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Implementation of Automatic Power Consumption Control in Smart Grid

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Abstract: Transformation to Smart Grid needs proper design of good communication and monitoring infrastructure for the Smart meters as well as understanding the power use pattern of the individual users for providing them uniform power supply as per the individual consumer's requirement.In the proposed system, the meter monitors and calculates the power and if the consumer exceeds the prescribed load limit it alarms. In case the consumer does not reduce his load meter automatically it cuts off the particular loads in consumer connection. GSM communications network are used to transfer electricity consumed data to the consumer as per programmed in the Arduino kit.

Keywords: GSM, Smart meter, Arduino.

I. INTRODUCTION

Now a days, electrical industry is poised to make the transformation from a centralized, producer-controlled network to one that is less centralized and more consumer interactive. The move to a smarter grid promises to change the industry's entire business model and its relationship with all stakeholders, involving and affecting utilities, regulators, energy service providers, technology and automation vendors and all consumers of electric power. A smarter grid makes this transformation possible by bringing the philosophies, concepts and technologies that enabled the internet to the utility and the electric grid. More importantly, it enables the industry's best ideas for grid modernization to achieve their full potential. It is an emerging technology that combines traditional electricity supply infrastructure with information technologies. Due to the recent advances in smart grid [2] as well as the increasing dissemination of smart meters, the electricity usage of every moment in a building can be detected and then transferred to the utility company. Thus, the utility company can adopt different price of electricity at each time slot of a day popularly known as 'Day Pricing' at the peak hours when the prices are high. A smart meter is usually an electronic device that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing. Smart meters enable two-way communication between the meter and the central system. Unlike home energy monitors, smart meters can gather data for remote reporting. Such an advanced metering infrastructure (AMI) differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter. Advanced Metering Infrastructure (AMI) are systems that measure, collect, and analyse energy usage, and communicate with metering devices such as electricity meters, gas meters, heat meters, and water meters, either on request or on a schedule. These systems include hardware, software, communications, consumer energy displays and controllers, customer associated systems, Meter Data Management (MDM) software, and supplier business systems. Government agencies and utilities are turning toward advanced metering infrastructure (AMI) systems as part of larger "Smart Grid" initiatives. AMI [3] extends current advanced meter reading (AMR) technology by providing two-way meter communications, allowing commands to be sent toward the home for multiple purposes, including "time-of-use" pricing information, demand-response actions, or remote service disconnects. The network between the measurement devices and business systems allows collection and distribution of information to customers, suppliers, utility companies, and service providers. This enables these businesses to participate in demand response services. Consumers can use information provided by the system to change their normal consumption patterns to take advantage of lower prices. Pricing can be used to curb growth of peak consumption. AMI differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter. Systems only capable of meter readings do not qualify as AMI systems.

The concept of a smart power grid is to use innovative ICT to control appliances at consumers' homes to save energy, reduce cost and increase reliability and transparency. To be able to achieve these goals, usual electricity distribution must be complemented by an intelligent monitoring and information system that keeps track of all electricity flowing in the system. Therefore, the smart grid will use automated meters, offering two-way communication and advanced sensors to improve electricity efficiency and reliability. A smart meter is the most essential component of advanced metering infrastructure (AMI) that connects the home energy management system of individual residences and a smart grid that optimizes the production, distribution, and consumption of electric power. Power strip type smart meters can be used to not only monitor but also control the electric power consumption at individual power outlet ports.

Detailed load flow can be collected by the smart meters to the consumers so they can manage their loads effectively. Smart energy meter used for Automatic Meter Reading(AMR) to increase the accuracy of the meter reading. Smart meters measure more detailed readings than Kilo Watt Hour so that utility can plan expansion of network and power quality.

