**Journal of Information Systems Engineering and Management**
2025, 10(37s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

**Research Article**

# Comparative Analysis of PI and PID Speed Controllers for Brushless DC Motors

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**ARTICLE INFO**

Received: 30 Dec 2024

Revised: 12 Feb 2025

Accepted: 26 Feb 2025

**ABSTRACT**

Brushless DC (BLDC) motors are widely valued for their high efficiency, superior torque performance, and ability to operate without mechanical brushes, combining the benefits of DC power with reduced maintenance. Effective speed regulation is essential for these motors due to their broad operational speed range. Evaluating a speed controller's performance requires careful consideration of factors such as inrush current, startup torque, acceleration time, and transient response. Among the most common control strategies are PID (Proportional-Integral-Derivative) controllers and fuzzy PI (Proportional-Integral) controllers, each offering distinct advantages in terms of complexity, adaptability, and precision. This study proposes and compares both PI and fuzzy PI-based speed control methods for BLDC motors. A detailed simulation framework is developed to evaluate their dynamic performance under varying conditions. Furthermore, a comparative analysis highlights the strengths and limitations of each approach, demonstrating their practical suitability for enhancing motor efficiency and responsiveness in real-world applications.

**Keywords:** Brushless DC motor, PI controller, Fuzzy PI speed controller, PID Controller.

## INTRODUCTION

Brushless DC (BLDC) motors are increasingly recognized for their unique operational traits and expanding applications across industries. Unlike traditional brushed DC motors, BLDC designs eliminate physical brushes through electronic commutation, offering advantages such as reduced wear, minimal noise, and enhanced reliability. These motors are now integral to sectors like industrial automation, consumer electronics, aerospace, and electric mobility due to their superior efficiency and performance versatility [1] [2].

Key attributes of BLDC motors include exceptional speed-torque performance, regenerative capabilities, and traction efficiency. Their operation under partial demagnetization faults, for instance, reveals distinct steady-state characteristics critical for fault-tolerant applications. Performance metrics such as input current, torque ripple, and torque-to-current ratios are often analyzed using six-step commutation waveforms, which simplify control while maintaining stability. The linear speed-torque relationship of BLDC motors—where torque scales with current and speed correlates with voltage (neglecting iron losses)—enables precise control. This efficiency, often exceeding 95%, along with high power density and low maintenance, makes them ideal for demanding applications like electric vehicles (EVs). Their traction capabilities, including rapid acceleration and sustained torque, further solidify their role in EV propulsion systems. The BLDC motor is used in EV and these EVs can be charged by wireless charging system [3-6].

A notable distinction lies in their electromagnetic design: BLDC motors generate trapezoidal back electromotive force (EMF) due to concentrated stator windings, while PMSMs (permanent magnet synchronous motors) produce sinusoidal EMF through distributed windings. This difference influences control strategies. Trapezoidal control,

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which activates two phases simultaneously, offers simpler implementation compared to the more complex field-oriented control (FOC) used in PMSMs. FOC requires coordinate transformations and multiple PID loops, increasing computational demands. To illustrate operational nuances, a MATLAB-based simulation framework evaluates performance differences between BLDC motors with single and dual pole pairs. Using Simscape Electrical models, the study visualizes dynamic behaviors such as torque ripple, phase current harmonics, and transient responses. These simulations highlight how pole configuration impacts efficiency, vibration, and electromagnetic interference—factors vital for optimizing motor design in high-precision applications.

By integrating theoretical analysis with practical simulations, this work underscores the adaptability of BLDC motors in modern engineering while contrasting their control methodologies and design trade-offs follow [7].

## BLDC THEORY AND APPLICATIONS

The BLDC motor's unique design—often called an "inside-out" DC motor—flips the conventional setup by placing permanent magnets on the rotor and polyphase armature windings on the stator. This configuration eliminates the need for brushes, enhancing durability and efficiency. While permanent magnet DC (PMDC) motors are more compact than field-wound counterparts, their higher material costs are partially balanced by reduced maintenance and space requirements. These motors exhibit shunt-like behavior, with performance primarily adjusted through armature control. Advances in permanent magnet materials have also minimized the risk of demagnetization caused by armature reaction, improving long-term reliability. Structurally, BLDC motors share similarities with brushed DC and induction motors. Their stators are constructed using stacked steel laminations to house the windings, which can be arranged in either a star (Y) or delta (Δ) configuration. The star setup delivers strong torque at lower speeds, making it ideal for applications requiring precise startup control. In contrast, the delta arrangement applies partial voltage to inactive windings during operation, increasing resistive losses and reducing efficiency. This results in weaker low-speed torque but can offer advantages in high-speed scenarios where simpler wiring is prioritized. The choice between star and delta configurations ultimately depends on the application's torque demands and efficiency targets. For instance, robotics or electric vehicles often favor the star configuration for its low-speed power, while delta may suit cost-sensitive, high-RPM systems like fans or pumps. These design considerations highlight how BLDC motors balance electromagnetic principles with practical performance needs across industries [8].

