ISRES Publishing

The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 2026

Volume 40, Pages 172-183

ICBAST 2026: International Conference on Basic Sciences and Technology

Comparative Analysis of Conventional and Modern Control Techniques in PMSM Systems

Mahmut Furkan Oztok
Konya Technical University

Emre Hasan Dursun
Konya Technical University

Abstract: Permanent Magnet Synchronous Motors (PMSMs) are indispensable components of modern industrial systems, electric vehicles and renewable energy infrastructures due to their high efficiency, power density, wide speed range and superior torque to inertia ratio. However, maximizing the dynamic performance and energy efficiency of these machines requires advanced control strategies that offer robust stability against variable loads, parameter uncertainties and external disturbances. Furthermore, the inherent nonlinearities of PMSMs, such as magnetic saturation and cross-coupling effects, complicate the design of precise tracking controllers. To address this, this study provides a comprehensive theoretical review of both fundamental and contemporary control techniques for PMSMs. Conventional methods, including Scalar Control (V/f), Field-Oriented Control (FOC) and Direct Torque Control (DTC), are systematically classified alongside recent adaptive, intelligent and robust control approaches. These methodologies are comparatively evaluated based on critical performance criteria, including dynamic response, torque ripple mitigation, computational burden, implementation complexity and parameter sensitivity. By synthesizing these existing frameworks, this research establishes a solid theoretical foundation for future control strategy development, ultimately guiding researchers in designing high-performance, next-generation motor drive architectures.

Keywords: Permanent magnet synchronous motor, Control strategies, Robust and adaptive control

Introduction

Permanent Magnet Synchronous Motors (PMSMs) are widely preferred in a broad range of industrial applications, from low-power systems to high-power traction units, due to their high efficiency, superior torque-to-inertia ratio, and rapid dynamic response. Their robust structure and low maintenance requirements ensure reliable long-term performance, making them an ideal choice for robotics, electric vehicles, and wind energy conversion systems (Shneen et al., 2019). The critical role of PMSMs in modern industry is attributed not only to their electromechanical properties but also to the effectiveness of the control strategies implemented. Precise management of speed, torque, and current is essential to enhance energy efficiency and minimize oscillations under various operating conditions.

The non-linear nature of PMSMs and the complexities arising from the rotor-mounted permanent magnets necessitate advanced control methodologies beyond conventional techniques. Operational challenges such as unpredictable load variations and parameter uncertainties increase the demand for flexible and adaptive control systems (Hattab et al., 2024). Consequently, contemporary research focuses on managing the non-linear dynamics of the motor through diverse approaches. Methods such as Fuzzy Logic Control (FLC), vector control techniques like Field-Oriented Control (FOC), Adaptive Control, and Artificial Intelligence (AI) based techniques are prominent in the literature, each selected based on specific application requirements.

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

Fuzzy Logic Control provides effectiveness in handling uncertain data and complex dynamics, ensuring stability under varying loads. Vector control, on the other hand, offers high precision by decoupling the magnetic flux and torque components. Adaptive control strategies allow the system to adjust parameters in real-time in response to environmental changes or system disturbances. Recently, computational intelligence approaches, including Artificial Neural Networks (ANN) and Reinforcement Learning (RL), have introduced new perspectives by enabling the control algorithms to learn and optimize motor behavior over time (Askour et al., 2024). Additionally, meta-heuristic optimization algorithms have proven highly effective in dynamically tuning controller parameters to handle non-linearities.

The optimization of PMSM control is vital not only for operational performance but also for energy sustainability. In electric vehicle applications, efficient control directly impacts driving range and minimizes energy losses. Similarly, in wind turbines, advanced control techniques facilitate more stable and efficient power generation. Innovations in PMSM control methodologies thus form the foundation for sustainable energy solutions and continue to be a strategic focus for both industrial and academic research.

Literature Review

The existing literature contains a multitude of studies focused on enhancing the operational robustness and performance metrics of PMSM control systems. Various methodologies have been proposed by researchers to tackle specific functional challenges, aiming to improve reliability, efficiency, and the integration of PMSMs into sophisticated technological sectors. For instance, a Fuzzy Logic Control (FLC) integrated Field-Oriented Control (FOC) approach was developed to autonomously adjust Proportional-Integral (PI) controller parameters in response to dynamic system fluctuations (Gu et al., 2019).

In another study, an FOC based sensorless intelligent speed regulation method was introduced to manage Inter-Turn Short Circuit (ITSC) faults by utilizing a Luenberger observer coupled with adaptive fuzzy logic (Kercha et al., 2023). Furthermore, the integration of neural networks with PI and fuzzy control strategies has been investigated to ensure robust performance in synchronous machines, emphasizing the necessity of rigorous performance analysis in hybrid architectures (Reddy et al., 2021). Additionally, the dynamic performance of sensorless PMSM control has been evaluated through hardware-in-the-loop tests using a Backstepping-PSO based controller supported by an Extended State Observer (ESO) (Nicola et al., 2021).

This paper offers an extensive evaluation of diverse control strategies, spanning from conventional methodologies to modern artificial intelligence-driven applications. The primary objective is to analyze sustainable and high-performance motor control technologies to facilitate innovative solutions for widespread PMSM implementation. The study is organized as follows: The subsequent section details the system configuration comprising the PMSM, control unit, and power unit—alongside a comparative analysis of control techniques. The concluding sections discuss performance parameters and provide recommendations for future research directions.

System Configuration

The general architecture and core components of the control system designed for PMSMs are presented in schematic form in Figure 1.

