

## **Brushless DC Motor Speed Control based on PID-Fuzzy Controller**

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**Abstract:** Brushless DC (BLDC) motors provide numerous advantages, including improved efficiency and lower maintenance requirements as compared to conventional DC motors. The demand for BLDC motors in the industry for a variety of applications is increasing over time. In order to meet the demands of users and industry, BLDC motors must be improved. The issue with BLDC motors is that they cannot run effectively when employing a certain controller in a non-linearity condition or application. The proposed methodology for this study is a PID-Fuzzy controller for controlling the speed of a BLDC motor. This paper comparing between standard PID and PID-Fuzzy controller-based speed control. Digital simulation in MATLAB/Simulink is used to analyze the efficiency of the BLDC motor speed. In conclusion, is that the PID-Fuzzy controller approach is the best for managing the speed of BLDC motors since it produces better outcomes than other methods. The outcomes of this research indicate that the PID-Fuzzy controller is better than the PID controller in terms of its ability to manage the speed of the BLDC motor and reduce the amount of settling time necessary to achieve the target speed.

**Keywords:** PID, Fuzzy Logic, BLDC Motor, Speed Controller

### **1. Introduction**

In the modern world, it is impossible for humans to get on with their lives, alone finding solutions to problems or successfully overcoming obstacles, without the help of various forms of technology. Humans compete with each other to develop new technologies that benefit society and improve it in a variety of ways. In industry, motors are essential or essential equipment that must be upgraded from time to time. To ensure manufacturing meets customer demand while meeting all consumer standards, the industry must improve its performance. Many applications, such as aircraft, electric vehicles, household appliances, robotics, and many more, employ motors as the primary component of their model and product. That is why motor development in the industry is necessary to ensure that motor

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efficiency may be improved. The current hot subject in this sector is motor efficiency, which is constantly being questioned by users and industry professionals. The motor's speed regulation is crucial for boosting the motor's efficiency. For new industry applications, conventional direct current (DC) motors are far behind. For a variety of reasons, the industry now favors brushless DC motors over traditional dc motors in many applications. One factor is that BLDC motors have fewer mechanical components since they no longer exchange the current in the armature coil using brushes and commutators [1]. Additionally, BLDC can enhance dynamic responsiveness due to its reduced rotor inertia and a number of other advantages [2].

Usually, BLDC motors used in linear applications have no problem with the controller used to detect motor speed. A type of application known as linear property application cannot include load variations, interference, or parameter modifications of any kind. In reality, a BLDC motor is a nonlinear motor because it is extremely sensitive to load disturbances and parameter fluctuations, both of which have the potential to modify the speed away from a constant speed that has been established by the user [3]. As a result of this, controllers play a very significant role in the operation of BLDC motors. It has been attempted to control motor speed in a variety of ways, however, these methods do not appear to be promising enough to adjust to varying loads and types of interference. It would be very beneficial for the business to come up with a reliable way to regulate the speed of BLDC motors.

In this paper, the BLDC motor drive system is modelled, simulated, and a suggested speed controller based on the PID-Fuzzy approach is developed. The ultimate goal of this goal is to demonstrate the effectiveness of the suggested controller by simulation. This paper will concentrate on controller design according to the point from the most recent PID-Fuzzy research demonstrating the effectiveness of PID-Fuzzy controllers. To control the BLDC, a PID-Fuzzy controller is presented when adjusting for load disturbance in motor speed. The settling time for both the PID and PID-Fuzzy controllers is recorded.

## 2. Materials and Methods

PID controllers use proportional, integral, and derivative functions to boost both the steady-state and transient responses. Integral PID controller action can remove or reduce steady state error [4]. When the system parameter has not changed or when the system is linear, PID controllers can function extremely effectively. The PID controller will function poorly and deliver bad results for the system or application that is exposed to load disturbance and parameter change, which might result in a longer rise time for the system itself. There are several ways to adjust the PID parameter, such as Ziegler-Nichol (ZN). This work uses the ZN approach, which is well known for being a trial-and-error procedure, to optimize the PID value [1]. Figure 1 shows the MATLAB Simulink design for BLDC motor with PID controller.

