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Development and Implementation of Transformer Breather Health Monitoring System Using IoT

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Abstract: ***The reliable and efficient operation of power transformers is crucial for maintaining a stable electrical grid. One critical aspect of transformer maintenance is monitoring the health of the transformer breather, which plays a vital role in preventing the ingress of moisture and contaminants. This paper proposes an innovative approach for health monitoring of transformer breathers using the Internet of Things (IoT). By integrating IoT technologies with transformer breather systems, real-time monitoring and analysis of breather conditions can be achieved, enabling proactive maintenance and optimizing the lifespan of the transformer. The proposed IoT-based health monitoring system consists of interconnected breather units equipped with sensors to capture relevant data such as humidity levels, temperature, color of the silica gel, and gas concentrations. These sensors continuously gather data and transmit it to a central monitoring system via wireless communication protocols. The IoT-based health monitoring of transformer breathers offers several advantages over conventional methods. It enables continuous, real-time monitoring, eliminating the need for manual inspections and reducing the risk of unexpected failures.***

Keywords: Transformer, Breather, IoT, Humidity sensor, Temperature.

I. INTRODUCTION

Power transformers are essential components in electrical power systems, responsible for stepping up or stepping down voltages to facilitate efficient transmission and distribution of electricity. These transformers are subjected to various operational stresses, including temperature variations, electrical and mechanical stresses, and the presence of moisture. Moisture, in particular, can be detrimental to the performance and lifespan of transformers, as it accelerates the degradation of insulation materials and can lead to the formation of corrosive by products. To mitigate the harmful effects of moisture, transformer breathers are employed as an integral part of the transformer's monitoring and maintenance system. Transformer breathers are devices that control the moisture levels inside the transformer's active parts and prevent the entry of moist air into the transformer during the cooling process. They consistof a desiccant material that absorbs moisture from the incoming air and helps maintain the desired level of drynessinside the transformer. By monitoring the condition of the transformer breather using IoT, operators can gain valuable insights into the health of the transformer. Any abnormalities in the breather's performance, such as excessive moisture accumulation or failure of the desiccant material, can indicate potential issues with the transformer, including insulation degradation, oil contamination, or even internal faults. Early detection of these problems through breather monitoring allows for timely maintenance and repair, preventing costly equipment failures and unplanned outages. The absence or deterioration of a transformer breather can lead to moisture ingress, contaminant build-up, reduced cooling efficiency, insulation deterioration, and increased maintenance and repair costs. To ensure the optimal performance and longevity of transformers, it is crucial to have functional and well-maintained breathers that actively monitor and control the moisture levels within the transformer. Overall, transformer breathers play a vital role in ensuring the longevity and reliable operation of power transformers. By implementing effective health monitoring strategies for transformer breathers, power system operators can proactively identify and address potential issues, ultimately leading to enhanced system performance, minimized downtime, and improved overall grid reliability.

II. RELATED WORK IN LITERATURES

1) *"Condition Monitoring of Breather for Transformer Health Assessment" Makarand Sudhakar Ballal Senior Member, IEEE Department of Electrical Engineering Visvesvaraya National Institute of Technology, Nagpur. 978-1-5386-9316-2/18/$31.00 ©2018 IEEE*

A moisture sensor was designed to monitor the moisture levelsin the breather of a transformer. The sensor was created by electrochemically anodizing an aluminum sheet. It wasobserved that the sensor exhibited high sensitivity above 20% relative humidity (RH). Even though the capacitance change below 20% RH was small,3 it was still sufficient for measurement purposes.

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The phase detection electronics circuit was developed to interface with the moisture sensor. This circuit was connected to an Arduino microcontroller board to generate a moisture- dependent PWM (Pulse Width Modulation) wave. The PWM wave was then used to control the power across a heating load by applying it to the gate of a TRIAC.
Moisture inside the breather was regulated by achieving a pre- set value for dehumidification. The waveforms at different operating points of the electronics circuit were recorded, and mathematical equations were derived for these operating points.
To test the drying efficiency of the breather, an experimental setup was created in the laboratory. However, over time, it was observed that the drying efficiency deteriorated. Byimplementing the proposed method of moisture control using aheater and moisture sensor in the breather, the need for visualinspections of the moisture level in the drying agent (silica gel)and regular replacement of the drying agent could be reduced. Ultimately, this automatic moisture control of the breather would enhance the operational reliability of the transformer.