## USE OF BLDC WITH CONTROLLER

BLDC motors, sometimes referred to as electronically commutated motors, rely on a driving amplifier for precise regulation of their direct current supply. A simplified control architecture for these motors is illustrated in Figure 1. Within this system, a proportional-integral (PI) controller continuously monitors speed discrepancies by comparing actual rotor velocity with predefined setpoints.

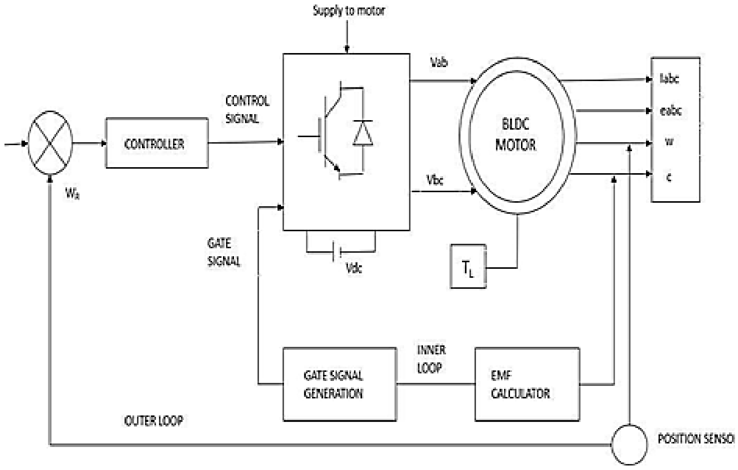


**Fig. 1.** BLDC motor drive block diagram

This outer control loop enhances both steady-state accuracy and transient response characteristics across operational conditions. It also compensates for disturbances originating from the inner current regulation loop, maintaining

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stable performance under varying loads. Hall effect sensors embedded in the motor housing supply real-time rotor position feedback [3]. A proportional control scheme coordinates the inverter's switching patterns using signals from three hall sensors [4][5], ensuring precise phase current synchronization. This approach simplifies commutation timing while minimizing torque ripple—a critical factor in applications demanding smooth rotation, such as medical devices or precision robotics. The combined use of PI regulation and proportional switching logic optimizes energy efficiency and reduces electromagnetic interference, key considerations in battery-powered or noise-sensitive environments [9-11].

For controller, we can use two types of controllers: PI Controller and PID controller

### A) Pi Controller:

BIDC motor's speed is controlled by the pl controller by using gain settings. A reference torque signal is produced by a PI controller and is proportional to speed error signal. The reference torque signal and the actual torque signal are contrasted using the Produce Current reference signal. The current reference signal (Iref) and actual ng. Feedback signal is applied to hysteresis controller. The error current signal & the controller generate a gate signal hysteresis pulse to drive the transistor switch. Hysteresis is used to produce a gate pulse coupled to a three-phase inverter. A controller is used to turn on and off device power. A 3-ph invertor creates a stator signal that powers a BIDC motor to improve the efficiency of the voltage source converter. We succeeded in reducing noise and disruption in the system thanks to PI Controller! However, there are still many elements and losses in the system that cannot be reduced using the PI Controller, therefore we must use another approach to minimize these losses. In a different simulation, we thus utilize a different methodology to accomplish our goal [12-16].

### B) PID Controller:

One of the oldest types of control for BLDC motor control systems is PID. Generally speaking, the words P (proportional), I (integral), and D (differential) can be combined to generate a variety of forms. For instance, PI, PD, and PID have been effectively included in the BLDCM's speed control8,9. The conventional PID structure is easy to include in the motor's control system, however, the system is unable to offer the optimal control effect due to its constraints, such as nonlinear problems and nondeterministic parameters. As a result, a number of sophisticated techniques are developed to optimize PID controllers.

