iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** V **Month of publication:** May 2023

DOI: https://doi.org/10.22214/ijraset.2023.52995

Review of Comparative Analysis of Speed Control Techniques of BLDC & PMSM Motor

Awantika Shinde[1], Ankita Shinde[2], Payal Patil[3]
[1, 2, 3]Walchand College Of Engineering, Sangli

Abstract: Electric vehicles are becoming increasingly popular due to their environmental benefits and the need to reduce dependency on fossil fuels. Due to their great efficiency, dependability, and low maintenance requirements, BLDC (Brushless DC) motors and PMSM (Permanent Magnet Synchronous motors) are frequently utilized in EVs. For these motors to operate as efficiently and as effectively as possible, control is essential. This study provides an overview of the control strategies utilized for BLDC and PMSM motors in EVs. This study examines and compares the torque ripple, efficiency, and cost of these motors, along with the different control techniques utilized. This review paper highlights the problems and potential in this area while providing a thorough analysis of the current state of the art in the control of BLDC and PMSM motors in EVs.

I. INTRODUCTION

An electric motor, a motor controller, and Batteries are the three essential parts of an electric vehicle. An electric vehicle's main energy source for propulsion is its electric motor. Using the electric motor, the battery's electric energy is converted into mechanical energy. The suitable transmission system transmits this mechanical energy to the wheels, which move the vehicle in the desired direction. Depending on the purpose of the vehicle, electric vehicles employ a variety of electric motor types. Because motor parameters have an impact on a vehicle's total performance, careful consideration must be given when choosing a specific motor for an electric vehicle.[1]

A Brushless DC motor (BLDC motor) is a motor that generates a trapezoidal back electromotive force (EMF) wave. This motor is known for its high-power-density, strong torque at the output, and excellent dynamic characteristics. straightforward structure and control process, as well as its high reliability, are some of the important features of the motor. As a result, the BLDC motor has gained extensive utilization in various industries such as machine tools, electric automotive, and aerospace. It has also started to replace conventional induction motors and brushed motors in numerous applications. [2]

There is growing interest in using permanent magnet synchronous motors (PMSM) in electric vehicles for high efficiency and weight reduction due to the superior dynamic performance, higher power factor, and higher power density as well as higher efficiency. A high ratio of torque-to-current, a high ratio of power-to-weight, high efficiency, and resilience are all potential benefits of permanent magnet synchronous motors. [3]

Effective speed control of PMSM motors involves regulating the rotational speed of the motor shaft, ensuring it operates at the desired speed with accuracy and stability. This control is achieved through advanced control algorithms, feedback mechanisms, and power electronic converters.

Section II comprises speed control techniques for BLDC Motors, Section III comprises the speed control techniques for PMSM Motors and Section IV shows the comparison between the two motors on various parameters. Overall, this paper offers valuable perspectives on the performance and control aspects of electric motors in the context of EV applications, with a specific emphasis on BLDC and PMSM motors.

II. SPEED CONTROL TECHNIQUES FOR BLDC MOTOR

Many different traction motor variations have been investigated for EVs. Still, Brushless direct current motors are more prevalent because of their features like simple design, small weight, a wide speed range, maintenance-free operation, plenty of starting torque, accurate and precise control, quick dynamic reaction, and excellent efficiency.[4] These motors are popular not just because of the torque characteristics and efficiency, but also because they have the advantage of being supplied with direct current, removing the drawbacks associated with brushes. Since BLDC motors have such a high-speed range, speed management is a critical concern. The BLDC Motor can be controlled using a variety of control methods which are discussed in this paper.

One of the most used control techniques to manage non-linear systems is Sliding Mode Control (SMC). The robustness of SMC against parameter changes and outside disruptions is its key characteristic.[5] The fundamental principle of this control is to generate a control law that compels the system's state to slide over a predetermined surface. (Known as the sliding surface) towards the desired setpoint. The controller makes sure that the state of the system stays on the sliding surface, even in the presence of disturbances, by switching between different control modes. The sliding mode controller produces a control signal that is provided to the motor inverter in order to adjust the motor phase currents and, hence, the motor speed. The controller is designed to make sure that the motor speed tracks the desired setpoint accurately, even during the disturbances, such as variations in the supply voltage or load torque. Drive systems such as BLDC and DC motors have been effectively controlled using SMC. The main benefits of SMC include its simplicity, high precision, and excellent reference tracking even when the system is subject to a variety of disturbances and parameter fluctuations.[2]

