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DESIGN OF BLDC MOTOR BASED POSITION CONTROL DRIVE

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ABSTRACT:

The objective of this work is to analyse an accurate position control of the BLDC motor using Field Oriented Control (FOC) algorithm. The BLDC motor, owing to its operational principle, boasts faster responses and higher torque, along with reduced noise, fewer spark-related issues, and lower maintenance requirements than classical DC motors. Field-Oriented Control (FOC) is an advanced control algorithm initially developed and utilized for induction and synchronous motor drives. By implementing a suitable coordinate system transformation, it becomes feasible to autonomously regulate the machine's flux and torque, akin to controlling a DC motor. To control its position accurately, you need to manipulate the stator currents and voltages. The FOC, also known as vector control, is a sophisticated control algorithm used to control BLDC motors. Field-Oriented Control (FOC) allows for the individualistic control of torque and flux. It offers a rapid dynamic response, exceeding the demands of applications such as washing machines. FOC eliminates torque ripple and enables precise motor control, delivering smooth and accurate performance across a wide range of speeds. In this project we use the FOC algorithm to identify the position control of BLDC motor. FOC delivers superior dynamic response in contrast to traditional control techniques. After performing the circuit in MATLAB and stimulating the circuit Analyze a waveform/ output. Before implementing the control system in a real BLDC motor, it is essential to simulate and test it thoroughly. Tools like MATLAB/Simulink are often used for simulation.

KEYWORDS: BLDC; FOC; Hall effect sensor; Motor; Position

I INTRODUCTION:

The operational principle of BLDC motors closely resembles that of DC motors. BLDC motors use electronic commutation, employing using a three-phase inverter as the power source, it modulates voltages or currents according to the rotor's position. In industrial applications, the demand often revolves around compact, high-power actuators while considering cost-effective solutions. As a result, the induction motor has been widely adopted in the industry primarily because of its cost-effectiveness. However, when examining BLDC motors, their similarity to permanent magnet synchronous motors (PMSMs) becomes evident. PMSMs exhibit superior efficiency compared to induction motors, possess lower inertia, and offer higher power density. While BLDC motors can be directly controlled similarly to DC motors, implementing FOC yields several advantages. Various control methods are available, including:

Trapezoidal Control: Trapezoidal Control, often referred to as the 6-step control, represents the most straightforward algorithm. In this method, a current pathway is established between a pair of windings during each of the 6 commutation steps, with the third winding remaining disconnected. Nevertheless, this approach results in notable torque fluctuations, which can lead to vibrations, noise, and performance that falls short of the standards set by alternative algorithms.

Sinusoidal Control: Sinusoidal Control, also known as voltage-over-frequency commutation, offers a solution to various challenges associated with trapezoidal control. It achieves this by providing a continuous, smoothly varying (sinusoidal) current to the three windings, effectively reducing torque fluctuations and ensuring a seamless rotation. However, it's important to note that these time-varying currents are managed using basic proportional-integral (PI) regulators, which can lead to reduced performance at higher speeds.

Field Oriented Control (FOC): It is also known as vector control, FOC provides better efficiency at excessive speed than sinusoidal control. Field-Oriented Control (FOC) guarantees peak efficiency, even under transient conditions, through precise control of both stator and rotor fluxes. FOC surpasses other control techniques in providing superior performance when dealing with dynamic load changes. Within variable frequency drives or variable speed drives, Field-Oriented Control stands as a method employed to govern the torque, and consequently, the speed of three-phase AC electric motors, accomplished through precise current control.