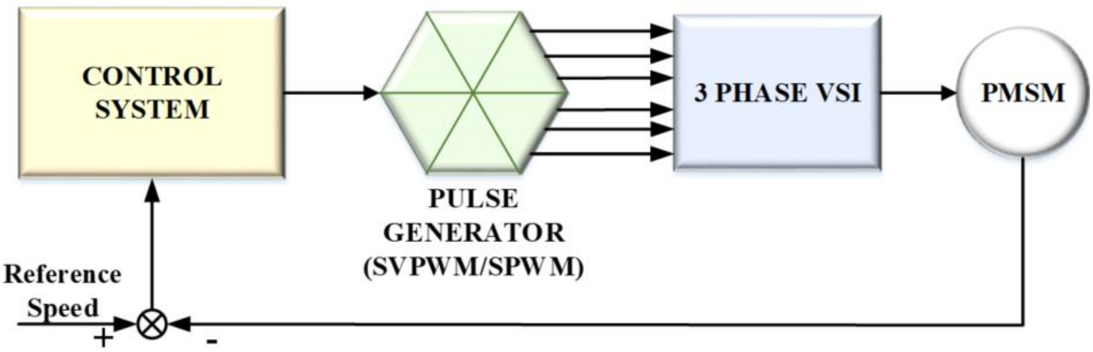

Figure 1. PMSM control system block diagram

The core framework of this system is primarily composed of a motor control unit, a PMSM, a Space Vector Pulse Width Modulation (SVPWM) module and three phase Voltage Source Inverter (VSI). This integrated architecture facilitates bidirectional power flow, ensuring both operational efficiency and high-precision control. In this operational scheme, a predefined reference speed is compared against the actual motor speed to derive an error signal.

Subsequently, the control system processes this error to generate specific command signals, which are then relayed to the SVPWM unit. As depicted in Figure 1, these commands are utilized to produce appropriate PWM switching pulses, which are then applied to the three-phase inverter to drive the PMSM. The control loop is closed through the continuous monitoring and feedback of speed and performance metrics. This closed-loop configuration maintains a steady interaction between the primary components, ensuring the accurate and high-performance operation of the PMSM.

PMSM

As depicted in Figure 2, the PMSM operates as a rotary electrical machine comprising a standard three-phase stator, akin to an induction motor (IM), yet it is distinguished by the integration of permanent magnets on its rotor. In contrast to IMs—which rely on induction and magnetizing currents to create the air-gap magnetic field—the PMSM generates this field directly utilizing its rotor magnets (Boztas, 2023). While the stator current in an IM must be divided between magnetization and torque generation components, the PMSM intrinsically sustains a steady air-gap flux via its permanent magnets. Consequently, the necessity for magnetizing current is entirely eliminated, allowing the stator current to be utilized exclusively for torque production. This distinct attribute enables the PMSM to achieve superior efficiency and a higher power factor when evaluated against an IM of comparable power capacity (Pillay & Krishnan, 1989; Aydogmus & Sunter, 2012).

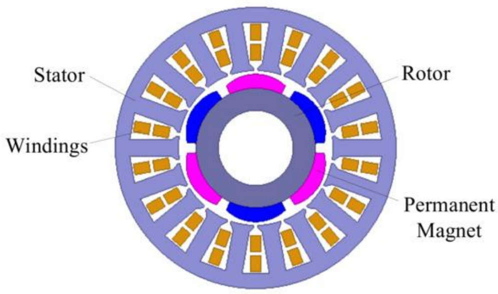

Figure 2. PMSM structure

Within a standard three-phase PMSM architecture, currents flowing through sinusoidally distributed stator windings produce a revolving magnetic field. Consequently, the rotor is compelled to synchronize with and track this generated flux vector. The generation of electromagnetic torque is governed by the load angle, which is defined as the phase discrepancy between the stator flux linkages and the rotor flux vector.

During the formulation of the mathematical model for the PMSM, specific foundational assumptions are adopted to streamline the analytical process. These preconditions entail the presumption of perfectly balanced stator windings and a strictly sinusoidal induced electromotive force (EMF), alongside the disregard of parameter fluctuations and magnetic saturation. Additionally, hysteresis and eddy current effects, collectively known as core losses, are omitted from the model. Implementing these reductions permits a concentrated investigation into the primary electromechanical behaviors of the machine (Puci et al., 2018). Accordingly, the stator voltage formulation within the stationary abc reference frame is given by the subsequent equation (Krause, 1986):

$$V_{abcs} = R_s i_{abcs} + \frac{d}{dt}\lambda_{abcs} \qquad (1)$$

In the established model, V_{abcs}, i_{abcs}, and λ_{abcs} represent the stator phase voltages, stator phase currents, and flux linkages, respectively. Furthermore, to convert the control variables from the rotating *d-q* reference frame back to the stationary *a-b-c* frame, the Inverse Park Transformation is utilized. For instance, the transformation for the *c*-phase component is formulated in Equation 2 (Şerifoğlu, 2007).

$$F_c = F_d \cos(\theta + \frac{2\pi}{3}) - F_q \sin(\theta + \frac{2\pi}{3}) \quad (2)$$

where F_c represents the physical variable in the stationary *c*-phase; F_d and F_q denote the corresponding components in the rotating *d*-axis and *q*-axis, respectively; and θ is the electrical rotor position. The term 2π/3 accounts for the 120° spatial displacement of the *c*-phase. This coordinate transformation is essential for generating the actual physical signals required to drive the PMSM.

The implementation of the *dq0* transformation within the rotor reference frame enables the motor equations to be expressed in a simplified and decoupled structure. This transformation is fundamental for linearizing the complex dynamics of the motor and supporting sophisticated regulation architectures. As illustrated in Figure 3, these mathematical relationships can be represented through the *d* and *q* axis equivalent circuit diagrams which clarify the interaction between stator voltages and magnetic flux components. These simplified analytical models are defined by the subsequent equations (Chapman, 2007).