A. Speed Control of a BLDC Motor using an Intelligent Fuzzy Sliding Mode Controller

With the intention of improving performance of the motor control system, this intelligent control approach for speed control of a Brushless Direct Control motor integrates sliding mode control, fuzzy logic, and an intelligent algorithm.The control method enhances the control precision and resilience by using a system of fuzzy inference to modify the sliding surface parameters of the sliding mode controller in real-time. A sliding mode controller and a fuzzy logic controller make up the two components of the control strategy.A Fuzzy logic controller consists of three units namely, a decision making unit, a fuzzification unit, and a defuzzification unit. The FLC is intended to modify the SMC's sliding surface's properties in real-time. The output obtained from the FLC, which is utilised to modify the sliding surface parameters, is produced by taking the error and its derivative as inputs. The FLC increases the control's precision and robustness by using a set of fuzzy rules to choose the proper values for the sliding surface parameters. The control approach achieves quick and precise speed control and is resistant to external disturbances and BLDC motor system uncertainties.[6]

B. Speed Control of BLDC Motor Drive using a Hybrid Fuzzy Sliding Mode Controller

This control approach enhances the the effectiveness of a Brushless Direct Current motor drive by integrating sliding mode control with fuzzy logic control. Compared to fuzzy logic control and traditional PI control, the controller strives to achieve superior speed regulation and transient response. For speed control when driving a BLDC motor, SMC is incredibly reliable and effective. The soundness and dynamic execution of the system are advanced. Yet, what is referred to as "chattering" is the primary issue with the SMC.The chattering is a result of the controller's erratically moving during control. High torque throbs are visible in the structure as a result of chattering. For the BLDC motor drive a hybrid fuzzy sliding mode controller is employed specifically for this reason. For drive speed control, a fuzzy controller is utilised simultaneously with a sliding mode controller. A fuzzy logic controller is used to calculate the switching gain of the sliding mode controller. The fuzzy logic controller takes the error rate and the error as input and produces a smooth and continuous gain value. This gain value is then used by the sliding mode controller to produce the control signal required for the motor. By doing this, the fuzzy controller lessens chattering while the sliding mode controller controls the drive's speed to the correct level.[4]

C. Speed Control of BLDC Motor with Sliding Mode Control and Observer

The BLDC motor speed control's performance is enhanced by the help of this control approach, which combines sliding mode control with observer techniques. The control technique eliminates the need for expensive sensors and improves control accuracy and robustness by using a sliding mode controller to create the control signal and an observer to determine the speed of the motor and position of rotor.

Understanding the position of rotor is crucial for the BLDC motor’s electronic commutation. As a result, Hall sensors or encoders are always included in BLDC motors as position sensors to provide precise rotor information. However, the major limitations of position sensors are their dependability, maintenance, expense, and variability in measurement readings when exposed to changes in ambient conditions.

In order to overcome the limitation, sliding mode observers (SMO) are used for the estimation, because of their desirable properties such as robustness, easy to implement and the ability to handle the parametric variations and the disturbances. Higher-order Sliding Mode Observer (HOSMO) is employed to calculate the rotor speed and position, which will ultimately lead to the removal of quadrature encoders (position sensors) and lower maintenance costs of motor.[7]

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue V May 2023- Available at www.ijraset.com

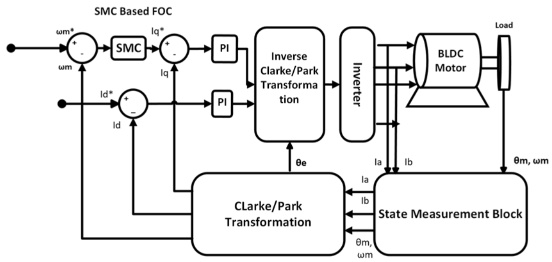


Fig1. BLDC motor control using SMC based FOC with Sliding Mode Observer

D. Speed Control of BLDC Motor using Sliding Mode Control Based on Sliding Mode Torque Observer

It is quite challenging to efficiently control a BLDC motor having low inductance with high performance requirements using both the intelligent control methods, such as neural network control method and fuzzy control method , and the traditional PI control method due to the ultra-low inductance and multi-parameter nonlinearity of the brushless DC motor control system.

