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DEVELOPMENT OF EXPERIMENT TEST BENCH FOR BLDC MOTOR CONTROLLER

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Abstract - Brushless DC (BLDC) motors are widely popular in industrial and consumer applications due to their high efficiency, torque density, low maintenance, and long life. However, stable speed control is challenging due to their complex dynamics. The proportional-integral-derivative (PID) controller is commonly used for BLDC motor speed control because of its simplicity and effectiveness. This report provides an overview of PID control for BLDC motors, covering fundamental principles, design methods, and implementation techniques. It explains the roles of the proportional, integral, and derivative terms in shaping the control response and discusses the selection of PID parameters based on motor and load characteristics. PID control remains a valuable and versatile tool for BLDC motor speed control, suitable for a wide range of applications. Understanding its principles and design helps engineers achieve precise and reliable speed regulation.

Keywords: BLDC motor, PID controller, speed control

1. INTRODUCTION

Brushless DC (BLDC) motors are increasingly popular in applications from industrial automation to consumer electronics due to their reliability and efficiency. Their high efficiency, large torque density, long life, and low maintenance make them a preferred choice in electrical engineering. However, stable speed control is challenging due to their complex dynamics. PID control is a popular method for BLDC motor speed control because of its simplicity, stability, and efficiency. It adjusts the voltage applied to the motor's windings by continually monitoring the motor's speed, comparing it to the desired set point, and processing the error signal. The proportional term addresses the current speed error, the integral term corrects steady-state errors, and the derivative term minimizes oscillations by anticipating future speed changes. Successful PID control depends on selecting the right proportional, integral, and derivative gains to ensure accurate speed tracking, minimal settling time, and reduced overshoot.

2. Literature Review

The implementation of PID controllers in BLDC motor systems enhances dynamic characteristics. Comparing BLDC models with and without PID controllers shows that the PID-controlled system reduces settling and peak times, ensuring both steady-state and transient stability. Improved speed response and reduced torque ripple contribute to a stable and efficient BLDC system, highlighting the superiority of PID controllers over controller-less models. This review also examines a modified PID controller in a three-stage BLDC motor system. The proposed PID controller performs well under step load variations and adjusts speeds from 10% to 80% of the pre-set speed in about 18 milliseconds, meeting most task requirements. These findings demonstrate the PID controller's effectiveness in dynamic response and speed regulation. A comparison between PI and PID controllers in BLDC systems reveals that PI controllers have better start-up characteristics, while PID controllers handle load changes more smoothly. The derivative component in PID controllers introduces oscillations but reduces the magnitude of the first oscillation, although it extends settling time compared to PI controllers. The review suggests that practical considerations should be factored into further analysis for better insights into the dynamic behaviour of BLDC motors under various conditions. Finally, the review explores diverse control approaches for BLDC motors, including speed, trajectory tracking, and acceleration control. Advanced strategies like Sliding Mode Control (SMC) outperform traditional PID controllers by exhibiting high disturbance rejection and stability. Simulations show that SMC efficiently guides the system to the preferred trajectory, emphasizing the benefits of advanced control strategies in optimizing BLDC motor dynamics.

3. SYSTEM DESCRPITON

The BLDC motor is essential in various industrial control applications due to its high output torque, minimal noise, high efficiency, and stability. It shares electrical characteristics with traditional DC motors and constructional similarities with Permanent Magnet Synchronous Motors (PMSM). BLDC motors use Hall effect sensors to detect rotor angle and facilitate phase winding excitation. Typically, they have a three-phase wound stator powered by an inverter and a rotor made of permanent magnets like alnico, Neodymium, or magnetite.

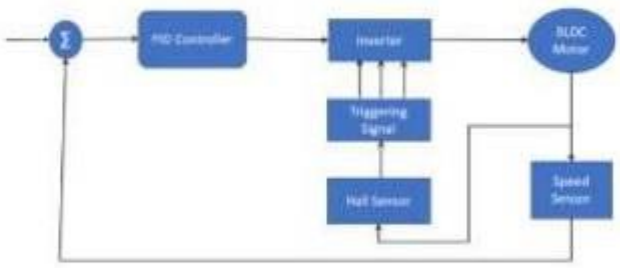

Fig. 2.1 Block diagram of a closed loop system of

BLDC motor speed control BLDC motors are highly reliable due to their electrical commutation. Three Hall effect sensors, placed at 120° intervals, detect rotor position and send feedback to the Voltage Source Inverter, enabling precise phase winding excitation. This sensor-based approach ensures accurate speed response.