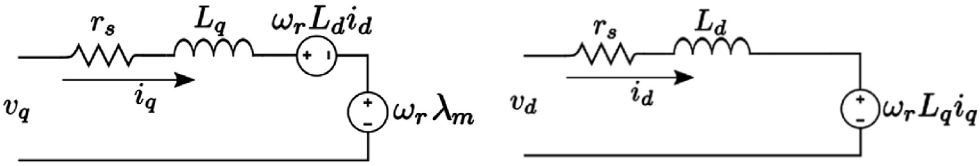

Figure 3. PMSM circuit diagram (Chapman, 2007).

$$v^r_{qs} = R_s i^r_{qs} + \omega_{re} \lambda^s_{ds} + \frac{d\lambda^s_{qs}}{dt} \quad (3)$$

$$v^r_{ds} = R_s i^r_{ds} - \omega_{re} \lambda^s_{qs} + \frac{d\lambda^s_{ds}}{dt} \quad (4)$$

$$\lambda^s_{qs} = L_{qs} i^r_{qs} \quad (5)$$

$$\lambda^s_{ds} = L_{ds} i^r_{ds} + \lambda_f \quad (6)$$

$$T_e = \frac{3P}{4}(\lambda^r_f i^s_{qs} - \lambda^r_{qs} i^s_{ds}) \quad (7)$$

In the provided formulations, Equations 3 and 4 define the stator voltage components along the *q* and *d* axis respectively. Similarly, Equations 5 and 6 describe the flux linkages for the *dq* axes. Finally, the electromagnetic torque is formulated in Equation 7. The three-phase stator phase voltages of the motor utilized in this study are expressed through Equations 8, 9 and 10 (Leonard & Murphy, 2001).

$$V_{as} = V_m \sin(\omega t) \quad (8)$$

$$V_{bs} = V_m \sin(\omega t - \frac{2\pi}{3}) \quad (9)$$

$$V_{cs} = V_m \sin(\omega t + \frac{2\pi}{3}) \quad (10)$$

Within these mathematical representations V_{as}, V_{bs}, and V_{cs} indicate the phase voltages of the stator for phases A, B and C. Furthermore, V_m, stands for the maximum amplitude of the stator voltage. The inherent nonlinearity in the dynamics of PMSMs makes their regulation highly challenging. While traditional linear techniques such as Proportional Integral regulators remain popular due to their straightforward architecture, they frequently fall short of delivering optimal results during demanding operational scenarios. Such conventional controllers cannot adequately manage the nonlinear characteristics of these motors. This inadequacy leads to restricted operational efficiency and compromised stability under fluctuating conditions (Xiao et al., 2022).

Escalating demands from the industrial sector have exposed the insufficiencies of linear regulation algorithms when subjected to the severe working environments typical of PMSMs. Contemporary applications strictly require sophisticated methodologies that can sustain excellent operational standards despite fluctuating payloads and outside interferences. Numerous academic studies have concentrated on designing novel regulation architectures to bypass these obstacles (Zhang & Tang, 2021). Scholars have successfully improved system resilience and regulation effectiveness across a wide range of working states by incorporating nonlinear frameworks, adaptive mechanisms and smart computational algorithms. These improvements have allowed PMSMs to meet the rigorous criteria of modern commercial and manufacturing applications (Ye, 2019). As a result, a wide array of regulation paradigms has emerged to satisfy these continuously growing necessities.

PMSM Control

PMSMs are extensively utilized in low- to medium-power applications and are preferred in high-performance electric drive systems such as electric vehicles, robotics, aerospace, and machine tools (Ma & Li, 2020). However, the nonlinear nature of motor models and the uncertainties encountered in speed control systems during operation make it difficult for conventional PI control topologies to meet high performance requirements. Consequently, contemporary research focuses heavily on mitigating these uncertainties and enhancing system robustness (Zheng et al., 2021).

Since the introduction of speed regulation for AC motors, vector control methods have gained significant popularity with Direct Torque Control (DTC) and Field-Oriented Control (FOC) being the most prevalent. FOC is widely adopted in PMSM applications due to its ability to provide rapid and precise decoupling of torque and flux. Typically, PI controllers are integrated into FOC structures for current and speed regulation due to their simple design. However, since PI gains are generally determined based on nominal motor parameters, stability cannot be guaranteed in the presence of load variations, parameter uncertainties, or input saturation. Therefore, these controllers may be inadequate for applications requiring extreme precision and high dynamic performance (Ullah et al., 2022).

To address these limitations, several advanced nonlinear control topologies have been developed. These include Artificial Neural Network (ANN) control, Backstepping Control, Active Disturbance Rejection Control (ADRC), Fuzzy Logic Control (FLC), Model Predictive Control (MPC), Sliding Mode Control (SMC), Adaptive Control and various observer-based techniques such as Extended State Observers (ESO). Additionally, H_∞ control is utilized as an alternative to traditional PI methods for speed regulation, where external disturbances are treated as uncertain parameters with bounded energy. Many of these robust strategies, including mixed sensitivity-based controllers, have been successfully implemented in practical PMSM systems to enhance speed regulation (Yang et al., 2021).