Because of the non-linear features of Brushless Direct Control motor control systems and the requirement for motor with low inductance management techniques for high-performance current control, this control technique employs a dual loop control structure to create the BLDC motor's control system with a very small inductor. This control system incorporates the exponential approach law sliding mode speed controller and sliding mode observer for the speed loop, as well as the current hysteresis control for the current loop. It can be seen that the overshoot is decreased, the change in speed when an interruption occurs is also decreased, and the performance is enhanced when compared to the PI Control technique.[2]

E. Variable Structure Control

To stabilise and control non-linear systems, Variable Structure Control along with sliding mode is a common control method. VSC, a form of nonlinear control, employs discontinuous feedback to achieve resilience and stability in dynamic and unpredictable systems. Variable Structure Control with switching is built on the idea of varying control rules or feedback gains according to the condition of the system. Several industries, including aerospace, robotics, power electronics, and automobile control, use this control method. The robustness, simplicity, and ability of VSC to handle non-linearities, uncertainties, and disturbances in the system are some of its benefits. The chattering phenomena, sensitivity to parameter changes, and difficulty in choosing the control parameters are some of the drawbacks of VSC.[8]

F. Speed Control of BLDC Motor Using ANN Regulator and PI Regulator

The classic proportional-integral (PI) control is a common control approach that changes the input voltage of the motor according to the discrepancy between the intended and actual motor speed. The PI control is a straightforward and efficient control system, but it has certain drawbacks, including nonlinearities and poor performance under shifting load situations.

The three-layer feedforward neural network used by the ANN control maps the input current and voltage to the motor's output speed. In order to teach the neural network the nonlinear connection between the input and output variables, backpropagation is used during training. The speed of the motor is then controlled by the trained neural network.[9]

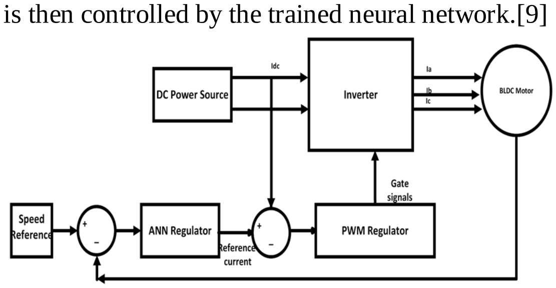


Fig 2. Speed Control of BLDC Motor using ANN Regulator

It has been found that ANN control offers better speed regulation and transient response than standard PI control after comparing the two control systems under various load circumstances. When compared to conventional PI control, ANN control has superior performance and resilience and a faster response time.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue V May 2023- Available at www.ijraset.com

1) Implementation of a Fuzzy Logic Controller for a Indirect Current Controlled Active Filter's Compensating Capacitor Voltage

In a system with an indirect current-controlled active filter (ICCAF), this fuzzy logic technique is used to manage the voltage of the compensating capacitor. ICCAF systems are frequently used in industrial and commercial applications to filter out harmonic currents from power systems. In order to make sure the system is functioning properly., the compensating capacitor voltage—an essential parameter in ICCAF systems—must be controlled. This control approach uses a fuzzy logic controller to continuously regulate the voltage of the compensating capacitor. The FLC accounts for both the error in the capacitor voltage between the desired and actual voltages as well as the evolution of the error over time. The FLC then modifies the pulse width modulation (PWM) converter's switching frequency in order to control the voltage of the compensating capacitor. This control method works effectively to regulate the voltage of the compensating capacitor and to control the system in real-time.[10]

III. SPEED CONTROL TECHNIQUES FOR PMSM MOTOR

A. Model Predictive Control Implementation of QTOSC and Inner Modulated-FS-MPC Torque Control for the PMSM Drive

This control scheme is based on a Model Predictive Control strategy that aims to achieve quasi-time-optimal speed control while maintaining high torque accuracy. The scheme consists of two main modules: outer controller i.e. speed control and inner controller i.e. torque control. The speed control module utilizes a Model Predictive Control algorithm to anticipate the motor's future behavior and optimize the control inputs, aiming to minimize the anticipated deviation between the actual speed and the expected speed. The speed control module i.e. Quasi time-optimal speed control (QTOSC) module is used. The torque controller uses a Finite set model predictive control (FS-MPC) module to approach the optimization of the voltage actuation**.** The control algorithm also uses the Kalman filter for the determination of the state of the system, for this Kalman filter uses stator currents and the rotor angle. This control maintains high torque accuracy, rejects disturbances, and maintains stable operation of the motor.[11]

