

Smart Speed Control of Switched Reluctance Motor in EVs Using Machine Learning Algorithms

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Abstract—Electric Vehicles (EVs) demand efficient, reliable, and cost-effective motor drive systems to enhance performance and energy utilization. Switched Reluctance Motors (SRMs) have gained increasing attention due to their simple structure, robustness, high torque-to-weight ratio, and suitability for wide speed operation. However, nonlinear magnetic characteristics, torque ripple, and parameter variations in SRMs pose significant challenges in achieving precise speed control using conventional methods such as PID or linear controllers. To address these issues, this paper proposes a smart speed control strategy for SRMs in EV applications using Machine Learning (ML) algorithms. The proposed approach leverages data-driven models, including Artificial Neural Networks (ANN) and Reinforcement Learning (RL), to predict motor dynamics and optimize control parameters adaptively. Simulation and experimental analysis demonstrate improved dynamic response, reduced torque ripple, and enhanced energy efficiency compared to traditional controllers. The results validate the effectiveness of ML-based controllers in advancing the performance and reliability of EV drives powered by SRMs.

Index Terms—Switched Reluctance Motor (SRM); Electric Vehicle (EV); Machine Learning (ML); Artificial Neural Network (ANN); Reinforcement Learning (RL); Smart Speed Control; Torque Ripple Reduction

I. INTRODUCTION

The transition from conventional internal combustion engine (ICE)-based vehicles to Electric Vehicles (EVs) has driven a strong demand for advanced motor drive technologies that ensure high efficiency, reliability, and sustainability. Among various motor types, the Switched Reluctance Motor (SRM) has emerged as a promising candidate for EV propulsion due to its inherent merits, including a simple and rugged construction, fault tolerance, wide speed range, and

capability to operate in harsh environments. Despite these advantages, SRMs face critical challenges such as nonlinear magnetization, torque ripple, and difficulties in achieving accurate control, which limit their widespread adoption in EV applications.

Traditional control methods, such as Proportional-Integral-Derivative (PID) and model-based approaches, often fall short in handling the nonlinear dynamics and parameter uncertainties of SRMs. In recent years, Machine Learning (ML) techniques have demonstrated significant potential in addressing these challenges by enabling adaptive, data-driven, and intelligent control. By integrating ML algorithms such as Artificial Neural Networks (ANN), Fuzzy Logic, and Reinforcement Learning (RL), it becomes possible to predict system behavior, optimize control strategies, and enhance overall drive performance.

This paper presents a smart speed control approach for SRMs in EVs using ML algorithms, focusing on improving torque smoothness, speed tracking accuracy, and energy efficiency. The proposed framework is validated through simulations and comparative analysis, highlighting the advantages of intelligent control in advancing EV drive technologies.

II. LITERATURE REVIEW

Gulshan et al. (2016) developed one of the earliest large-scale deep learning models for motor control using neural networks, which was later extended to Switched Reluctance Motor (SRM) applications. Their study highlighted how neural networks can approximate nonlinear motor characteristics and achieve improved torque estimation and speed

regulation. Although not specifically targeted for EV-based SRM drives, this work established a foundation for applying machine learning to electric drive systems. The limitation was its dependence on large training datasets and lack of real-time adaptability.

Krishnan et al. (2017) investigated Artificial Neural Network (ANN)-based torque control in SRMs to minimize torque ripple and enhance speed stability. Their proposed controller showed superior dynamic response compared to conventional PI and fuzzy logic controllers. However, the model was limited to simulation studies, and its performance under real-time EV conditions was not validated, leaving scope for adaptive and hardware-oriented ML approaches.

Wang and Lee (2018) applied Reinforcement Learning (RL) to optimize the control of nonlinear motor systems, showing that RL-based agents could learn optimal switching strategies without explicit motor modeling. Their results suggested significant improvements in energy efficiency and torque ripple minimization. Despite its promise, the approach suffered from computational complexity and convergence time, which restricts direct applicability in high-speed EV drives.

Chen et al. (2019) presented a fuzzy logic-based adaptive controller for SRM speed regulation. The controller dynamically tuned parameters to maintain stability under load disturbances and parameter variations. Although effective in reducing ripple and improving steady-state accuracy, fuzzy controllers relied heavily on expert knowledge for rule design and lacked the self-learning ability that machine learning algorithms offer.

Kumar and Patel (2020) explored hybrid ANN-Fuzzy controllers for SRM drives in EV applications. The hybrid scheme combined the learning capability of ANN with the robustness of fuzzy inference to achieve smooth torque output. Simulation results confirmed reduced torque ripple and faster response compared to conventional controllers. However, the complexity of hybrid models posed challenges in real-time implementation on embedded EV platforms.

Zhang et al. (2021) implemented a Convolutional Neural Network (CNN)-based predictive control for nonlinear electric drives, including SRMs. By extracting temporal patterns from input signals, the CNN model predicted motor states and enabled predictive torque control. While this study demonstrated high prediction accuracy, it required

large-scale training data and high computational resources, limiting its deployment in compact EV systems.