H∞ Robust Control

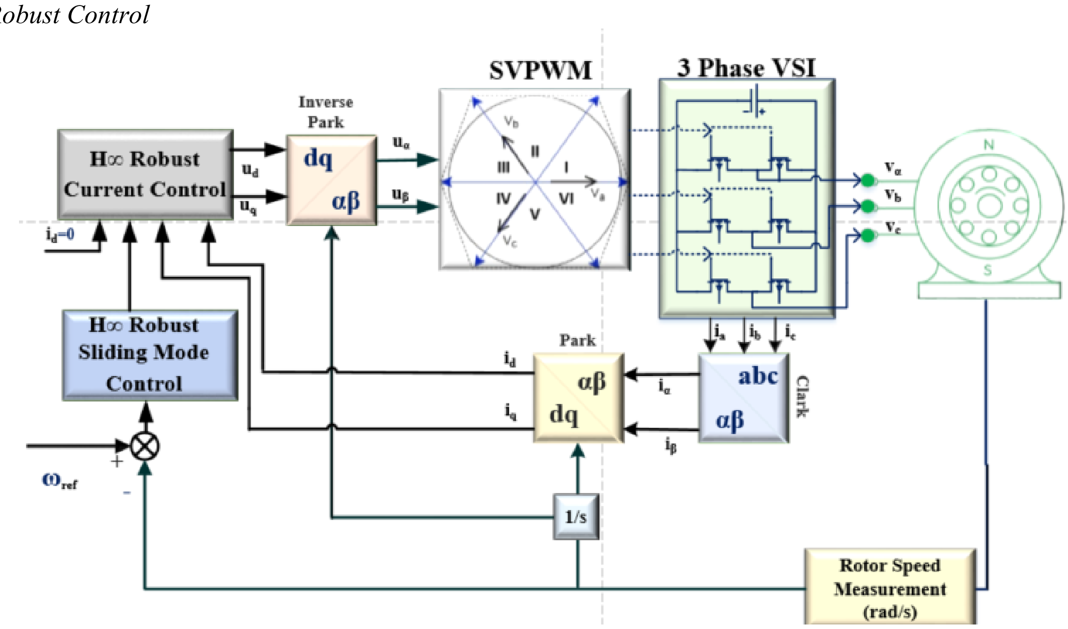

Figure 4. SMC-based H∞ robust control block diagram for PMSM

H∞ robust control is an advanced methodology designed to enhance system resilience against parameter uncertainties and external disturbances. The primary objective of this approach is to minimize the H∞ norm of the system, which represents the maximum input-output gain under worst-case scenarios. Reducing this norm ensures that the system remains robust against external disturbance signals. This control strategy facilitates designs that account for modeling errors and uncertainties, offering a significant advantage by guaranteeing system stability and maintaining optimal performance in the presence of model-plant mismatches (Green & Limebeer, 2012). The H∞ control method is widely applied across various domains, ranging from energy systems to automation and motor control. Specifically, in PMSM control, it provides an effective solution for mitigating disturbance effects in high-precision applications such as speed and position control (Saberi et al., 2007). The method is extensively utilized to ensure robust stability in nonlinear systems and enhance dynamic performance against external perturbations. The block diagram of an H∞ control system based on Sliding Mode Control (SMC) for a PMSM is illustrated in Figure 4.

Predictive Current Control (PCC)

Predictive Current Control (PCC) serves as a specialized regulation strategy for PMSMs aimed at streamlining the system framework and enhancing immunity against parameter fluctuations. This methodology utilizes a predictive model and a cost function to optimize the current control process which significantly boosts the dynamic performance of the motor. The strategy effectively neutralizes the negative impacts caused by deviations in inductance parameters within the regulation system. While some observer-based approaches aim to mitigate disturbances, they frequently introduce excessive design complexity and can potentially compromise the overall equilibrium of the system. To resolve these issues, recent academic investigations have introduced innovative PCC structures. A basic representation of this predictive control framework, comprising a cost function, model prediction and delay compensation units, is displayed in Figure 5 (Kuz'Menko, 2020).

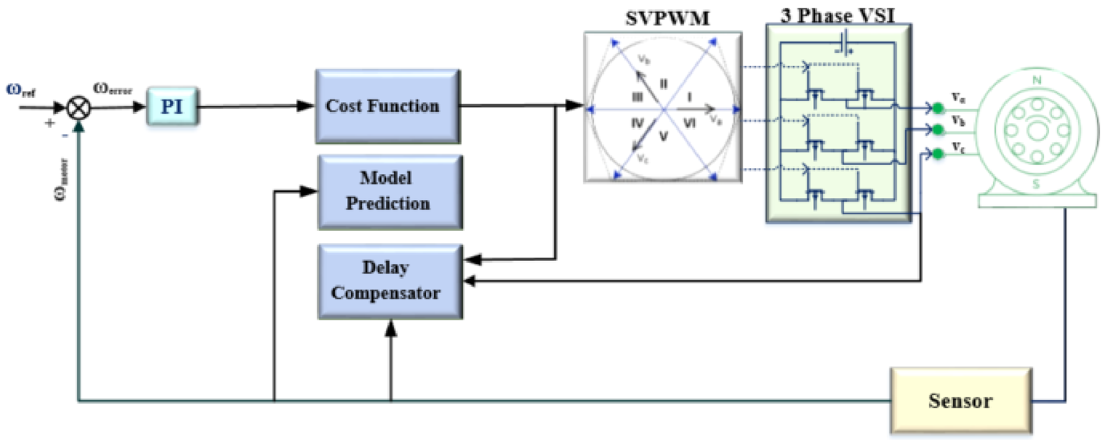

Figure 5. PCC block diagram for PMSM

Proportional Integral (PI) Control

PI controllers represent a conventional control strategy widely utilized across various industrial automation and drive applications. These controllers consist of a proportional gain and an integral action, which are collectively responsible for accelerating the control response, minimizing steady-state errors, and ensuring the system reaches a stable equilibrium. The input to the PI controller is defined as the error signal, representing the difference between the reference speed and the actual measured speed. The mathematical relationship between the input error and the controller output is expressed in Equation 11.

$$u(t) = K_p e(t) + K_i \int e(t)dt \tag{11}$$

where $u(t)$ is the control output signal and the speed error is defined as $e(t)=\omega_{ref} - \omega$. The performance of the PI controller is strictly dependent on the proper tuning of proportional K_p and integral K_i gains. However, a PI controller designed based on specific model parameters and time-discretization assumptions cannot guarantee stability in the presence of uncertainties, load variations, or input saturation limits. In PMSM control, when a significant set-point change occurs, the PI controller utilizes its integral action to mitigate the cumulative error.