B. A Modular Control Scheme with Minimization of Pulsating Torque for PMSM Speed Control

This control strategy is used for achieving smooth and efficient speed control of PMSMs with minimized pulsating torque. The control scheme consists of three modules: PI speed regulator, Iterative control module (ILC), and PI current control module. The tracking error between the actual oscillatory torque and the required torque is kept in the memory of the ILC module for one complete cycle, and it is then utilised to produce the reference current for following cycle. The ILC torque control scheme requires torque feedback data to function successfully and also the torque transducer has the disadvantage of low bandwidth. In this control scheme, it is recommended to incorporate a torque estimation module employing a gain-shaped sliding-mode observer. This module enables the estimation of torque ripples that might surpass the bandwidth limitations of a torque transducer. This model is helpful when PMSM is utilized as a high-performance servo.[12]

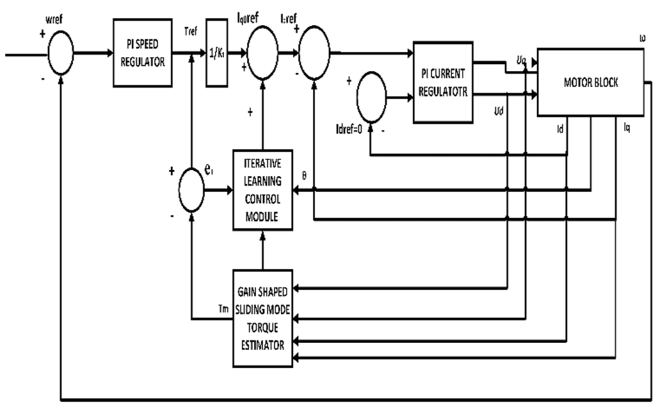


Fig (3) Modular control scheme of PMSM

C. Sensorless Control with Neural Adaptive-Band Filtering and Signal Injection For Speed Control of PMSM Fractional Horsepower Drives

In this control strategy, to accomplish precise speed control of PMSM using sensorless control strategy, ingestion of high frequency pulsing voltage and technique of adaptive voltage band filtering based on linear neural network based adaptive linear neuron (ADALINE) is used.

An adaptive band filter is used to extract required speed information from stator current sidebands. This filter is adaptive for two functions, first, it extracts frequency components inside the bandwidth, and for this, it adapts the weights online, second function is it is able to modify the filter's bandwidth based on variations in the drive's speed commands. This adjustment directly impacts the learning rate of the system.

When a speed command is given, and there are larger errors in the instantaneous speed estimation, the bandwidth of the filter is increased. This results in a broader frequency range being considered, allowing the desired sidebands of the current to be selected. This selection enables a quicker convergence of the filter. After the drive attains a steady-state speed, where the estimated speed aligns with the actual speed, the filter's bandwidth is narrowed. This narrow bandwidth serves as a selective filter, eliminating any undesired harmonics of the stator current.

The control strategy achieves accurate speed control with minimal hardware requirements and reduced cost while maintaining high efficiency and robustness.[13]

D. Non-Salient Permanent Magnet Synchronous Machine: Adaptive Voltage Feedback Controllers for Enhanced Control

In this control system for the voltage feedback controller, an adaptive control parameter tuning method is proposed. Limited voltage margin in the flux-weakening region causes the current dynamic performance to unavoidably suffer, which in turn causes voltage-loop performance to suffer. The current dynamic performance is crucial in the overmodulation zone because the objective of the flux-weakening controller is to avoid voltage saturation by modulating the current command.

When the voltage reference scaling factor becomes greater than one i.e. reference voltage locates outside the boundary of the inscribed circle of a hexagon. Thus, conflict arises between the current reference modifier and voltage feedback controller as the voltage command lies between the boundary of the hexagon and the reference voltage circle. The voltage feedback controller tries to bring the voltage command vector toward the reference circle while the current reference modifier tries to bring the voltage command vector toward the boundary of the hexagon. The voltage reference modifier resolves this conflict by modifying the boundary of the hexagon into a voltage reference when the voltage reference lies outside the boundary of the hexagon.

