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Hybrid Powered IoT-Based BLDC Motor Monitoring System for Electric Vehicles

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***Abstract:** This paper proposes a hybrid powered internet of things (IoT) system for monitoring the condition of brushless DC Motors (BLDC) in electric vehicles (EVs). This IoT system has been designed and developed using a hybrid energy storage system that helps to enhance the life span of motor and battery. This system employs a range of sensors, including load, vibration, temperature, voltage and current sensors integrated with an Arduino UNO and ESP8266 microcontroller. These components gather real time data from motors side and transmitted to the cloud server. The IoT system ensures that the system is capable of capturing and reporting vital motor parameters to the cloud server and an automatic notification is sent to operators when Motors abnormality is detected. An effective BLDC motor monitoring system can be achieved by early monitoring with instant notification to operators. The main benefits are cost reduction of maintenance, increased reliability, optimised motor performances and improved overall efficiency of the system.*
***Keywords:** BLDC Motor, Internet of Things (IoT), Arduino UNO, ESP8266 Microcontroller, Electric Vehicles (EVs)*

I. INTRODUCTION

The BLDC motor drive system is a critical component of electric vehicles (EVs) because it is responsible for delivery of both speed and torque across a wide operating range, while maintaining precise and safe motor control [1]. Early detection of abnormalities with real time notification is crucial for enhancing the reliability and efficiency of BLDC motors. Motor parameters such as load, vibration, temperature, voltage and current are widely recognized for diagnosing electrical and mechanical failures, which are often caused by issues such as bearing and stator faults [2]. According to a survey by the Institution of Electrical and Electronics Engineering (IEEE), 44% of motor failures system from bearing issues, where 24% are related to the stator [3]. Majority of mechanical failures in motors are mechanical imbalance, rolling and bearings because a continuous stress on them can result in the major failures. A vibration sensor and current sensor are able to detect a motor's rough running of bearing increasing vibration and unbalance shaft current due to the flux disturbance caused by rotor eccentricities. Bearing failure also causes temperature rise to exceed Motor's predetermined low temperature [4]. An electric vehicle mainly comprises a battery management system. Here hybrid power is a concept of adapting the dual power source in an electric vehicle in combination with the battery and solar cell. In the current scenario, we are utilising Lithium-ion batteries as they are a much more effective and preferred type. Temperature affects this battery to a greater extent [5]. There is a parameter called state of charge (SOC) which demonstrates the remaining charge of the battery in EVs [6]. All the electric vehicles if not operated under SOC then they could be dangerous. During charging and discharging process parameters such as voltage, current, temperature should be monitored to operate the vehicle under SOC [7].

For enhanced the remote monitoring of Motor's parameter internet of things (IoT) is introduced. Our proposed wireless IoT-based sensor addresses these concerns by integrating these active sensors and transmitting data to the cloud in real time with minimal power required. Compared with traditional wired systems, IoT offers many advantages such as lower cost, simplicity of installation, automated data analysis and instant notifications. The main benefits are such as cost reduction of maintenance, increased reliability, optimized BLDC motor performance and improvement of accuracy in failure prediction [8].

II. LITERATURE REVIEW

1) It focuses on large scale Li-ion and battery management systems over Cloud Computing, which basically gives an overview about the cloud computing algorithm for Battery monitoring system of large Li-ion battery, cloud-based health monitoring is discussed [9].
2) This paper basically describes the monitoring of voltage current temperature via battery management system over cloud computing in real time monitoring. It also gives a hardware device overview. This provides an IoT base solution towards venting of Li-ion batteries due to overcharging [10].

