

A Research Study on Various Control for Speed Control of BLDC Motor

Neethu Salim¹ and J. Jency Joseph²

¹⁻²Electrical and Electronics Department, Karunya Institute of Technology & Sciences, Coimbatore, India
Email: neethusalimmathew@gmail.com, jencyjoe@karunya.edu

Abstract—In present days, Brushless DC Motor (BLDC) is the superlative motor that is growing universally because of dependability, effectiveness, less maintenance, and better dynamic response. Due to the above-mentioned progress, BLDC is freshly utilized in various applications such as vehicles, machines, high voltage, and internal pieces of equipment. Furthermore, the proportion of torque distributed to motor size is greater in all the applications where load space models are considered as severe characteristics. BLDC motors are extensively applied in numerous productions and quickly increase in electrical equipment and industrial materials for electrical drives. The recent intellectual motion presentations request precise position and speed control because of the promising machine-driven and power-driven assets of BLDC. Till now, so many control procedures have been established to increase the BLDC motor performance. For the past few years, scholars are restricted in the direction of expansion for BLDC, as demonstrating greater to the traditional motor drives. This research paper provides a concept of numerous approaches, controllers for BLDC electric motor and current developments.

Index Terms— Brushless DC Motor, Speed, Torque Electrical drives, Vehicles.

I. INTRODUCTION

Generally, the BLDC motor is separated into two different kinds due to the dissimilarity of winding that drives the waveforms [1]. In that, one is square type of Permanent Magnet Synchronous Motor (PMSM), since the motor current is the type of square that is referred as BLDC. The second one is the sine-based PMSM since the motor current is a type of sine form [2]. While associated through the sinusoidal PMSM, BLDC motor drive has the evident advantage, because it has a quick response, simple control structure, higher power density/output torque to create the motor show on their specific perspective. For that reason, the research and the presentation of BLDC have been rewarded progressive consideration [3]. In most cases, old types of an electric motor have been substituted by their industrial recompenses. While comparing with other motor types, most of the time, square wave BLDC motors are preferred in all the applications. Because of high efficiency and reliability features, it minimized the motor volume, enhance the exploitation frequency of magnetic substantial, aggregating the motor output [4].

In a real-time environment, BLDC motor design contains a composite procedure for example control structure assortment, forming, model constraints regulation, etc. So, proficient information of the structure is essential for fine-tuning the regulator constraints of BLDC to achieve the ideal behavior. In recent times, numerous up-to-date control resolutions are suggested for speed control of BLDC [5]. On the other hand, the traditional PID process

is modest, steady, relaxed alteration, and has high dependability [6]. But then again, most of the industrialized developments using dissimilar gradations are having constraint unpredictability, nonlinear, and improbability of system scientific model. Modification in PID control constraints is less strength and more problematic, consequently, it's challenging to accomplish the ideal state during field circumstances in the definite assembly. While comparing with other controllers, the Fuzzy PID technique is an improved way of directing and regulating the composite and uncertain classical systems which provides a better dynamic response, easy/operative control, settling time, and overshoot features [7].

II. RECENT TRENDS IN BLDC MOTOR

Presently BLDC motor is additionally exploited with some other types of motors because of their less maintenance features. The present researches primarily concentrated on two subsequent regions: (i) Progress novel equipment to increase the reliability of the system and supplementary minimize the size/weight of the motor. (ii) Suitable control method is selected to prolong the possibility of application.

A. Four Quadrant Operation

This segment offered the proposal and employment of numerical regulator structure for BLDC with four-quadrant operation. The projected regulator is executed in the PIC microcontroller. The speed control is accomplished using a PI regulator. For the duration of the braking process, the energy produced is deposited in a rechargeable battery. Relay circuits are applied to resource the electrically powered motor for the period of motoring operational mode and control the battery throughout the mode of the braking period.

B. Power Factor Correction (PFC)

In recent times, several configurations for PFC converter served BLDC electrical drives have been implemented [8]. One of the suggested configurations is the Bridgeless Buck-Boost converter. Here, PI is utilized to regulate the dc voltage to differ the operation of speed which decreases the conduction loss. This suggested topology assist to minimize the loss by eliminating the rectifier usage. The recommended converter is premeditated to control the intermittent current type. In Pulse Width Modulation (PWM), pulses are used to tune the converter button for delivering an essential PFC at the source side and load side.

