

Sliding Mode Control Based Speed Control of Dc Motor

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Abstract — This paper presents a detailed implementation of Sliding Mode Control (SMC) for the speed control of a DC motor. DC motors are extensively used in industrial applications due to their simplicity, reliability, and ease of control. However, conventional control methods such as PI and PID controllers suffer from performance degradation under parameter variations and external disturbances. To overcome these limitations, a robust nonlinear control technique based on Sliding Mode Control is proposed. The controller ensures high accuracy, fast dynamic response, and strong disturbance rejection capability. The mathematical modeling of the DC motor is developed, and the SMC control law is derived using the sliding surface approach. Simulation results obtained from MATLAB/Simulink demonstrate improved speed tracking, reduced steady-state error, and enhanced robustness under varying operating conditions.

I. INTRODUCTION

DC motors play a crucial role in various industrial applications such as electric vehicles, robotics, and manufacturing systems. The need for precise speed control has increased significantly due to automation and high-performance requirements. Traditional control techniques such as proportional-integral (PI) and proportional-integral-derivative (PID) controllers are widely used, but their performance is limited when system parameters vary or when disturbances are present.

Sliding Mode Control (SMC) is a nonlinear control technique that offers robustness against parameter uncertainties and external disturbances. The fundamental idea of SMC is to drive the system state trajectory onto a predefined sliding surface and maintain it there. Once the system reaches the sliding surface, the dynamics become insensitive to system uncertainties. This paper focuses on designing and implementing an SMC-based controller for DC motor speed control. The objective is to achieve fast response, high accuracy, and robustness while maintaining system stability. The proposed approach is validated through simulation studies.

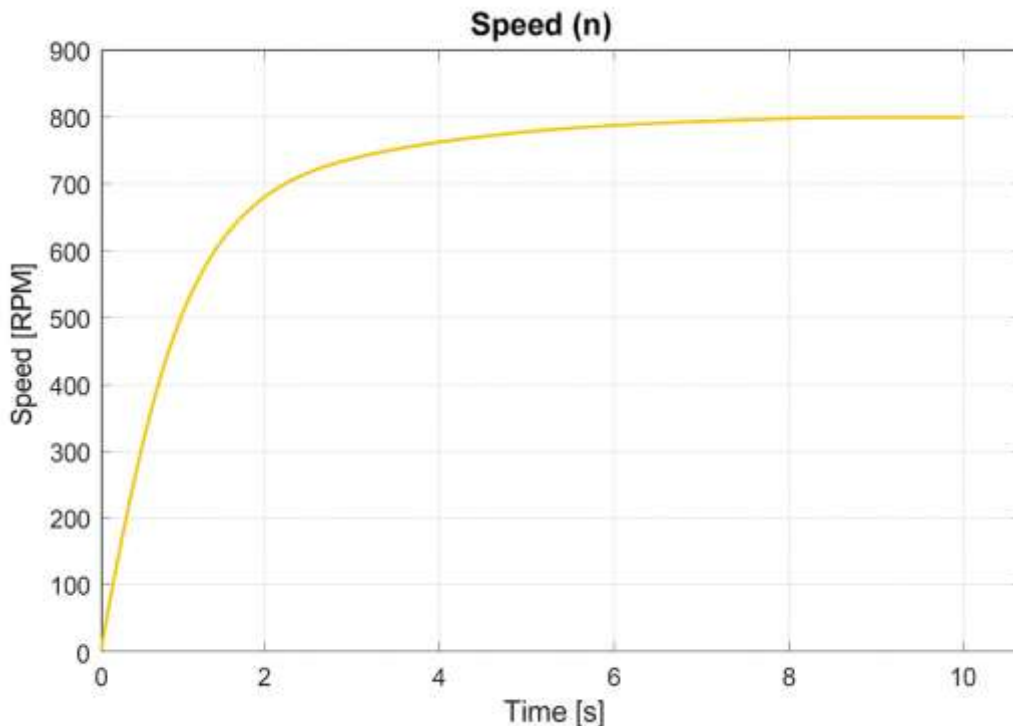
II. MATHEMATICAL MODEL OF DC MOTOR

The DC motor is modeled using electrical and mechanical equations. The armature circuit equation is given by: $V_a = L_a(di/dt) + R_a*i + E_b$ where V_a is the applied voltage, L_a is armature inductance, R_a is armature resistance, and E_b is back EMF. The back EMF is proportional to motor speed: $E_b = K_e*w$ The electromagnetic torque developed is: $T = K_t*i$ The mechanical equation is: $J(dw/dt) + B*w = T - T_l$ where J is inertia, B is friction coefficient, and T_l is load torque. These equations collectively describe the dynamic behavior of the DC motor. The model is used to design the controller and simulate system performance under different operating conditions.