3) It suggests the acquiring of Current-Input-device in the cell structure moreover it supports to behave Built-in positive temperature coefficient and uses NDIR sensors for detection of Co2 sensors [11].
4) It proposed information about the measurement of network impact from electric vehicles during fast and slow charging. The network impact provides information that there could be different impacts over first charging and slow charging due to weak or strong grids or different areas [12].
5) It describes all about battery management systems, it uses an IoT based approach using SOC estimation that suggests a system which installs. Here wireless battery management system and further concludes over middleware application server and packet core network by incorporating MQTT server [13].
6) This work on the problem of SOC estimation for judgement of battery management system, it proposes an adaptive method of SOC estimation which gives a hybrid model based on conventional coulomb computing and with EKF correction this provides quick and reliable error monitoring and control [14].
7) Here hybrid energy sources for electric vehicles optimize power distribution, enhancing BLDC motor performance through advanced converter designs and energy-efficient controllers, vital for sustainable EV technology [15].
8) In this paper hybrid-powered electric vehicle designs incorporating BLDC motors address power fluctuations by integrating auxiliary energy systems, enhancing reliability and extending battery life [16].
9) This paper describes BLDC motor monitoring enhances and remote-control using sensors for parameters like temperature and speed, offering real-time data through cloud platforms like Thing Speak, improving system reliability [17].
10) It describes hybrid energy sources, combining batteries and ultracapacitors, to improve BLDC motor performance by managing power demands dynamically, ensuring sustainability and consistent operation in electric vehicles [18].
11) It focuses on advanced controllers like fuzzy-PI hybrids that reduce torque ripples and noise in BLDC motors, offering smoother operation and increased efficiency, crucial for electric vehicle applications [19].
12) This work on the hybrid power systems incorporating intelligent converters optimize BLDC motor performance by balancing energy sources, extending operational life, and reducing environmental impact in electric vehicles [20].

III.PROPOSED FRAMEWORK

The proposed system comprises sensors for data acquisition purpose which collects the information and then it will proceed to the communication. The communication component stores the collected data in the IoT device, So that it can be sent to the cloud data storage with assured security in the cloud server via IoT getaway. The solar cell and Li-ion battery is used for storing DC charge as these types of batteries have higher energy density.

This overall system may help our motor monitoring system and also give better performance.

TABLE I. Comparism Table of Wireless System

Bluetooth Based Wireless System	Cloud Based Wireless System	IoT Based Wireless System
All the data collected through the application of the motor will be display on personal computer (PC) with LABVIEW program and android smartphone. It will show real-time monitoring of voltage, current, temperature etc.	Platform is executed and validated through using the small-scale cloud-based simulator that use Google cloud and other IoT devices. This technique validates that resistances, SOCs and capacities of individual battery cells can be accurately estimated by the hyperthreading of condition monitoring.	The system used will show the current location, battery status, motor condition and time via internet by incorporating GPS system which will be display on application.

By choosing internet of things (IoT) in BLDC Motor monitoring system of electric vehicles and Anns the performances of EVs by contributing to improve reliability, safety and user satisfaction. It is best feed for the proposed system as it enables battery monitoring and allows for real time monitoring by equipping accurate information about basic parameters such as current and voltage of the battery.

TABLE II. Comparism of EVs Motor

Parameters	Brushless DC Motor	Switched Reluctance Motor	Induction Motor
Power(kW)	110	77	93
Maximum Speed	9000	12000	12000
Based Speed	4000	2000	3000
Efficiency	80-90%	Increases with speed	80-90%

BLDC Motor has remarkable high efficiency and a better dissolution of heat, generally BLDC Motors are used to work with lesser settling time and lesser overshoot time. This type of Motors may have lesser losses hence have a better efficiency. It is a cheap and efficient device. Thus, BLDC Motor will be better to work in electric vehicle devices. It has a better power of weight ration which provides better efficiency for vehicles. It is also beneficial for cloud integration where the data will be sent to the cloud for remote monitoring and it also provides an easy platform for vehicle owners to access all understandable information.

IV. PROPOSED METHODOLOGY

Our proposed methodology consists of an Arduino UNO and ESP8266 microcontroller, owing to its low cost, low power consumption, and satisfactory accuracy. The Load, vibration, voltage, current, and temperature were measured using appropriate sensors such as a REES52 load sensor, ADXL345 accelerometer, ACS712 current sensor, ZMPT101B voltage sensor, and DS18B20 temperature sensor. ESP8266 transmits sensor data to a cloud-based server via the Internet. When a motor fault or abnormal condition is detected, operators are automatically notified.

