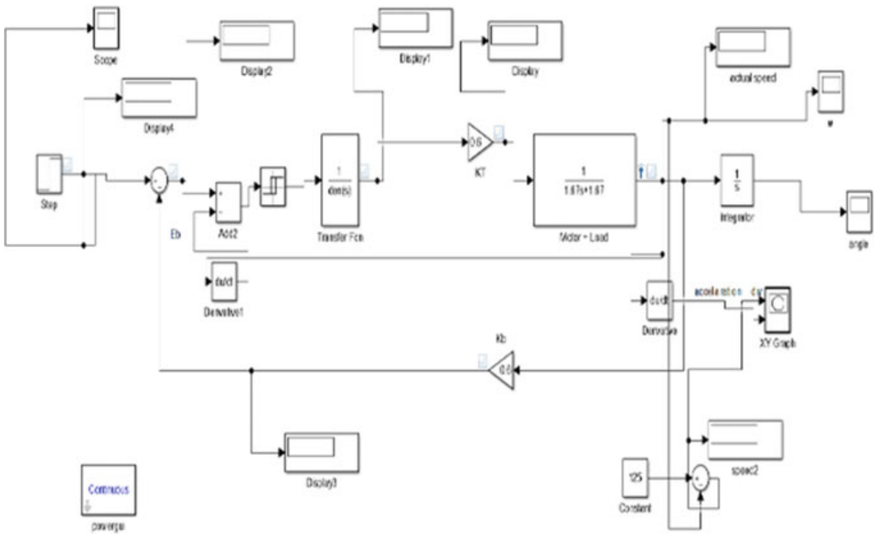

Fig. 3 Simulation model of DC motor with load with SMC

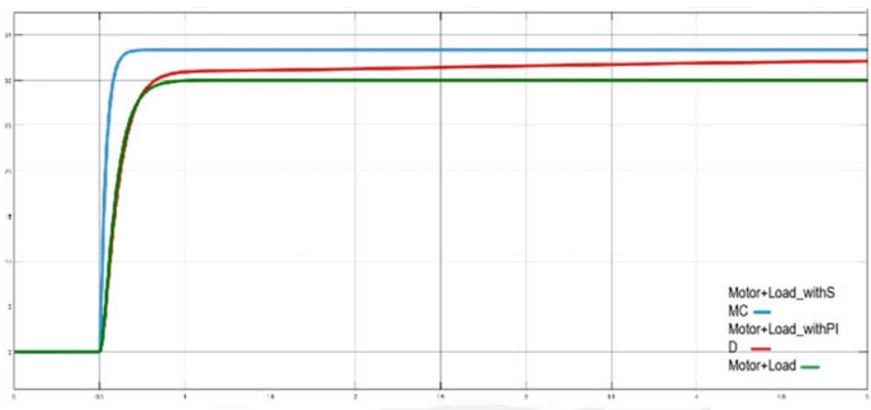

Fig. 4 Comparison of DC motor speed **a** without controller **b** with PID **c** SMC controller

Figure 5 shows the graph between time and speed where SMC gives the better result than PID.

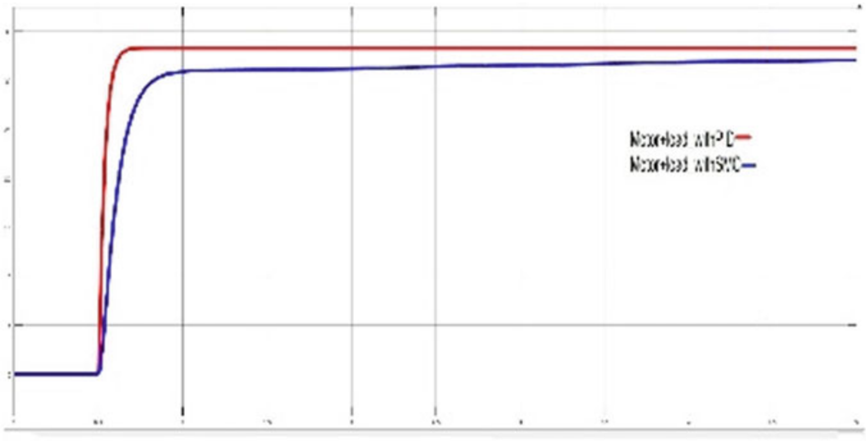

Fig. 5 Comparison of DC separately excited motor **a** with PID **b** with SMC

5 Conclusion

Due to their benefits of easy speed and position control and broad adjustability range, DC motors are commonly utilized as actuation devices in industrial applications. There has been provided a mathematical model of a DC motor. The speed of a DC motor has been controlled using a conventional SMC controller. The performance curves produced with and without controllers, as well as those from the conventional SMC controller, are compared using time domain requirements. The SMC controller aids in increasing the motor's speed. Comparison of PID with load and with load with SMC it is seen that SMC gives the better result than PID. As the DC motor's parameters are modified and a control signal is applied to it, the controller constants in the simulation's output can automatically update.

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