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Power Saving and Sensorless Vector Control Method in IPMSM Drive

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***Abstract:** An enhanced sensorless vector control method for an Interior Permanent Magnet Synchronous Motor (IPMSM) drive, with a primary focus on improving power efficiency, rotor position estimation without mechanical sensors, and ensuring operational robustness under voltage disturbances like sag and swell. The system employs Field Oriented Control (FOC) integrated with a closed-loop observer in MATLAB/Simulink to estimate the rotor speed and position using stator current and voltage feedback. This eliminates the need for traditional back-EMF-based estimation or mechanical sensors. A power-saving mechanism is introduced to reduce unnecessary energy consumption by dynamically adjusting inverter switching based on load demand. Furthermore, the system includes a voltage sag/swell detection strategy to maintain stable motor performance under grid disturbances. Simulation results demonstrate effective sensorless operation, efficient energy consumption, and robustness under dynamic load and input conditions.*

***Keywords:** IPMSM, Sensorless Control, Vector Control, Field Oriented Control (FOC), MATLAB/Simulink, Rotor Position Estimation, Power Saving, Voltage Sag and Swell.*

I. INTRODUCTION

Interior Permanent Magnet Synchronous Motors (IPMSMs) are widely used in electric drives due to their high power density, efficiency, and precise control capabilities. Traditional vector control techniques rely on mechanical sensors such as encoders or resolvers for rotor position and speed feedback. However, these sensors increase system cost, complexity, and reduce reliability in harsh environments.

To overcome these limitations, sensorless vector control techniques have gained prominence. This work presents a sensorless control strategy implemented in MATLAB/Simulink, focusing on power saving, eliminating mechanical sensors, and improving robustness during voltage sag and swell conditions.