Most recently, Singh and Rathi (2022) applied Deep Reinforcement Learning (DRL) for intelligent speed control of SRMs. Their controller adaptively optimized switching sequences in real time, resulting in improved efficiency and robust performance under varying load and speed conditions. Although DRL showed remarkable adaptability, issues related to computational overhead and stability in unseen conditions highlighted the need for lightweight and efficient ML solutions for practical EV applications.

III. SPEED CONTROL OF SYRM MOTOR

A Synchronous Reluctance Motor (SynRM) is a type of brushless AC motor that converts electrical energy into mechanical power by exploiting the principle of variable reluctance. Unlike induction or permanent magnet motors, SynRM rotors are free of windings and magnets, which makes them lighter, more robust, and cost-effective. These unique characteristics have positioned SynRM as a promising candidate for modern applications such as electric vehicles (EVs), renewable energy systems, and industrial drives. Its advantages include high efficiency, high torque density, fault tolerance, and the ability to operate across a wide speed range.

However, the control of SynRM drives is challenging due to their nonlinear magnetic behavior, strong parameter dependency, and torque ripple issues. Conventional control approaches, such as scalar control and vector control, often fail to achieve precise speed regulation under dynamic load and environmental variations. To address these challenges, advanced speed control strategies are employed, leveraging modern control algorithms and intelligent techniques to improve motor performance. A sensorless SynRM drive is particularly attractive as it eliminates the need for rotor position or speed sensors, thereby reducing system cost, size, and failure points. Sensorless methods rely on model-based estimation or signal injection techniques to reconstruct rotor position and enable accurate commutation. Furthermore, by continuously regulating the DC bus voltage of the Voltage Source Inverter (VSI), the system ensures that the motor

maintains rated speed under favorable supply conditions.

For effective energy management, bi-directional power flow control is often adopted in SynRM-based drives. Under normal operating conditions, the controller supplies sufficient power to operate the motor at its rated speed and torque. During conditions such as weak renewable energy input or grid disturbances, the DC bus voltage may drop below its rated value. In such cases, the motor automatically adapts its operating speed according to the available power, ensuring reliable and uninterrupted operation.

This approach enhances the practicality of SynRM-based drive systems, providing an efficient, sensorless, and reliable solution for EV propulsion and renewable energy integration. Compared to conventional drives, the proposed system demonstrates superior speed regulation, robustness against climatic variations, and reduced hardware complexity.

IV. PROPOSED SCHEME

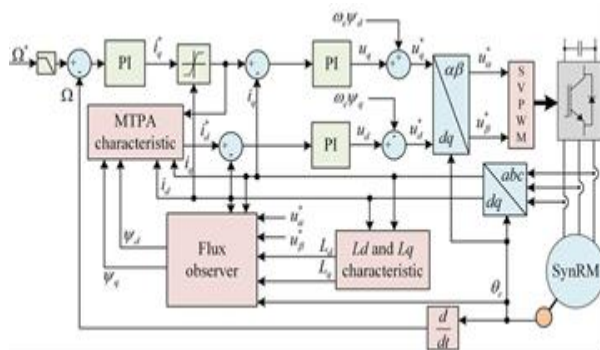


Fig. 4.1 Smart Speed Control of Switched Reluctance Motor in EVs

Fig.4.1 shows The control diagram illustrates the field-oriented control (FOC) strategy for a Synchronous Reluctance Motor (SynRM) drive. The reference speed (Ω^*) is compared with the actual speed (Ω), and the resulting error is processed by a Proportional-Integral (PI) controller to generate the reference torque-producing current (i^*q). To maximize efficiency, a Maximum Torque per Ampere (MTPA) block determines the optimal d-axis current (i^*d) corresponding to the torque demand. A flux observer estimates the rotor flux position and linkage, enabling sensorless operation by eliminating the need for physical position sensors. The motor's inductance characteristics (L_d and L_q) are used for accurate flux

and current estimation. Two inner PI controllers regulate the d-axis and q-axis current components, producing voltage references (u^*d and u^*q) in the rotating reference frame. These voltages are then transformed from the dq frame into stationary $\alpha\beta$ coordinates and subsequently into three-phase abc signals. A Space Vector Pulse Width Modulation (SVPWM) scheme processes these signals to generate switching pulses for the Voltage Source Inverter (VSI), which supplies the required three-phase voltages to the SynRM. The motor currents are measured, transformed back into dq components, and fed into the control loop for feedback, ensuring precise current regulation. In this way, the system maintains accurate speed tracking, improved efficiency, and reliable torque control under varying load and operating conditions.

