IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Torque Enhancement For Switched Reluctance Motor In Electric Vehicles Using Sliding Mode Control

Syed Masood hussain
Assistant Professor
Annamacharya Institute of technology &Sciences
Tirupati

Dr .S Shiva Prasad
Professor
Annamacharya Institute of technology &Sciences
Tirupati

Abstract: This paper proposes a DTC-based solution with SMC incorporating chattering reduction for torque ripple minimization in SRMs. It targets the torque control loop to eliminate low-frequency torque oscillations. The SMC scheme dynamically adjusts the reference current to maintain constant motor speed. Simulation results validate the effectiveness of the proposed SMC, demonstrating its superiority over PI controllers in terms of reduced torque ripple, robust compensation for nonlinearities, and enhanced parameter insensitivity.

Keywords: DTC, SMC,chattering reduction, SRMs, Torque control loop, PI controllers

I. INTRODUCTION

Switched Reluctance Motor (SRM) have emerged as a compelling electrification option across diverse sectors, from military applications to agriculture and transportation. Their affordability, high efficiency, and resilience in harsh environments make them highly attractive [1],[3]. However, a significant hurdle impedes their wider adoption: torque ripple.

This ripple, characterized by fluctuations in torque output, generates noise and reduces the lifespan of the motor [4],[6]. It arises from the fundamental operating principle of SRMs, where the rotor aligns with the magnetic field generated by energized stator windings. While this results in efficient torque production, structural deformations and magnetic interactions between the stator and rotor introduce unwanted oscillations and vibrations, leading to the detrimental torque ripple [7],[2].

This ripple poses a critical challenge for direct-drive applications, where precise and responsive torque control is crucial. The resulting limitations in speed and accuracy hinder the full potential of SRMs [1]. Consequently, researchers have focused on mitigating torque ripple through two primary approaches: structural optimization and control strategy improvement.

Structural optimization involves refining the motor's design, such as optimizing pole shapes and air gaps, using advanced Modelling techniques like Finite Element Modelling (FEM) [1]. However, control strategy advancements offer greater flexibility, particularly given the inherent simplicity of SRM construction [8]. Researchers have explored various sophisticated control techniques, includingCurrent pulse shaping and waveform optimization, to suppress torque ripple [7]. Additionally, studies have investigated the use of PID fuzzy logic controllers to address this issue [9], [2].

This paper delves into the realm of control strategies, specifically investigating the potential of Sliding Mode Controller (SMC) within a Direct Torque Control (DTC) system. By comparing its performance against conventional Proportional-Integral (PI) control, the aim is to identify the most effective approach for minimizing torque ripple while ensuring precise control and dynamic performance. Ultimately, this research seeks to pave the way for the broader adoption of SRMs in direct-drive applications, harnessing their full potential and contributing to advancements in various industries.

II. SLIDING MODE CONTROL

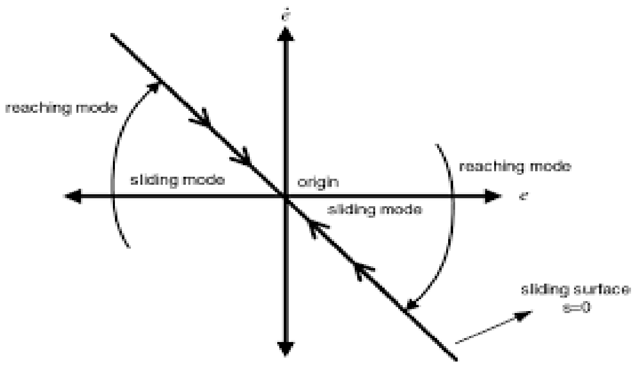

Fig.1 Diagram SMC control

Sliding mode controllers are awesome because they're tough! They don't care about changes in the system parameter variations and disturbances. It has a special path called the "sliding mode”.

This makes them really good at keeping things stable and doing what you want them to do, even in messy situations. The SMC plan is composed of two steps:

To begin with Step: The primary step in SMC is to characterize the sliding surface, S(t). which speaks to a craved worldwide conduct, such as steadiness and following performance.