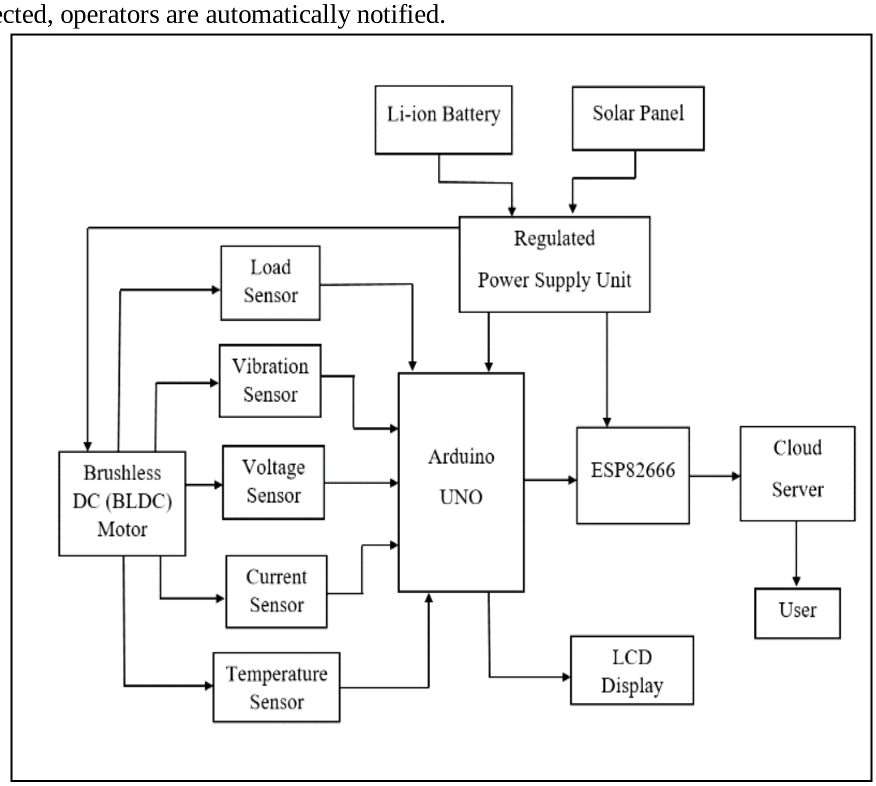

Fig. 1 Block Diagram of the proposed System

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V. MODELING AND ANALYSIS

A. Main Components used

The proposed system comprises of the following components with detailed discussions.

1) Li-ion Battery

In real-world projects, a large battery with the same characteristics is used in an electric car; however, a modest size of 12V/1.3A Li-ion battery is employed while creating the model. The Li-ion battery serves as the energy storage unit in the hybrid vehicle, providing power for the propulsion and auxiliary systems. It stores electrical energy in a chemical form, which is released during discharging to power the vehicle's electric motor. The voltage and current of the battery were monitored at regular intervals to ensure a safe and efficient operation.

2) Solar Panel

Solar panels convert solar energy into electrical energy by using photovoltaic cells. It supplements the vehicle's power supply by charging the battery during sunlight hours, thereby extending the range of the vehicle and reducing its reliance on external charging sources. The solar panel output was monitored to optimize the charging efficiency.

3) Supply Charging Indicator

The supply changing indicator constantly monitored the power input to the electrical system of the vehicle. It detects whether power is supplied from the battery or solar panel.

4) Dynamic Switching

Dynamic switching is facilitated between power sources based on the system requirements and availability. For example, during daylight hours or when the vehicle is parked in sunlight, the system may prioritize the solar power input to charge the battery. Conversely, when the solar energy is insufficient or unavailable, the system automatically switches to drawing power from the battery.

5) Arduino UNO

The microcontroller board can function as a continuous battery-powered power source. The Arduino UNO acts as the brain of the monitoring system and controls and coordinates the functions of the other components. It reads data from sensors, processes them using predefined algorithms, and provides commands for system operations. Arduino UNO may also manage communication with external devices and execute control logic to optimize battery usage.

6) LCD 20x4 Display

The LCD provides real-time feedback on the status and performance of hybrid vehicle battery systems. It presents information, such as the battery and solar supply, either on or off. The display enhances user awareness and allows for quick assessment of the motor temperature under operating conditions.