II BLDC MOTOR POSITION CONTROL DRIVE USING FOC:

A BLDC motor involve of a rotor with permanent magnets and a stator with winding. It operates based on the interplay between the magnetic fields generated by the stator and rotor. The benefits of FOC for position is high precision that FOC allows for accurate and dynamic position control with reduced position error, Reduced torque ripple that FOC minimizes torque ripple, resulting in smoother motor operation, Energy efficiency that Precise control reduces energy consumption and enhances efficiency, Fast response that is FOC enables rapid changes in position commands, making it suitable for dynamic motion control. FOC based position control of BLDC motors finds applications in various industries, including Robotics and automation for precise motion control, CNC machining for accurate tool positioning, Electric vehicles for stable and efficient wheel positioning. Aerospace systems for antenna and control surface positioning etc., The Position Control Algorithm is to achieve position control, you will need a position control algorithm. This algorithm calculates the desired Id and Iq values based on the desired position or trajectory. FOC delivers superior dynamic response in contrast to traditional control techniques. After performing the circuit in MATLAB and stimulating the circuit Analyze a waveform/ output. Before implementing the control system in a real BLDC motor, it is essential to simulate and test it thoroughly. Tools like MATLAB/Simulink are often used for simulation.

SENSORED FOC:

Sensor-ed Field-Oriented Control (FOC) is a motor control technique used with Brush less DC (BLDC) motors that incorporates position feedback from sensors to achieve precise and efficient control. FOC sensors, including Hall-effect sensors, encoders, and resolvers, are integrated to offer real-time data on the rotor's position and speed. The application of FOC extends to the control of AC synchronous and induction motors. Originally developed for demanding motor applications, FOC was designed to ensure seamless operation across the entire speed spectrum, provide full torque even at zero speed, and deliver exceptional dynamic performance, including rapid acceleration and deceleration. It provides precise and accurate position and speed control due to real-time feedback from sensors (such as Hall-effect sensors, encoders, or resolver). This accuracy is crucial in applications where precise motion control is required, such as robotics and CNC machining. These Field-Oriented Control offers high-precision, stable, and efficient motor control, making it appropriate for a wide range of applications across various industries. Its ability to provide accurate position and speed feedback, along with its stability and reliability, makes it a preferred choice for demanding applications where performance and control accuracy are paramount.

SENSORLESS FOC:

Sensorless Field-Oriented Control (Sensor less FOC) is a motor control technique used with Brushless DC (BLDC) motors that eliminates the need for position sensors like encoders, Hall-effect sensors, or resolvers. Instead, it relies on the motor’s back-electromotive force (EMF) and other inherent characteristics to appraise the rotor position and achieve precise motor control. In sensor less FOC the Limited Low-Speed Performance of Sensor less FOC can struggle to accurately appraise rotor position and control the motor at exceptionally low speeds or when the motor is at a standstill. This limitation can result in reduced control precision and efficiency at low speeds. It often requires an initialization process to determine the initial rotor position. This can be complex and time-consuming, especially in applications where the motor may start from arbitrary positions.

SENSORED FOC ADVANTAGES:

Sensored Field-Oriented Control (FOC) in Brushless DC (BLDC) motors offers several advantages that make it a preferred choice for applications demanding high-precision and reliable motor control. Its advantages are High Position and Speed Accuracy, Stability and Reliability, Precise Torque Control, Flexibility and Customization, etc., BLDC motors provide accurate and precise control over position, speed and torque. Sensored FOC is convenient for high-performance applications that demand precise control, high efficiency, and reliability, such as electric propulsion in drones, electric bicycles and electric Vehicles.

III BLOCKDIAGRAM:

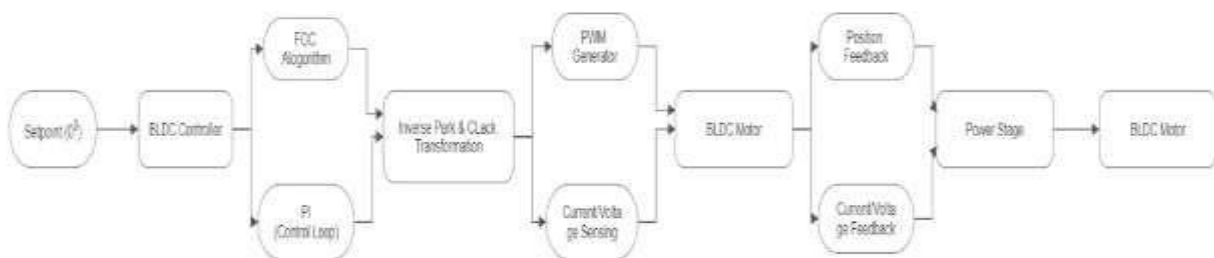

Fig 1. OVERVIEW OF MATLAB BLOCK

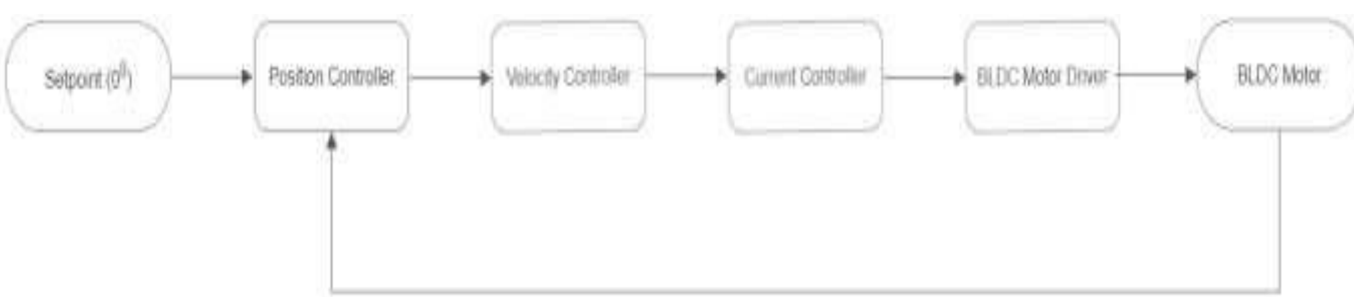

Fig 2. POSITION ACCURACY BLOCK DIAGRAM

Response Time: Minimize the response time of the motor to changes in the desired position. A faster response time ensures that the system can react quickly to external disturbances or changes in the desired trajectory.

Efficiency: Optimize the motor's energy efficiency by using FOC, which adjusts the voltage and current to minimize losses and heat generation in the motor. This is essential for applications where energy efficiency is critical.

Stability and Robustness: Ensure the control system is stable under various operating conditions and robust against external disturbances. It should be able to handle variations in load and environmental factors without compromising performance.

Sensor Feedback: Hall effect sensors are used to provide feedback about the rotor's position and speed. This feedback is crucial for implementing FOC accurately, as it allows the control system to adjust the motor's phase currents in real-time to align with the rotor's position.

Safety: Implement safety features to prevent damage to the motor or equipment in case of faults or abnormal conditions. This may include overcurrent protection, over-temperature protection, and fault detection mechanisms.

User Interface: Provide a user-friendly interface for setting and monitoring the desired position and configuring control parameters. This allows operators or users to interact with the system effectively.

Integration: Ensure the control system can be easily integrated into the target application, including compatibility with communication protocols, such as CAN, Modbus, or Ethernet, for industrial automation and remote control.

Testing and Calibration: Develop procedures for testing and calibrating the control system to guarantee its accuracy and reliability over time.