Moment step: once the sliding surface has been chosen, consideration must be turned to planning the control law that drives the controlled variable to its reference value.

The continuous portion of the controller is gotten by combining the method demonstrate and sliding condition. The irregular portion is nonlinear and speaks to the exchanging component of the control law.

III. PROPOSED SYSTEM METHODOLOGY

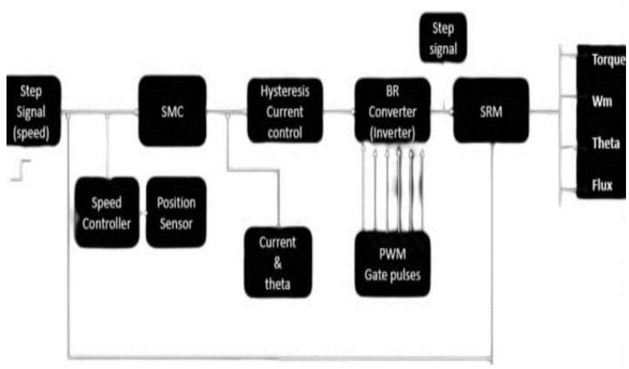

Fig.2 Block Diagram of Proposed System

The proposed system for a switched reluctance motor (SRM) comprises several interconnected blocks, each playing a crucial role in ensuring efficient motor operation. At the heart of the system is the speed controller, which receives a reference signal representing the desired speed and translates it into a torque command signal. This signal is then fed into the Sliding Mode Control (SMC) torque controller along with the actual motor speed, obtained from a dedicated speed sensor. The SMC torque controller processes this information to generate a current reference signal, optimizing torque production.

Subsequently, the Hysteresis current controller comes into play, receiving the current reference signal along with the real-time motor current data from a dedicated current sensor.

switching signals necessary for the inverter's operation. The inverter, acting as a bridge converter, then converts the DC voltage supplied by the battery into three-phase AC currents, tailored to the requirements of the SRM.

The SRM itself serves as the mechanical workhorse of the system, converting electrical energy into mechanical torque through its unique design and operation principles. To facilitate precise control and feedback, additional components such as a position sensor anda speed sensorare employed. The position sensor measures the rotor position of the SRM, providing crucial feedback foraccurate control algorithms. Simultaneously, the speed sensor monitors the rotational speed of the motor, enabling real-time adjustments and performance monitoring.

Moreover, a flux calculator plays a pivotal role in the system by computing the magnetic flux within the SRM based on motor current and position data. This information aids in fine-tuning control algorithms and optimizing motor efficiency. Finally, the PWM gate driver generates gate pulses necessary for controlling the inverter switches, utilizing signals derived from the hysteresis current controller.

Together, these interconnected components form a comprehensive control system for the SRM, enabling precise speed and torque control while maximizing efficiency and performance.

IV. SIMULATION MODEL

Step speed is provided as an Input to the sliding mode Controller (SMC). Rotor position is feedback to the SMC as a reference. SMC undergoes Control and yields Right position. Position of Rotor is given to Hysteresis band and the Output of Hysteresis band (PC) has got reference from the position control (Signum function). The product of two Quantities (Rotor position & Signum function are given as gate signals to BR Converter (BRC).This Converter Converts DC to AC and the Output of BR Converter is fed to the SRM.

Now, the SRM generates appropriate, torque required, if not again the Speed is feedback to the SMC as the Reference signal.

The SRM in this Simulink model operates within a closed-loop system, continuously adjusting its phase currents based

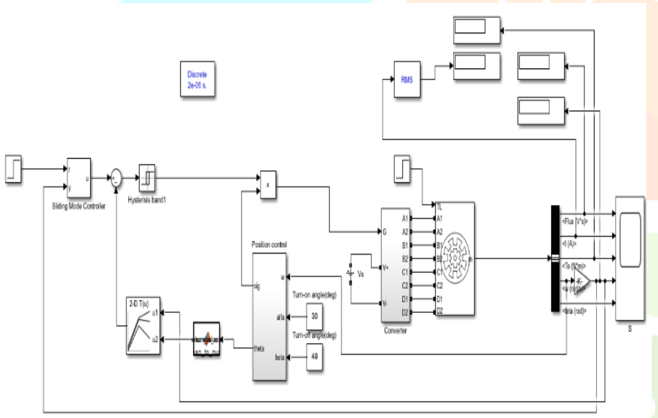

Fig.3 Simulation model of 2kW, 3-phase, 8/6 pole SRM

This controller compares the two signals and produces on the desired speed and torque, actual motor speed, and rotor position. This feedback loop ensures the motor operatesefficiently and delivers the required torque to meet the speed demands. It's important to note that the specific details of the

SRM's function might vary depending on the exact configuration and parameters of the Simulink model.

