Improvement of Speed Control Performance in BLDC Motor Using PID Controller

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Abstract - *The Brushless Direct Current (BLDC) motor has emerged as a highly efficient and reliable alternative to conventional brushed DC and induction motors, owing to its superior performance characteristics and maintenance-free operation. This paper focuses on soft computing technique for BLDC motor speed control. The closed loop controller architecture employed PID control approaches to get around the maximum overshoot and extended settling times and performance analysis of BLDC motors. Advanced control techniques such as Pulse Width Modulation (PWM), Field-Oriented Control (FOC), and Hall-effect or sensor less feedback mechanisms further enhance its operational efficiency and reliability. The speed control of BLDC Motor was simulated using MATLAB/SIMULINK and the results are obtained. The simulation results revealed that the proposed PID Controller provides better performance than conventional controller. The prototype model of BLDC motor is presented, and the speed response of BLDC motor is observed by LCD display*.

Key Words: **- Brushless DC Motor, PID Controller, DSP, Pulse Width Modulation.**

1. INTRODUCTION

In recent years the development of high-performance motor drive is very important in industrial as well as other purpose applications such as automotive, computer, steel rolling mills, electric trains and robotics, etc.

BLDC motors have several advantages over brushed DC motor such as high efficiency, long life, noise immunity, small size and less maintenance due to absence of brush and commutator arrangement. As the name implies, BLDC motors do not use brushes for commutation; instead, the BLDC motor employs electronic commutation which makes it a virtually maintenance-free motor. Also, they are more efficient due to the permanent magnets which results in virtually zero rotor losses.

However, the BLDC motor constitutes a more difficult problem than its brushed counterpart in terms of modelling and control system design due to its multi-input nature and coupled nonlinear dynamics.

The Brushless Direct Current (BLDC) motor has revolutionized the field of electric motors with its exceptional efficiency, reliability, and durability. Its superior performance characteristics, such as high torque-to-weight ratio, high speed range, and maintenance-free operation, make it an ideal choice for a wide range of applications, including robotics, automotive, aerospace, and industrial automation. However, the control of BLDC motors is a complex task due to their nonlinear dynamics and inherent instability. In recent years, there has been a growing demand for advanced control techniques to optimize the performance of BLDC motors. One such technique is the Proportional-Integral-Derivative (PID) control, which has been widely used in various control applications due to its simplicity and effectiveness. This project aims to design and implement a PID-based speed control system for BLDC motors, leveraging the capabilities of MATLAB/SIMULINK for simulation and analysis.

This report presents the findings and results of the project, including the design, simulation, and prototype development of the BLDC motor speed control system. The report is organized as follows: Section II provides a detailed overview of the BLDC motor and its control techniques, Section III describes the design and simulation of the PID-based speed control system, Section IV presents the results and discussion, and Section V concludes the report with future directions.

This project focuses on designing and simulating a speed control system for Brushless Direct Current (BLDC) motors using a Proportional-Integral-Derivative (PID) controller. The simulation results demonstrate the effectiveness of the PID controller in tracking the desired speed with improved accuracy and stability. The project's findings highlight the potential of PID control for BLDC motor applications, offering enhanced performance and reliability.

2. TRANSFER FUNCTION MODEL OF BLDC MOTOR

A) Construction of BLDC Motor

A brushless DC motor (BLDC) has permanent magnets on the rotor and electromagnets (stator windings) on the stator. It works by using an electronic controller to power the stator windings in a specific sequence, creating a rotating magnetic field that interacts with the rotor's magnets. This interaction produces torque, causing the rotor to rotate and maintain continuous motion, eliminating the need for brushes and a commutator found in brushed DC motors.

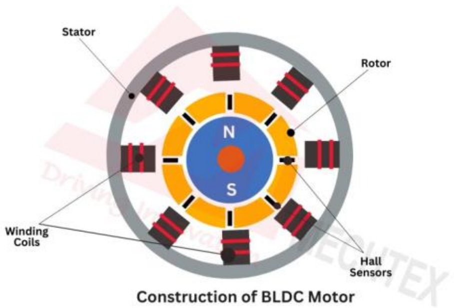

FIG.1 Construction of BLDC motor.

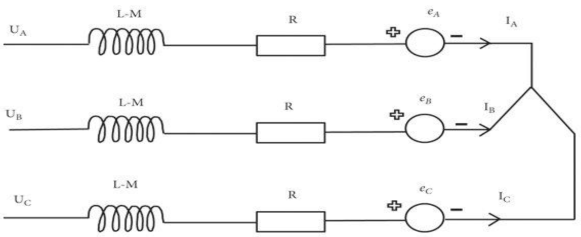

Fig.2 Equivalent circuit of BLDC motor

The mechanisms of back-EMF and electromagnetic torque are all the same with those of the traditional brushed DC motor; thus, similar analysis methods can be adopted.