II. METHODOLOGY

In smart grid, advanced metering infrastructure (AMI) is an important task for predicting the power consumption such that the balance of supply and demand in power system can be achieved. For designing a good communication infrastructure for the smart meters, it is necessary to study the short term power consumption pattern which is equivalent to the information source pattern in communication system. To design a system to reduce the power consumption for individual user in scheduled duration instead of power cuts there will be a scheduled restricted power supply. GSM based [1] remote controlling station is implemented from where we send control information consist maximum power consumption. If the customer use more power then allowed power, after the warning the system will shut down the power supply automatically. The proposed system is capable of automatic meter reading and power uses reading in Mobile phone of the customer.

Smart meter is designed to measure voltage and load currents by the use of rectifier converting ac-dc then providing the dc output to hall effect voltage and current sensors instead of traditional potential transformer as well as current transformers and then the collected values of current.

A. Block Diagram

The design of smart energy meter involves the measuring of load current and voltage and then feeding them to Arduino IC which converts it into the real power consumed by the load. Microcontroller is used to perform the calculations related to power and energy consumed and shows the reading on LCD as well as it sends the readings on the LCD to the consumer with the help of GSM modem. Meter reading are sent from GSM modem and received on mobile successfully.

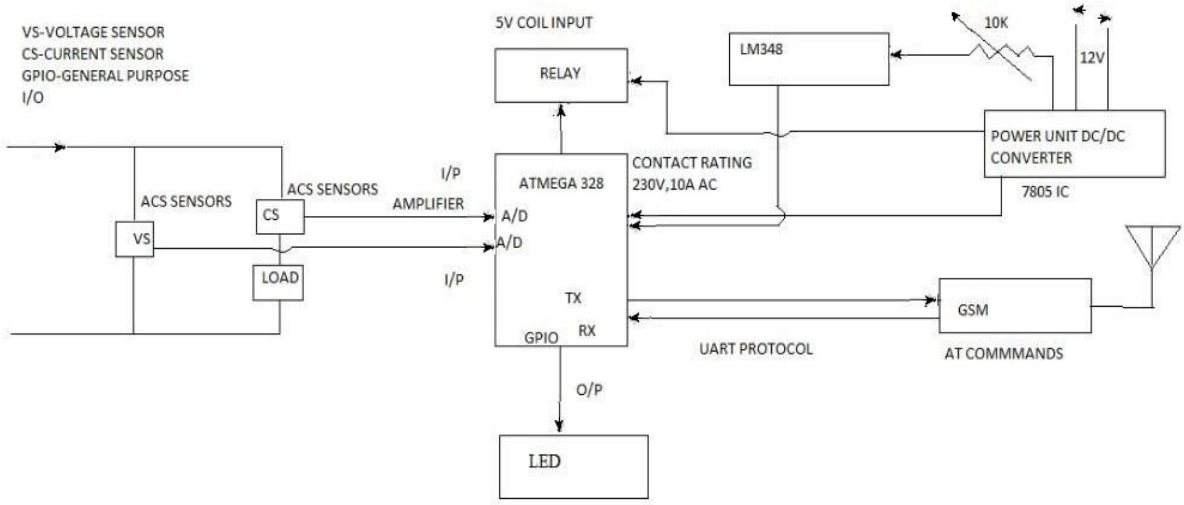

Fig.1.Block Diagram

Two-way communication is done by the smart meter and utility administration as well as between meter and customer so that customer is able to check the status of his consumed Energy units can manage the load accordingly to reduce his bills.

Smart metering [5] communication is centralized meter reading, so meter readers don't need to visit each customer data collection. However, for testing and maintenance meters may need to observe occasionally.

The supply is given in AC which is converted into DC using the bridge rectifier as the hall effect sensors requires DC input for functioning. The voltage and current sensors measures the RMS values of voltage and current and feed them to Arduino ATMEGA 328 which has an in built microcontroller as well as DC-DC converter. Arduino microcontroller is an open source of computer hardware and software company, project and user community that designs and manufactures kits sense control the physical world. The Arduino microcontroller is responsible for calculations of power consumption. In Smart meter we have used sensors to measure voltage and current instead of current and voltage transformers for more accurate results.