By employing the proposed voltage feedback controller and utilizing current and voltage reference modifiers, the performance of the system enhances in both the flux weakening and overmodulation regions.[14]

E. Enhancing Transient Performance of PMSM with High-Order Disturbance Observer-Based PI-PI Control System and Tracking Anti-Windup Technique

PMSMs offer several advantages over DC motors, including their compact design, high air-gap flux density, high power density, and superior torque-to-inertia ratio. Comparatively speaking, PMSMs are more efficient than induction motors. Direct Torque Control (DTC) is a widely employed method for streamlining control systems in PMSM applications. Benefits of DTC include four-quadrant operation, quick acceleration, and smooth starting. By streamlining motor modelling, the control system becomes less difficult. DTC may, however, result in less torque and current ripples. An additional control method applied in PMSM applications is called field-oriented control (FOC). It provides four-quadrant functioning, quick acceleration, and smooth starting. DTC minimizes the complexity of the control system and simplifies the motor modelling. To mitigate torque and current ripples, the implementation of cascaded PI-PI control is recommended for effective closed-loop control of PMSMs. This control structure offers direct access to the armature current limiter through a simple saturation block. The outer loop regulates the motor speed by providing the reference current or torque, while the inner loop governs the armature currents or torque. In conclusion, PMSMs have a number of benefits over DC motors and induction motors. For PMSM applications, DTC and cascaded PI-PI control are efficient control strategies that simplify the control system while offering dependable operation and easy access to the limit armature current.[15]

IV. COMPARISON BETWEEN BLDC AND PMSM

Brushless Direct Current motors and Permanent Magnet Synchronous Motors are two prevalent varieties of electric motors utilized in electric vehicles. Both types of motors have their own advantages and disadvantages, which makes them suitable for different applications.

BLDC motors have a simple construction and are less expensive compared to PMSM motors. They also have a wide speed range and can provide high torque at low speeds. This feature makes them suitable to use for EVs that demand a lot of torque at low speeds, such as electric bicycles and scooters. BLDC motors are also efficient, reliable, and have a long life span.

On the other hand, the power density of PMSM motors is higher, has better efficiency, and has a wider operating range than BLDC motors. They are also more expensive as the cost of the rare earth magnets which are required in the construction. PMSM motors are suitable for use in EVs that require high speed, such as electric cars, because they can operate at high speeds without experiencing significant losses in efficiency.

COMPARISON BETWEEN PMSM AND BLDC[16]

Comparison Criteria	PMSM	BLDC
Power Density	PMSM motors exhibit high power density.	BLDC motors offer good power density, although slightly lower compared to PMSMs.
Efficiency	PMSMs generally demonstrate high efficiency	BLDC motors also exhibit good efficiency but may have slightly lower efficiency compared to PMSMs.
Back EMF	PMSMs produce a sinusoidal back EMF waveform, resulting in smoother motor operation with reduced harmonics.	BLDC motors generate a trapezoidal back EMF waveform, which may lead to increased harmonics and slightly less smooth operation compared to PMSMs.
Torque	PMSMs offer high torque capabilities	BLDC motors also provide good torque, although they may have slightly lower torque values compared to PMSMs,
Core loss	PMSMs typically exhibit lower core losses due to their optimized magnetic design and sinusoidal current waveforms.	BLDC motors may have slightly higher core losses compared to PMSMs due to the trapezoidal current waveforms and associated harmonics.
Switching loss	PMSMs generally have relatively higher switching losses	BLDC motors can have slightly lower switching losses compared to PMSMs
Speed	PMSMs offer a wide speed range and can achieve high speeds while maintaining precise control and stability	BLDC motors have a limited speed range compared to PMSMs and may not be suitable for applications requiring extremely high speeds