7) Brushless DC (BLDC) Motor

The Brushless DC (BLDC) motor is the primary propulsion source in hybrid vehicles and is driven by electrical power from the battery. It operates efficiently and quietly, providing torque and speed control for the vehicle acceleration and deceleration. BLDC motor performance is monitored to ensure optimal operation and detect anomalies that may indicate mechanical or electrical issues.

8) Voltage Sensor

The voltage sensor measured the electrical potential difference across the supply terminals. It provides accurate readings of the battery's voltage, enabling the monitoring system to assess the state of charge and detect abnormalities such as overvoltage or under voltage conditions.

9) Current Sensor

The current sensor measured the flow of electric current into and out of the battery. It monitors charging and discharging currents, helps to optimize energy management, and prevents overcurrent situations that could damage the battery or other components.

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10) Load Sensor

The load sensor measured the rotational speed of the shaft of the BLDC motor. It provides feedback for speed control and allows the monitoring system to adjust the motor performance according to driving conditions.

11) Motor Temperature Sensor

The motor temperature sensor monitored the temperature of the BLDC motor during operation. This helps prevent overheating, which can degrade the motor performance and reduce the lifespan. Temperature data are used to adjust the motor operation and activate cooling systems, if necessary, to maintain optimal performance and reliability.

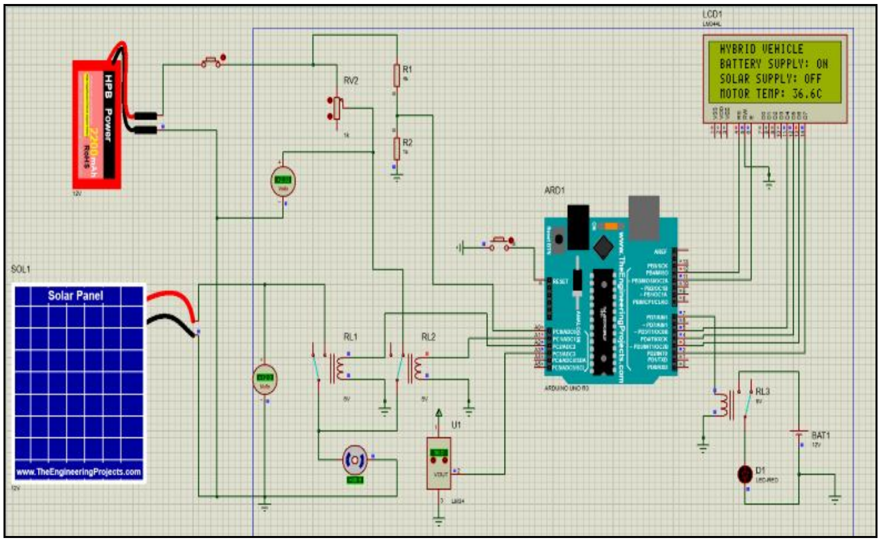

Fig. 2 Proposed system hardware simulation using Proteus software

VI. RESULT

The connected Internet of Things (IoT) based system with a cloud platform for monitoring the BLDC motor. The system was tested through simulation to check the measurement sensitivity, motor condition and reliability of the data communication between the sensor module and cloud server platform. The simulation also assessed how well the system manages, analyzed data and sends notification to the operators, showing that it can accurately track motor conditions and quickly alert operators if any issues are detected.