2) *"Transformer Failure Analysis: Reasons and Methods" Jaspreet Singh Punjab State Power Corporation Ltd, Moga, Punjab, India. International Journal of Engineering Research & Technology (IJERT) ISSN: 22780181Published by, www.ijert.org ACMEE – 2016*

In this paper, the failure modes of transformers are discussed, and a failure analysis is conducted on distribution transformers in one sub-division of PSPCL (Punjab State Power Corporation Limited). The failure analysis focuses ontransformers of various capacities that failed between 2010 and 2015.
The analysis follows the guidelines outlined in the IEEE standard C57.125, which includes onsite inspection, external inspection, diagnostic testing, internal inspection, and tear down analysis. These steps aim to determine the causes of transformer failure. The findings of the analysis indicate that insulation failure and line surges are the primary causes of transformer failures. Additionally, a significant number of transformers are failing due to manufacturing defects, overloading, improper maintenance, moisture, and oil contamination.
There are cases where the exact cause of failure is unknown, but it is speculated that power quality problems may be responsible.

3) *"A Moisture-in-Breather Model for Transformer Health Monitoring" Shailesh Kumar, T. Islam, K. K. Raina. IEEE ©2015 IEEE*

A new model has been proposed to estimate the moisture levels in the silica gel and air inside the breather of a power transformer. This model enables the condition monitoring of the transformer with respect to moisture entering through the breather.
The mathematical model incorporates both steady-state and transient-state sub models. When the system reaches a steady-state condition, the model calculates the moisture content in the silica gel. The development of the model takesinto account the operating mode of the power transformer, which depends on the temperature fluctuations of the oil within it.
To obtain the frequency domain response of the model, the Laplace transform is employed. Through simulation, the model's output amplitude represents the dynamic response ofa sensor placed in the breather of the power transformer.

4) *"Development of IOT Based Solution for Monitoring and Controlling of Distribution Transformers" A. Ajitha Department of EEE Anurag group of Institutions Hyderabad, India, Dr.T. Anil Kumar.*

The use of an IoT-based solution for monitoring and controlling distribution transformers is a more convenient and effective method compared to manual monitoring. This paper focuses on transmitting real-time data from each transformer to an IoT platform using LoRa (Long Range) modules.
There are several advantages to this method. Firstly, it allows for continuous monitoring of distribution transformers (DTs), ensuring that any abnormalities can be detected in a timely manner.
This enables prompt alerts to be sent, facilitating the rectification of any issues and ultimately extending the lifetime of the distribution transformers.
Additionally, this IoT-based framework simplifies troubleshooting in the distribution network and ensures the continuity of power supply to consumers. By receiving alerts on a web application for any violations in the rated values of parameters, immediate actions can be taken to prevent any dangerous failures in the distribution network.