The SMS is being received by smart meter programmable interface and the action is performed by the meter according to the provided information. A major feature of smart energy meter is that the meter itself cut-off the supply if the consumer exceeds the prescribed load limit or violates the load limit using relay as well as it reconnects the connection of energy if the load comes to prescribed limit by reducing the load manually. Another major feature of smart meter is that it gives a led signal can be replaced by buzzer which alarms the consumer load is exceeding upper limit for which he got the utility connection. In case consumer does not reduce his load meter automatically cut off the consumer connection. GSM communications network are used to transfer electricity consumed data to the consumer as per programmed in the Arduino kit.

III.HARDWARE REQUIREMENTS

A. Voltage Sensors

The Smart Voltage Sensors are used to measure the potential difference between the ends of an electrical component. This range of Voltage Sensors can be used to measure both DC and low-voltage AC circuits. The Smart Voltage Sensors are equipped with a micro controller that greatly improves the sensor accuracy, precision and consistency of the readings. They are supplied calibrated and the stored calibration (in Volts) is automatically loaded when the Voltage Sensor is connected.

A simple but very useful module that uses a potential divider to reduce any input voltage by a factor of 5. This allows using the analogue input of a microcontroller to monitor voltages much higher than it is capable of sensing. For example, with a 0-5V analogue input range, it is able to measure a voltage up to 25V. The module also includes convenient screw terminals for easy and secure.

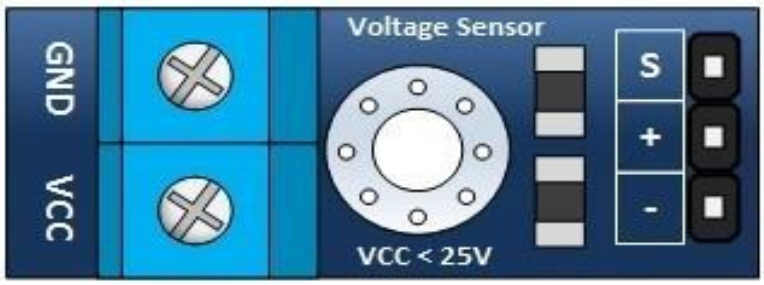

Fig.2. Voltage Sensor

B. Current Sensors

The ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems. The device package allows for easy implementation by the customer. Typical applications include motor control, load detection and management, switch mode power supplies, and overcurrent fault protection. The device is not intended for automotive applications.

“The Hall-effect is the production of a voltage difference (the Hall voltage) across an electrical conductor, transverse to an electric current in the conductor and a magnetic field perpendicular to the current.

The Hall coefficient is defined as the ratio of the induced electric field to the product of the current density and the applied magnetic field. It is a characteristic of the material from which the conductor is made, since its value depends on the type, number, and properties of the charge carriers that constitute the current.

Fig.3. Current Sensor

The ACS712 Current Sensors are designed to be easily used with micro controllers like the Arduino. These sensors are based on the Allegro ACS712ELC chip. These current sensors are offered with full scale values of 5A, 20A and 30A. The basic functional operation of each of these devices is identical. The ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems. The device package allows for easy implementation. Typical applications include motor control, load detection and management, switch mode power supplies, and overcurrent fault protection. The device is not intended for automotive applications. The device consists of a precise, low-offset, linear Hall circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which the Hall IC converts into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer.