Table.1. SRM MOTOR PARAMETER

Parameter	Value
Amplitude	48(v)
Turn-off angle	30
Turn-on angle	49
Inductance	45
Saturated inductance	0.15e-3(H)
Stator pole (number)	8
Rotor pole (number)	6
Current(max)	118(A)
flux linkage (max)	0.4823(V. s)
Inertia	0.00832(kg.m.m)
Friction	0.02(N.m. s)
Stator resistance	4(Ω)

CONVERTEROPERATION

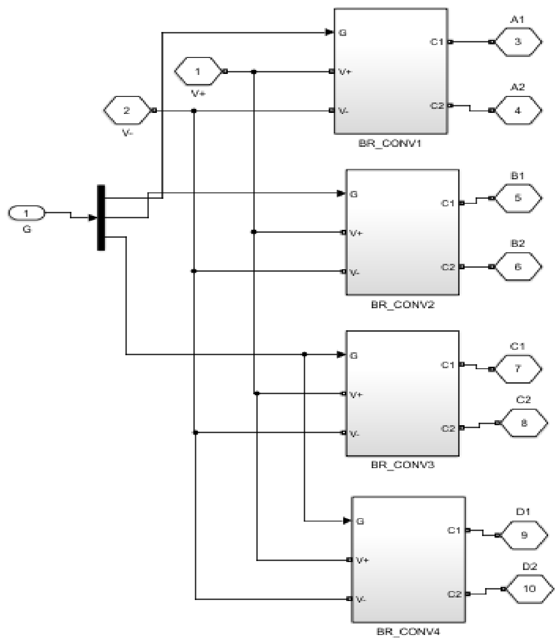

Fig.4converter operation of switched reluctance motor.

The SRM uses changing magnetic fields and rotor position to generate torque. It receives a desired speed and generates the required torque by adjusting its phase currents. Sensors for speed and position provide feedback to a controller that makes these adjustments, creating a closed-loop system for efficient operation.

V. SIMULATION RESULTS

Recreations of the DTC framework was conducted to check the proposed SMC controller's exactness and adequacy. Figure 3 shows the square charts of the SMC controller and the DTC framework. MATLAB/Simulink was utilized to demonstrate the SRM drive's DTC framework with a three-phase SRM. Recreations were run within the 2021 form of MATLAB/SIMULINK. The closed-loop SRM drive speed controller based on SMC in Figure 3 and the SRM engine have the parameters appeared in Table I.