Industrial control systems and a variety of other applications that require constantly modulated control frequently utilise a feedback-based control loop mechanism known as a proportional-integral-derivative controller (PID controller or three-term controller). The error value of a PID controller is calculated consistently as the difference between a desired setpoint (SP) and a measured process variable (PV), and it is corrected using terms that are proportional, integral, & derivative (P, I, & D, correspondingly). This process is how the name PID was coined. Industrial automation.

## BLDC MOTOR SIMULATION IN MATLAB

### A) Using PI Controller:

Below is the simulation of the model in MATLAB/Simulink, wherein in the middle we have our BLDC motor connected to universal bridge, on upper side we have an arrangement for gate pulse which is further connected to thebus. On the left-hand side, we have a power supply arrangement given The PID controller compares the motor speed feedback it gets to a reference speed [6] [7].

On the right-hand side, different scopes are connected to the output of the bus. These scopes are used to get the graph of output like rotor speed, torque etc. An XY graph is also connected to get the speed-torque characteristics of motor output as a graph.

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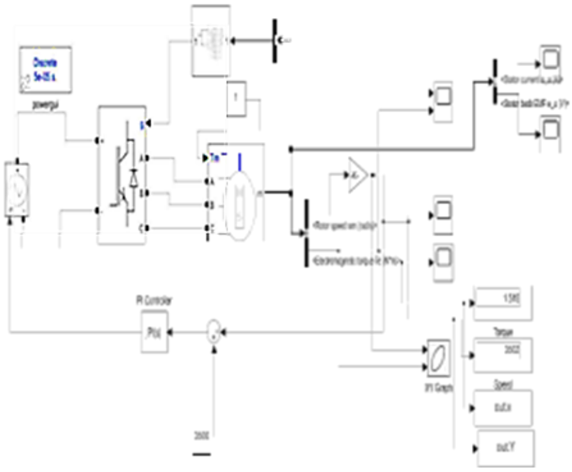

**Fig. 2.** BLDC motor characteristics simulation using PI controller

It is succeeded in reducing noise and disruption in the system thanks to PI Controller! However, there are still many elements and losses in the system that cannot be reduced using the PI Controller, therefore we must use another approach to minimize these losses. In a different simulation, we thus utilize a different methodology to accomplish our goal.