C. Direct Torque Control (DTC)

Generally, the DTC technique converts measures from the a-b-c axis to a direct-quadrature axis. q-axis current is used to control the torque whereas the d-axis is used to control the flux. Dissimilar to traditional techniques, the DTC method through 3-phase transmission can regulate the performance deprived of disturbing the commutation process. This scheme practices a look-up table for directing the vectors of voltage moderately over the PWM procedure which resultant in modest regulator achievement and rapid torque response [9].

D. P-I Controller

Here in this portion, the P-I controller is used as a major regulator. In the forward path, the proportional along with an integral stretch has the assets of creating the error as zero for a minimum step variation. Even though, this regulator creates the zero error which might proceed a significant quantity of period to achieve. The standard of a PI regulator is to institute a mechanism with proportion and integration process, at that moment, select an appropriate linear arrangement to regulate the progression.

E. PID Controller

Nowadays, the rapid expansion of learning and equipment needs a structure that has sophisticated response time, developed device precision and better constancy. PID is the most recent control scheme which is exploited to tune linear process designs. But then again, many manufacturing developments are non-linear environments and more or less progression is challenging and cannot recognize accurate exemplary. So, the wide-ranging PID controller cannot accomplish accurate regulation of the above-mentioned practices [10].

F. Fuzzy Logic Control (FLC)

In the traditional technique, the controllers' constraints are adjusted for specific working situations and those situations cannot diverge. On the other hand, in real-time presentations, the working circumstances along with the structural constraints possibly will diverge and henceforth the existing control system provides inaccurate outcomes. The above-mentioned drawback can be overwhelmed through FLC [11]. It is demonstrated that the presentation of FLC is easily adequate during fluctuating circumstances. The effortlessness and execution in the

project create FLC as an additional feature and was favored for mechanical, robotics, manufacturing applications, etc.

III. METHODS FOR SPEED CONTROL PROCESS

Various methods have been utilized for controlling the speed of BLDC drives, a few of them are described here:

A. Sensorless Control

Nowadays, BLDC without using hall sensors is receiving attractiveness due to the Hall sensors which raise the motors inclusive price and were penetrating to the heat dissimilarities. Numerous approaches have been familiarized to evaluate the position of the rotor short of hall sensors. The precise commutation instantaneous has been perceived by including a supplementary interval of 30° to zero-crossing prompt with the help of a phase shifter. The consequence of common-mode noise has been removed through the measurement of line voltage [12].

B. Sensor based Control Method

To switch the windings of the BLDC motor, initially, the stator windings would need to be strengthened in a proper arrangement. Also, it is significant to recognize the position of the rotor to appreciate that winding has to be strengthened by the sequence. Here, the position of the rotor is distinguished and recognized with the help of Hall-effect sensors that are entrenched into the windings of the stator. The concerning standard amongst the sensor and BLDC is significant for contracted captivating pointed encoder which completely depends upon 3-D type Hall sensors. This exterior outline parallels with the penetrating orders of irresistible sensors [13].

C. Genetic Algorithm (GA)

GA-based control technique is a standard search process that is extensively exploited where an intelligent exploration technique is beneficial. This technique is designated to establish a process to adjust the parameters present in proportional gain. Initially, the results of motor speed at a certain time domain were attained by pretending the BLDC in MATLAB software. Next, the GA process is exploited to produce a fixed number of primary arbitrary constraints. By using this exploration procedure, the constraints are altered to produce a response that is nearer to the preferred response.

D. Artificial Neural Network (ANN) based control

ANN mechanism is fundamentally utilized to estimate the disruption from the result and adjusts the numerous PID constraints conferring to it. Parameter tuning, reduces the disruption and enhances the regulator performance. ANN-based adaptive controller deals with the benefit of rapid achievement deprived of connecting any internal closed loops. Conversely, it agonizes from the drawback of consequence in unmeasured instabilities and quantity of instabilities.

IV. TAXONOMY BASED LITERATURE SURVEY

Several methods are proposed by investigators in the BLDC Drives with speed control process. Here, transient assessments and significant effects to the existing works are presented in table 1.