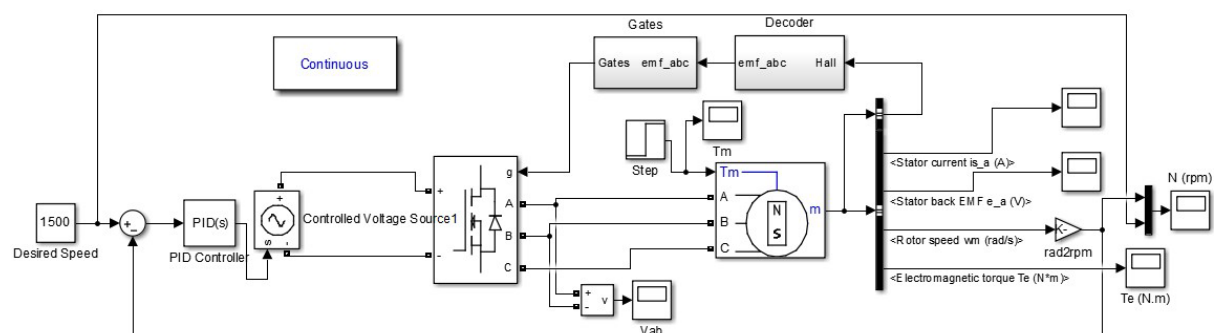
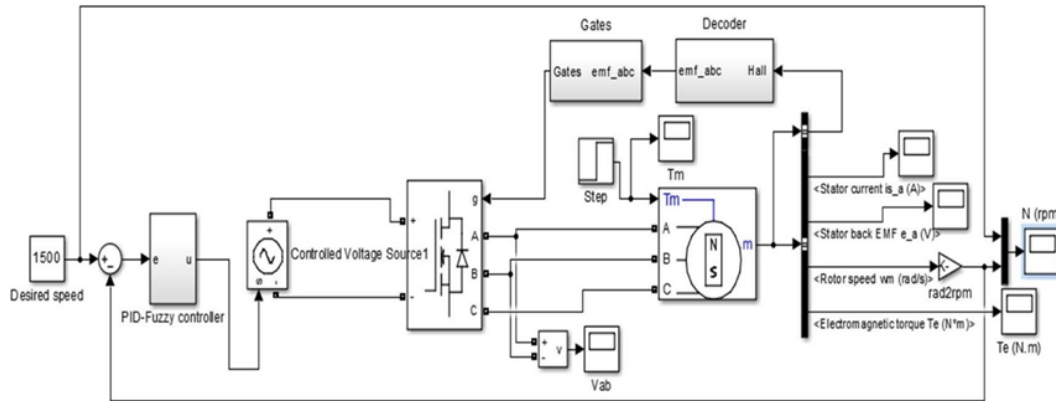


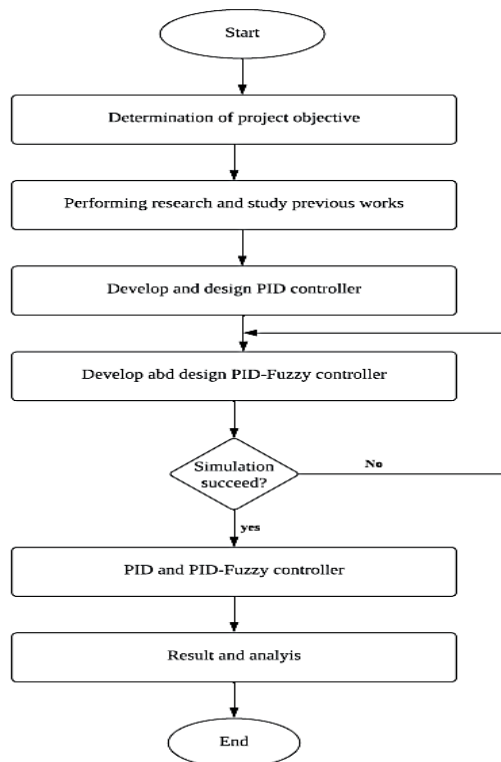
Figure 1: MATLAB Simulink design for BLDC motor with PID controller

Fuzzy logic is a control system that is based on a linguistic control strategy obtained from expert knowledge and then turned into an automated control strategy. In contrast to other control methods, fuzzy logic control does not need a large number of mathematical computations. Fuzzy logic, on the other hand, requires just simple mathematical computations to reproduce or simulate expert knowledge [5][6]. Despite the fact that it simply requires a basic computation, fuzzy logic may deliver high performance for any system or application. Figure 2 presents the Simulink PID-Fuzzy BLDC motor model that is used in this paper.



**Figure 2: Simulink PID-Fuzzy BLDC motor model**

The BLDC motor modeling and simulation phase can be considered completed when the simulation produced a trapezoidal back-EMF waveform. It was discovered that the PID-Fuzzy controller may achieve a superior outcome or faster reaction speed than the PID controller. Figure 3 shows the project's flowchart. This project advanced with the creation and designing of the PID and PID-Fuzzy controllers.