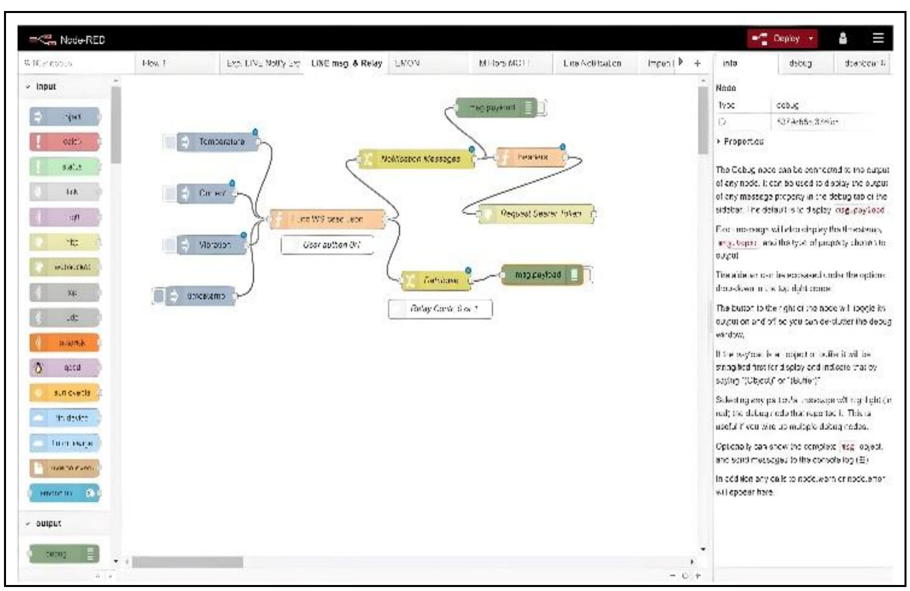

Fig. 3: Proposed system software simulation using Node-red cloud-based platform

A. Temperature Measurement

The temperature sensor is available to detect an abnormal increase in BLDC Motor's temperature and display the measured value in degree Celsius. As we have used DS18B20 temperature sensors on motor casing, the normal motor performed with load will see that the temperature rises slowly. When the same motor will run with loose bearing the temperature rises much faster, an abnormal notification is sent to the operator.

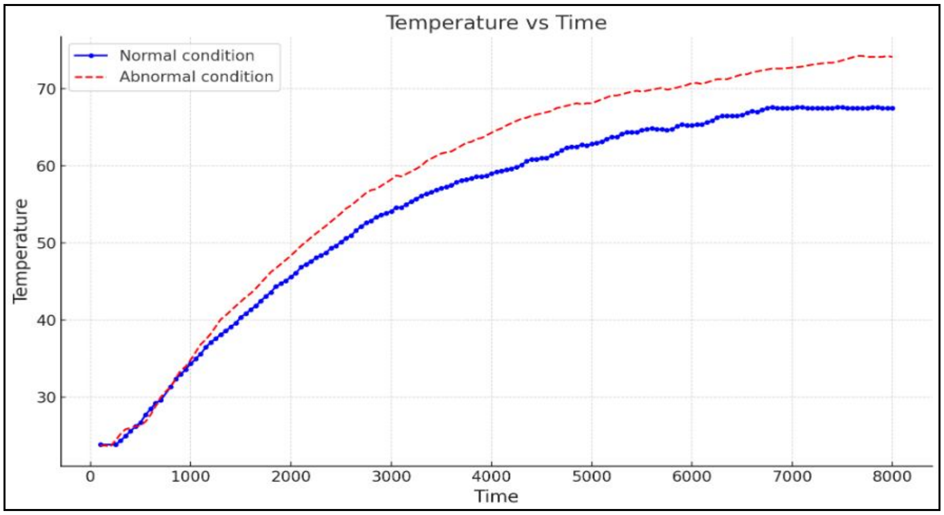

Fig. 4: BLDC Motor's temperature comparison between normal and abnormal condition

B. Vibration Measurement

The vibration sensor is sufficiently sensitive and the sensor nodes sampling rate is fast enough to detect frequencies that are potentially harmful to the motor's operation. The sampling rate used in measuring the motor's vibration is approximately 8 kHz. This is the maximum sampling frequency of the ADXL345 analogue to digital sampling frequency limit without any special technique. In faulty condition when motor vibration exists sampling frequency and then abnormality is detected, an alert notification will be sent.