C. Arduino

Arduino is an open-source computer hardware and software company, project and user community that designs and manufactures kits for building digital devices and interactive objects that can sense and control the physical world. It will do the mathematical calculation and get the reading from voltage sensor and current sensor. The Arduino Uno is a microcontroller board based on the (ATmega328).It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

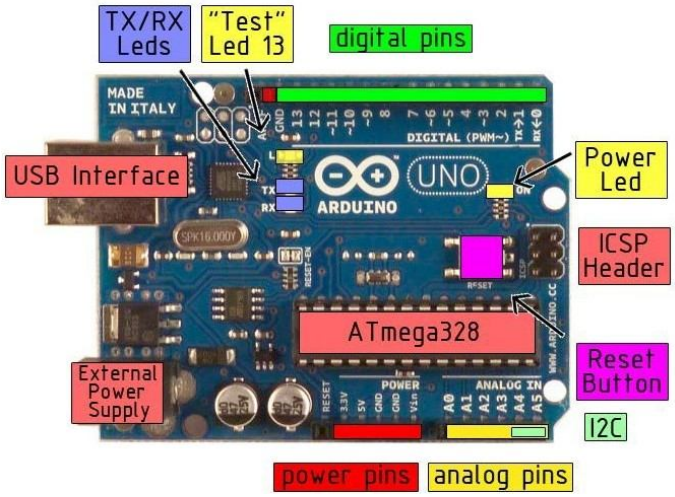

Fig.4.Arduino board

D. GSM Module

SIM800 is a complete Quad-band GSM/GPRS solution in a SMT type which can be embedded in the customer applications. SIM800 support Quad-band 850/900/1800/1900MHz, it can transmit Voice, SMS and data information with low power consumption. With tiny size of 24*24*3mm, it can fit into slim and compact demands of customer design. Featuring Bluetooth and Embedded AT, it allows total cost savings and fast time-to-market for customer applications.

Fig.5.GSM Module

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IV. IMPLEMENTATION

A. Flow Chart Process

From the flow chart diagram, it can be seen that the energy consumption is continuously monitored by Arduino and if the limit exceeds it sends the update to the customer through GSM communication.

The main steps of automatic power consumption control are below:

1) In reading it measures Voltage, Load Current and Power consumed.
2) Through SMS customer is updated about his power consumption.
3) Smart energy meter cut-off the power supply if the load exceeds the limit.
4) GSM metering network is used to transfer the electricity data to the customer. Antenna, attached on or near the meter box, can be used for improvement of signal strength in GSM communication.