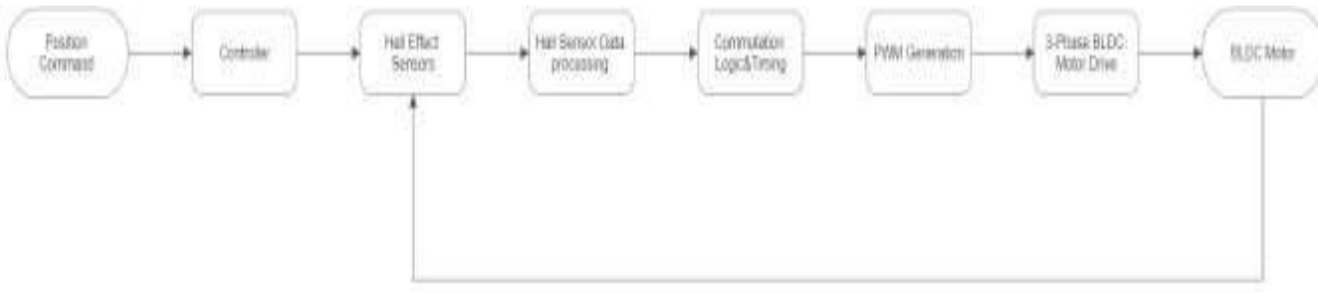

Fig 3. HALL SENSOR BLOCK DIAGRAM

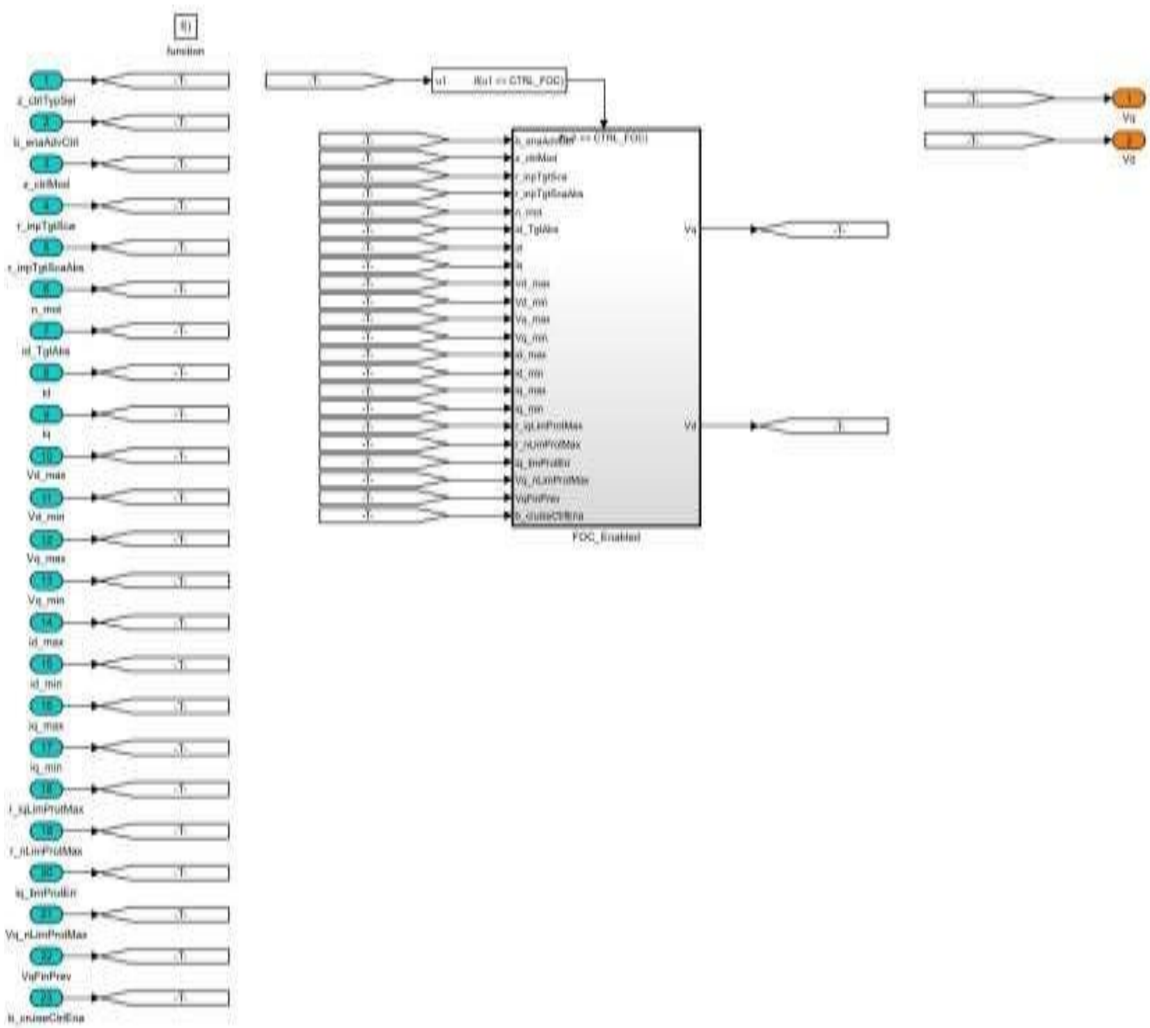

Fig .4 FIELD ORIENTED CONTROL BLOCK

- ✓ Interface the position sensors (Hall effect sensors or encoders) with the microcontroller or DSP to provide real-time feedback on the rotor's position.
- ✓ Implement current and voltage sensing for monitoring and control purposes. Current sensors help ensure safe operation and can be used for fault detection.
- ✓ Implement a closed-loop control system that uses feedback from the sensors to adjust the motor's control