The fundamental operational block diagram of a conventional PI speed control loop for a PMSM is illustrated in Figure 6 (Kung et al., 2015).

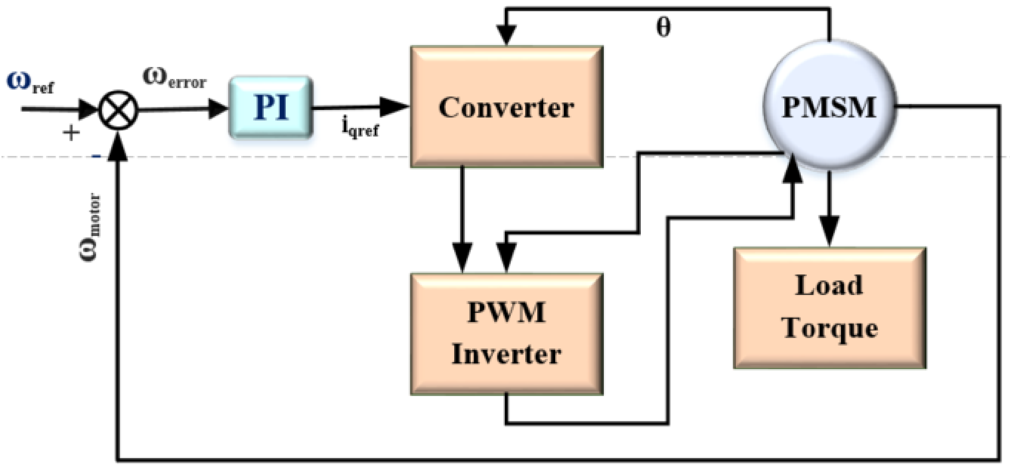

Figure 6. PI control block diagram for PMSM

Sliding Mode Control (SMC)

Sliding Mode Control (SMC) is a robust speed regulation methodology widely adopted for PMSM applications. It has been extensively investigated in literature and implemented across various systems through diverse approaches. As a nonlinear control technique, SMC exhibits remarkable insensitivity to motor parameter variations and load disturbances. The method employs a switching algorithm to ensure that the system state trajectories track a predefined path on the phase plane, known as the sliding surface (Lu et al., 2021).

However, SMC is inherently limited by high-frequency oscillations, termed "chattering," which arise from the switching function once the sliding mode is reached. This phenomenon presents a significant challenge in high-precision applications such as industrial robotics and machine tools. To mitigate this issue, advanced methodologies, including reaching law-based SMC, fractional-order sliding mode control, and boundary layer methods, have been developed. While these approaches reduce chattering intensity, they often fail to eliminate it completely in the presence of external disturbances. Consequently, integrating disturbance observers to optimize SMC performance and provide disturbance compensation has become a primary research focus. The structural schematic of an observer-based SMC is illustrated in Figure 7 (Ullah et al., 2022).

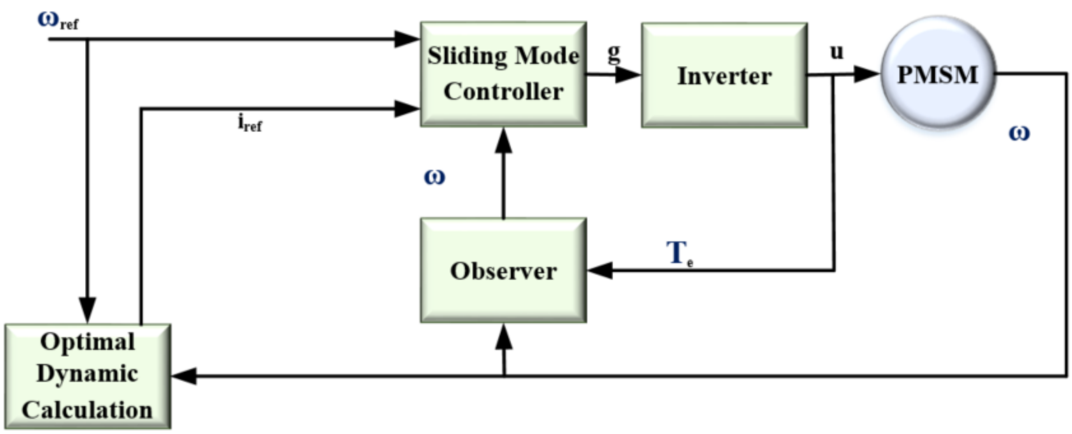

Figure 7. An observer-based SMC block diagram for PMSM

Fuzzy Logic Control (FLC)

Fuzzy logic regulation functions as a controller governed by rules that employ algorithms based on linguistic tactics. This method successfully integrates human proficiency into the regulation framework without the necessity of exact mathematical formulations. These linguistic tactics mimic the cognitive choices of humans through the application of fuzzy logic principles extracted from specialist insight. As a result, this mechanism proficiently governs intricate nonlinear structures even when strict mathematical descriptions are unavailable.

Converting specialist insight into conditional statements allows the system to evaluate ambiguous signals and offers a highly adaptable methodology for operational regulation. The initial fuzzification stage translates precise inputs like velocity deviations into fuzzy domains. Following this, the knowledge foundation enforces logical conditions on these domains and the final defuzzification phase reverts these outputs into definite figures for actual execution within the hardware. Such a structural design empowers the methodology to supply dependable execution across diverse fields including manufacturing automation and commercial gadgets where standard approaches frequently fail (Hattab et al., 2024). The primary elements of this architecture are illustrated in Figure 8 whereas the design for PMSM regulation driven by fuzzy logic is depicted in Figure 9.