**Figure 3: Project flowchart**

### 3. Results and Discussion

The success of the project may be measured by the speed or waveform response that is produced after simulating the BLDC drive model with the suggested PID controller and the PID-Fuzzy controller. One sort of waveform is a graph showing the relationship between speed and time. PID controllers and fuzzy PID controllers will both have their simulation results compared and illustrated as part of this research so that the advantages of using PID-Fuzzy controls can be demonstrated. The speed response of a BLDC motor will be measured as part of this research using both a controller with a non-charged load and a controller with a charged load.

The simulation result of a BLDC drive system is provided to demonstrate the feasibility of the proposed PID-Fuzzy speed controller under varying operating speed circumstances. This study demonstrates the simulation results for both PID and PID-Fuzzy controllers to test system resilience. To begin, constant speed simulation testing is observed during the start-up response by employing constant reference speeds of 3000rpm, 1500 rpm, 500 rpm, and 1000 rpm with no load disturbance. Second, both systems are put through their paces under load disturbance operating circumstances. Initially, the systems are operating steadily at the specified reference speed with no load condition, and then the load is unexpectedly adjusted to 0.2 Nm after 3 seconds for the PID and PID-Fuzzy controllers.

PID and PID-Fuzzy controllers are used separately in this research to replicate the BLDC drive system with no load or constant speed. Test circumstances for this project are 3000 RPM, 1500 RPM, 1000 RPM or 500 RPM. This means that the controller was tested when it is being used, or the reference speed will be changed to match the four-speed values.

It can be seen from Figure 4 that the PID speed controller requires 5.554 seconds in order to achieve steady state speed. As for the PID-Fuzzy speed, the controller requires 0.9374 seconds to reach the steady state condition. Meanwhile, in figure 5, the PID speed controller requires 5.0626 seconds in order to achieve steady state speed. The PID-Fuzzy speed controller requires 1.19.19 seconds to reach the steady state condition. Figures 4 and 5 show the speed response waveform for BLDC Motor when using the PID controller and PID-Fuzzy controller for no load disturbance conditions. The desired speed for those simulation results was set at 3000rpm, 1500 rpm, 1000 rpm and 500rpm.