III. METHODOLOGY

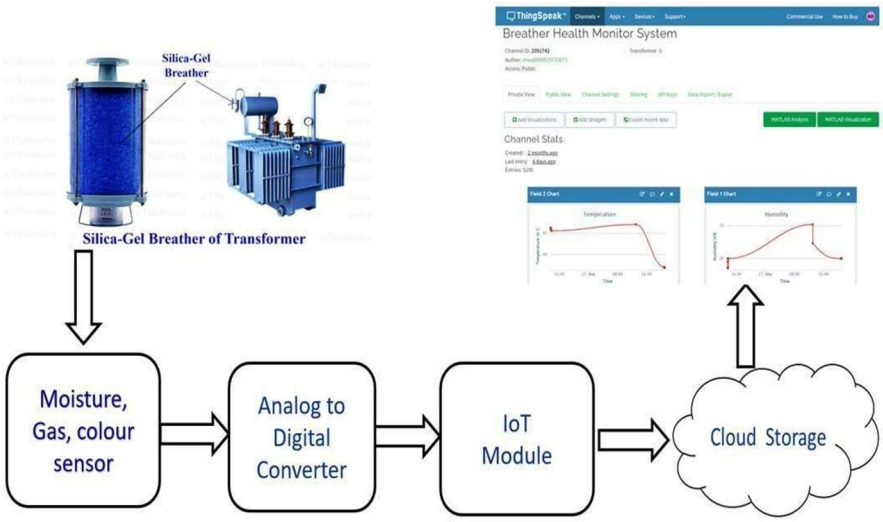


Fig.1 Process flow diagram

1) *Moisture Sensor:* Inserted in the breather it is used to sense moisture content present in the breather. Color sensor is used to detect color of silica gel which is implanted on the breather. Analog to digital converter-Is used to covert the sensors analog output signal in to the digital signal.
2) *IoT Module:* Is used to share the sensor data it is collected by IoT gateway (Node MCU8266) where the data is sent to the cloud storage. Cloud data is displayed using computer or smart phone by thiswe can get to know condition of the breather.
3) *Humidity Sensor:* A humidity sensor is integrated into the breather to detect and measure the moisture content present in the breather. It monitors the level of humidity, helping to identify any excessive moisture that may have accumulated. This information is crucial for assessing the condition of the breather and identifying potential issues such as water ingressor high humidity levels.
4) *Color Sensor:* The color sensor is utilized to determine the color of the silica gel implanted on the breather. Silica gel is commonly used as a desiccant to absorb moisture. By detecting the color of the silica gel, the color sensor can indicate its moisture-absorbing capacity. This enables users to assess whether the silica gel needs to be replaced or regenerated based on its color change.
5) *Analog to Digital Converter (ADC):* The analog output signal generated by the humidity sensor and the color sensor is converted into a digital signal using an analog to digital converter. This conversion allows the sensor data to be processed and transmitted in a digital format, making it compatible with digital systems and devices.
6) *IoT Module:* An IoT module is employed to enable the sharing of sensor data collected from the breather. The IoT module, in conjunction with an IoT gateway such as the Node MCU8266, facilitates the wireless transmission of the sensor data to a cloud storage platform. This allows for centralized data storage and accessibility from anywhere.
7) *Cloud Storage and Display:* The sensor data collected from the breather is sent to the cloud storage platform through the IoT gateway. Once stored in the cloud, the data can be accessed and displayed using a computer or a smartphone. This provides users with a convenient way to monitor and assess the condition of the breather remotely. By analyzing the data displayed on the computer or smartphone, users cangain insights into the breather's condition, including moisture content and silica gel color, and take appropriate actions if necessary.

A. IoT Module

The Internet of Things (IoT) describes the network of physical objects “things” that are embedded with sensors, software, and other technologies for the purpose ofconnecting and exchanging data with other devices andsystems over the internet.
At the moment, there are a wide variety of development boards with the ESP8266 chip that differ in the number of accessible GPIOs, size, form factor, etc. The most widely used ESP8266 boards are the ESP-01, ESP8266-12E Node MCU Kit, For a comparison of these board, you can read this guide: ESP8266 Wi-Fi Development Boards comparison.

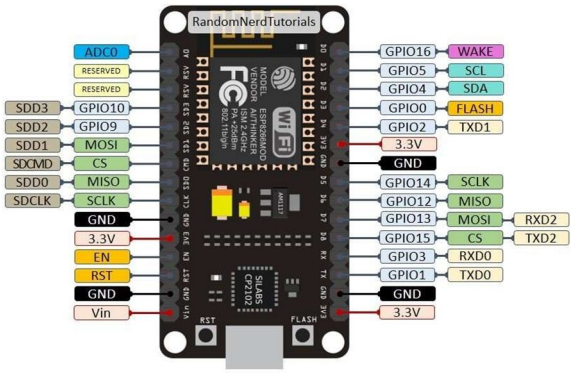


Fig.2 Node MCU 8266 pin diagram

B. NodeMCU ESP8266

NodeMCU is an open-source Lua based firmware and development board specially targeted for IoT based Applications. It includes firmware that runs on the ESP8266Wi-Fi SoC from Express if Systems, and hardware which is based on the ESP-12 module.

C. Brief About NodeMCU ESP8266

The NodeMCU ESP8266 development board comes with the ESP-12E module containing the ESP8266 chip having Tensilica Xtensa 32-bit LX106 RISC microprocessor. This microprocessor supports RTOS and operates at 80MHz to 160 MHz adjustable clock frequency. NodeMCU has 128 KB RAM and 4MB of Flash memory to store data and programs. Its high processing power with in-built Wi-Fi / Bluetooth and Deep Sleep Operating features make it ideal for IoT projects.
NodeMCU can be powered using a Micro USB jack and VIN pin (External Supply Pin). It supports UART, SPI, and I2C interface.