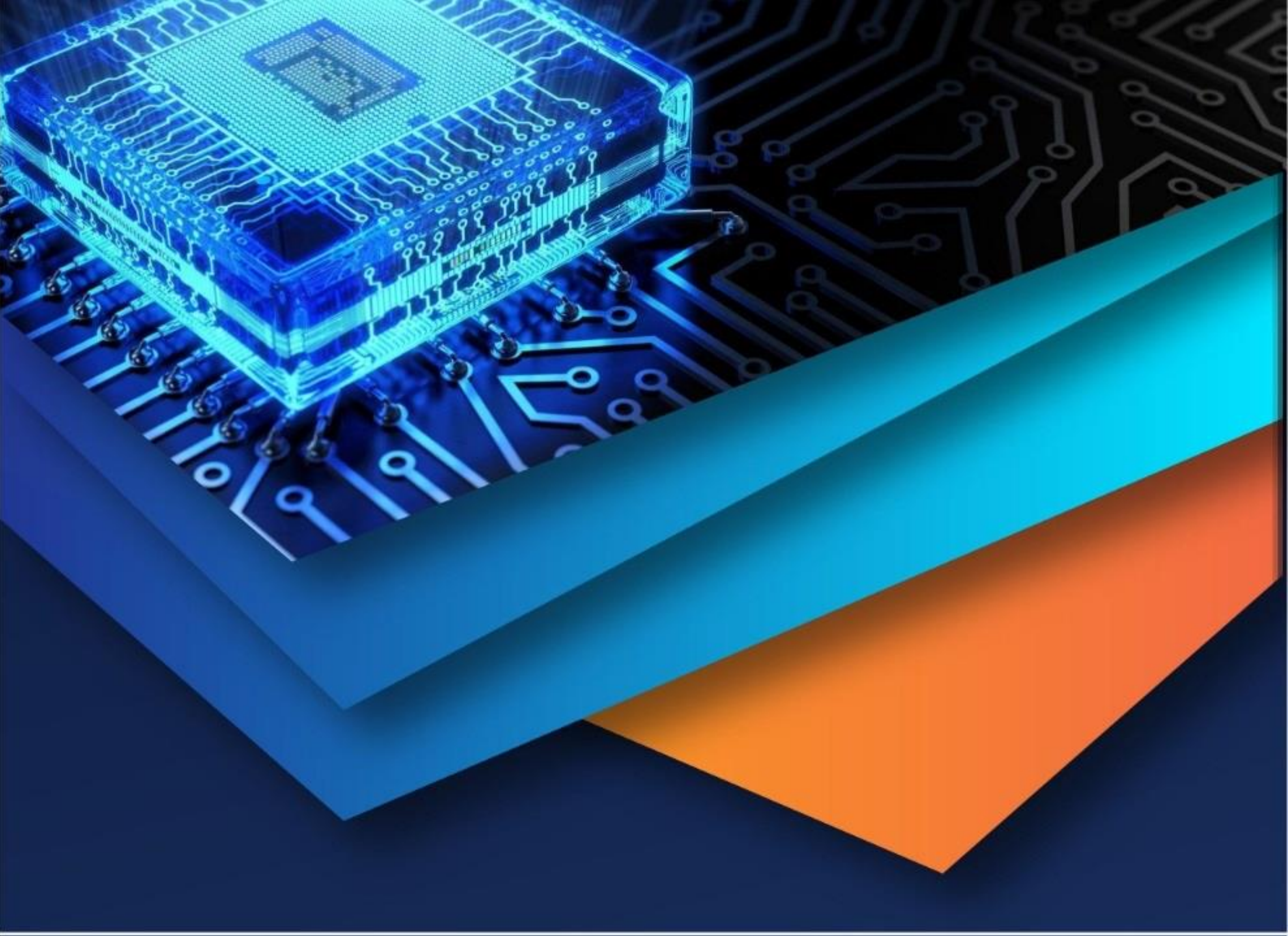
V. CONCLUSION

In terms of control, PMSM motors are more difficult to control than BLDC motors due to their sinusoidal back EMF waveform, which requires more advanced control techniques. However, PMSM motors offer better control and higher efficiency when properly controlled. Overall, the choice between BLDC and PMSM motors for EVs depends on the specific application and requirements of the vehicle. BLDC motors are suitable for low-speed and low-power applications, while PMSM motors are suitable for high-power and high-speed applications.

REFERENCES

[1] S. Ravindra Jape and A. Thosar, "COMPARISON OF ELECTRIC MOTORS FOR ELECTRIC VEHICLE APPLICATION." [Online]. Available: http://www.ijret.org
[2] P. Shah, P. Ubare, D. Ingole, and D. Sonawane, "Performance Improvement of BLDC Motor Speed Control Using Sliding Mode Control and Observer," in 2021 International Symposium of Asian Control Association on Intelligent Robotics and Industrial Automation, IRIA 2021, Institute of Electrical and Electronics Engineers Inc., Sep. 2021, pp. 247–252. doi: 10.1109/IRIA53009.2021.9588766.