signals in real-time. This ensures that the motor maintains the desired position accurately.
- ✓ Conduct thorough testing and validation of the system to ensure it meets the specified requirements. This includes performance testing, reliability testing, and safety.

IV RESULTS:

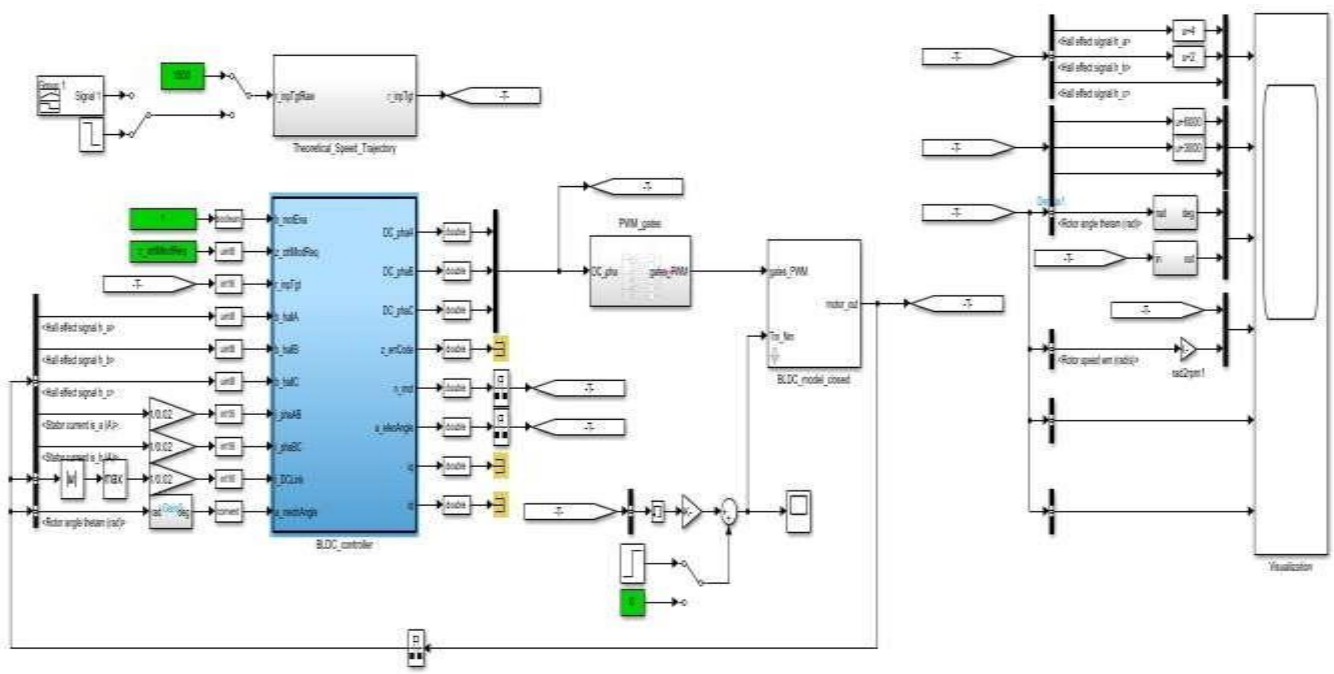

Fig 5, MATLAB MAIN CIRCUIT

Experimental Setup:

- ✓ Begin by briefly describing the experimental setup, including the hardware components used, such as the BLDC motor, sensors, microcontroller or DSP, motor driver, and control algorithm implementation.