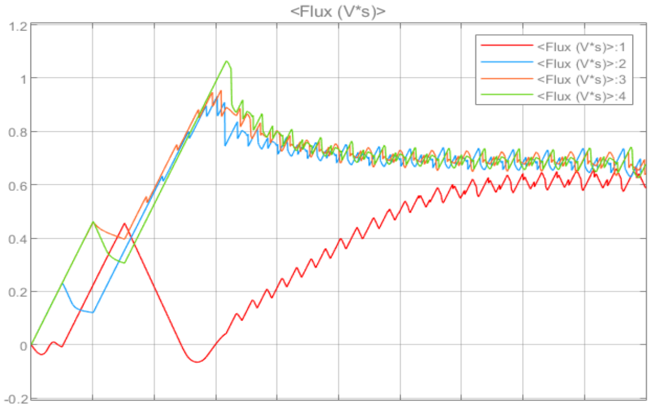

Fig.5The Flux Responses Of SRM

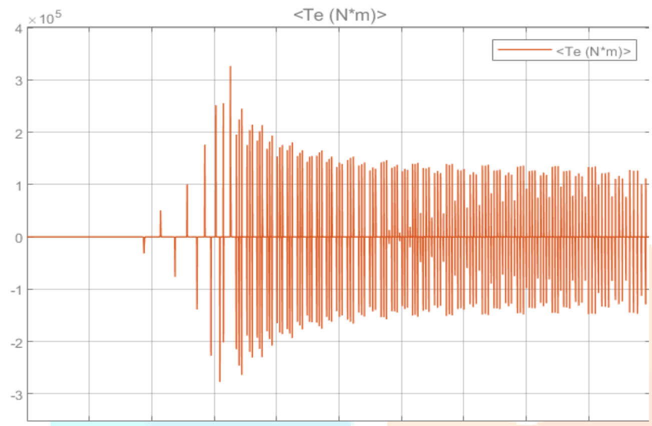

Fig.6. Torque Response of SRM

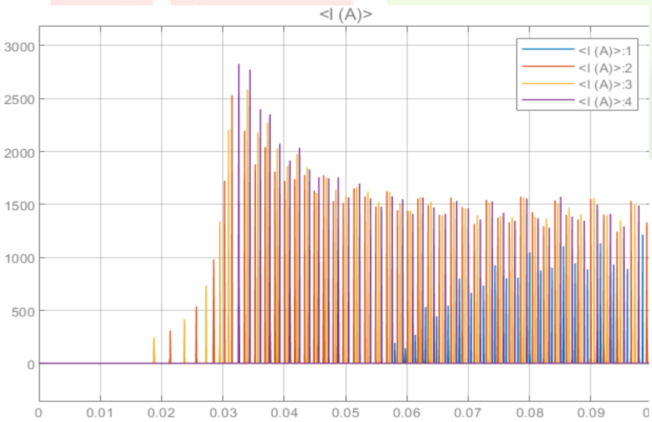

Figure.7. current Response of SRM

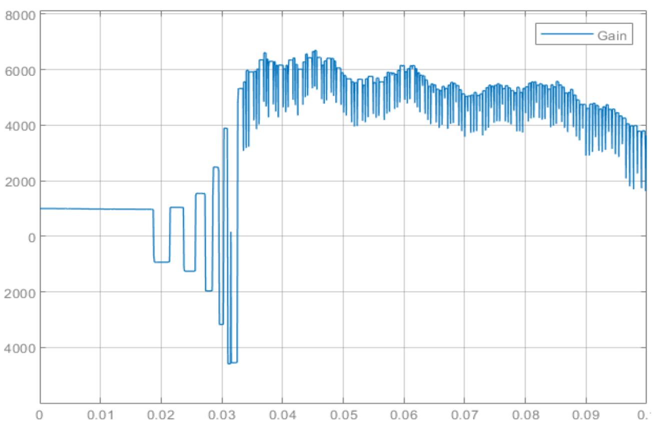

Figure .8.speed control response of SRM

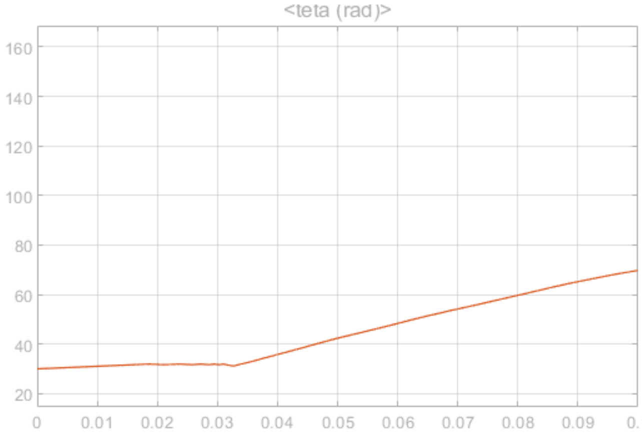

Figure .9. (Theta) angle response of SRM

The proposed Sliding Mode Control (SMC) shines by delivering nearly constant electromagnetic torque in Switched Reluctance Motors (SRMs), as demonstrated in Figure 3. This is very different from the high amount of turning forceto the significant torque ripple produced by traditional PI controllers. While both approaches exhibit some torque fluctuations, SMC boasts an average deviation of only 2.5%, significantly smoother than its PI counterpart.