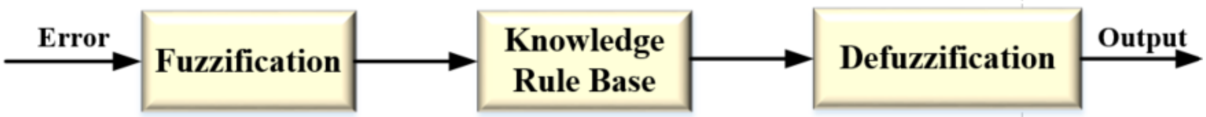

Figure 8. FLC General Working Scheme

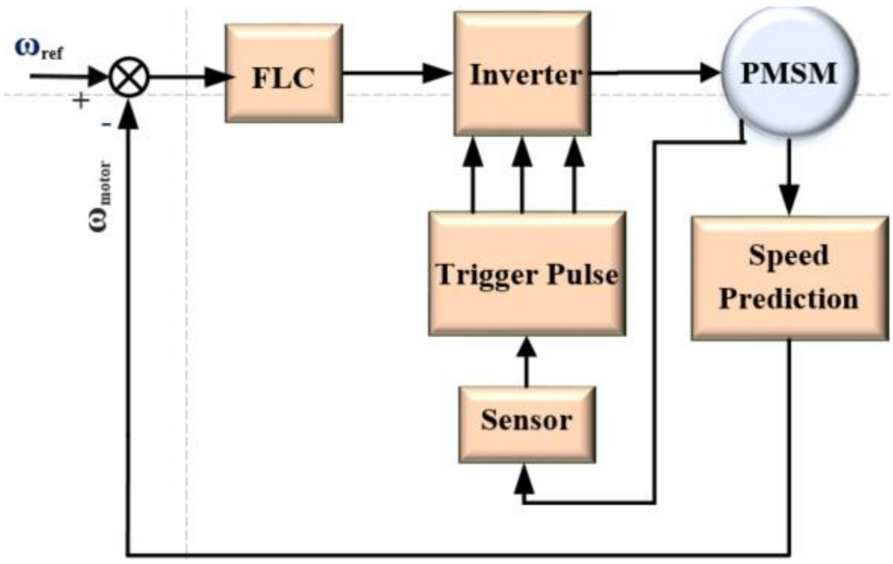

Figure 9. FLC block diagram for PMSM

Artificial Neural Network (ANN)-Based Control

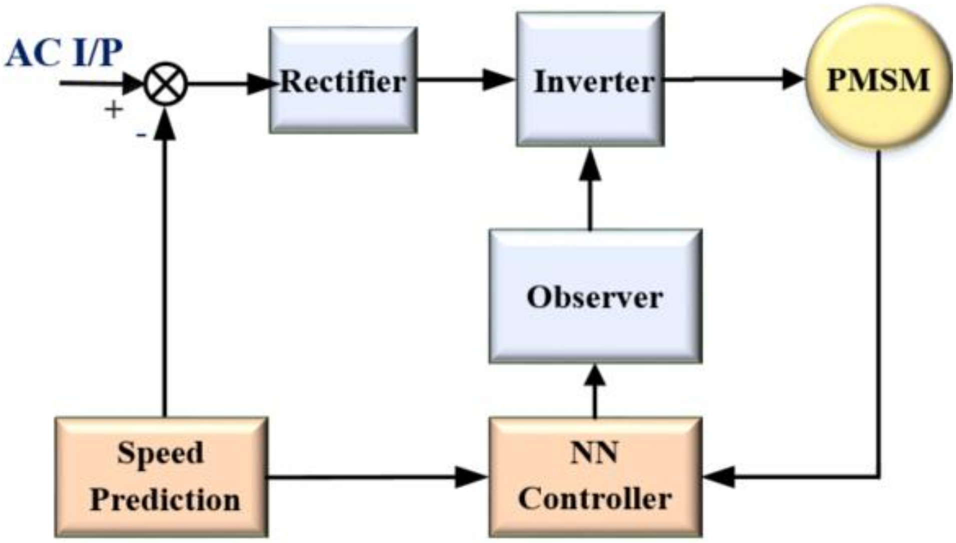

Figure 10. ANN-based control block diagram for PMSM

ANN-based control is a learning-oriented approach that can be implemented for speed, position, or current regulation in PMSMs. By modeling the nonlinear dynamics of the motor, ANNs learn and predict complex system behaviors. This methodology is particularly preferred for providing control under parameter uncertainties or varying operating conditions. Compared to conventional control methods, ANNs optimize system performance through their offline learning capabilities and online adaptation features. In PMSM control, ANNs are generally utilized for the adaptation of PI controller gains or for providing direct speed and torque control. Consequently, energy efficiency is increased, and system stability is significantly improved (Ghamri et al., 2019). A general block diagram of a PMSM control system regulated by an ANN is illustrated in Figure 10.

Field Oriented Control (FOC)

Field oriented control is broadly acknowledged as a remarkably efficient and dependable methodology for governing permanent magnet synchronous motor operations. Throughout the previous twenty years, swift progress within power electronics, processing capacities and microelectronics has promoted the widespread adoption of vector regulation mechanisms within superior alternating current applications. This methodology permits accurate regulation by separating magnetic flux and rotational force elements, like the functioning attributes of an independently stimulated direct current machine (Öztok & Dursun, 2025).

The technique utilizes current regulation circuits engineered to manage electrical flows across the d and q axis individually. A standard diagram representing this framework, which includes an external velocity circuit and separate internal current loops to attain maximum efficiency in these motor structures, is presented in Figure 11. Inside these sequential circuits, standard proportional integral mechanisms are customarily utilized for velocity and flow management, guaranteeing the productive and steady functioning of the driving machinery (Petkar&Kumar,2020).