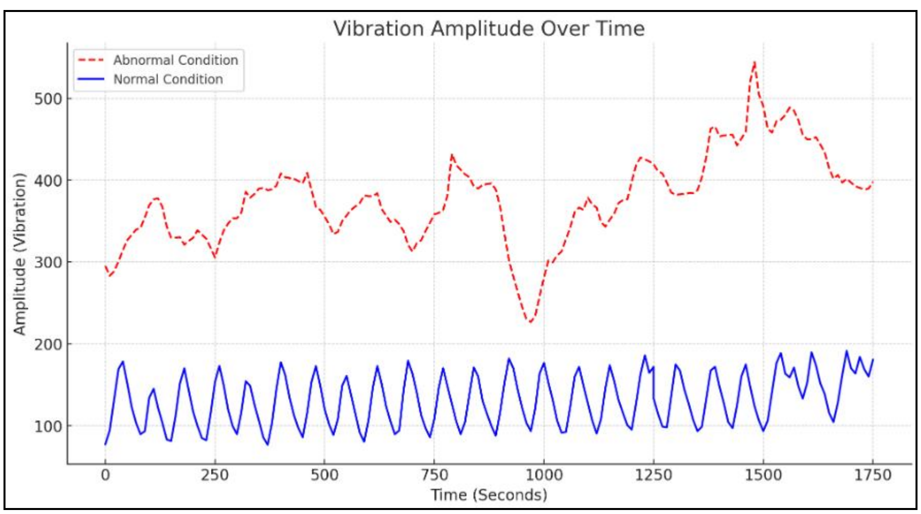

Fig. 5: BLDC Motor's vibration comparison between normal and abnormal condition

C. Voltage Measurement

The combination of solar cells with Li-ion batteries for better performances. When there is a sudden rise in acceleration, the peak power demand rises and hence battery life gets reduced and sudden peak in discharge. In that situation, when the system identifies excess power demand or crisis the supply unit switches between the battery supply and solar cells. Thus, an uninterrupted voltage limit is maintained.

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D. Current Measurement

Current variations are detected by the ACS712 current sensor. The sensor will also measure and gather data to the cloud server. Whenever, the motor faces any abnormalities such as stator fault or shorted phase windings then it consumes larger current as compared to normal working condition. In this situation the sensor records the deviation and sends an abnormal notification to the users.

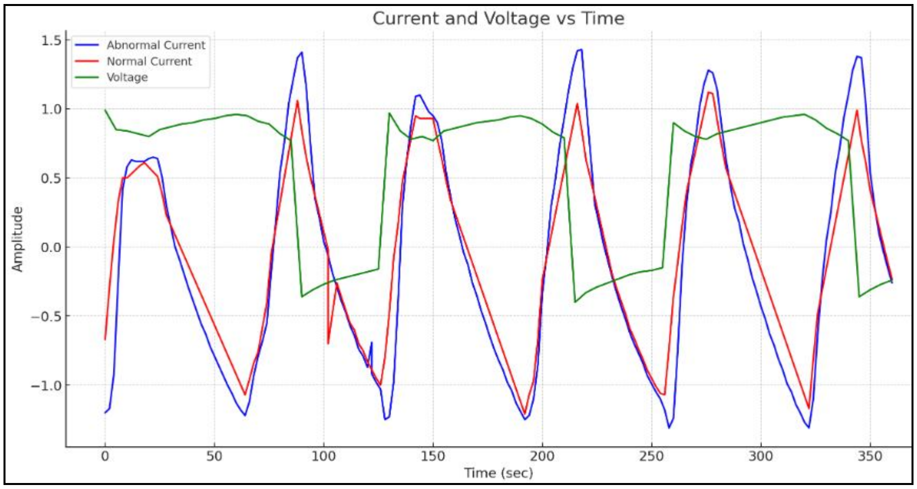

Fig. 6: BLDC Motor's voltage and current.

VII. CONCLUSIONS

This paper briefly explains the BLDC motor monitoring system of electric vehicles (EVs), by combination of solar cells with Li-ion battery supply. The hardware designs are done by considering several parameters which are important for BLDC motor drive condition monitoring in electric vehicles (EVs). Temperature, current, voltage and vibration signal have been analyzed to predict any mechanical abnormality such as motor faulty ball bearing and roto imbalanced or cracked. Signals gathered by our IoT based sensors were fed into the cloud-base server for analysis and to determine the motor's health conditions. Moreover, the mechanical abnormality of the rotor can be predicted at the early stage. It also helps to increase the lifespan of the battery and make it reliable to use for electric vehicles (EVs). The proposed system is operated satisfactorily and possibly adopted in the future EVs due to its size, operational cost and flexibility of IoT based smart features.