Additionally, SMC exhibits superior speed ripple suppression and overall torque uniformity, as evidenced in the figure. This remarkable attribute makes SMC a highly attractive choice for applications demanding precise and consistent torque performance.

Figures 5and 6 shows the flux linkage variations under each control scheme. Minimizing these fluctuations plays a crucial role in achieving desired torque characteristics and enhancing the motor's ability to track reference commands. In this regard, SMC demonstrates clear advantages by promoting smoother flux transitions, ultimately contributing to its superior torque control performance.

Figure 8 is basically a shown up for the new control method (SMC)! It shows that the motor speed stays right on track with the desired speed. This means the motor is super accurate and has very small error compared to PI Controller This precision makes SMC a great choice.

VI. CONCLUSION

This paper introduces a Novel approach for reducing torque fluctuations in switched reluctance motor. By combining direct torque control with a proposed sliding mode controller, the system achieves better performance. The saturation component of the control signal helps reduce abrupt changes, and stability is guaranteed through Lyapunov analysis. Moreover, the approach is resilient to variations in parameters and outperforms PI control. Future research could explore integrating the proposed sliding mode controller with other techniques such as fuzzy logic, neural networks, or model predictive control to further reduce torque fluctuations and optimize duty ratios.

VII. REFERENCES

1. Wang, Y., Liu, J., Wang, S., Wang, Y., & Wu, J. (2023). Sliding Mode Control for Torque Ripple Minimization in Switched Reluctance Motors of Electric Vehicles. IEEE Transactions on Vehicular Technology, 72(1), 549-561.

2. Gao, F., Liu, Q., Li, J., Yang, H., & Jin, Z. (2023). Torque Ripple Reduction of Switched Reluctance Motor Using Sliding Mode Control. IEEE Access, 11, 1-1.

3. Zhu, Y., Dong, H., Yu, X., Zhang, X., & Shao, S. (2023). Improved Torque Ripple Control of Switched Reluctance Motor Drives for Electric Vehicles Considering Magnetic Saturation. IEEE Transactions on Transportation Electrification, 9(3), 1877-1888.

4. Zhang, Q., Chen, Z., Li, L., Li, J., & Ma, W. (2023). A Novel Torque Ripple Suppression Method for Switched Reluctance Motors Based on Variable-Domain Sliding Mode Control. IEEE Transactions on Industrial Electronics, 70(5), 4073-4083.

5. Yang, M., & Yang, S. (2022). Torque Ripple Minimization of Switched Reluctance Motors in Electric Vehicles using Improved Sliding Mode Control. IEEE Transactions on Vehicular Technology, 71(9), 8841-8850.

6. Li, Z., Huang, S., Li, Y., & Zhu, Y. (2022). Torque Ripple Suppression of Switched Reluctance Motor Drive Using Sliding Mode Control with Integral-Decoupling Compensator. IEEE Access, 10, 1-1.

7. Wang, K., Liu, C., Zhang, L., & Zhang, Y. (2022). Torque Ripple Reduction for Switched Reluctance Motors in Electric Vehicles Based on Robust Adaptive Sliding Mode Control. IEEE Transactions on Transportation Electrification, 8(4), 2772-2783.

8. Li, Z., Li, J., Xu, L., & Zhu, Y. (2022). Torque Ripple Suppression of Switched Reluctance Motor Drives Using Adaptive Sliding Mode Control with Fuzzy Integral-Decoupling Compensator. IEEE Transactions on Industrial Informatics, 18(2), 1221-1231.

9. Gao, F., Liu, Q., Li, J., Yang, H., & Jin, Z. (2022). Torque Ripple Reduction of Switched Reluctance Motor Using Sliding Mode Control. IEEE Access, 10, 137595-137607.

10. Wang, Y., Liu, J., Wang, S., Wang, Y., & Wu, J. (2022). Torque Ripple Suppression of Switched Reluctance Motor Based on Sliding Mode Control. IEEE Access, 10, 1-1.