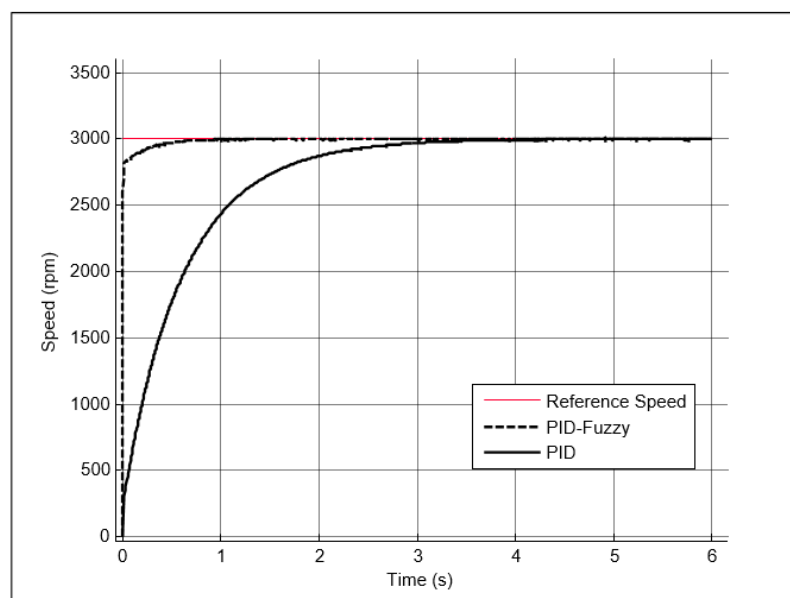
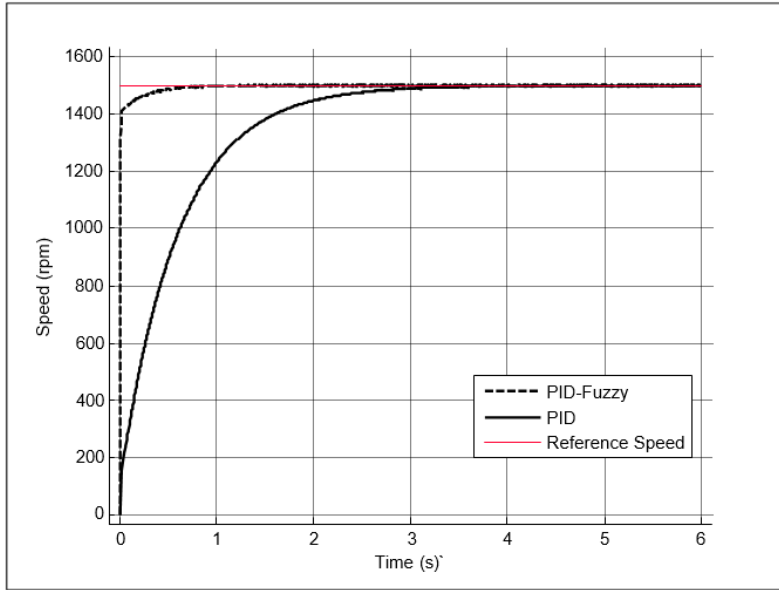
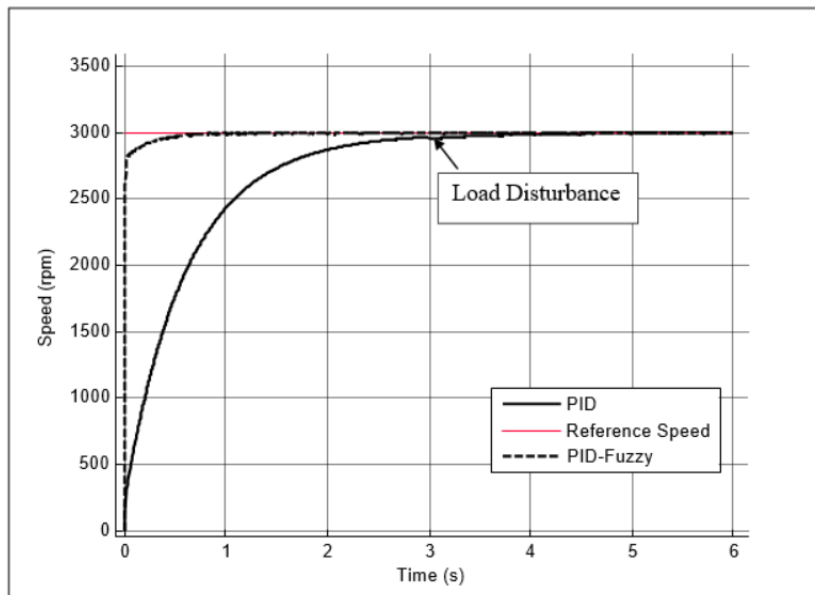


