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**Project Report: Speed Control of BLDC Motor Using PID Controller in Simulink**

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**1. Aim and Objective**

The aim of this project is to **design and simulate a speed control system for a Brushless DC (BLDC) motor** using a **PID controller** in MATLAB/Simulink.
The objectives are:

- To control motor speed accurately using feedback and tuning.
- To implement electronic commutation using logic gates and Hall-effect sensors.
- To understand gate pulse generation and inverter switching for BLDC motor operation.

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**2. Introduction to BLDC Motor**

A **Brushless DC (BLDC) motor** is a type of synchronous motor that operates using **DC power through an electronic inverter**. The rotor has **permanent magnets**, and the stator has **electromagnet coils**.

Unlike traditional brushed motors, a BLDC motor:

- Has **no brushes**, reducing wear and increasing lifespan.
- Requires **electronic commutation** using position feedback.
- Offers **high efficiency, fast dynamic response**, and **low maintenance**.

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**3. Working Principle of a BLDC Motor**

- When DC power is supplied to the stator windings through an inverter, a **rotating magnetic field** is produced.
- The **permanent magnet rotor** follows this rotating field, causing motion.
- **Hall-effect sensors** detect the rotor's position and send signals to commutation logic circuits.
- This logic controls the **MOSFET switches** in the inverter to energize the correct windings at the right time.
- The process continues in a loop, producing continuous rotation.

### 4. Description of the Simulink Model

The Simulink model consists of the following major blocks:

➤ **PMSM Block (BLDC Motor Equivalent)**

Used to simulate the actual BLDC motor. This block includes rotor dynamics and electromagnetic torque behavior.

➤ **PID Controller**

Compares actual rotor speed with reference speed and adjusts the output to reduce the error. It controls the DC voltage input to the inverter.

➤ **Hall-effect Sensors**

Generate 3-bit binary output indicating rotor position. This feedback is essential for determining commutation sequences.

➤ **Commutation Logic**

Implements **AND gates**, **MUX**, and **DEMUX** to generate switching signals based on Hall sensor inputs.

➤ **Gate Pulse Generator**

Generates control pulses for 6 MOSFETs of a 3-phase inverter. These pulses determine when and how long a MOSFET conducts.

➤ **3-Phase Inverter**

A set of 6 MOSFET switches that convert DC to 3-phase AC to drive the motor.

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### 5. Control Strategy

- A **PID controller** is used for speed control. It minimizes error by adjusting the control input to the inverter.
- **Hall-effect sensors** detect rotor position and send feedback.
- Commutation logic decodes Hall signals and generates **gate pulses**.
- The **inverter switches** respond to these gate pulses and drive the motor windings.