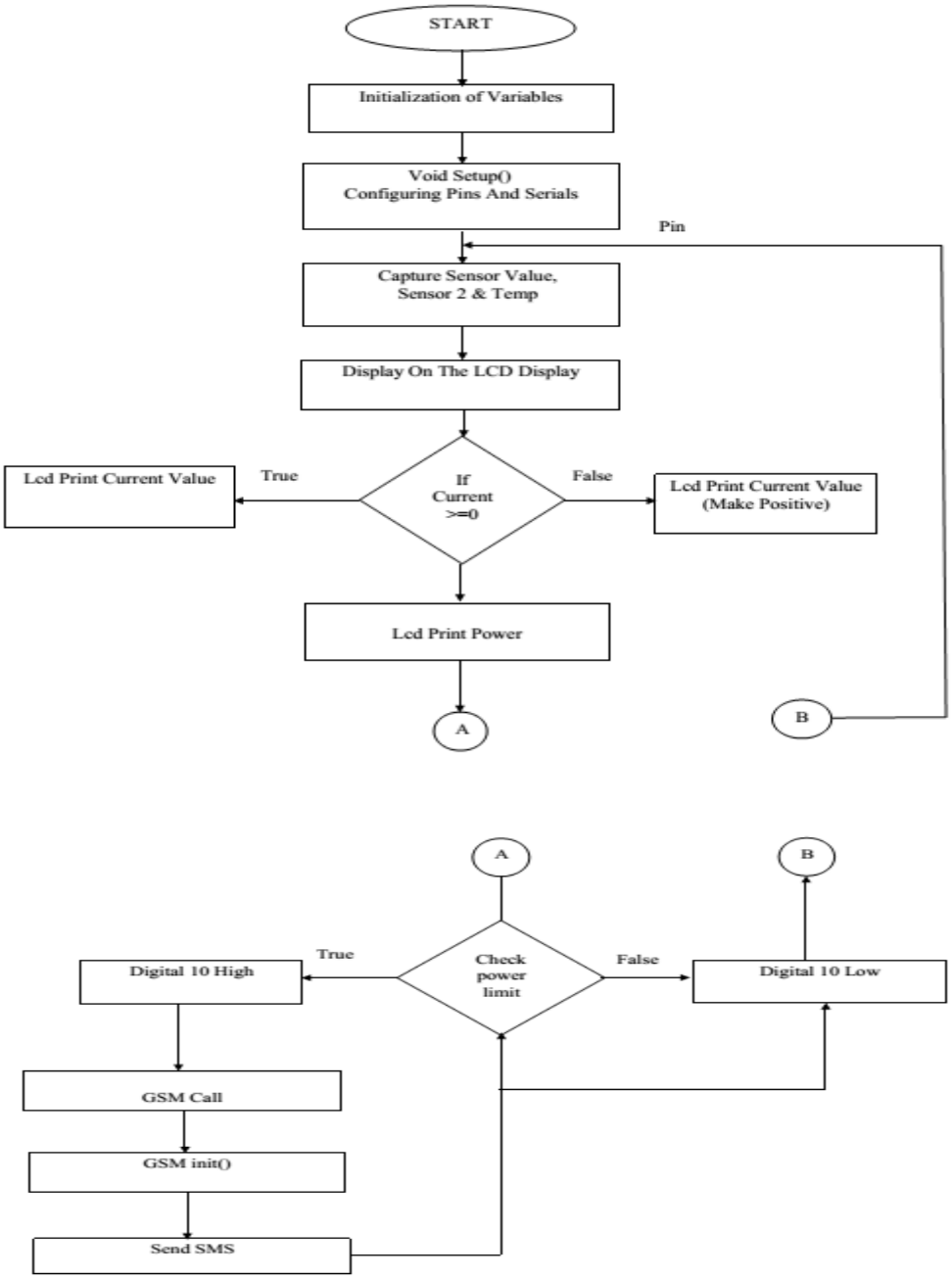

Fig 6. Flow Chart

B. Hardware

The proposed smart meter can be used for power consumption control and it can reduce the power consumption with the help of limited or reduced power supply. The proposed system will provide secure and efficient way for power measurements. In the existing system meter reading is done manual process and it is the wastage of time and it causes more man power but the proposed system provides many features than the system that have been previously used. Arduino microcontroller is used to monitor and control of power consumption. In this proposed work, different sets power consumption data of various households analyzed and interpreted and their daily behavior patterns are monitored and controlled. GSM provides numerous advantages over methods that have been previously used.

Fig 7. Hardware

The supply is given in AC which is converted into DC using the bridge rectifier as the hall effect sensors requires DC input for functioning. The voltage and current sensors measures the RMS values of voltage and current and feed them to Arduino ATMEGA 328 which has an in built microcontroller. The Arduino microcontroller is responsible for calculations of power consumption. In Smart meter sensors are used to measure voltage and current instead of current and voltage transformers for more accurate results.
The SMS is being received by smart meter programmable interface and the action is performed by the meter according to the provided information [6].

V. CONCLUSIONS

The proposed system monitors and calculate the power using Arduino and send the information to the customer using GSM communication.A major feature of smart energy meter is that the meter itself cut-off the supply if the consumer exceeds the prescribed load limit or violates the load limit using relay as well as it reconnects the connection of energy if the load comes to prescribed limit by reducing the load manually. Another major feature of smart meter is that it gives a led signal can be replaced by buzzer which alarms the consumer load is exceeding upper limit for which he got the utility connection. In case consumer does not reduce his load meter automatically cut off the consumer connection. GSM communications network are used to transfer electricity consumed data to the consumer as per programmed in the Arduino kit. Power theft can be reduced and proper power control can be achieved.