Figure 4: Constant speed result when the reference speed is 3000 rpm

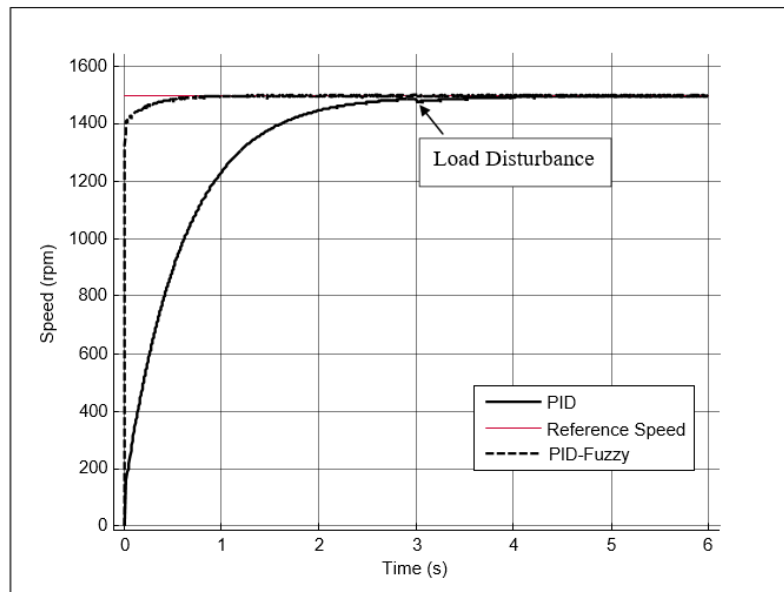


**Figure 5: Constant speed result when the reference speed is 1500 rpm**

Whereas in Figure 6, the PID-Fuzzy speed controller with 0.2 Nm load disturbance injected to the BLDC motor drive system takes 0.0210 seconds to reach a steady state. While the PID speed controller needs 2.631 seconds in order to achieve constant speed after the load disturbance is applied to the system. It can be seen from Figure 7 that the PID-Fuzzy speed controller with 0.2 Nm load disturbance injected to the BLDC motor drive system takes 0.0073s to reach a steady state. While the PID speed controller needs 2.4426s in order to achieve constant speed after the load disturbance is applied to the system. Figures 6 and 7 show the speed response waveform for BLDC Motor when using the PID controller and PID-Fuzzy controller under load disturbance conditions. The sudden load 0.2Nm is applied at the time 3sec. The desired speed for those simulation results was set at 3000rpm, 1500 rpm, 1000 rpm and 500 rpm.



**Figure 6: Result for load disturbance when reference speed at 3000 rpm**



**Figure 7: Result for load disturbance when reference speed at 1500 rpm**

Table 1 tabulates the recorded settling time for every simulation. From Table 1, it can be concluded that the PID-Fuzzy controller was able to produce a sufficient speed response. Also can be seen the settling time for the BLDC motor driver was substantially smaller than that of the PID controller in terms of obtaining the target output.

From Table 1, the PID-Fuzzy speed controller for the BLDC motor drive system reaches the steady state condition or reference speed for 500 rpm, 1000 rpm, 1500 rpm, and 3000 rpm at times of 1.1650 seconds, 1.2058 seconds, 1.1919 seconds, and 0.9374 seconds, respectively, when there is no load given or injected to the system. The PID speed controller needs 4.5460 seconds, 4.6709 seconds, 5.0626 seconds, and 5.5540 seconds, respectively, for the speed reference of 500 rpm, 1000 rpm, 1500 rpm, and 3000 rpm in order to achieve steady state speed.

It takes the PID-Fuzzy speed controller with 0.2 Nm load disturbance supplied to the BLDC motor drive system 0.0059 seconds, 0.0032 seconds, 0.0073 seconds, and 0.0210 seconds, respectively, to reach a steady state when the reference speed is set to 500 rpm, 1000 rpm, 1500 rpm, and 3000 rpm, respectively. After a load disturbance has been introduced into the system, the PID speed controller needs 1.5650 seconds, 2.1382 seconds, 2.4426 seconds, and 2.631 seconds in order to keep the reference or constant speed of 500 rpm, 1000 rpm, 1500 rpm, and 3000 rpm, respectively.

**Table 1: Recorded Settling time for every simulation**

Testing Condition	Settling time (sec)			
	Constant Speed (without load)		Load Disturbance (0.2 Nm)	
	PID	PID-Fuzzy	PID	PID-Fuzzy
500rpm	4.5460	1.1650	1.5650	0.0059
1000rpm	4.6709	1.2058	2.1382	0.0032
1500rpm	5.0626	1.1919	2.4426	0.0073
3000rpm	5.554	0.9374	2.631	0.0210

This project demonstrates two different kinds of controllers that are used to regulate the speed of BLDC motor operations. The PID controller and the PID-Fuzzy controller are the two kinds of controllers that are going to be developed as part of this project. When compared to a PID speed

controller, a PID-Fuzzy speed controller has the ability to reject disturbances more effectively. Additionally, the PID-Fuzzy speed controller's settling time for each simulation is shorter than that of the PID controller, allowing it to more quickly obtain the output speed that is desired. When there is just a slight difference in speed, the motor speed tends to track the reference speed with greater precision. When a load disturbance occurs, PID speed controllers take a little bit longer to recover from than PID-Fuzzy speed controllers do in order to maintain the speed reference that was previously specified. Additionally, the PID-Fuzzy speed controller maintains a careful check on the speed at all times. In tests conducted under the same conditions, the performance of the PID-fuzzy controller is superior to that of the PID controller. This is true whether or not the BLDC motor being tested is under load

#### 4. Conclusion

This paper demonstrated two different types of controllers utilized in BLDC motor speed control applications. The first controller is a PID controller, and the second is a PID-Fuzzy controller, both of which are proposed in this study. Based on the results, the PID-Fuzzy speed controller outperforms the PID speed controller in terms of disturbance rejection. The motor speed more closely tracks the reference speed with a slight speed differential. The PID speed controller recovers the speed twice as fast as the PID-Fuzzy speed controller in order to retain the speed reference supplied during load disturbance. Furthermore, the PID-Fuzzy speed controller tracks the speed very precisely. When identical conditions are used, the PID-fuzzy controller outperforms the PID controller when the load or no load is supplied to the BLDC motor.

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