II. SIMULATION MODULE

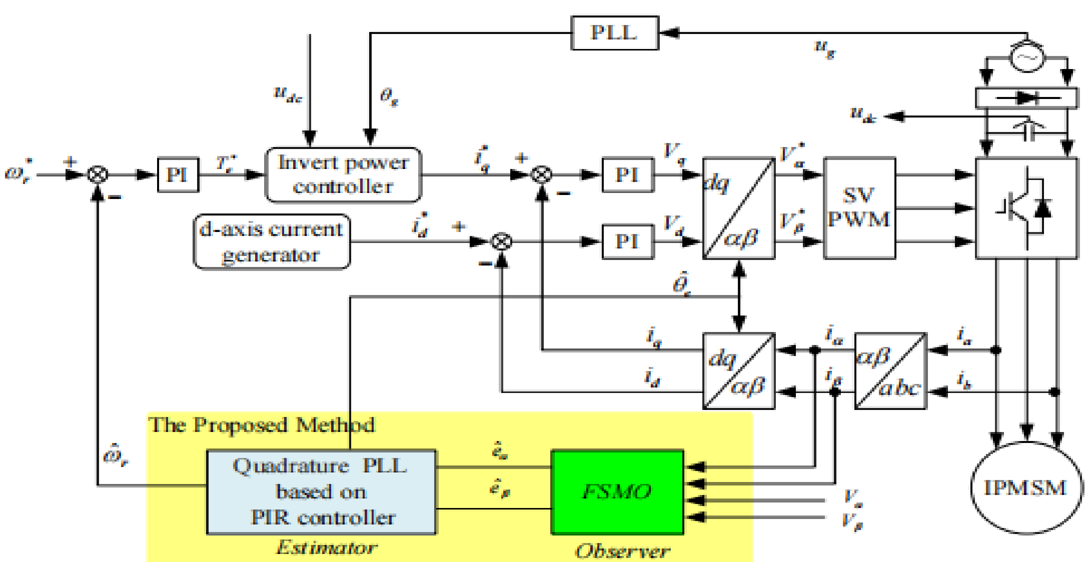

Fig. Block diagram of Power Saving and Vector Control Method in IPMSM Drive

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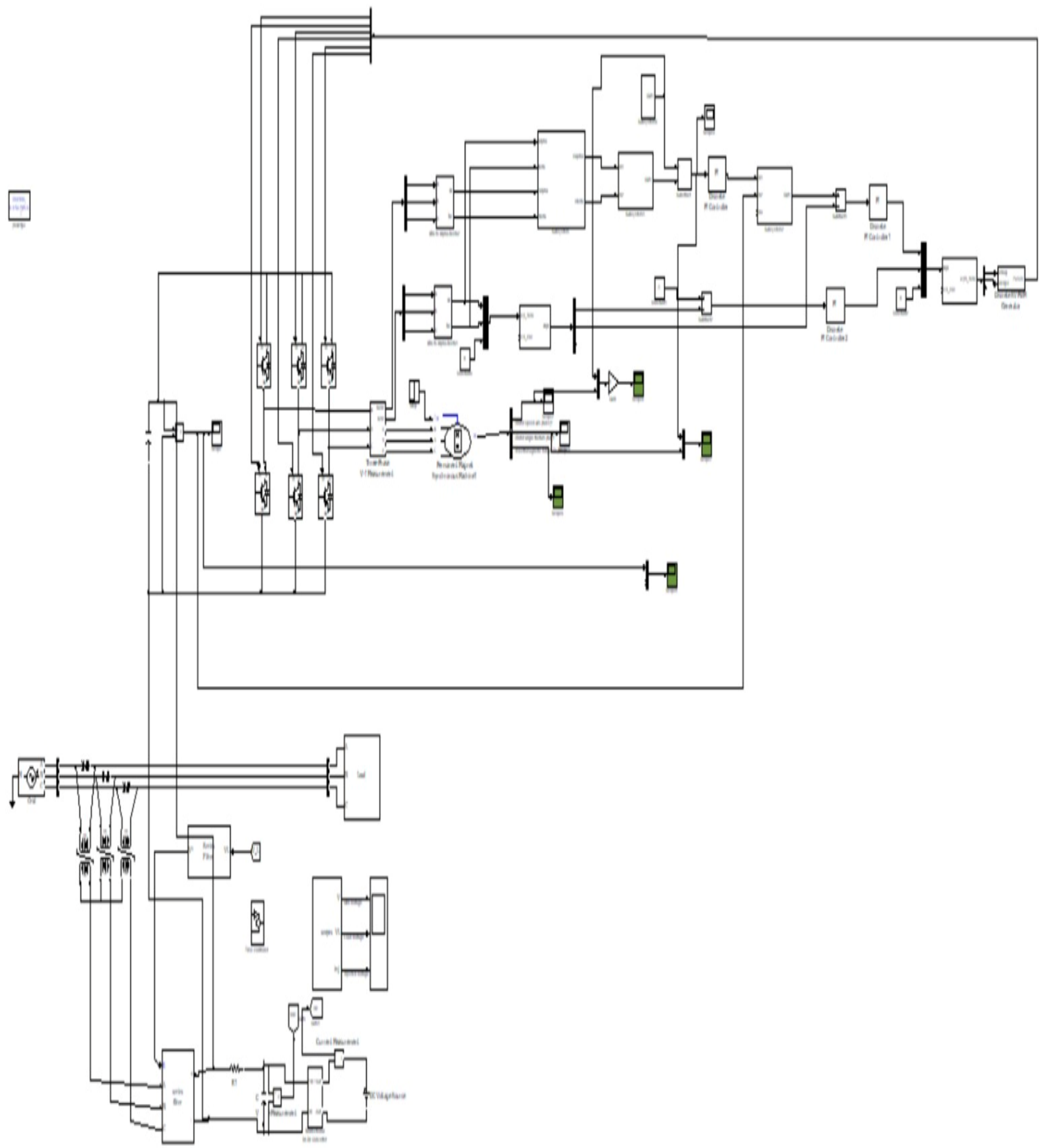
The proposed drive system consists of the following main components:
* Three-Phase AC Supply
* Diode Bridge Rectifier
* DC-Link with Film Capacitor
* Voltage Source Inverter (VSI)
* Interior Permanent Magnet Synchronous Motor (IPMSM)
* Closed-loop Sensorless Controller (MATLAB/Simulink)