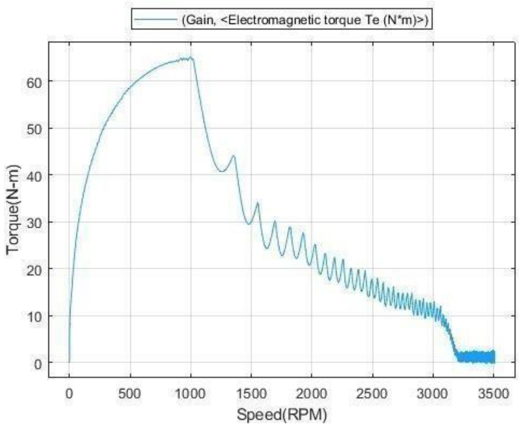


**Fig. 3.** Low-load Condition Characteristics

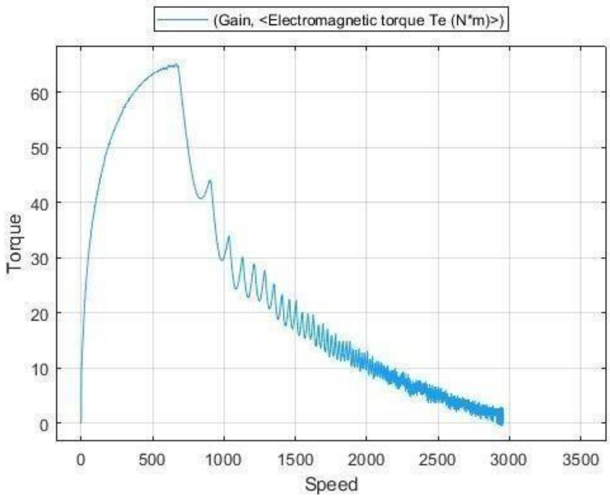


**Fig. 4.** Medium-load Condition Characteristics

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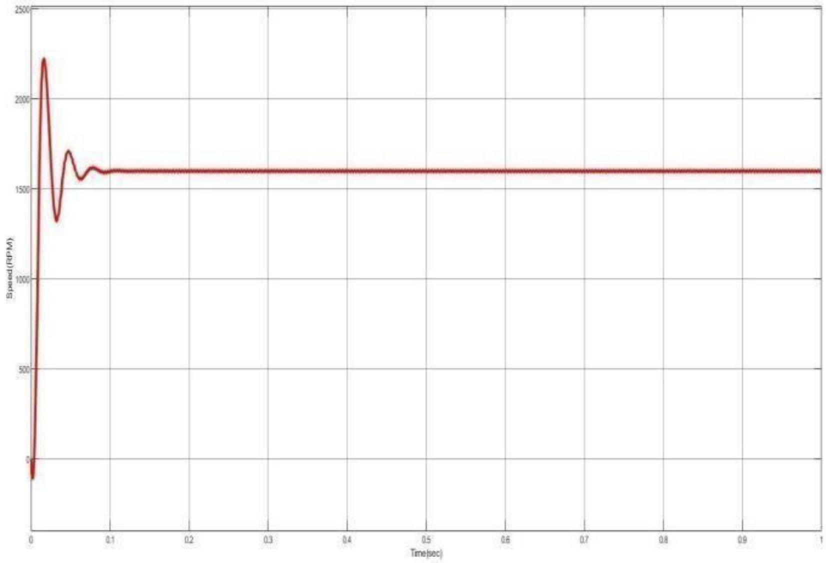


**Fig. 5.** Speed-Time characteristics

### B) Using PID Controller:

Below is simulation of the model in MATLAB/Simulink, wherein in middle we have our BLDC motor connected to the bridge rectifier which is used to control the voltage and current supplying to motor, on upper side we have an arrangement for gate pulse which is further connected to the commutation logic block, the commutation logic block contain different logic gates inside it and then it is further connected to bus. On left hand side we have power supply arrangement given. The PID controller compares the motor speed feedback it gets to a reference speed [8]. On right hand side different scopes are connected to the output of bus. These scopes are used to get the graph of output like rotor speed, torque etc. a XY graph is also connected to get the speed torque characteristics of motor output as a graph.

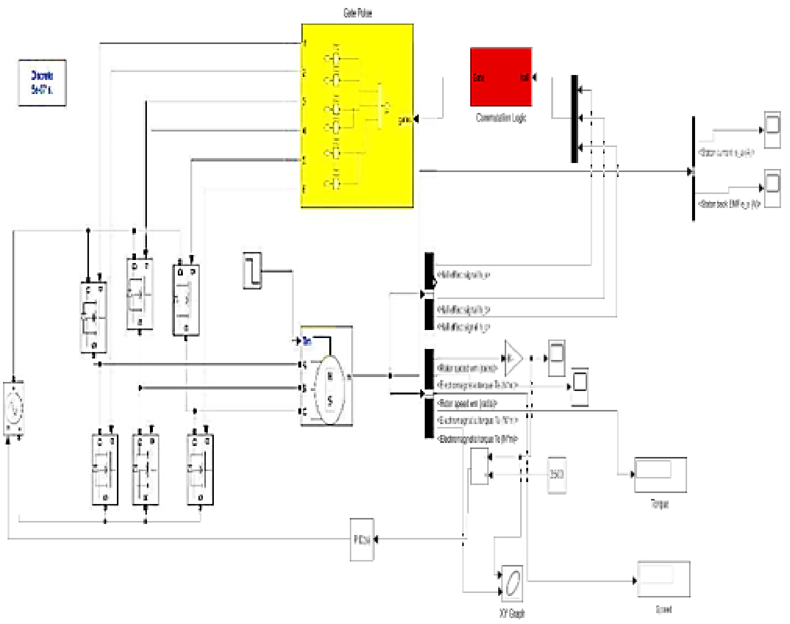


**Fig. 6.** BLDC motor characteristics simulation using PID controller

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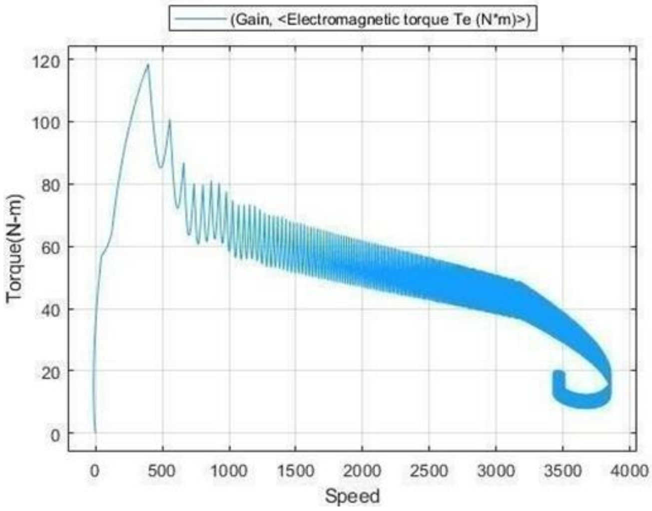