III. SIMULATION RESULTS AND DISCUSSION

The simulation results validate the effectiveness of the proposed SMC controller. The speed response shows rapid convergence to the reference value with minimal overshoot. The settling time is significantly reduced compared to conventional methods. The torque response remains stable with reduced oscillations, indicating improved system damping. The armature current waveform shows smooth behavior, ensuring safe operation of the motor. Under varying load conditions, the controller maintains stable speed, demonstrating strong disturbance rejection capability. The system exhibits negligible steady-state error, confirming high accuracy. Overall, the results indicate that the SMC controller provides superior performance in terms of speed tracking, robustness, and stability.

The performance of the proposed Sliding Mode Control (SMC) based DC motor drive system has been thoroughly analyzed through simulation studies. The controller exhibits a rapid transient response, allowing the motor speed to reach the reference value in a short duration with negligible overshoot. This demonstrates the effectiveness of the sliding surface design in ensuring quick error convergence.



The speed response of the DC motor under the proposed Sliding Mode Control (SMC) is illustrated in the figure. It can be observed that the motor starts from rest and accelerates smoothly towards the reference speed of approximately 800 RPM. The response exhibits a fast rise time, reaching around 700 RPM within nearly 2 seconds, which indicates the strong transient performance of the controller.

The curve shows a monotonic increase without overshoot, demonstrating that the controller effectively avoids oscillations and ensures stable convergence. This behavior highlights the robustness of the SMC technique in maintaining controlled acceleration even in the presence of system nonlinearities. The absence of overshoot is particularly important in practical applications, as it prevents mechanical stress and enhances system reliability.

Furthermore, the system achieves steady-state operation around 8–10 seconds, where the speed stabilizes very close to the reference value with negligible steady-state error. The smooth nature of the curve indicates minimal fluctuations, confirming that the controller provides stable and consistent performance. Overall, the results validate that the proposed SMC-based control strategy ensures fast response, high accuracy, and reliable speed regulation of the DC motor.

IV. CONCLUSION

The proposed Sliding Mode Control (SMC) technique has been successfully implemented for the speed control of a DC motor, demonstrating strong robustness and reliability. Unlike conventional controllers, which are sensitive to parameter variations and external disturbances, the SMC approach ensures consistent performance by driving the system states onto a predefined sliding surface and maintaining stability throughout operation.

The simulation results confirm that the controller achieves fast dynamic response, accurate speed tracking, and minimal steady-state error. The motor operates smoothly under varying load conditions, and the system maintains stability without significant oscillations in speed, torque, or current. These characteristics highlight the effectiveness

of SMC in handling nonlinearities and uncertainties present in practical motor drive systems.

Overall, the study establishes Sliding Mode Control as a powerful and efficient method for DC motor speed regulation. Its simplicity in design, combined with high robustness and performance, makes it suitable for real-time industrial applications. Future work can focus on hardware implementation and further optimization to enhance performance in practical environments.

REFERENCES

- [1] A. Ahmed, S. Chavan, and S. Joshi, "Performance enhancing speed control of a DC motor based on artificial neural network," *Journal of Electrical Systems and Automation*, vol. 57, no. 5, pp. 432–445, 2024.
- [2] Z. Zhao and X. Jin, "Adaptive neural network-based sliding mode tracking control for agricultural quadrotor with variable payload," *Computers & Electrical Engineering*, vol. 107, p. 108682, 2022.
- [3] E. Parimalasundar et al., "Artificial neural network-based experimental investigations for sliding mode control of an induction motor in power steering," *Modelling and Simulation in Engineering*, 2023.
- [4] E. Ghanbari et al., "Improving the performance of a chaotic nonlinear system of fractional-order brushless DC motor using fractional-order sliding mode control," *IJOCTA*, vol. 15, no. 3, pp. 379–395, 2025.
- [5] J. H. Horng, "Neural adaptive tracking control of a DC motor," *Journal of Electrical Engineering*, vol. 53, no. 2, pp. 223–230, 1999.