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III. METHODOLOGY

This project involves the simulation of two integrated systems using MATLAB/Simulink: the vector control of an Interior Permanent Magnet Synchronous Machine (IPMSM) and the compensation of voltage sag and swell using a Dynamic Voltage Restorer (DVR). The IPMSM system is modeled to demonstrate precise speed and torque control through Field-Oriented Control (FOC). It begins with a three-phase voltage source supplying power to the IPMSM. The stator voltages and currents are measured and transformed from the three-phase ABC reference frame to the stationary αβ frame using Clarke transformation, and further into the rotating dq0 frame using rotor angle information generated from sine and cosine functions. These transformations enable independent control of torque and flux. Compared to surface-mounted PMSMs, IPMSMs have saliency (different d-axis and q-axis inductances), which allows for additional torque generation through reluctance torque, making vector control even more effective. The dq components of the current are regulated by Proportional-Integral (PI) controllers, which produce reference voltages. These are then converted back to the αβ frame and fed into a Discrete Space Vector PWM (SVPWM) generator. The SVPWM block outputs gate pulses to the inverter, which in turn drives the IPMSM with the desired AC voltage. The entire system is monitored using scopes that track rotor speed, torque, and other electrical parameters, while the simulation is managed through a discrete Powergui block with a 5e-5 second sampling time. Step inputs are used to test dynamic performance under varying load or speed conditions.In parallel, a DVR-based voltage compensation system is implemented to mitigate power quality issues such as voltage sag and swell, which commonly occur in power systems. The DVR is connected in series with the grid and load to inject a compensating voltage during disturbances.