Table.1 Pin description of NodeMCU ESP8266

Pin Number	Pin Name	Pin Function
1	RESET	Active Low External Reset Signal
2	ADC(TOUT)	ADC Pin Analog Input
3	CH_PD	Active High Chip Enable
4	GPIO16	General purpose IO
5	GPIO14	General purpose IO
6	GPIO12	General purpose IO
7	GPIO13	General purpose IO
8	VCC	Power Supply
9	Ground	Ground
10	GPIO15	General purpose IO, should be connected to ground for booting from internal flash
11	GPIO1	General purpose IO, Serial Tx1
12	GPIO0	General purpose IO, Launch Serial Programming Mode if Low while Reset or Power ON
13	GPIO4	General purpose IO
14	GPIO5	General purpose IO
15	GPIO3	General purpose IO, Serial Rx
16	GPIO1	General purpose IO, Serial Tx

D. NodeMCU ESP8266 Specifications & Features

1) Microcontroller: Tensilica 32-bit RISC CPU Xtensa LX106
2) Operating Voltage: 3.3V
3) Input Voltage: 7-12V
4) Digital I/O Pins (DIO): 16
5) Analog Input Pins (ADC): 1
6) UARTs: 1

7) SPIs: 1
8) I2Cs: 1
9) Flash Memory: 4 MB
10) SRAM: 64 KB
11) Clock Speed: 80 MHz
12) USB-TTL based on CP2102 is included onboard, EnablingPlug n Play
13) PCB Antenna
14) Small Sized module to fit smartly inside your IoT projects

E. Cloud Storage and Monitoring using Things Speak

ThingSpeak is an IoT analytics service that provides a platform for aggregating, visualizing, and analyzing real-time data streams in the cloud. It offers instant visualizations of dataposted by devices connected to ThingSpeak. One unique feature of ThingSpeak is the ability to execute MATLAB code within the platform, enabling online analysis and real-time data processing. ThingSpeak is commonly utilized for prototypingand proof-of-concept IoT systems that require analytics

By utilizing ThingSpeak, users can store and analyze their data in the cloud without the need for complex web server configurations. Additionally, the platform offers the creation of advanced event-based email alerts, which can be triggered based on incoming data from connected devices.

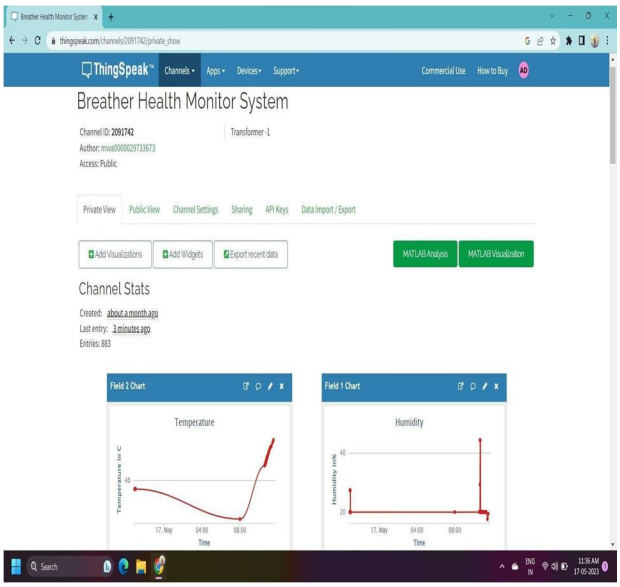


Fig.3 ThingSpeak visual picture

IV. RESULTS AND DISCUSSIONS

Table.2 Temperature sensor readings

Sl.No	Time Period	Temperature in ^{0}C
1	12-04 AM	32.4
2	04-08 AM	33.1
3	08-12 PM	38
4	12-04 PM	42
5	04-08 PM	40
6	08-12 PM	35

Table.3 Humidity sensor readings

Sl.No	Time Period	Humidity in %
1	12-04 AM	26
2	04-08 AM	31
3	08-12 PM	22
4	12-04 PM	20
5	04-08 PM	24
6	08-12 PM	27

Table.4 Gas sensor readings

Sl.No	Time Period	Gas value
1	12-04 AM	0.76
2	04-08 AM	0.52
3	08-12 PM	0.44
4	12-04 PM	0.41
5	04-08 PM	0.36
6	08-12 PM	0.38

Table.5 Color sensor readings

Sl.No	Time Period	Color value
1	12-04 AM	530
2	04-08 AM	140
3	08-12 PM	37
4	12-04 PM	19
5	04-08 PM	160
6	08-12 PM	570