Positioning Accuracy:

- ✓ Present data and analysis regarding the positioning accuracy achieved using the sensored FOC algorithm. This may include measurements of positioning error in degrees or radians compared to the desired positions.

Speed and Torque Control:

- ✓ Discuss the system's ability to control the motor's speed and torque accurately. Present data on speed and torque profiles and how well they match the desired values.

Steady-State Performance:

- ✓ Describe the steady-state performance of the system, including how quickly it reaches the desired position and how well it maintains it under varying loads.

Dynamic Response:

- ✓ Analyze the dynamic response of the system. This could involve examining the motor's ability to respond to sudden changes in position commands or external disturbances.

Torque Ripple:

- ✓ Discuss any torque ripple observed during operation and how well the FOC algorithm mitigates it.

Efficiency and Power Consumption:

- ✓ Present data on the system's efficiency and power consumption under different operating conditions. Discuss how well the FOC algorithm optimizes power usage.

Noise and Vibration:

- ✓ Evaluate the noise and vibration levels generated during motor operation. Discuss any measures taken to reduce noise and vibration and their effectiveness.

Safety and Fault Tolerance:

- ✓ Discuss the safety features implemented in the system, such as overcurrent protection and fault detection. Present any instances of fault detection and the system's response to them.

Controller Tuning:

- ✓ Describe the process of tuning the FOC controller, including the selection of PI controller gains or other control parameters. Discuss the impact of tuning on system performance.

Comparison to Specifications:

- ✓ Compare the results achieved to the initial specifications and requirements of the project. Highlight any areas where the system meets or exceeds expectations and areas that may require further improvement.

Discussion of Challenges:

- ✓ Discuss any challenges or limitations encountered during the project, such as sensor noise, hardware constraints, or computational limitations, and how they were addressed.

Future Improvements:

- ✓ Suggest potential areas for improvement or future work, such as optimization of control algorithms, sensor selection, or hardware enhancement.

V CONCLUSION:

The goal of this project was to design a BLDC motor-based position control drive. The result was successful, with the FOC control algorithm than the more traditional controller of trapezoidal commutation with a sine and random position setpoint. When using a step input, the results were comparable, though the FOC controller was noticeably less noisy, and is better at making small adjustments. The most difficult part of implementing the field-oriented control with the potentiometer is that the individual components could not be tested individually. The design of the trapezoidal controller was natural.

In conclusion, the implementation of Field-Oriented Control (FOC) in our BLDC motor-based position control drive project revealed both its advantages and challenges. FOC, being a complex control algorithm, demands careful attention to its various components. Space vector modulation, a crucial part of FOC, is intricate and not conducive to manual operation. Ensuring its correctness relies heavily on the accurate functioning of the current controller. Conversely, the current controller relies on precise rotor position information, which necessitates the use of a potentiometer attached to the motor. However, the potentiometer can limit the range of rotor positions, making it challenging to verify the current controller's performance independently. This interdependence among the system components complicates the debugging and tuning process.

SUGGESTION:

In summary, our experience with implementing sensored FOC in our BLDC motor-based position control drive underscores the intricate constructive collaboration required among its various elements. While challenging, achieving optimal performance requires a comprehensive approach that considers both the current and position controllers. This project has illuminated the importance of meticulous design, precise sensor feedback, and a comprehensive understanding of FOC to unlock the full potential of BLDC motor-based position control.