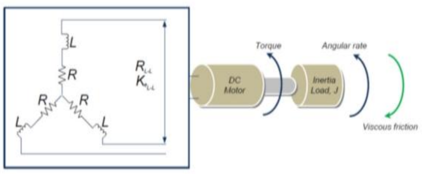

Fig.3 Brushless DC Motor Schematic Diagram

At any time, the two phases are excited either AB or BC or CA. The simplified equivalent circuit will be as Fig.4.

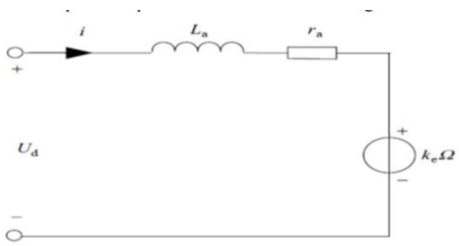

Fig.4 simplified equivalent circuit of the BLDC motor

B) Transfer Function

The transfer function is one of the most important concepts of control theory and the transfer function based mathematical models are widely used in automatic control fields. The Transfer Function model of BLDC motor is shown below in FIG.5.

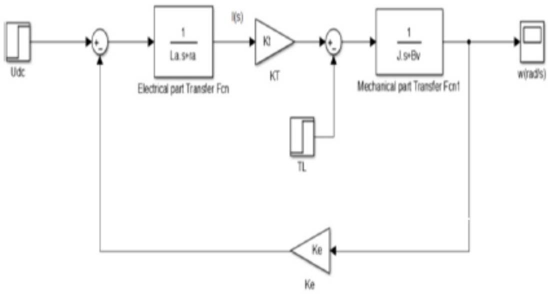

FIG.5 Block Diagram of Transfer Function Model of BLDC Motor

Table -1: SPECIFICATION OF BLDC MOTOR

The speed response of BLDC Motor under open loop condition is discussed below. The parameters of BLDC Motor are shown in table 1.

RATING	SYMBOL	VALUE	UNITS
DC resistance	R	0.25	Ω
Inductance	L	0.32	mH
Maximum Flux Linkage	Φ_m	65	mV/rad/sec
Number of Poles	P	8	
Peak Torque	T_p	2.83	Nm
Rated Voltage	V	15	V
Rotor Inertia	J	0.0042	Kg. m^2
Friction Coefficient	B_v	0.0096	N
Power	P	472	W
Rated Current	I	43.5	A

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3. DESIGN OF PID CONTROLLER

The transfer function model of PID (Proportional-Integral-Derivative) controller in its standard "parallel" form is $K(s) = K_p + K_i/s + K_d.S$

This equation is derived by taking the Laplace transform of the controller's time-domain equation, where K_P is the proportional gain, K_i is the integral gain, and K_d is the derivative gain. The peak overshoot is reduced using PID controller and hence the system stability was improved. The values of the PID are tuned by Ziegler-Nichols's methods. The tuned PID values are K_p=0.135211, K_i=135.211 and K_d=3.38e-5.

A) Simulation of Speed Control of BLDC Motor using PID Converter

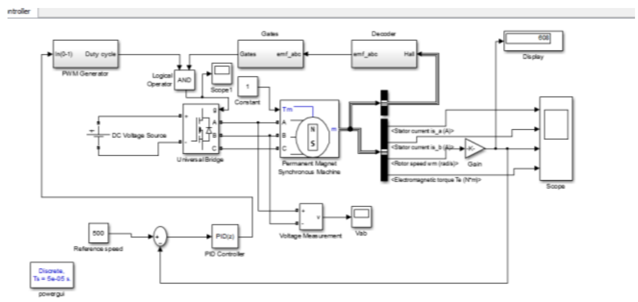

FIG.6 Simulation diagram of speed control of BLDC motor using PID controller

The simulation model consists BLDC Motor, PID controller, and three subsystems which are Decoder, Gates, PWM Generator. There are two bus selectors, one of them is connected with BLDC motor and other one is connected with decoder, as we can see from above figure.

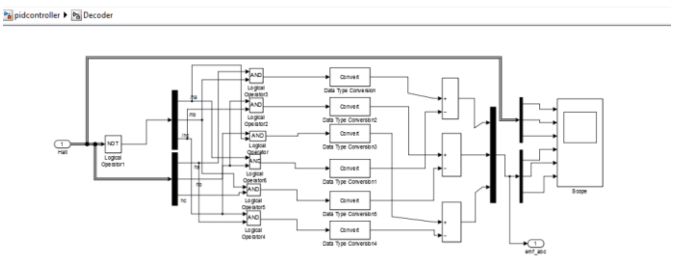

FIG.7 Decoder with input Hall and output emf_abc

The Decoders output is connected to the gates input and both PWM generator and gates output is connected to AND Gate. The PID controller is connected to PWM Generator. Gates and PWM Generator subsystem diagram is shown below in FIG.8 and FIG.9.