IV. SIMULATION RESULTS

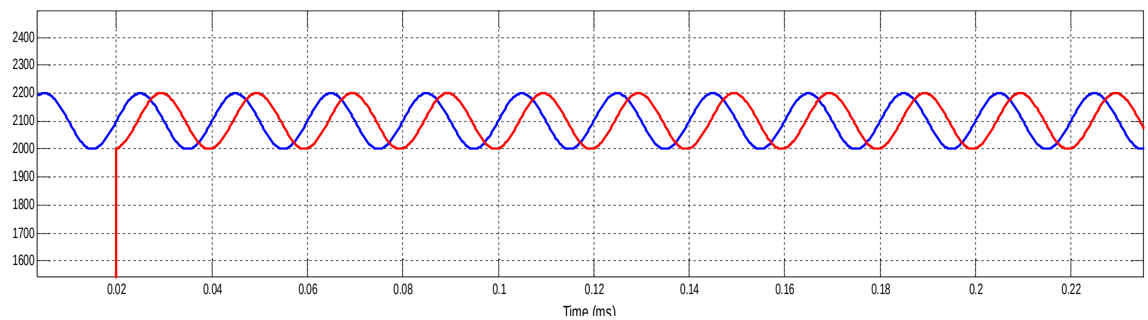

Fig:Speed Estimation in IPMSM

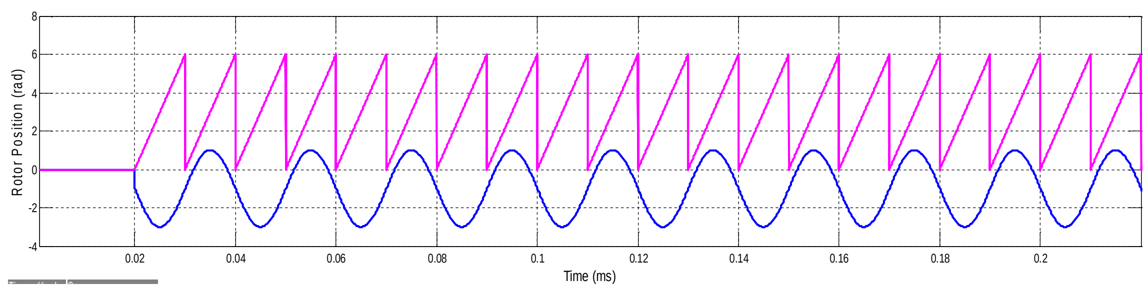

Fig: Rotor Position

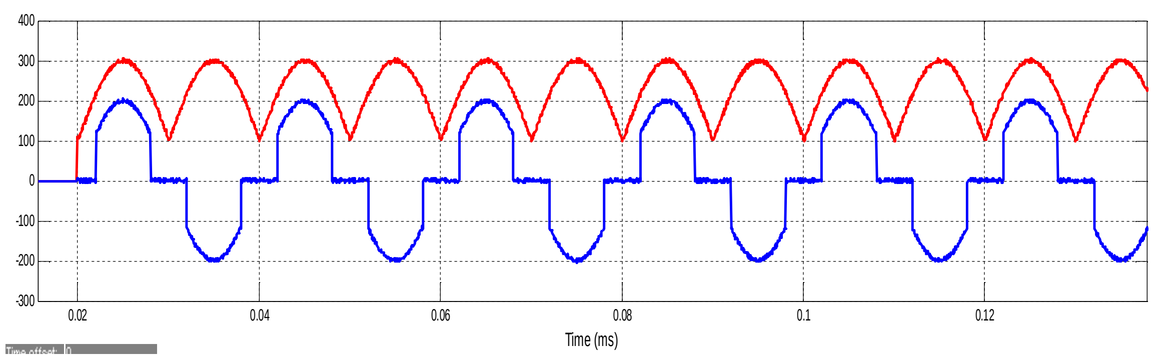

Fig:Voltage & Current Waveforms

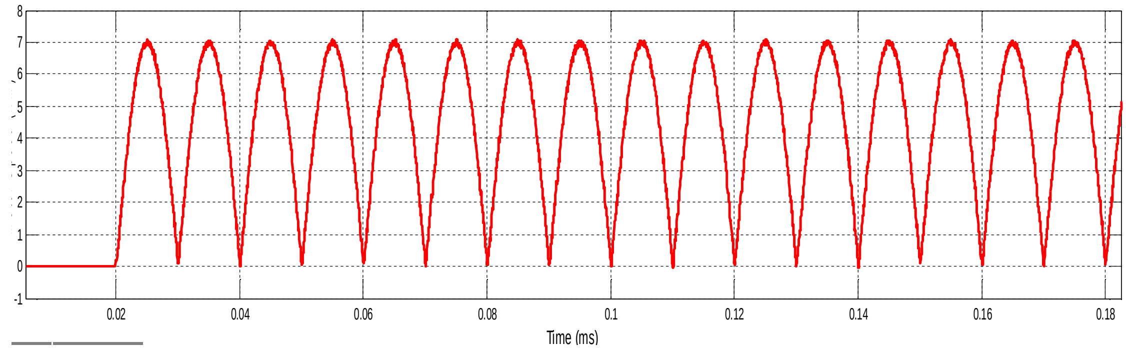

Fig:Motor Torque

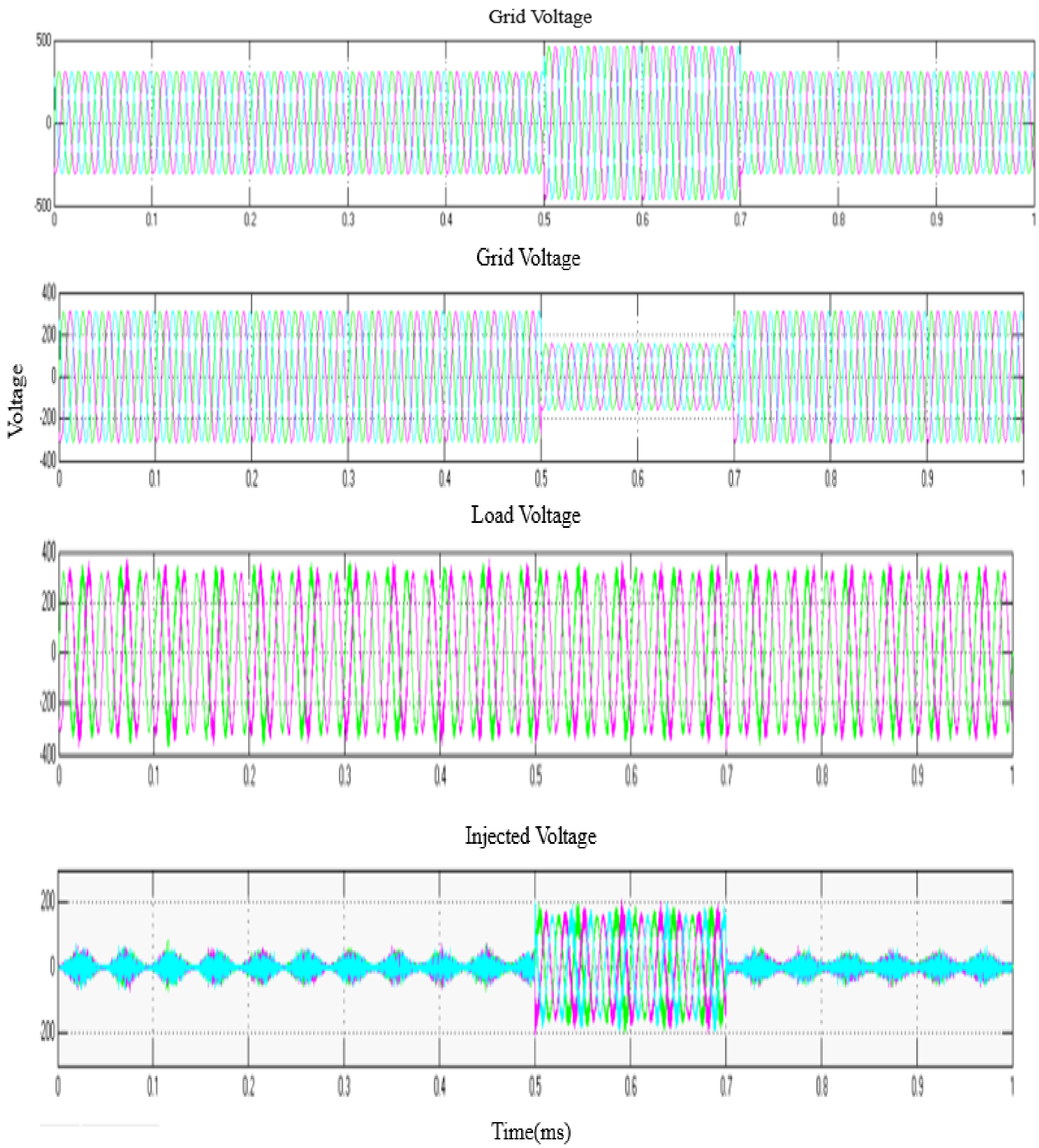

Fig:Voltage Swelland SagCondition

The above graphs illustrate the results obtained from simulating the system in MATLAB/Simulink. These results demonstrate several key performance aspects:.

1) Stable Speed and Torque Performance Under Varying Load Conditions:
The simulation results show that the system maintains a consistent and stable speed as well as torque output, even when the load on the motor changes. This indicates robust control capabilities and reliable performance in dynamic operating environments.

2) Accurate Rotor Position Tracking Using Sensor less Feedback:
The system effectively tracks the rotor position without relying on physical sensors. This sensor less feedback method ensures precise estimation of the rotor's angular position, which is crucial for the control and operation of the motor

3) Effective Compensation During Voltage Sags andSwells:
The system is able to detect and compensate for voltage fluctuations, such as sags (drops) and swells (increases), in the power supply. This compensation helps to sustain normal motor operation and protect it from potential damage caused by these disturbances.

V. CONCLUSION

This paper demonstrates a sensorless vector control system for IPMSM drives with power-saving features and voltage disturbance handling. The model-based estimator provides accurate rotor information without mechanical sensors. The power optimization strategy and sag/swell compensation increase system efficiency and robustness, making it suitable for industrial applications requiring high reliability and compact design.