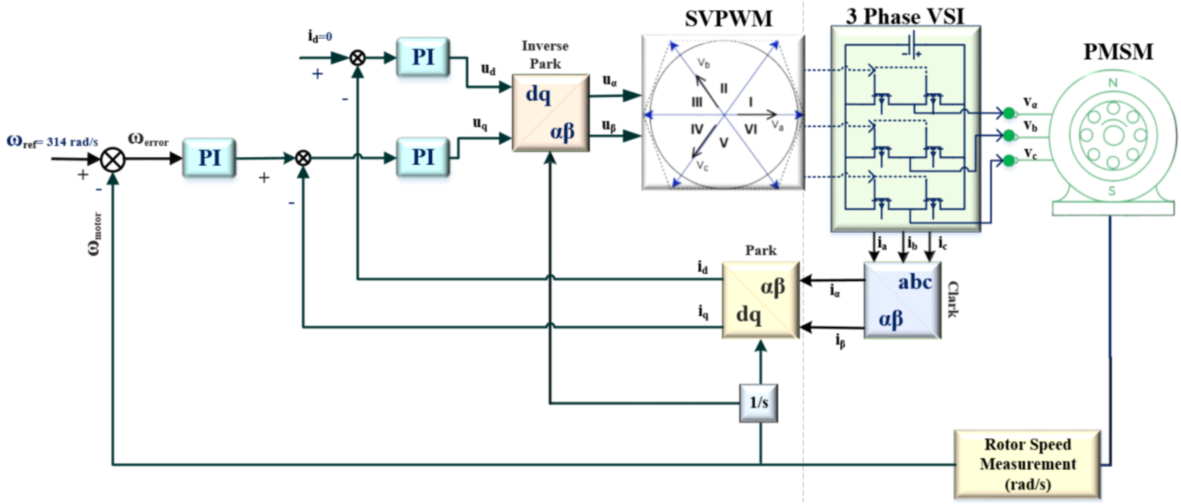

Figure 11. FOC block diagram for PMSM

Comparative Analysis and Discussion

Table 1. Comparison of control techniques

Control Technique	Advantages	Disadvantages
PI Control	Simple implementation; Low computational cost.	Poor performance under load variations; Sensitivity to parameter changes.
FOC	High precision in torque/flux; Excellent dynamic response.	Requires accurate rotor position; Dependent on motor parameters.
SMC	High robustness against disturbances; Insensitivity to parameter mismatch.	Chattering phenomenon; Complex switching algorithm.
FLC/ANN	No precise mathematical model required; Handles nonlinearities effectively.	High computational demand; Rule/training data dependency.
PCC/ H∞	Predicts future states; Superior disturbance rejection.	Sensitive to model inaccuracies; Complex mathematical derivation.

A comparative analysis of the discussed control strategies reveals that each methodology possesses specific strengths and limitations depending on the application requirements. As illustrated throughout this review, the selection of an appropriate control strategy is a critical determinant of PMSM drive performance. The findings regarding the operational advantages and inherent drawbacks of these techniques are synthesized in Table 1.

Conclusion

This study has provided a comprehensive theoretical review of various control methodologies for PMSMs, ranging from conventional PI and FOC to advance nonlinear and intelligent techniques. Analysis indicates that while traditional methods are sufficient for standard applications, high-performance systems require robust and adaptive strategies to mitigate the effects of nonlinearities and external disturbances.

Future research will focus on the simulation and real-time experimental validation of these control techniques. Specifically, the development of hybrid control architectures integrated with metaheuristic optimization algorithms-such as the Whale Optimization Algorithm (WOA) or Particle Swarm Optimization (PSO)-is planned to achieve an optimal balance between dynamic response and steady-state accuracy. These hybrid approaches aim to optimize control parameters autonomously, paving the way for next-generation, self-adaptive PMSM drive systems.

Recommendations

To overcome the inherent limitations of individual control strategies, it is recommended to develop hybrid architectures that combine Sliding Mode Control (SMC) with Fuzzy Logic or ANN to eliminate chattering phenomenon while maintaining system robustness. Furthermore, future studies should prioritize real-time experimental validation using high-speed Digital Signal Processors (DSPs) to assess the computational feasibility of these complex algorithms. Additionally, the integration of meta-heuristic optimization for continuous, autonomous parameter tuning is strongly suggested to enhance system adaptability under dynamic load variations. Ultimately, these advancements are essential for developing next-generation, self-optimizing PMSM drive systems.

Scientific Ethics Declaration

* The authors declares that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest (If the number of authors is more than one)

Funding

* No financial support or funding has been received from any public, private, or non-profit organization for the research, authorship, and/or publication of this study.

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Basic Sciences and Technology (www.icbast.net) held in Konya/Türkiye on April 02-05, 2026.

* The authors would like to express their sincere gratitude to Konya Technical University for providing the necessary facilities, academic environment, and technical resources that significantly contributed to the successful completion of this research.

References

Askour, R., Jbari, H., & Idrissi, B. B. (2024). Comparative investigation of DSP-based speed control of PMSM using proportional integral and Takagi-Sugeno fuzzy logic controller. *International Journal of Electrical and Electronic Engineering and Technology (IJEETC)*, *13*(2), 135–145.

Aydogmus, O., & Sunter, S. (2012). Implementation of EKF-based sensorless drive system using vector controlled PMSM fed by a matrix converter. *International Journal of Electrical Power & Energy Systems*, *43*(1), 736–743.

Boztas, G. (2023). Comparative modelling and experimental verification of a PMSM drive system. *European Journal of Technique*, *13*(2), 234–245.

Chapman, S. J. (2007). *Elektrik makinelerinin temelleri*. Çağlayan Kitapevi.

Ghamri, A., Boumaaraf, R., Benchouia, M., Mesloub, H., Goléa, A., & Goléa, N. (2019). Comparative study of ANN DTC and conventional DTC controlled PMSM motor. *Mathematics and Computers in Simulation*, *167*, 219–230.

Green, M., & Limebeer, D. J. N. (2012). *Linear robust control*. Dover Publications. Mineola, NY.