A controlled voltage source drives the inverter circuit, following 120° commutations. The inverter operates in six intervals, energizing two-phase windings at a time, which provides inherent short circuit protection. Unlike PMSM motors, BLDC motors have a trapezoidal backEMF waveform and use concentrated phase windings. The report includes mathematical modelling and Simulink modelling of the BLDC motor with back-EMF sensing, demonstrating mathematical and transfer function The block diagram in Fig. 2.2.1 shows a BLDC Motor system controlled by a power converter and a control algorithm. Rotor position sensors respond to command signals, which include torque, voltage, and speed commands. BLDC motor types are classified based on the control algorithm structure into two main categories: voltage source-based and current source-based drives. Both drive types use a PMSM with either non-sinusoidal or sinusoidal backEMF waveforms.

III PID CONTROLLER

The PID controller is crucial in feedback control systems across various industries for regulating processes and systems. It consists of three components:

Proportional: Reacts to the current error, which is the difference between the desired set point and the actual value, generating a control signal proportional to this error. Larger errors result in stronger corrective actions.

Integral: Considers cumulative past errors to generate a control signal aimed at eliminating any residual error, addressing steady-state errors that persist despite proportional action. Derivative: Anticipates future error trends by assessing the rate of change, predicting and counteracting potential future errors to reduce oscillations and improve response time.

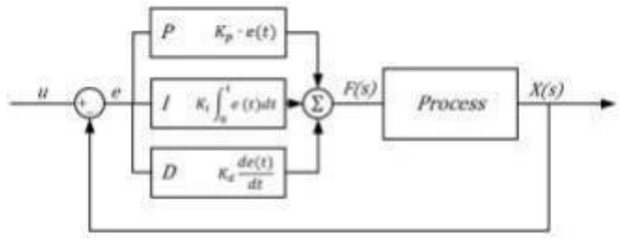

Fig. 2.2 Block Diagram of PID Controller

The above Fig. 2.3.1 shows the block diagram of the PID controller summing of the three blocks of controller given to process and feedback is taken from output.

The PID controller continuously computes an output by integrating these components, adjusting the system's input to maintain the desired set point with minimal deviation. Known for its simplicity, effectiveness, and versatility, the PID controller is widely used in applications ranging from industrial temperature control to robotics.

This chapter covered the fundamental principles and operational mechanisms of BLDC motors, and the methodology of speed regulation through a closed-loop system, illustrated with a block diagram. Additionally, we examined the PID controller and its block diagram. This foundation sets the stage for exploring advanced control methodologies and simulations in the next chapter. Mathematical Modelling of BLDC Motor and Controller. The integration of BLDC (Brushless DC) motors and PID (Proportional-Integral-Derivative) controllers represents a significant advancement in modern control systems, enhancing precision and efficiency across various applications. Mathematical modelling of BLDC motors involves understanding their electromagnetic principles, governing equations, and dynamic behaviour. Similarly, modelling the PID controller requires a comprehensive grasp of its algorithmic framework to regulate and optimize motor performance.

To model a three-phase BLDC motor, we need to establish the phase voltage equations based on several key assumptions:

1. The three-phase stator windings have equal resistances (R) and inductances (L).
2. Air gap between the stator and rotor is uniform.
3. Losses in the motor are negligible.
4. Balanced voltage is applied.
5. Motor operates at its rated current.
6. The windings have constant self-inductances and mutual inductances.
7. Ideal MOSFET switches are used.

4. CALCULATION

The work detailed in this report encompasses the development of a BLDC motor PID controller, beginning with simulation and progressing to hardware implementation. The initial simulation phase provided valuable insights into system behavior and helped fine-tune the PID parameters for optimal performance. Following the successful simulation, the hardware implementation phase involved careful construction, integration, and testing of components to ensure reliability and functionality. The PID controller, executed on a microcontroller such as Arduino, enabled realtime feedback and adjustments, allowing the BLDC motor to operate with precision and efficiency. The successful outcomes of both the simulation and hardware phases highlight the effectiveness of the PID control strategy in regulating the BLDC motor's speed and position. Utilizing components like MOSFETs for power switching and SMPS for a stable power supply, the system achieved smooth operation and precise motor control. With positive results from both phases, the BLDC motor PID controller is well-positioned to meet the demands of its intended applications, offering consistent and reliable performance. Ongoing refinement and optimization could further enhance the controller's capabilities, ensuring its suitability for a wide range of industrial and automation scenarios.

5. FUTURE SCOPE

The project can be extended in several directions, including:

1. Implementing machine learning algorithms to create self-tuning PID controllers that can automatically learn and optimize control parameters based on real-time performance data.

2. Designing the BLDC motor in passive mode using a transfer function.

3. Applying the controller in electric vehicles to improve control, efficiency, and reliability.

4. Utilizing the controller in applications requiring precise speed control, such as medical equipment and industrial systems

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