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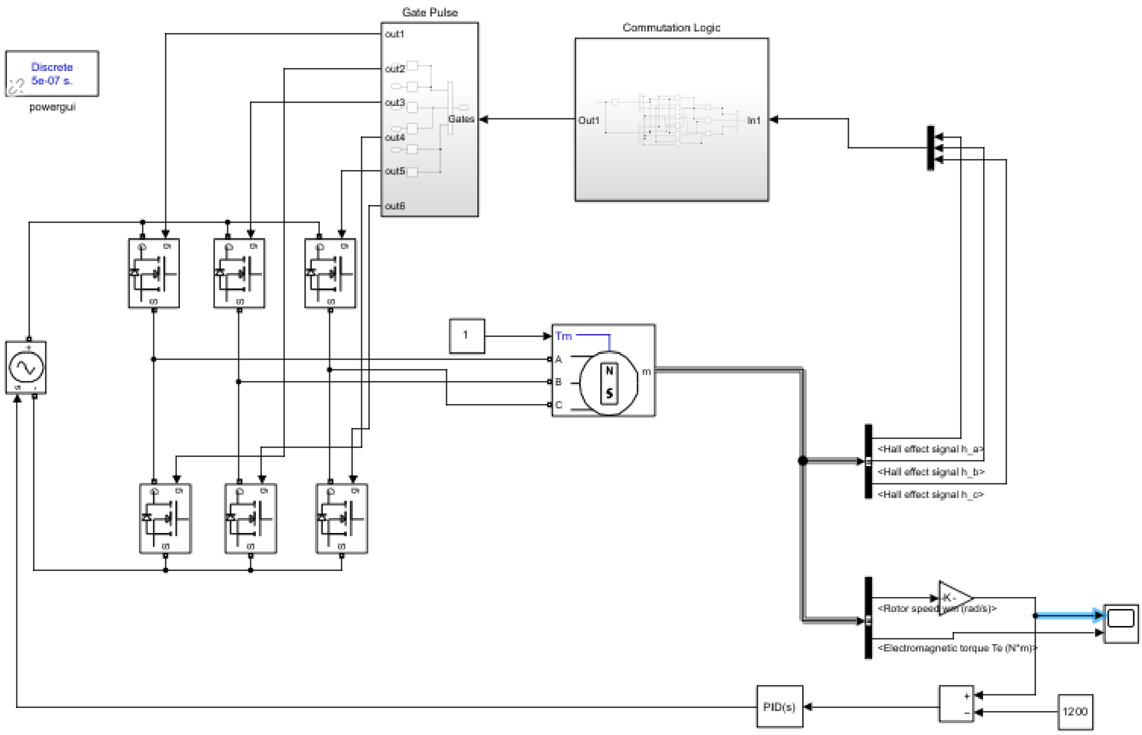
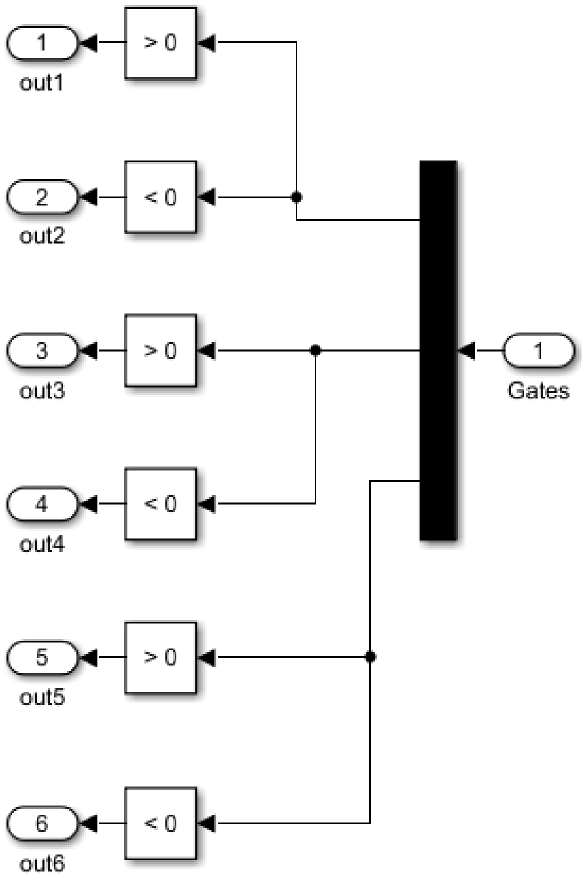
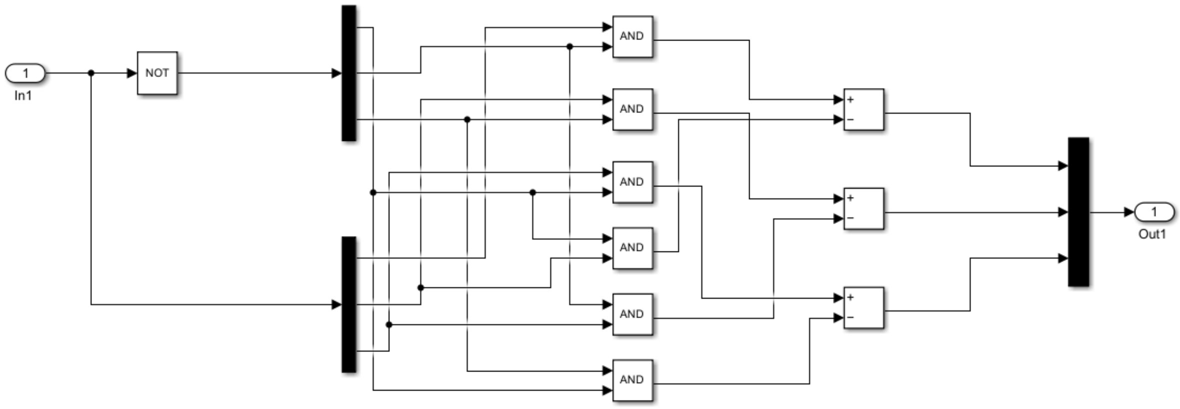
## 6. Circuit Diagram:




## Gate pulse block:



**Commutation Block:**

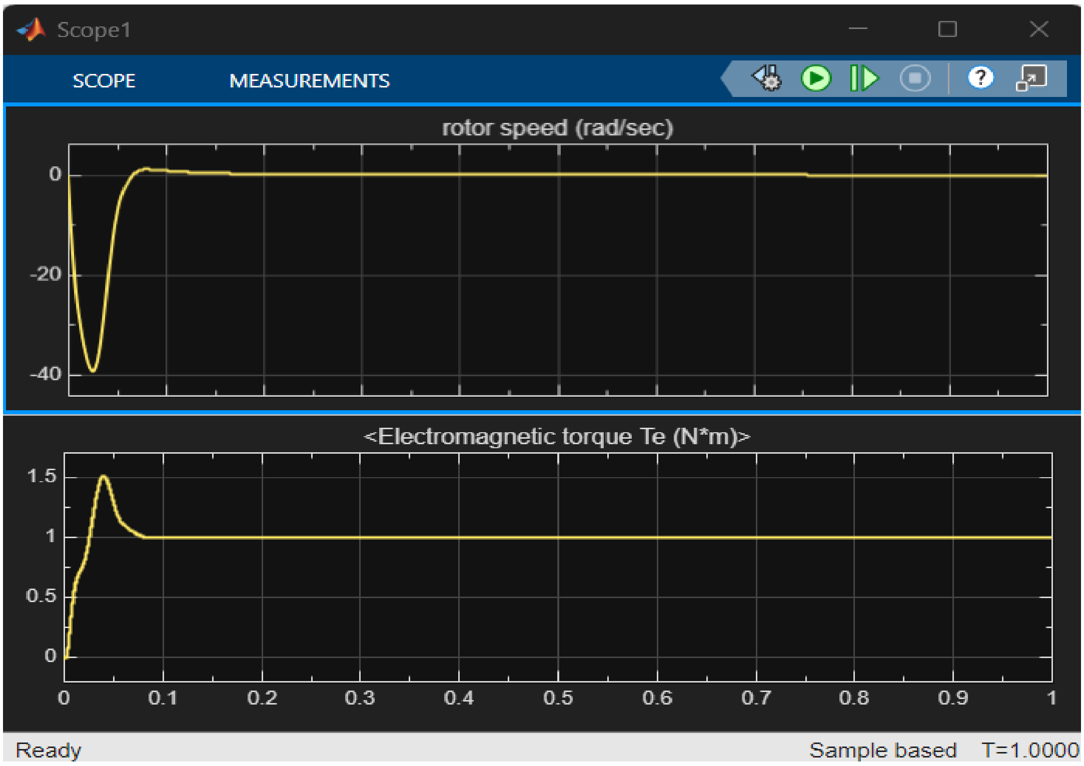



**7. Simulation and Results**

The Simulink simulation produces:

- **Rotor Speed (rad/s)** – Plotted against time to see how quickly and accurately the motor reaches the desired speed.
- **Electromagnetic Torque** – Shows the torque generated by the motor in real time.
- **Gate Pulses** – Logical waveforms showing switching patterns for MOSFETs.
- **Hall-effect Signals** – Position feedback signals to verify commutation sequence.

**7. Output Waveform:**



**8. Advantages of This Approach**

- Simple and effective control using **PID**.
- Smooth and reliable **electronic commutation**.
- Easy to simulate and modify in MATLAB.
- Close to real-time behavior with realistic component modeling.
- Scalable to actual embedded system implementation.

**9. Alternatives and Enhancements**

| **Component** | **Alternatives** |
|---|---|
| PID Controller | Fuzzy Logic, Sliding Mode, Adaptive Control |
| Hall Sensors | Optical Encoder, Resolver |
| MOSFET Inverter | IGBT, SiC Switches |
| Simulink PMSM Block | Custom motor model using Simscape blocks |
| Gate Pulse Logic | SVPWM or Sinusoidal PWM techniques |

**10. Conclusion**

This project successfully demonstrates **speed control of a BLDC motor using PID** in Simulink.
It highlights key aspects like:

- **Electronic commutation logic** using logical blocks.
- Use of **gate pulse generation** for MOSFET control.
- Integration of **PID control and sensor feedback**.

The system achieved accurate speed regulation, smooth motor operation, and practical modeling of a BLDC drive system, making it suitable for real-world embedded applications.