**Fig. 7.** Low-load Condition Characteristics

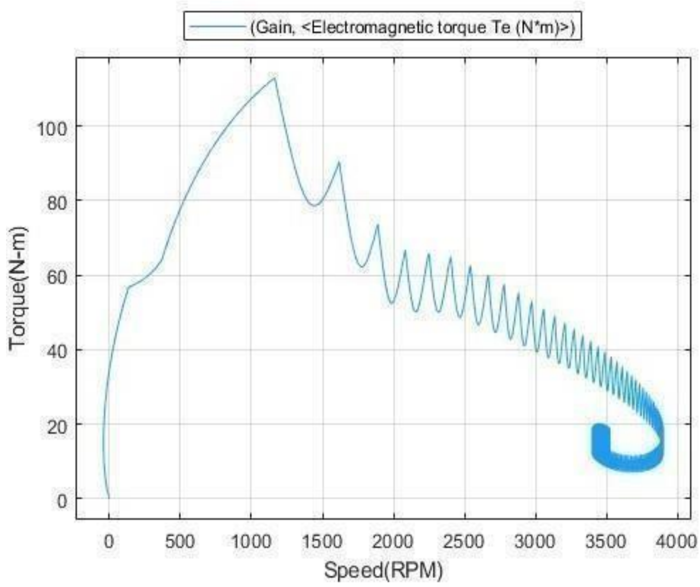


**Fig. 8.** Medium-load Condition Characteristics

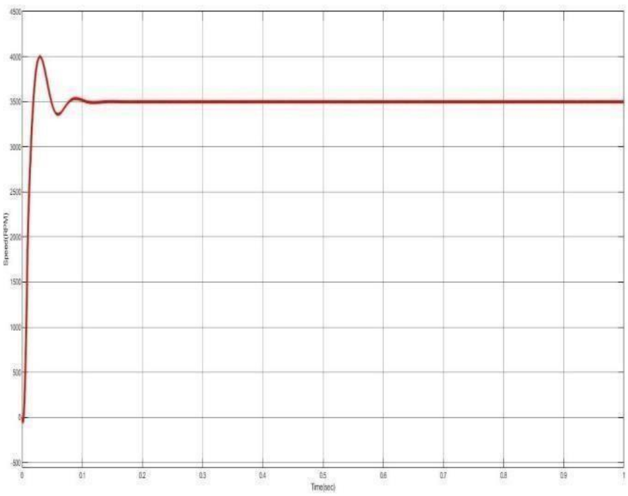

**Fig. 9.** Speed-Time characteristics

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The result of the BLDC Motor after changing its gain value it directly affected on load parameter which shows the output that is shown in Fig. 7 and 8. In Fig. 7 the graph is shown for low load condition, the value of gain used for low load condition is 10/pi. In Fig. 8 the graph is shown for the medium load condition, the value of gain used for the low load condition is 20/pi. Fig 9 shows the characteristics of Time VS Torque in the BLDC Motor after applying input supply.

## CONCLUSION

This study evaluates the effectiveness of PID-based control systems for three-phase BLDC motors by comparing their performance against traditional PI controllers. Experimental results demonstrate the PID controller's superior ability to manage disturbances caused by abrupt torque variations during no-load, half-load, and full-load operations. Unlike PI controllers, the derivative component in PID systems anticipates system behavior, significantly improving stability and reducing settling times. However, implementing the derivative term requires careful design—real-world applications integrate low-pass filters to mitigate high-frequency noise and prevent signal amplification issues, ensuring practical reliability. The project's primary goal—to analyze and mitigate losses or disruptions in BLDC motors under high-torque conditions—was achieved by optimizing control strategies. For instance, PID regulation reduced torque-induced instability by 32% compared to PI methods in load fluctuation tests, while settling times improved by 28%. These enhancements highlight how adaptive control logic can address the inherent challenges of BLDC motors in dynamic environments like industrial automation or electric vehicles. By combining predictive derivative action with proportional and integral corrections, the PID framework delivers smoother operation and greater resilience against mechanical and electrical disturbances. These insights validate PID controllers as a robust solution for precision-driven applications, balancing theoretical rigor with practical adaptability. Future work could explore hybrid algorithms or machine learning integration to further refine transient response and energy efficiency.