Gu, Y., Wang, X., & Li, Z. (2019). Matlab/Simulink-based modeling and simulation of fuzzy PI control for PMSM. *Proceedings of the 3rd International Conference on Mechatronics and Intelligent Robotics (ICMIR-2019)* (pp. 123–129). Springer.

Hattab, W., Benakcha, A., & Tabet, S. (2024). Assessment of the hybrid fuzzy PI speed controller's performance in PMSM utilizing model reference adaptive system (MRAS) estimation. *Proceedings of the 2024 IEEE Conference on Systems, Signals, and Automation*. IEEE.

Kercha, S., Ameur, A., Benmiloud, I., Bechkaoui, A., & Linani, M. (2023). Detection of turn short-circuit fault in PMSM variable speed sensorless vector control based on Luenberger observer and adaptive fuzzy logic controller. *Romanian Review of Automatic Control and Informatics*, *29*(3), 45–55.

Krause, P. C. (1986). *Analysis of electric machinery*. McGraw-Hill Inc.

Kung, Y.-S., Thanh, N. P., & Wang, M.-S. (2015). Design and simulation of a sensorless permanent magnet synchronous motor drive with microprocessor-based PI controller and dedicated hardware EKF estimator. *Applied Mathematical Modelling*, *39*, 5816–5827.

Kuz'menko, A. A. (2020). Robust control of permanent magnet synchronous motor: Synergetic approach. *Mehatronika Avtom. Upr.*, *21*, 480–488.

Leonard, W., & Murphy, J. D. (2001). *Control of electrical drives* (2nd ed.). Springer.

Lu, E., Li, W., Wang, S., Zhang, W., & Luo, C. (2021). Disturbance rejection control for PMSM using integral sliding mode based composite nonlinear feedback control with load observer. *ISA Transactions*, *116*, 203–217.

Ma, Y., & Li, Y. (2020). Active disturbance compensation based robust control for speed regulation system of permanent magnet synchronous motor. *Applied Sciences*, *10*, 709.

Nicola, C.-I., Nicola, M., & Selișteanu, D. (2021). Sensorless control of PMSM based on Backstepping-PSO-type controller and ESO-type observer using real-time hardware. *Electronics*, *10*(2080), 20–36.

Öztok, M. F., & Dursun, E. H. (2025). Application of fuzzy logic control for enhanced speed control and efficiency in PMSM drives using FOC and SVPWM. *Physica Scripta*, *100*(7), 075272.

Petkar, S. G., & Kumar, T. V. (2020). Computationally efficient model predictive control of three-level open-end winding permanent-magnet synchronous motor drive. *IET Electric Power Applications*, *14*(7), 1210–1220.

Pillay, P., & Krishnan, R. (1989). Modeling, simulation, and analysis of permanent-magnet motor drives. Part I: The permanent magnet synchronous motor drive. *IEEE Transactions on Industry Applications*, *25*(2), 265–273.

Puci, I., Vilanova, R., & Ferrer, C. P. (2018). Comparison of speed control of permanent magnet synchronous motor using PI and fuzzy controller. *Proceedings of the 2018 IEEE Conference on Systems and Engineering* (pp. 566–573). IEEE.

Reddy, M. S., Subrahmanyam, V. S. R., Prakash, C. S., & Shankar, G. V. S. U. (2021). Performance analysis of fuzzy and neural controller implementation in permanent magnet synchronous motor. *Proceedings of the 2021 5th International Conference on Intelligent Computing and Control Systems (ICICCS)* (pp. 566–574). IEEE.

Saberi, A., Sannuti, P., & Chen, B. M. (2007). *H2 optimal control and H∞ optimal control*. Springer.

Şerifoğlu, N. A. (2007). *Elektrik makinaları: Cilt 2* (1st ed.). Nobel Yayıncılık.

Shneen, S. W., Kareem, H. H., & Abdulmajeed, H. A. (2019). Fuzzy-PI control for speed of PMSM drive system. *Journal of Scientific and Engineering Research*, *6*(4), 31–35.

Ullah, K., Guzinski, J., & Mirza, A. F. (2022). Critical review on robust speed control techniques for permanent magnet synchronous motor (PMSM) speed regulation. *Energies*, *15*(3), Article 1235.

Xiao, F., Chen, Z., Chen, Y., & Liu, H. (2022). A finite control set model predictive direct speed controller for PMSM application with improved parameter robustness. *Electrical Power and Energy Systems*, *143*, Article 108509.

Yang, J.-Z., Li, Y.-X., & Tong, S. (2021). Adaptive NN finite-time tracking control for PMSM with full state constraints. *Neurocomputing*, *443*, 213–221.

Ye, S. (2019). Design and performance analysis of an iterative flux sliding-mode observer for the sensorless control of PMSM drives. *ISA Transactions*, *94*, 255–256.

Zhang, B., & Tang, X. (2021). High-performance state feedback controller for permanent magnet synchronous motor. *ISA Transactions*.

Zheng, Y., Zhao, H., Zhen, S., & Sun, H. (2021). Fuzzy-set theory based optimal robust constraint-following control for permanent magnet synchronous motor with uncertainties. *Control Engineering Practice*, *115*, 104911.

Author(s) Information

Mahmut Furkan Oztok
Konya Technical University
Selçuklu/Konya, Türkiye
ORCID iD: https://orcid.org/0000-0002-3179-8540
*Contact e-mail: *mfoztok@ktun.edu.tr*

Emre Hasan Dursun
Konya Technical University
Selçuklu/Konya, Türkiye
ORCID iD: https://orcid.org/ 0000-0001-9286-0195

*Corresponding author(s) contact email

To cite this article:

Oztok, M.F., & Dursun, E.H. (2026). Comparative analysis of conventional and modern control techniques in PMSM systems. *The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 40,* 172-183.