TABLE I. LITERATURE REVIEW OF CONVENTIONAL METHODS WITH ITS PERFORMANCES

Author	Methodology	Advantage	Disadvantage	Performance Measures
Pandi Maharajan and Arockia Edwin Xavier [1]	Spider Based Controller	This spider controller considers the problem of ripples in torque produced in BLDC drives. It attempts to diminish the ripple in torque which originates through minor dc-link capacitor.	Although, the value of a dc-link capacitor is small and negligible in this suggested structure, so it is not applicable for high power applications.	Torque, Speed and Current.
Basim Alsaid, Wael and Salah, Yazeed Alawneh [2]	Digital Sensor Control	This digital sensor substitutes the three traditional sensors into a solitary one which minimizes the complication and cost.	Although precise speed regulation is essential for numerous applications, that was attained by closed-loop, not by open-loop for this type of control.	EMF, Speed, Torque and Current
Vanchinathan	Bat	In this research, BA produces an	The possible results of BA are	Speed,

and Valluvan [3]	Algorithm based FOPID controller	ideal constraint for a fine-tuning regulator that can vary the mathematical values which completely depends on repetition and deliver improved results that differ from slight to better-quality utilization.	remarkably difficult because the accuracy of operator condition of speed regulation can be determined by motor only.	Torque, EMF and Stator current.
Murali Dasari, et al. [4]	Genetic Algorithm - ANFIS (GA-ANFIS)	The projected method has provided an improved presentation for quick alteration in resistance/speed and demonstrated its determination in tracing sinusoidal modification in the sample speed.	GA-ANFIS produces high computational costs because of ascent learning and composite assembly.	Rotor Speed, Current, and Voltage.
D. Potnuru et al. [5]	Flower Pollination Algorithm (FPA)	This recommended FPA control has avoided the problems associated with complex nonlinearity concerns. Furthermore, PID improvements are adjusted for BLDC motor drives.	The performance of settling and rise time is high. Likewise, this algorithm provides a supplementary steady-state error.	Speed and Transient Performances.
Prakash et al. [6]	Particle Swarm Optimization (PSO)	This projected PSO is utilized to control the coefficient setting of PID values. The outcomes displayed individuality by steadiness, strength and rapid response.	Theoretically, it produces a constant torque but then again the ripple in torque occurs because of commutation in-phase current and deficiency in EMF.	Speed and Torque
Potnuru [7]	Grasshopper Optimization Algorithm (GOA)	The closed-loop control of GOA behavior is much better for the duration of steady-state and transient situations. Also, it produces less error in all the conditions.	However, this system is not applicable for open loop control.	Speed control
Anup Kumar Singh, and Swapnajit Pattnaik [8]	Direct Matrix Converter (DMC)	Here, the DMC converter minimizes the losses because the switches count gets reduced to nine whereas the previous converter uses 12 switches. Also, the structure turns out to be strong by eliminating a massive dc-link capacitor.	This proposed DMC is associated with a single-phase that cannot be appropriate to use for high-power industrialized motors.	Speed, Torque, EMF and Power Factor.
L.K. Agrawal et al [9]	Fuzzy Controller	This projected method produces better efficiency. The simulation outcomes displayed that the vibrant behavior of the drive is moderately reasonable for several loading circumstances.	This suggested procedure provides operative speed response. On the other hand, it cannot provide a better response through a varying load.	Rise Time, Overshoot time, Speed and EMF
Arun Prasad K. M, Usha Nair [10]	F-SMC (Fuzzy-Sliding Mode Controller)	Here, in this method, the motor speed variation under an overloaded situation is minimized. Also, the issue of peak overshoot is removed and the settling/rise time is upgraded.	Though, this procedure turns out to be difficult and an accurate speed controller is essential for high power applications.	Rise Time, Settling time, Peak overshoot and Speed
Ming-Shyan et al [11]	Adaptive network-dependent fuzzy inference	This suggested method is applied for fine-tuning speed, so that the motor can achieve the predefined values. Likewise mechanically adjusts the premise constraints values, accordingly, the feedbacks are higher than the existing control.	However, constraints values were easily disturbed by low determination and noise, so the speed of the motor process gets restricted.	Speed and Current
Akbar Karimi Pouya [12]	Adaptive Neural Fuzzy Controller	This projected method had improved behavior under lower speed and higher speed in terms of calculating the settling and rise time over the existing Fuzzy PID controller.	This method cannot have a better performance at all the speed variations due to the non-linearity of load and varying conditions of the device at dissimilar speeds.	Speed, Torque, Settling time and Rise time.
Ali Mousmi, Ahmed Abbou, Yassine El Houm [13]	Novel Hybrid Combination of fuzzy and SMC	The suggested control displayed improved presentation in terms of response and speed during various instabilities. Also enhanced extra 5 times deprived of dropping steadiness.	The proposed method can force the structure in a limited time only. Moreover, chattering issues occur which reduces the performances of precision limits.	Speed and Response Time
Devendra	Hall Effect	The recommended hall effect model	Although, fluctuation occurs while	Speed and

Potnuru, Alice Mary K, Saibabu Ch [14]	Sensor based control	constraints has been delivered and efficiently available and its magnitude is manageable for the duration of the implementation period.	converting the values from ADC to DAC. Similarly the price convoluted in fast control model is somewhat more.	Rotor position
Md Mahmud, S. M. A. et al [15]	Adaptive PID Controller	The recommended APID procedure is applied for the speed control of BLDC motor. The performances of undershoot, overshoot, Pre-shoot can be minimized further with the help of high-frequency filter.	It has almost reached all the objectives but quiet essential to eliminate the noise for even speed regulation.	Speed and Torque
Sayed Alireza Sadrossadat, Omid Rahmani [16]	Artificial Neural Network (ANN)	This paper introduces a novel method for parametric modelling termed ANN based metric technique, which combines and optimises several goal functions of a BLDC motor.	In this case, efficiency was improved although speed was reduced and cost was increased.	Speed and Efficiency
Muhammed A.Ibrahim et al [17]	Genetic Algorithm based Proportional Integral Derivative (GA-PID)	A GA-PID controller uses a genetic algorithm to improve the performance of the system. GA calculates PID controller coefficients to provide an ideal PID as a hybrid PID with GA controller.	However, the system's maximum overshoot is larger than with a traditional controller.	Rise Time, Settling time, Peak overshoot and Speed
Kolano, Krzysztof [18]	Improved Sensor Control Method	The article suggests Improved Sensor Control as an alternative for traditional system control methods using BLDC motor sensors. A switching estimation approach is also used to determine the inverter switching sites.	Individual control sectors have varying durations, affecting the duty of the inverter transistors directly. Transistors are not switched at the ideal time due to this error.	Speed, Flux and Torque
More, Priyanka Bharat, and A. A. Godbole [19]	Fuzzy SMC Controller	The FUZZYSMC-based speed control of a BLDC motor is shown in this study. The obtained error is transmitted to the controller, which regulates the DC voltage fed to the inverter and adjusts the speed accordingly.	This technology necessitates knowledge of the uncertainty bound, which promotes high frequency oscillation.	Speed, Torque, Settling Time and Rise Time
Md Mahmud, S et al [20]	Flower Pollination Algorithm (FPA)	A Flower Pollination Algorithm (FPA) has been proposed for controlling the speed of a BLDC motor in this work. The finest result of this study is a steady increase in speed and a reduction in rising time.	Conversely, the proposed regulator proceeds lengthier period to influence the motor reference speed.	Rise Time, Settling time, Peak overshoot and Speed

V. CONCLUSION

This research has essentially concentrated on numerous experiments in the speed control of BLDC motors. This research is supportive to identifying the structure of BLDC motor through the appropriate regulator in recent developments and succeeding levels of problematic detection. Generally, the motor drive speed is well-ordered by adjusting the duty ratio value of PWM signals. Till now, there are various kinds of regulators (PI, PID, Optimization-based PI, Fuzzy, etc.) applied for adjusting the motor speed at the preferred range. Those controllers are exploited conferring to the type of application requirements. It denotes that the application requires the smallest error values where the PI technique is applied. For the period of more speed error, the fuzzy type method is designated by adjustment and the PI technique is nominated where high steady-state accuracy is compulsory. The above-mentioned literature, clearly shows that, still, there is a lot of work that has to be done on speed control. So, this research paper will help the researchers to understand the state-of-the-art in process of speed control. In the future, the speed control can be enhanced by different modeling of BLDC motor with recent advancements in Fuzzy based controllers.

REFERENCES

- [1] M. P. Maharajan and S. A. E. Xavier, "Design of speed control and reduction of torque ripple factor in BLDC motor using spider based controller," *IEEE Trans. Power Electron.*, vol. 34, pp. 7826–7837, November 2018.
- [2] B. Alsayid, W. A. Salah, and Y. Alawneh, "Modelling of sensed speed control of BLDC motor using

- MATLAB/SIMULINK,” *International Journal of Electrical and Computer Engineering*, vol. 9, pp. 3333, October 2019.
- [3] K. Vanchinathan, and K. R. Valluvan, “A metaheuristic optimization approach for tuning of fractional-order PID controller for speed control of sensorless BLDC motor,” *Journal of circuits, systems and computers*, vol. 27, pp. 1850123, November 2018.
 - [4] M. Dasari, A. S. Reddy, and M. V. Kumar, “GA-ANFIS PID compensated model reference adaptive control for BLDC motor,” *International Journal of Power Electronics and Drive Systems*, vol. 10, pp. 265, March 2019.
 - [5] D. Potnuru, K. A. Mary, and C. S. Babu, “Experimental implementation of Flower Pollination Algorithm for speed controller of a BLDC motor,” *Ain Shams Eng. J.*, vol. 10, pp. 287–295, June 2019.
 - [6] P. Salawria, R. S. Lodhi, and P. Nema, “Implementation of PSO-based optimum controller for speed control of BLDC motor,” *International Journal of Electrical, Electronics and Computer Engineering*, vol. 6, pp. 104–109, January 2017.
 - [7] D. Potnuru, and A. S. L. V. Tummala, “Implementation of grasshopper optimization algorithm for controlling a BLDC motor drive,” In: *Nayak, J., Abraham, A., Krishna, B., Chandra Sekhar, G., Das, A. (eds.) Soft Computing in Data Analytics, Advances in Intelligent Systems and Computing*, vol. 758, Springer, Singapore, pp. 369–376, December 2019.
 - [8] A. K. Singh, and S. Pattnaik, “Matrix Converter Operated Hysteresis Current Controlled BLDC Motor Drive for Efficient Speed Control and Improved Power Quality,” *Procedia Computer Science*, vol. 167, pp. 541–550, April 2020.
 - [9] L. K. Agrawal, B. K. Chauhan, and G. K. Banerjee, “Speed control of brushless DC motor using Fuzzy controller,” *International Journal of Pure and Applied Mathematics*, vol. 119, pp. 2689–2696, December 2018.
 - [10] K. M. A. Prasad, and U. Nair, “Intelligent fuzzy sliding mode controller based on FPGA for the speed control of a BLDC motor,” *International Journal of Power Electronics and Drive Systems*, vol. 11, pp. 477–486, March 2020.
 - [11] M. S. Wang, S. C. Chen, and C. H. Shih, “Speed control of brushless DC motor by adaptive network-based fuzzy inference,” *Microsyst. Technol.*, vol. 24, pp. 33–39, January 2018.
 - [12] A. K. Pouya, “Design of adaptive neural fuzzy controller for speed control of BLDC motors,” *Majlesi journal of Electrical Engineering*, vol. 11, pp. 37, March 2017.
 - [13] A. Mousmi, A. Abbou, and Y. E. Houm, “Real-time implementation of a novel hybrid fuzzy sliding mode control of a BLDC motor,” *International Journal of Power Electronics and Drive Systems*, vol. 10, pp. 1167, September 2019.
 - [14] D. Potnuru, A. Mary., and Ch. Saibabu, “Design and implementation methodology for rapid control prototyping of closed loop speed control for BLDC motor,” *Journal of Electrical Systems and Information Technology*, vol. 5, no. 1, pp. 99–111, May 2018.
 - [15] M. Mahmud, S. M. A. Motakabber, A. H. M. Z. Alam, A. N. Nordin, and A. K. M. A. Habib, “Modeling and Performance Analysis of an Adaptive PID Speed Controller for the BLDC Motor,” *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 7, pp. 272–276, 2020.
 - [16] S. A. Sadrossadat and O. Rahmani, “ANN-based method for parametric modelling and optimising efficiency, output power and material cost of BLDC motor,” *IET Electric Power Applications*, vol. 14, no. 6, pp. 951–960, January 2020.
 - [17] M. A. Ibrahim, A. Kh. Mahmood, and N. S. Sultan, “Optimal PID controller of a brushless dc motor using genetic algorithm,” *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 10, no. 2, pp. 822–830, June 2019.
 - [18] K. Kolano, “Improved Sensor Control Method for BLDC Motors,” *IEEE Access*, vol. 7, pp. 186158–186166, 2019.
 - [19] P. B. More and A. A. Godbole, “Fuzzysmc based Speed Control of BLDC Motor,” *International Journal of Engineering Research & Technology*, vol. 8, no. 12, pp. 314–318, December 2019.
 - [20] M. Mahmud, S. M. A. Motakabber, A. H. M. Z. Alam, and A. N. Nordin, “Utilizing of Flower Pollination Algorithm for Brushless DC Motor Speed Controller,” in *Emerging Technology in Computing, Communication and Electronics*, 21-22 December 2020, Bangladesh, pp. 1–5.