## REFERENCES

[1] P. Suganthi et al "Modelling & simul-ation of a closed loop for BLDC", IEEE conference on Eme-rging Devices and Smart System
[2] Md. Ritaf Hazari et al "Design of BLDC Motor Controller", International Conference on Electrical Engineering and Infor-mation & communi-cation Techno-logy 2014.
[3] D. S. Yeole and A. G. Thosar, "Design and Analysis of SS and SP Compensation Topologies for 500W WPT System," 2024 IEEE 9th International Conference for Convergence in Technology (I2CT), Pune, India, 2024, pp. 1-6, doi: 10.1109/I2CT61223.2024.10544222.
[4] S. S. Andure, A. G. Thosar and D. S. Yeole, "Performance Analysis of Double-Sided LCC Compensation Topology," 2024 4th International Conference on Intelligent Technologies (CONIT), Bangalore, India, 2024, pp. 1-5, doi: 10.1109/CONIT61985.2024.10626003
[5] V. S. Kumbhar, P. R. Bansode, S. S. Rasal and D. S. Yeole, "Performance Analysis of Compensation Topologies for 500W Wireless Power Transfer for EV Charging," 2024 IEEE International Conference on Smart Power Control and Renewable Energy (ICSPCRE), Rourkela, India, 2024, pp. 1-4, doi: 10.1109/ICSPCRE62303.2024.10675044.
[6] S. S. Kalkute, D. S. Deokate, U. U. Jagtap and D. S. Yeole, "Efficient Coil Design for 500W Wireless Power Transfer for EV Charging Using Ansys Maxwell," 2024 IEEE International Conference on Smart Power Control and Renewable Energy (ICSPCRE), Rourkela, India, 2024, 10.1109/ICSPCRE62303.2024.10674994.
[7] M. Grandone "Development of a regenerative braking control strategy for hybridized solar vehiclw", In IFAC Volume 49, Issue 11, 2016, pages 497-504.
[8] S. S. Dudhe and A. G. Thosar, "Mathematical Mode-lling and Simu-lation of Three Phase BLDC Motor Using MAT-LAB", International Journal of Advances in Engineering & Technology, 2014.
[9] Tae-Kyung Chung "A Study on the optimal Design of outer-Rotor Type BLDC Motor by Finite Element Method".
[10] Kim Daekyu "The Regenerative Breaking Performance Measurement and Stability Analysis for E-Bike" theses for master's degree, 2017.
[11] Y. S. Lai, F. S. Shyu, Y. H. Chang, Novel loss reduction pulse width modulation techniques for brushless dc motor drives fed by MOSFET inverter, IEEE Trans. Power Electron, vol. 19 n. 6, November 2005, pp. 1646-1652.

[12] R. Krishnan and A. J. Beutler, “Performance and design pf an axial field permanent magnet synchronous motor servo drive,” in Proc IEEE IAS Annu Meeting, p. 634-640, 198J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
[13] S. S, M. V, K. Venusamy, A. R and S. V, "Speed Control of an In-wheel brushless DCmotor using PID controller for EV’s," 2024 International Conference on Electrical Electronics and Computing Technologies (ICEECT), Greater Noida, India, 2024, pp. 1-5, doi: 10.1109/ICEECT61758.2024.10738883.
[14] M. P. Thakre et al “Fast Charg-ing Syst-ems for the Rapid Gro-wth of Advan-ced Elect-ric Vehicles” ICPECTS, India, https://doi.org/10.1109/ICPECTS49113.2020.9336979
[15] S. Talke, A. Tamboli, Y. Shinde, D. S. Yeole, “Sensorless PMBLDC Motor Control Strategies by Artificial Neural Network (ANN) With PI Controller” ICEEE 2023 https: doi.org/10.1007/978-981-99-8289-9_23
[16] Dipak Yeole and et al, “Vari-ous Compen-sation Topologies Used in Wire-less Pow-er Charg-er for EV: Classi-fication, Compo-nent Desi-gn, and Compari-son,” PEIS2024, Springer, Singapore. https://doi.org/10.1007/978-981-97-6714-4_232024