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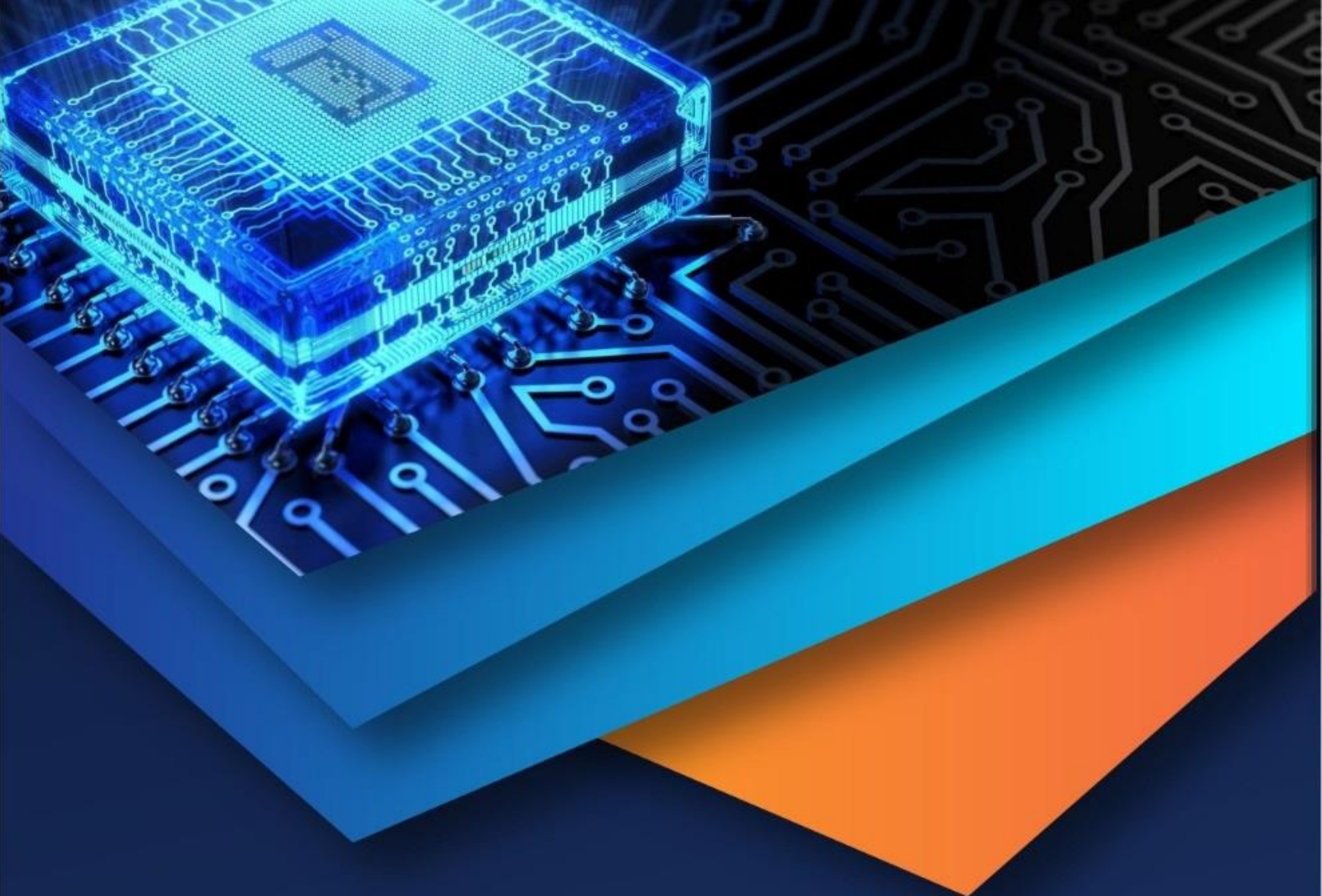

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