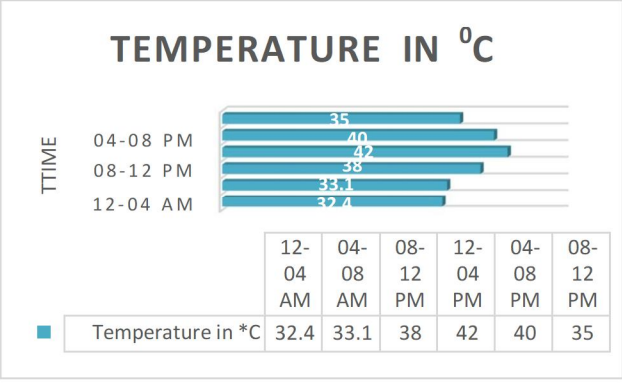
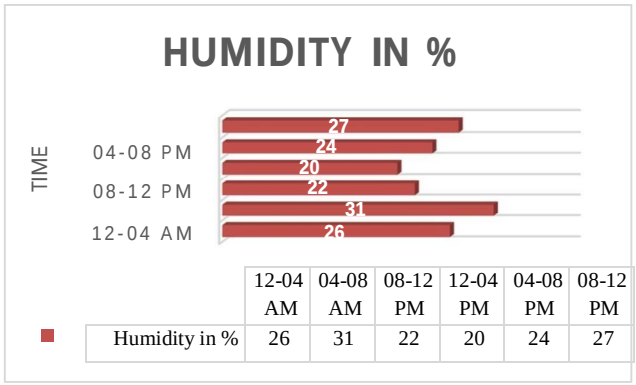
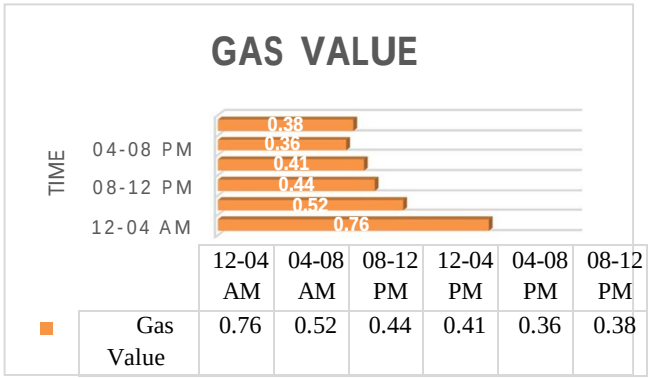


Fig.4 Temperature V/s Time Characteristics



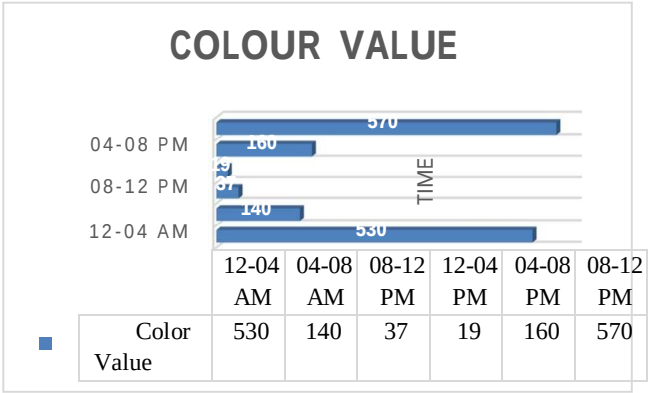
	12-04 AM	04-08 AM	08-12 PM	12-04 PM	04-08 PM	08-12 PM
Humidity in %	26	31	22	20	24	27

Fig.5 Humidity V/s Time Characteristics



	12-04 AM	04-08 AM	08-12 PM	12-04 PM	04-08 PM	08-12 PM
Gas Value	0.76	0.52	0.44	0.41	0.36	0.38

Fig.6 Gas value V/s Time Characteristics



	12-04 AM	04-08 AM	08-12 PM	12-04 PM	04-08 PM	08-12 PM
Color Value	530	140	37	19	160	570

Fig.7 Color V/s Time Characteristics



Fig.8 Project Model Tested and installed on 11KVTransformer in Campus

The readings tabulated in the above tables are calculated as theaverage of the recorded readings within a specific time period.

V. CONCLUSION

The development and implementation of a transformer breather health monitoring system using IoT technology provide significant benefits and advancements in the monitoring and maintenance of transformers. By leveragingIoT capabilities, real-time data from the breather can be transmitted to an IoT platform for continuous monitoring and control.