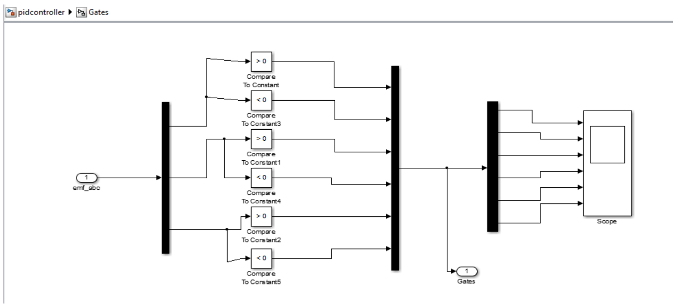

FIG.8 Gates subsystem

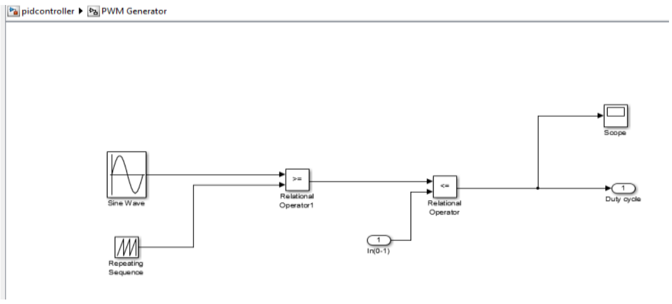

FIG.9 PWM Generator

The result of the simulation is showed in display as we can see at FIG.6. It shows the output of the simulation of speed control of BLDC motor using PID Controller and the scope shows the output waveforms.

A PID controller is an instrument used in industrial control applications to regulate temperature, flow, pressure, speed and other process variables. PID (proportional integral derivative) controllers use a control loop feedback mechanism to control process variables and are the most accurate and stable controller. It is a combination of all three types of control methods.

PID-control is most commonly used because it combines the advantages of each type of control. This includes a quicker response once time because of the action of P control, the system will respond to a change very quickly. Due to the action of I control, the system is able to be returned to the setpoint value. Finally, because it is so critical for the system to remain at a constant setpoint, D control will measure the change in the error, and help to adjust the system accordingly. On the contrary, as mentioned previously, when used individually, it has a slower response time compared to the quicker P-only control. So, the PID controller seems to be the most adequate controller which provides the accuracy and stability.

B) Output of the simulation

The output of the BLDC Motor speed control system demonstrates the effectiveness of the PID controller in achieving precise speed control. The simulation results show that the motor speed tracks the desired reference speed with minimal overshoot and steady-state error.

Key Output Parameters

1. **Speed Response:** The motor speed follows the desired reference speed accurately.
2. **Torque Output:** The motor torque output is stable and meets load requirements.
3. **Current Output:** The motor current is within the specified limits, ensuring safe operation.

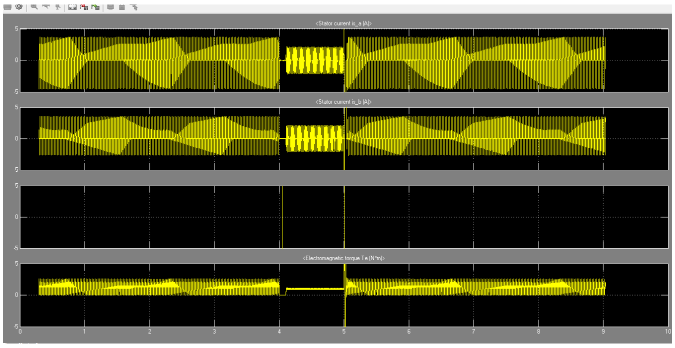

FIG.10 Speed response of BLDC Motor using PID Controller

The simulation of results is presented in the form of plots and graphs, showing the motor speed, torque, and current output over time. These results demonstrate the performance and stability of the PID controller in controlling the BLDC motor speed. The results are shown in the scope as we can see on the FIG.6.

4. CONCLUSION

This paper demonstrated the design and simulation of a speed control system for BLDC motors using a PID controller. The simulation results show that the PID controller provides excellent speed tracking performance, reduced overshoot, and improved stability. The project's findings confirm the effectiveness of PID control in BLDC motor applications, making it a viable solution for industrial and automation systems. Future work can focus on implementing the PID controller on a hardware platform and exploring advanced control techniques to further optimize BLDC motor performance.

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