VI MATLAB SIMULATIONS:

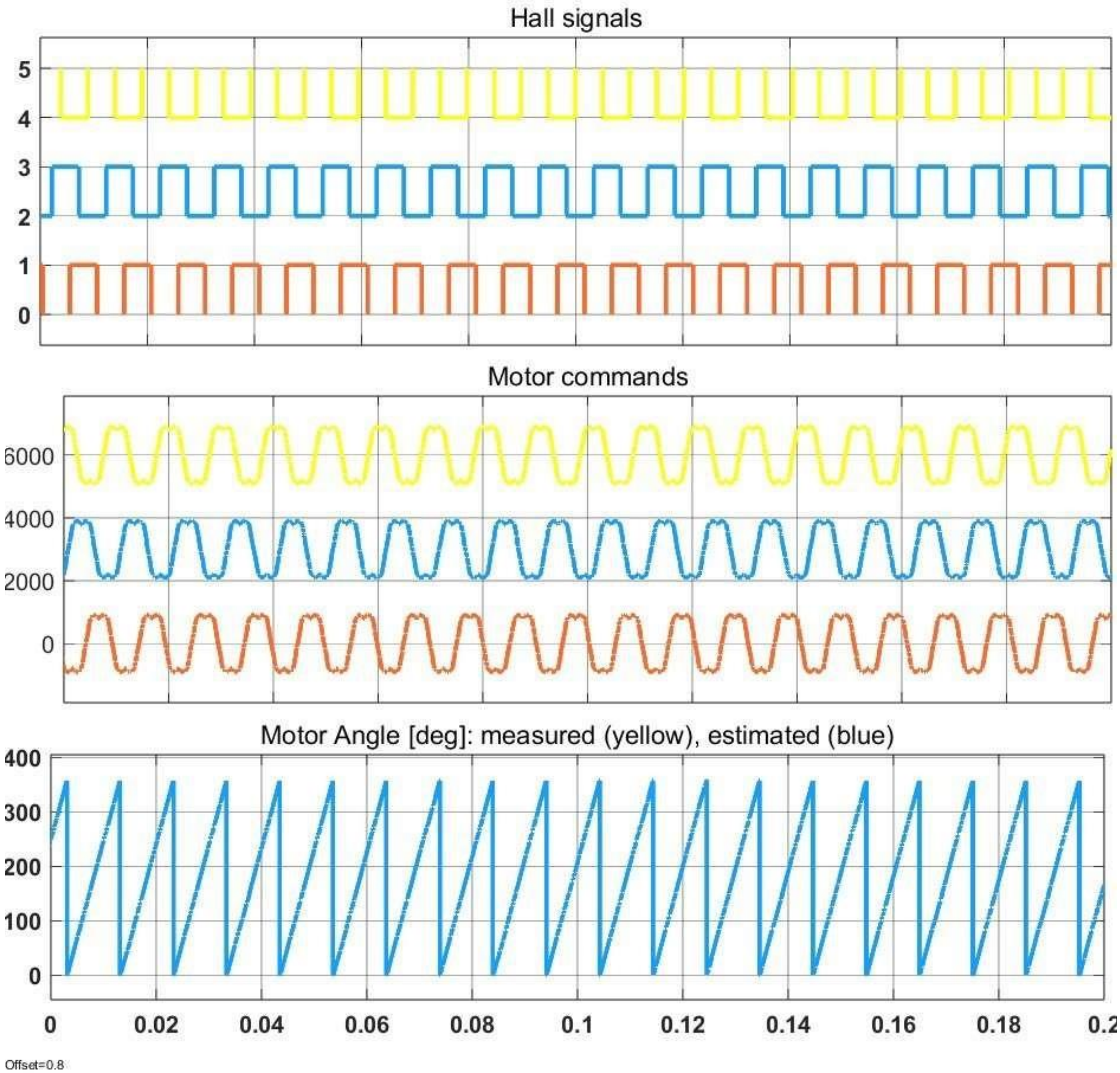

Fig 6. Output simulations

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