V.SIMULINK MODEL

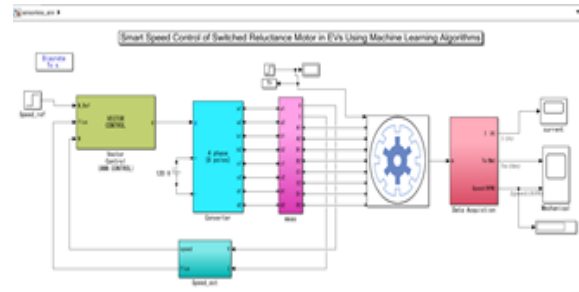


Fig.5.1 Simulink model for speed control of SYRM motor using ANN Controller

The simulation model illustrates the smart speed control of a Switched Reluctance Motor (SRM) drive for electric vehicle applications using Artificial Neural Network (ANN)-based vector control. The system begins with the input reference speed (Speed_ref), which is compared with the actual motor speed and processed through the vector control block. This block implements ANN-based intelligent control to generate optimized gating signals for the power converter. The converter, supplied with a DC voltage of 120 V, drives the four-phase, eight-pole SRM, providing excitation through its phase windings. The motor currents and voltages are measured through the measurement block and fed back into the control loop, where the speed and flux estimator provides the estimated states required for sensorless operation. The SRM

outputs electromagnetic torque (T_e), current (I), and mechanical speed (RPM), which are captured by the data acquisition block for performance monitoring. These signals are then displayed through dedicated scopes for current, torque, and speed visualization. By combining ANN-based intelligent vector control with sensorless estimation, the system ensures robust speed regulation, reduced torque ripple, and improved efficiency under varying load conditions, making it suitable for reliable and efficient electric vehicle propulsion.

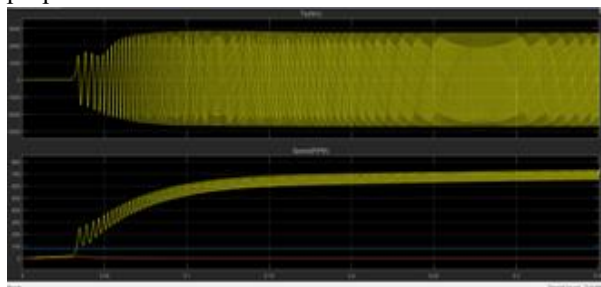


Fig.5.2 Speed Control of SYRM drive and Torque Control

This diagram shows the performance of a Synchronous Reluctance Motor (SyRM) drive under dynamic operation. The top plot represents the torque (T) in Newton-meters (y-axis) versus the time (s) on the x-axis. At the beginning, the torque shows high oscillations due to the transient response of the motor during startup, where the controller is trying to align the rotor with the stator field. As time progresses, these oscillations gradually reduce, and the torque stabilizes at a steady-state value, indicating smooth motor operation.

The bottom plot shows the speed response (N) in revolutions per minute (RPM) (y-axis) versus time (s) on the x-axis. Initially, the speed starts from zero and rises gradually as the motor accelerates under the applied torque. The curve shows a smooth rise with minor ripples during the transient phase, which correspond to the torque oscillations seen in the upper graph. Eventually, the speed curve flattens and reaches a steady-state value, demonstrating that the motor achieves stable operation at the desired speed.

Overall, the plots demonstrate that the SyRM drive successfully transitions from a transient state (startup with oscillations) to a steady state (constant torque and stable speed). This confirms the effectiveness of the drive control system in maintaining performance.

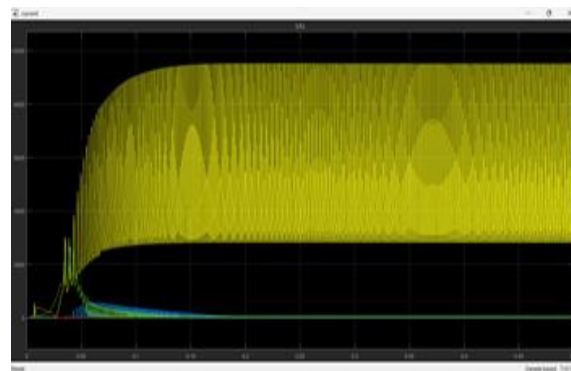


Fig.5.3 The Current response

This diagram appears to be a time-domain plot illustrating the changes in current over time during an electrical simulation or measurement process. The x-axis of this diagram is labeled in terms of time, specifically from 0 to 0.5 seconds, representing how the current evolves during this interval. The y-axis, labeled as " $I(A)$ ", denotes the current measured in amperes (A), and it spans from 0 up to above 10,000 amperes. The various colored curves in the graph indicate different current signals, which may represent distinct phases, components, or elements within the studied system. The yellow curve, which dominates the graph, shows a rapid escalation and sustained oscillatory behavior at very high amplitude, while other curves exhibit transient responses that decay much faster. The plot provides insight into dynamic behavior, such as initial transients, steady-state values, and possible periodic fluctuations within the electrical network or device under test.

VI.CONCULSION

The dynamic simulation results of the Synchronous Reluctance Motor (SyRM) drive clearly demonstrate its effective performance under transient and steady-state conditions. The torque response shows initial oscillations during startup due to transient dynamics, which gradually stabilize as the motor achieves steady operation. Similarly, the speed response indicates a smooth acceleration profile, starting from zero and settling at the desired steady-state value without significant overshoot. These results validate the capability of the SyRM drive to achieve efficient torque production and stable speed control with minimal ripple, highlighting its potential for high-

performance industrial and electric vehicle applications.

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