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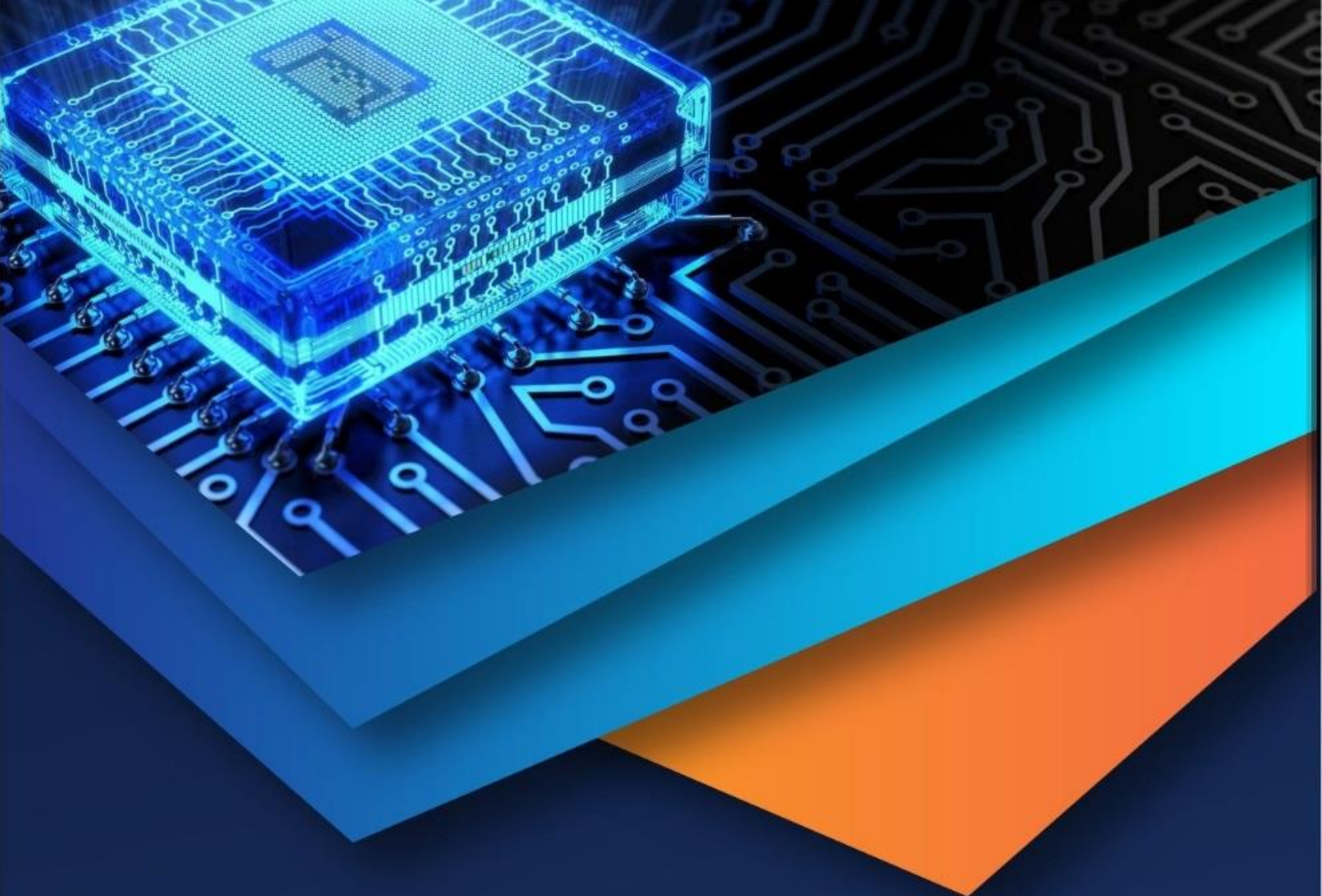

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