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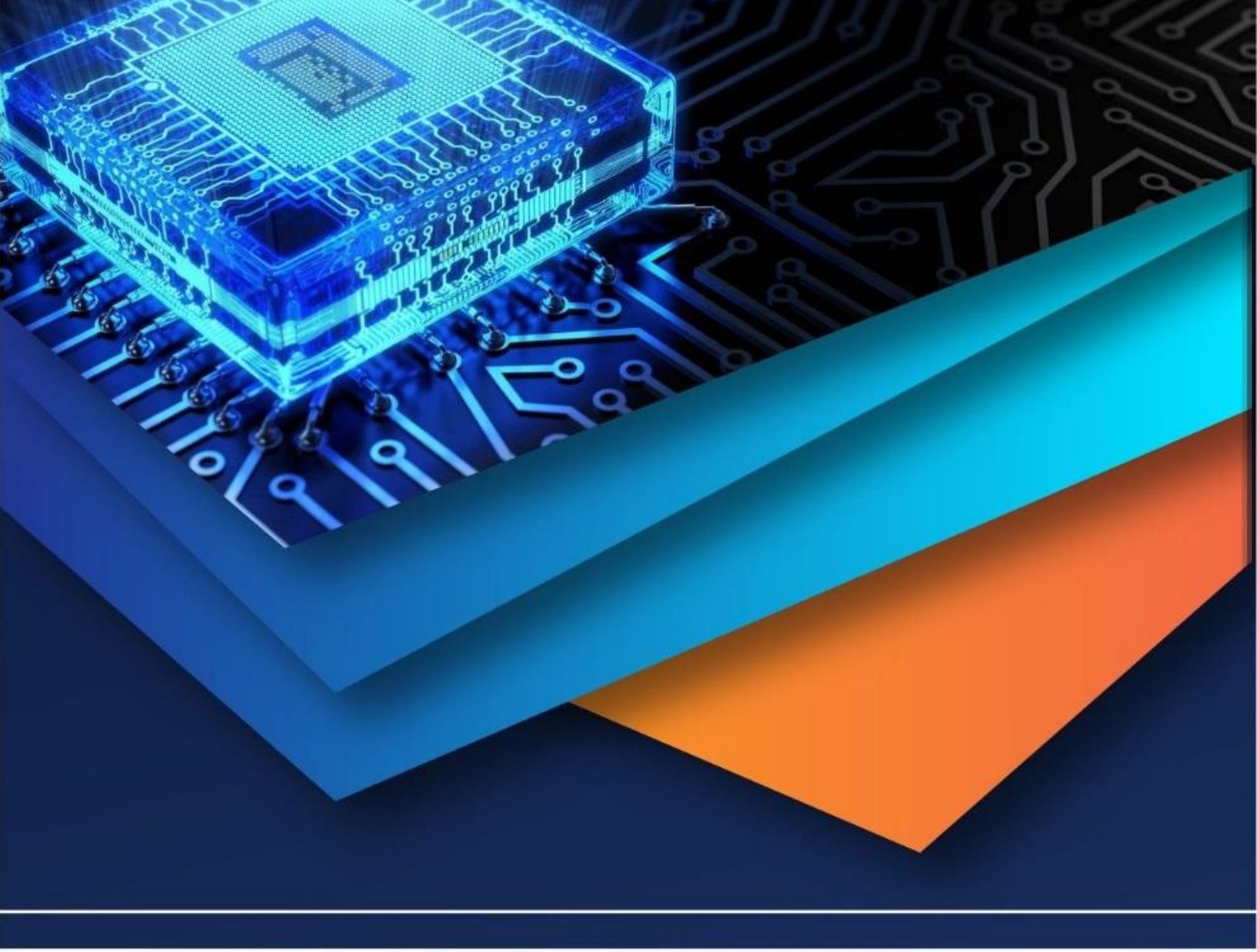

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