The IoT-based solution offers several advantages over traditional manual monitoring methods. It enables continuous monitoring of distribution transformers (DTs), ensuring timely detection of abnormalities and providing alerts to rectify any issues promptly. This capability extends the lifetime of distribution transformers, simplifies troubleshooting in the distribution network, and ensures the continuity of power supply to consumers. The implementation of IoT technology in transformer breather health monitoring systems also enhances the reliability and efficiency of maintenance operations. With the ability to receive alerts and notifications on web applications, any violations in the rated values of parameters can be immediately addressed, preventing dangerous failures in the distribution network.

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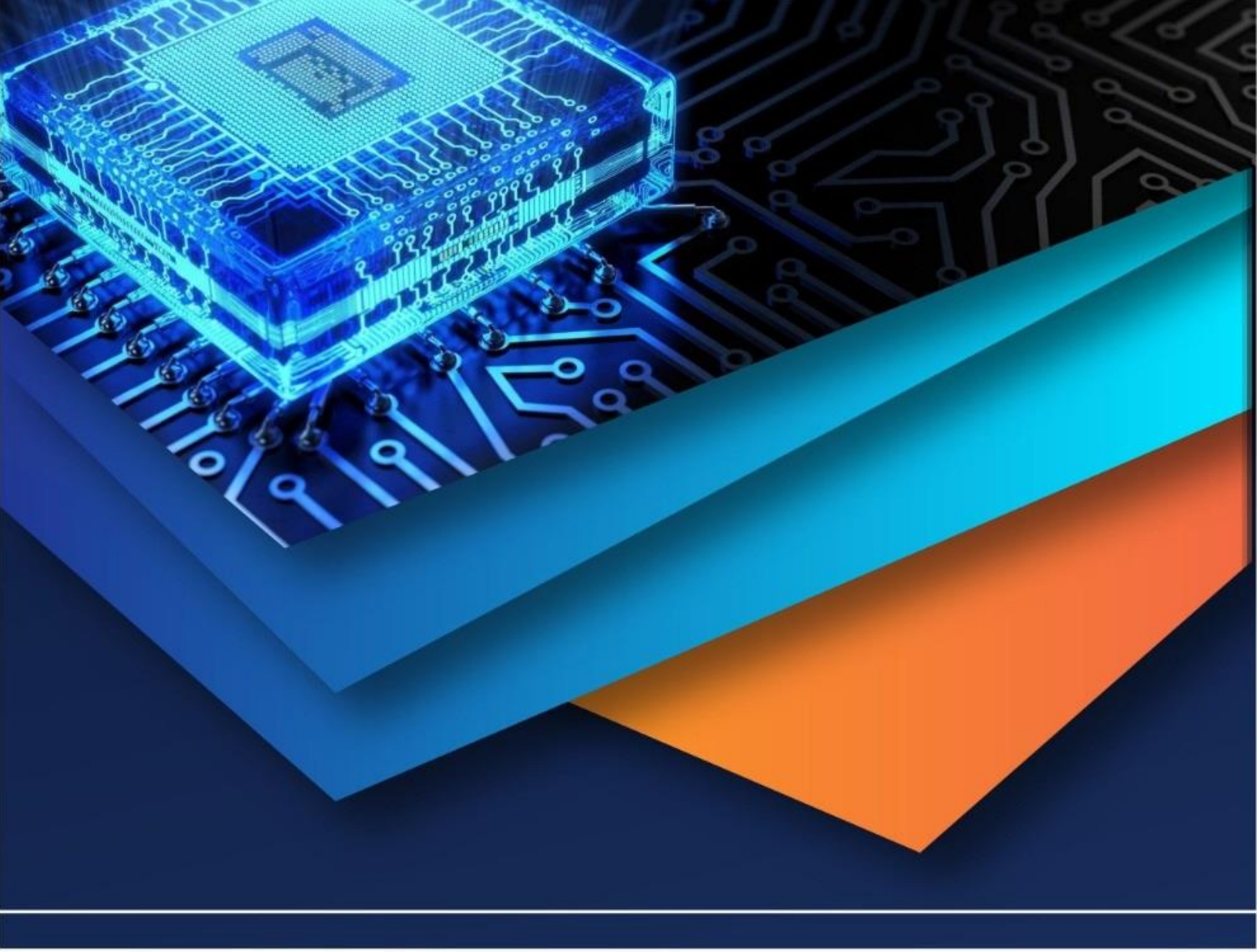
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