[3] Institute of Electrical and Electronics Engineers. Madras Section and Institute of Electrical and Electronics Engineers, 2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS).
[4] IEEE Staff, 2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES). IEEE, 2016
[5] IEEE Staff, 2017 International Conference on Innovative Mechanisms for Industry Applications (ICIMIA). IEEE, 2017
[6] IEEE - International Conference on Innovative Mechanisms for Industry Applications 2017 Bangalore, Institute of Electrical and Electronics Engineers, Institute of Electrical and Electronics Engineers Bangalore Section, IEEE - International Conference on Innovative Mechanisms for Industry Applications 2017.02.21-23 Bangalore, International Conference on Innovative Mechanisms for Industry Applications 2017.02.21-23 Bangalore, and ICIMIA 2017.02.21-23 Bangalore, IEEE - International Conference on Innovative Mechanisms for Industry Applications (ICIMIA 2017) proceedings of ICIMIA 2017, 21st-23rd February 2017.
[7] P. Shah, P. Ubare, D. Ingole, and D. Sonawane, “Performance Improvement of BLDC Motor Speed Control Using Sliding Mode Control and Observer,” in 2021 International Symposium of Asian Control Association on Intelligent Robotics and Industrial Automation, IRIA 2021, Institute of Electrical and Electronics Engineers Inc., Sep. 2021, pp. 247–252. doi: 10.1109/IRIA53009.2021.9588766.
[8] J. Y. Hung, W. Gao, and J. C. Hung, “Variable Structure Control: A Survey,” 1993.
[9] D. E. Beladjine, D. Boudana, A. Moualdia, M. Hallouz, and P. Wira, “A Comparative Study of BLDC Motor Speed Control Using PI and ANN Regulator,” in 18th IEEE International Multi-Conference on Systems, Signals and Devices, SSD 2021, Institute of Electrical and Electronics Engineers Inc., Mar. 2021, pp. 1291–1295. doi: 10.1109/SSD52085.2021.9429474.
[10] C. V. Suru, M. Popescu, M. Linca, and A. Stanculescu, “Fuzzy Logic Controller Implementation for the Compensating Capacitor Voltage of an Indirect Current Controlled Active Filter,” in EPE 2020 - Proceedings of the 2020 11th International Conference and Exposition on Electrical And Power Engineering, Institute of Electrical and Electronics Engineers Inc., Oct. 2020, pp. 39–44. doi: 10.1109/EPE50722.2020.9305570.
[11] E. Fuentes, C. A. Silva, and R. M. Kennel, “MPC Implementation of a Quasi-Time-Optimal Speed Control for a PMSM Drive, with Inner Modulated-FS-MPC Torque Control,” IEEE Transactions on Industrial Electronics, vol. 63, no. 6, pp. 3897–3905, Jun. 2016, doi: 10.1109/TIE.2016.2519326.
[12] J. X. Xu, S. K. Panda, Y. J. Pan, T. H. Lee, and B. H. Lam, “A modular control scheme for PMSM speed control with pulsating torque minimization,” IEEE Transactions on Industrial Electronics, vol. 51, no. 3, pp. 526–536, Jun. 2004, doi: 10.1109/TIE.2004.825365.
[13] A. Accetta, M. Cirrincione, M. Pucci, and G. Vitale, “Sensorless control of PMSM fractional horsepower drives by signal injection and neural adaptive-band filtering,” IEEE Transactions on Industrial Electronics, vol. 59, no. 3, pp. 1355–1366, Mar. 2012, doi: 10.1109/TIE.2011.2167729.
[14] C. Wang, Z. Q. Zhu, and H. Zhan, “Adaptive Voltage Feedback Controllers on Nonsalient Permanent Magnet Synchronous Machine,” IEEE Trans Ind Appl, vol. 56, no. 2, pp. 1529–1542, Mar. 2020, doi: 10.1109/TIA.2019.2957723.
[15] B. Sarsembayev, K. Suleimenov, and T. D. Do, “High Order Disturbance Observer Based PI-PI Control System with Tracking Anti-Windup Technique for Improvement of Transient Performance of PMSM,” IEEE Access, vol. 9, pp. 66323–66334, 2021, doi: 10.1109/ACCESS.2021.3074661.
[16] SKR Engineering College, Institute of Electrical and Electronics Engineers. Madras Section, and Institute of Electrical and Electronics Engineers, International Conference on Energy, Communication, Data Analytics & Soft Computing (ICECDS) - 2017 : 1st & 2nd August 2017.



10.22214/IJRASET

INDEX COPERNICUS 45.98

ISRA JIF IMPACT FACTOR: 7.129

SJIFactor TOGETHER WE REACH THE GOAL IMPACT FACTOR: 7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY