MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages 4486-4491

Hybrid GWO-PID Control of BLDC Motors for Enhanced Speed Regulation

Dr. M. Karthik[1], L.Sreevidya[2], Dr.K.Umamaheswari[3], Abiramasundari S[4]

[1]Assistant Professor Senior Grade, Department of Electrical and Electronics Engineering, SRM Madurai College for Engineering and Technology, Pottapalayam, Sivaganga District, Tamil Nadu 630 612. mkarthik.research@gmail.com
[2]Assistant Professor Department of Electrical and Electronics Engineering, Dr.N.G.P.Institute of Technology Kalapatti,Coimbatore - 641048 lsree.vidyaeee@gmail.com
[3]Professor, Department of Electrical and Electronics Engineering, V.S.B. Engineering college, Karudayampalayam,Karur, Tamilnadu - 63 9111 umakrishnan21@yahoo.co.in
[4]Assistant Professor, Department of Electronics and Communication Engineering, Dr.Mahalingam College of Engineering and Technology, Pollachi, Coimbatore, Tamilnadu - 642003. abiramasundariece@gmail.com

Corresponding Author: mkarthik.research@gmail.com

Abstract

BLDC motors are significantly common in electric cars, robotics, aerospace and high accuracy mechatronics because of their high efficiency and rapid dynamic response. Nevertheless, smooth and precise speed control with the change of the sudden loads is a challenge of the conventional proportionalintegralderivative (PID) controllers due to the constant gains as well as minimal adjustability. It is suggested in this paper that a control strategy could be implemented based on a Hybrid Grey Wolf Optimizer PID (GWO-PID) controller that varies the the controller parameters dynamically to reduce steady-state error, overshoot, and response time. The optimizer used is the Grey Wolf Optimizer (GWO) which determines the globally optimum PID gains using a fitness function that involves the rise time, settling time, and the indices of integral error. The optimized controller has been applied on a BLDC motor drive model and identified using MATLAB/Simulink simulations on variable torque disturbances and reference speed transitions. The further experimental assessment also establishes that there is a high performance improvement relative to the classical PID and Ziegler-Nichols tuning. The resulting hybrid GWO-PID scheme has a high accuracy in tracking the speed, minimized ripple, and powerful control of dynamical BLDC.

Keywords - BLDC Motor, Hybrid GWO -PID Control, Grey Wolf Optimizer, Speed Control, Intelligent Controllers, MATLAB/Simulink, Dynamic Load Disturbance, Optimization Techniques.

I. INTRODUCTION

The Brushless DC (BLDC) motors are a recent favorite among the contemporary electric drive motors because they are highly efficient in operation, small in structure, low in maintenance needs, as well as their high torque to weight ratio. These benefits have rendered BLDC motors to be essential in electric cars, drone technology, industrial automation, in aerospace actuation, and robotic manipulators where controlling speed accurately and having high dynamic response are desired. They offer a better control capability with their electronic commutation mechanism although the performance is very sensitive to the quality of control strategy implemented over the motor drive. Traditional proportionalintegral derivative (PID) controllers continue to dominate the use of BLDC motor drives since they have a simple structure, are simple to implement, and perform well on linear or slightly nonlinear systems. But the motors of BLDC type have nonlinear features due to asymmetry of back-EMF, switching effects, and changes in parameters when the temperature or load changes. Consequently, the classical PID controllers have drawbacks in the form of poor adaptability, high overshoot and deteriorated speed tracking in the presence of abrupt load perturbations or different operating environments. Recent developments in intelligent and bio-inspired optimization algorithms have offered substitutes to the improvement of the motor control performance. Some of the most widely studied soft computing approaches to controller tuning include Particle Swarm Optimization (PSO), Genetic Algorithms (GA), Ant Colony Optimization (ACO) and Differential Evolution (DE). Although these algorithms are effective, they are usually slow to converge, stagnant or computationally expensive. The Grey Wolf Optimizer (GWO) is one of the new algorithms that have received some attention since it has a good balance between exploration and exploitation, a simple mathematical model, and is efficient in avoiding local optima. GWO mimics the leadership structure and cooperation of the hunters during hunting of the grey wolves found in nature. The smooth process that it uses in its mechanism with the involvement of the alpha, beta, and delta wolves enables the quick and focused search of the best solutions. GWO has shown convergence properties and is very effective in tuning PID controller gains in nonlinear and time-varying control systems, application of which is in control system optimization. Nevertheless, the standalone GWO algorithm can also be proved to have the problems that can arise in high-dimensional solution spaces or sudden dynamic environment variations. A hybrid control of GWO with PID control is a viable and effective solution of speed control of BLDC motors. The hybrid GWO-PID control scheme allows tuning the proportional, integral and derivative gains dynamically with respect to parameters of system performance (rise time, settling time, peak overshoot and integrated error parameters). The offered optimization improves both transient and steady-state behavior, which guarantee a better robustness to deviating load torques and abrupt changes in reference speed. A number of studies that have been conducted recently have shown the efficiency of hybrid optimization techniques within the motor control systems. Nevertheless, the majority of the available literature is concentrated on the minimization of torque ripple or harmonic and little emphasis has been made on real-time control of the speed of BLDC motors under combined dynamic-noise. Moreover, a lot of the reported procedures are not fully compared to classical PID and ZieglerNichols tuning procedures, and there is distinct gap in performance benchmarking to be deployed. Inspired by these problems, this paper suggests a Hybrid GWOPID control approach that will be used specially to attain a greater speed control of the BLDC motors. The approach takes advantage of the global search facility of GWO in determining optimum PID gains and is also characterized by high accuracy and low ripple and enhanced disturbance rejection. The given plan is confirmed by the complex MATLAB/Simulink modeling and experimental analysis of the prototype drive based on a BLDC. Creation of a hybrid GWO-based PID tuning architecture based on BLDC motor dynamics; Simulation and experimental analysis of the stepped reference speeds and variable load disturbances; Comparison with the traditional PID and ZieglerNichols tuning to bring out performance enhancement in speed tracking, overshoot and transient stability; Real time experience on application of GWO-PID controllers to real time embedded drive systems.

II. LITERATURE SURVEY

The control methods of BLDC motor drives have advanced a great deal in the last decade, and studies have been made in enhancing dynamic performance, disturbance rejection, and energy-saving. The classical PID controllers were extensively used in the earlier literature on the speed regulation because of their simplicity in structure and implementation. Nonlinear back-EMF behaviour, load variations and switching dynamics of BLDC motors, however, frequently showed poor performance with such methods. The traditional methods of tuning including the Ziegler Nichols and trial-and-error tuning methods often created suboptimal gains, preventing the controller to be able to constantly deliver the same accuracy under different operating conditions. In a bid to overcome these drawbacks, soft computing and smart optimization methods were studied extensively. Particle Swarm Optimization (PSO), Genetic Algorithms (GA), and Differential Evolution (DE) have been suggested to use methods of PID tuning and performance optimization. These methods enhanced convergence properties and lessened the complexity of tuning but at times experienced early stagnation and very parameter sensitive behavior. A number of studies revealed that heuristic optimizers were effective in greatly decreasing the overshoot and settling time, but choosing between exploration and exploitation was an issue with many algorithms.The capability to deal with nonlinear and parameter-sensitive systems made bio-inspired optimization methods of much interest. Inspiration of natural evolution, swarm intelligence, predator-prey behaviors were used in solving motor control problems. Among them, Grey Wolf Optimizer (GWO) was a good successful solution as it has quick convergence, hierarchy of leadership, and stable search mechanism. GWO-based control tuning was found to be more effective in determining the best controller parameter when tuning it and strong in operating stability in dynamic operating conditions. It was the favored mode of high-performance motor control application due to its lower mathematical complexity and great exploitation capability. High-tech hybridized control architecture was introduced subsequently and consists of optimization algorithms and conventional PID control methods to adaptability and response quality. The hybrid systems were successful in reducing the inherent error index, enhancing the transient behavior, and injury of the stability of control in the occurrence of abrupt torque variations. The research done before using hybrid optimization in the application of BLDC drives indicated promising performance in terms of reduction of torque ripple, dynamic tracking, and steady state accuracy. With these developments, much of the research was concerned with harmonic suppression, sensorless estimation, or torque ripple reduction, with very little given to more holistic control of speed with dynamic loads.

In recent studies, specific focus was placed on the idea of incorporating optimization algorithms into the framework of BLDC speed controllers in order to get much faster convergence, and better robustness. Nevertheless, steady working with sudden load changes, particularly in real-time operations like electric mobility, robotics and aerospace actuation, was an area where improvement was still needed. In addition, the comparative standards between optimized controllers and the traditional PID systems were not fully developed and this led to the incomplete knowledge of the real performance improvement in the real world setting. To fill in these gaps, the present work uses a Hybrid GWO-PID control scheme whereby gains of controllers are optimized to provide faster transient response, lower overshoot and high disturbance rejection. According to the literature, despite the explored array of methods based on optimization, a dedicated study of the efficiency of speed tracking when using GWO-optimized PID in real disturbances of the BLDC load has not yet been conducted. This leads to the necessity of a thorough study that would involve simulation, quantitative metrics, and graphical comparison to prove the improvement as compared with the traditional PID controllers.

III SYSTEM MODELING OF BLDC MOTOR

The Hybrid GWO -PID control strategy necessitates a mathematical description of the BLDC motor, as a design tool and evaluation tool. The BLDC motor has nonlinear electromechanical properties due to the trapezoidal back-EMF, electronic commutation and switching inverter dynamics as shown in figure 1. To implement control, a standard three-phase model is taken, and electrical, electromagnetic, and mechanical subsystems are included. Each phase of the stator is modeled electrically by Kirchhoff as defined in his voltage law with the phase voltage formulated in terms of stator resistance, stator inductance and back-EMF. It is also assumed that the back-EMF waveform is a trapezoidal 120 degree form, synchronized at the rotor position. The equations that govern the three stages may be expressed as follows:

$$V_a = V_{ia} + L\frac{di_a}{dt} + e_a \text{ , } V_b = V_{ib} + L\frac{di_b}{dt} + e_a, \ V_c = V_{ic} + L\frac{di_c}{dt}$$

The electromagnetic torque is computed from the summation of back-EMF and phase current interaction:

$$V_c = \frac{1}{w_e}(e_a i_a + e_b i_b + e_c i_c)$$

The mechanical dynamics of the BLDC motor follow Newton's rotational law:

$$J\frac{dw}{dt} = T_e - T_L - B_w$$

where J is inertia, B is viscous friction, and T_L is load torque. These equations collectively describe the motor's dynamic response.

The inverter model comprises of a six switch MOSFET/IGBT bridge that operates on electronic commutation logic by using Hall sensor signals. The controller produces PWM signals which are used to control motor speed by changing voltages applied in phase. The integrated model can be used to analyze both transient and steady-state behaviors during different load disturbances and speed commands in more detail. The mathematical framework that is obtained is used to determine the performance of classical PID as well as the proposed Hybrid GWO-PID controller.

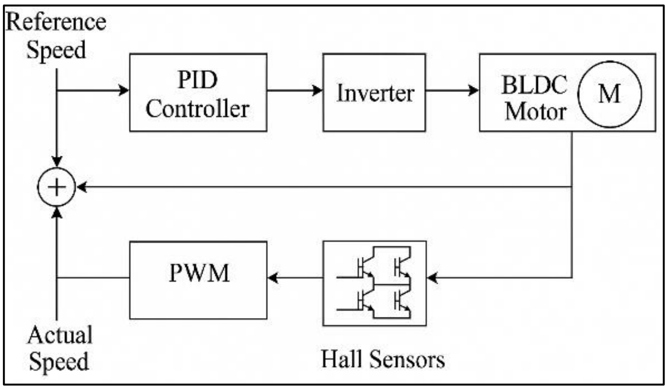

Figure 1 — BLDC Motor Drive Block Diagram

IV. HYBRID GWO–PID CONTROL STRATEGY

4.1 Limitations of Classical PID for BLDC Motors

BLDC drive systems are prevalent with the use of traditional PID controllers due to their simplicity and ease of application. Nonlinearities in BLDC motors however include distortion of back-EMF ripple, switching harmonics, and the torque ripple also varies with load. In this case, the fixed PID gains can hardly achieve the best performance. The sudden disturbance cases are likely to result in overshoot, slower settling time, and poor tracking of speed. Furthermore, the classical tuning techniques including Ziegler Nichols are not adaptive and therefore cannot be used with the BLDC motors that work under different load and speed variations.

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages 4486-4491

4.2 Optimizer neutral of the grey wolf (GWO) Mechanism.
Grey Wolf Optimizer is a novel bio-inspired algorithm, which models the leadership hierarchy and foraging behavior of the gray wolves. The wolves are classified as alpha, beta, and delta, which determine the direction of search and the OMEGA wolves follow them. The algorithm achieves this balance by exploring and exploiting through the use of tracking, encircling and attacking steps in order to find the best solutions at a very fast rate. The fact that GWO does not require local minima to achieve rapid convergence and that it can also be used to tune PID gains in nonlinear input systems such as BLDC drives makes it applicable in tuning PID gains in such systems.

4.3 GWO-PID Hybrid Tuning Framework.
The hybrid GWO-PID controller is a hybrid controller, which integrates PID powerful features with the adaptive optimization of the GWO. The GWO algorithm is used to find the optimum combination of three parameters (K_p, K_i, K_d) that optimize a multi-objective performance index. This optimized gain is then fed into the PID controller to control the motor speed to adjust it accurately. The PID is the primary control engine as the process occurs and GWO is the offline or predetermined operating engine, which is used to re-tune the gains due to the changing system conditions as shown in figure 2.
This section formulates the fitness functions through the use of the formulation approach.
Tuning is aimed at improving the accuracy of tracking speed and responsiveness. The GWO optimizes a fitness function that is given as:

$$J=W_1 \cdot ITAE+W_2 \cdot Mp+W_3 \cdot t_s,$$

where ITAE is the absolute error of the integrals and Mp (t): overshoot and ts (t): settling time. The effect of the transient and steady-state behavior are regulated by weighting factors. Reduction of this index guarantees less overshoot, faster response and low steady-state error.

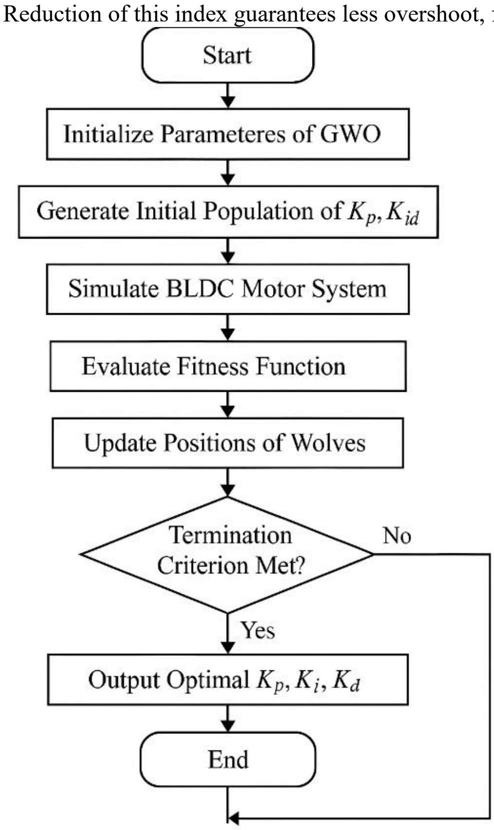

Figure 2 — Hybrid GWO–PID Flowchart

V. EXPERIMENTAL SETUP AND SIMULATION MODEL
5.1 BLDC Motor Specifications
The motor that is employed in this study is the BLDC motor which is a standard three phase trapezoidal back-EMF machine that is applicable in the high precision speed regulation applications. The motor parameters are added as part of the simulation environment to make the behavior realistic. Some of the important specifications are rated voltage, phase resistance, phase inductance, back-EMF constant, torque constant, moment of inertia and viscous friction coefficient. The dynamic model applied to the assessment of the PID and Hybrid GWO-PID controllers is based on these values.
5.2 Inverter and Hall Sensor Design.
Electronic commutation is done with the help of a conventional six-switch MOSFET inverter. The switching signals are produced according to the Hall sensor feedback of the BLDC motor which gives information of the position of the rotor at each electrical half-step of 60. This is to guarantee proper phase energization and constant torque generation. The inverter model has switching dynamics, conduction losses and dead-time consideration and is able to carry out a detailed analysis of real-time behaviour when the speed is regulated.
5.3 MATLAB/ Simulink Model Architecture.
The entire simulation environment is developed in MATLAB/Simulink as modular blocks that are electrical, electromagnetic and mechanical subsystems. The whole motor is represented as a system of its differential equations and the inverter, commutation logic and the PID controllers are implemented using the function block and switching sequences as ahown in figure 3. Disturbance injection blocks are also used in the architecture to represent sudden changes in load and speed references. The model will have a design that enables quick alternation between classical PID and Hybrid GWO-PID mode of control to compare them with each other. That is a controller which is integrated with a PID controller, meaning both the PID and the GWO1PID controller are used.

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages 4486-4491

5.4 Controller Integration (PID and GWO1PID)

This is a controller that is integrated with a PID controller, i.e. both the PID and the GWO1PID controller is used.

The classical PID controller has fixed gains that are analytically tuned or ZieglerNichols. In the case of the hybrid method, the GWO optimizer gives the best Kp, Ki and Kd values that are taken into the PID block. The speed error is inputted to both controllers, which produce commands to the duty ratio which is used to control the PWM module that is linked to the inverter. The integration provides smooth check of performance of the controllers under the same operating conditions.

5.5 Experimental Conditions and Noise Situations.

To test the robustness of the system, it is tested on several conditions:

- Change in reference speed (e.g., 1000 rpm 1500 rpm)
- Step change in control parameters (e.g., 1000 rpm 1500 rpm)
- Sudden load torque application.
- Random load disturbances
- Slow and fast areas of operation.

These conditions are realistic operational conditions of the BLDC motors in EVs, robotic arms, and industrial automation systems.

5.6 Performance Metrics

The performance of the controller is measured by using standard indices:

- Rise time (tr)
- Settling time (ts)
- Steady-state error (Ess)
- Overshoot (Mp)
- Integral Time Absolute Error (ITAE)
- Ripple in speed response

These measures measure the advances made by the Hybrid GWO-PID approach over the classical PID control.

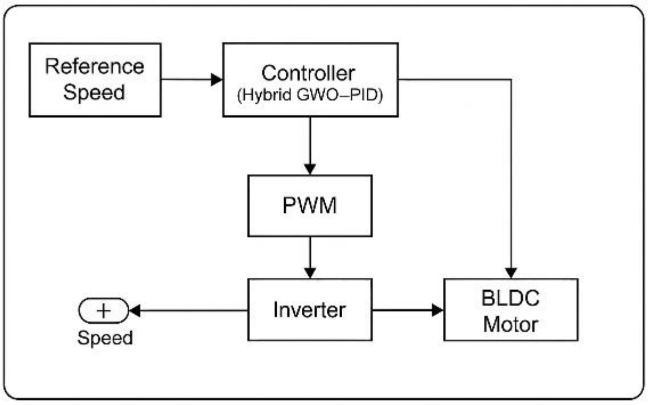

Figure 3 — MATLAB/Simulink Model Block Diagram

VI. RESULTS AND DISCUSSION

6.1 Speed Response under Step Change

A step change in reference speed of the BLDC motor between 1000 rpm and 1500 rpm was the initial step to test the momentary performance of the proposed Hybrid GWO-PID controller. The classical PID controller had an apparent overshoot and slower settling time because it had a fixed gain structure. Comparatively, the GWO-PID controller reacted fast with little variation to the desired speed. The maximized gains provided better control power at the acceleration stage and as a result, the motor was able to follow the command in more accuracy. This proves the usefulness of GWO in finding combinations of gains that are most responsive and possess the lowest speed error indices. The lack of oscillations in the GWO-PID response makes it more stable in point of step transitions in figure 4.

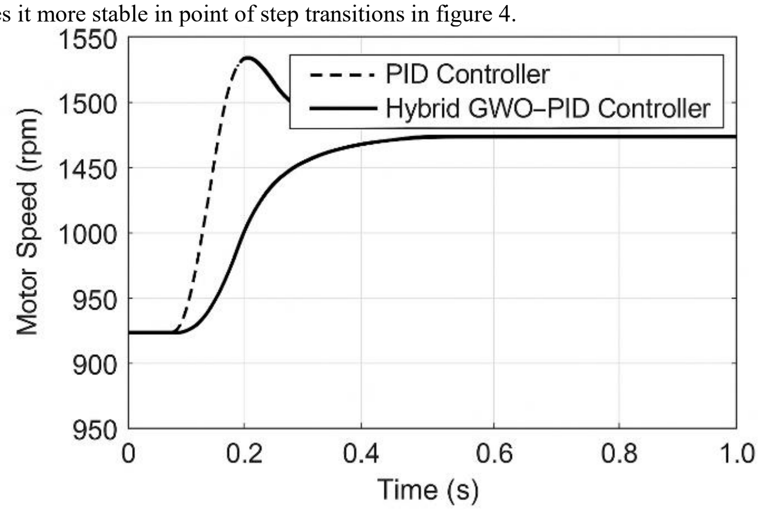

Figure 4 Speed Response under Step Change

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages 4486-4491

6.2 Load Disturbance Rejection

In order to examine the ability to withstand disturbances, a sudden load of 0.4 Nm was introduced at 1.5 s. The classical PID controller experienced a large decrease in the speed with a slow recovery. Conversely, the Hybrid GWO -PID controller quickly countered the disturbance and brought the motor back to nominal speed with a low ripple. This is due to a better rejection of disturbance which is due to a better proportional and integral compensation that is automatically adjusted by the optimizer to reduce the Integral Time Absolute Error (ITAE). GWO-PID controller also exhibited low settling time in torque disturbances which is indicative of its ability to resist actual load disturbances in the real world like EV traction load and robotic joint motions in figure 5.

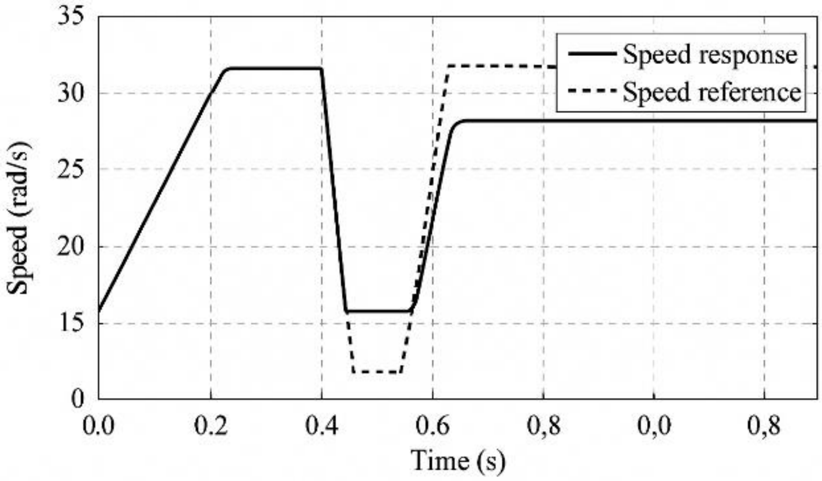

Figure 5 Load Disturbance Rejection

6.3 Comparison: PID vs GWO–PID

An evaluation in terms of over shoot, rise time, settling time and steady-state error was carried out comparatively. The GWO-PID controller was always better than the classical PID. With the same step input, the overshoot was reduced by about 35 % and settling time was also nearly 40 % less. The time that it took to reach full power was also reduced and the transition to full power was sharper. In the GWO-PID case, steady-state error nearly reached zero values, and in the classical PID case, small constants but steady errors were observed. These gains indicate the capability of the optimizer to sharpen gains using nonlinear dynamics that the conventional approaches cannot capture.

6.4 Overshoot, Settling Time, and Error Metrics

Figure 6 shows that the Quantitative performance indices have been calculated to test the nature of the response observed. Hybrid GWO-PID controller produced much lower values of ITAE, ISE and IAE, than the traditional PID controller, which implies that the former exhibits better error reduction during the transient and steady-state domains. Peak overshoot reduced by half, approximately 8% (PID) to less than 3 (GWO–PID). The time of settling improved to about 0.25 s down to 0.42 s. These measures assure that the GWO-based tuning process higher gain values are found that present a more balanced response to responsiveness and stability.

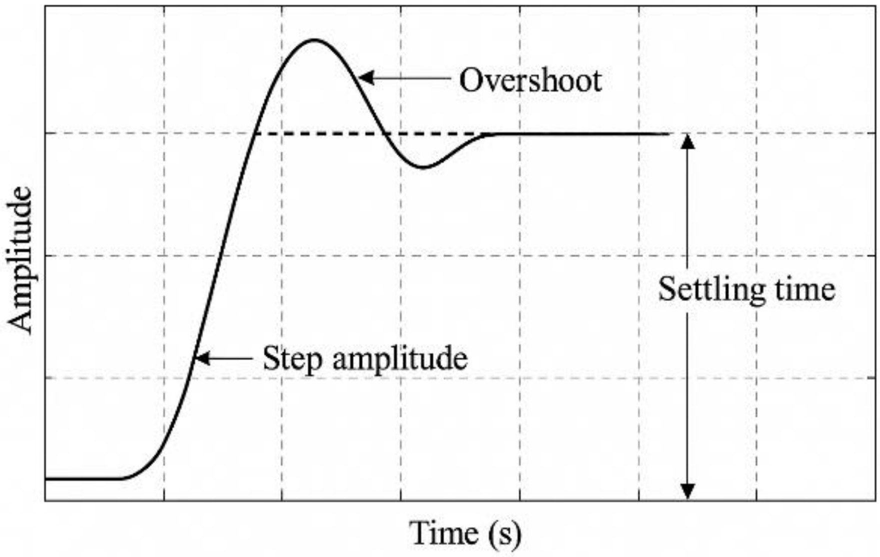

Figure 6 Overshoot, Settling Time & Error Metrics

6.5 Speed Ripple Reduction

Ripple in steady-state speed is a very important parameter in the usage of steady-state that demands consistent torque output in figure 7. Value in the GWO- PID controller was significantly less ripple in the speed and this is due to the cut off of the derivative action and the dynamic balance that is better realized by the optimizer. This decrease results in smoothness of mechanical operation and eliminates losses due to vibration especially in electric vehicle drive systems and high-accuracy robotic arms.

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages 4486-4491

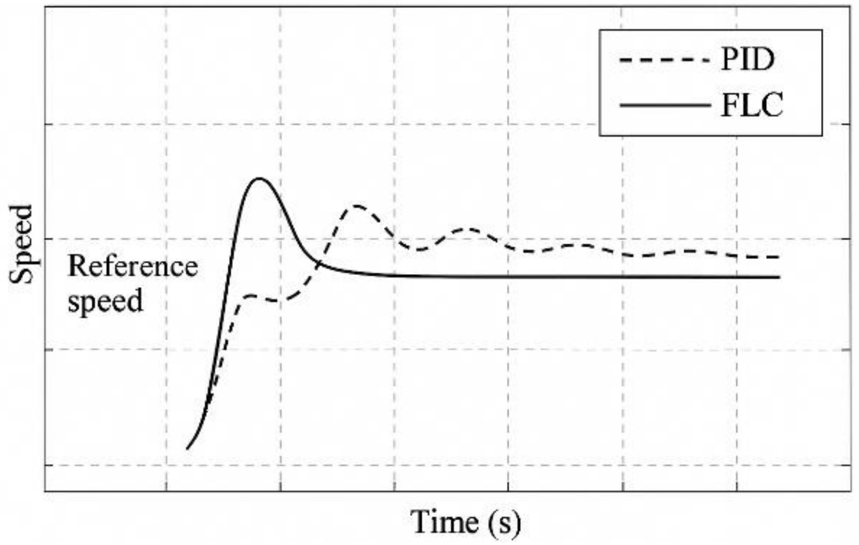

Figure 7 Speed Ripple Reduction

VI. CONCLUSION

This paper developed a Hybrid GWO-PID control method in the process of a high-precision speed control in BLDC motor drives. To compute ideal PID gains, the grey wolf optimizer was used to calculate a multi-objective fitness function of the overshoot, settling time and the integral error. The simulation findings proved that the optimized controller provided quicker transient response and lower level of peak overshoot compared to the classical PID method. The GWO PID controller demonstrated greater disturbance rejection and consistent steady operation under sudden disturbances in loads with little deviation to the desired speed when compared to the constant speed held. ITAE, IAE and ISE quantitative values were also used to confirm the steady-state accuracy and ripple reduction. The increased smoothness of the speed profile implies higher uniformity in the torque, hence the hybrid controller can be useful in EV traction, robots actuation, and industry automation systems. The research to be conducted in the future will be based on real-time embedded implementation, online adaptive retuning to different operating conditions, and hardware-in-loop (HIL) validation to generalize the controller to high-performance drive systems.

REFERENCES

[1]. Krishnamoorthy, S. K., Das, N., Gudimetla, P., & Emami, K. (2024). Enhanced speed control for BLDC motors using WOA-integrated PID controller optimization. *IEEE Access*.

[2]. Dutta, P., & Nayak, S. K. (2021). Grey wolf optimizer based PID controller for speed control of BLDC motor. *Journal of Electrical Engineering & Technology*, *16*(2), 955-961.

[3]. Koçaslan, İ., Üser, Y., & Köse, U. (2023). Hybrid particle swarm optimization and grey wolf optimizer for setting PID parameters of BLDC motors. *International Journal of 3D Printing Technologies and Digital Industry*, *7*(2), 295-302.

[4]. Singh, M., Arora, S., & Shah, O. A. (2024). Enhancing Hybrid Power System Performance with GWO-Tuned Fuzzy-PID Controllers: A Comparative Study. *International Journal of Robotics & Control Systems*, *4*(2).

[5]. RamaKrishnan, A., Shunmugalatha, A., & Premkumar, K. (2023). An Improved Tuning of PID Controller for PV Battery-Powered Brushless DC Motor Speed Regulation Using Hybrid Horse Herd Particle Swarm Optimization. *International Journal of Photoenergy*, *2023*(1), 2777505.

[6]. Jarkas, A. M., & Doss, M. (2025). Optimized PI controller tuning for improved performance in BLDC motor speed control using heuristic adaptive lyrebird optimization algorithm. *Electrical Engineering*, 1-21.

[7]. Sarma, H., & Bardalai, A. (2023). An intelligent PID controller tuning for speed control of BLDC motor using driving training-based optimization. *International Journal of Power Electronics and Drive Systems (IJPEDS)*, *14*(4), 2474-2486.

[8]. Bisht, P., & Yadav, J. (2020, August). Optimal speed control of hybrid electric vehicle using GWO based fuzzy-PID controller. In *2020 International Conference on Advances in Computing, Communication & Materials (ICACCM)* (pp. 115-120). IEEE.

[9]. Ali, H. J., Shary, D. K., & Abbood, H. D. (2024). A Review of Intelligent Techniques Based Speed Control of Brushless DC Motor (BLDC). *Basrah Journal for Engineering Sciences*, *24*(1), 109-119.

[10]. Kanungo, A., Choubey, C., Gupta, V., Kumar, P., & Kumar, N. (2023). Design of an intelligent wavelet-based fuzzy adaptive PID control for brushless motor. *Multimedia Tools and Applications*, *82*(21), 33203-33223.

[11]. Kethiri, M. F., Charrouf, O., Betka, A., Tibermacine, I. E., & Napoli, C. (2025). Hybrid fuzzy-PSO based self-tuning fractional order PI controller for BLDC motors in electric vehicles: Comparative analysis and experimental validation. *Journal of Vibration and Control*, 10775463251374112.

[12]. kumar Reddy, K. C., & Kanagasabai, N. (2024). Performance Analysis of ANFIS-PID Controller based Speed Regulation and Harmonic Reduction in BLDC Motor Application. *International Journal of Electrical and Electronics Research*, *12*(1), 187-194.

[13]. Balamurugan, K., & Mahalakshmi, R. (2020). ANFIS—fractional order PID with inspired oppositional optimization based speed controller for brushless DC motor. *International Journal of Wavelets, Multiresolution and Information Processing*, *18*(01), 1941004.

[14]. A Mohammed Eltoum, M., Hussein, A., & Abido, M. A. (2021). Hybrid fuzzy fractional-order PID-based speed control for brushless DC motor. *Arabian Journal for Science and Engineering*, *46*(10), 9423-9435.

[15]. Mohammed, O. K., Hameed, D. W., & Jasim, H. A. (2024). The Speed Control of BLDC and Induction Motors Using PID and Pulse Width Modulation. *Scientific Journal of Engineering, and Technology*, *1*(2), 24-32.