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Design of MPPT Controllers for PV Cells using Matlab

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Abstract: Nowadays, the Photovoltaic cell is one ofthe most essential parts in the electrical field to convert photo light to voltage and current, at the desired output voltage and frequency by using various control techniques. To increase the production of photovoltaic-based cleaner energy, the maximum power point tracking (MPPT)controller is employed. This project presents the design of an MPPT Controller for Photovoltaic systems. The MPPT controller is used to control and get Maximum Power Point (MPP) from the source.

The output power of a photovoltaic (PV) module depends on the solar irradiance and the operating temperature; therefore, it is necessary to implement MPPT controllers to obtain the maximum power of a PV system regardless of variations in climatic conditions. This project reviews the most used MPPT algorithms, which are Perturb and observe (P&O), Incremental conductance method (ICM), and Fuzzy logic control (FLC).

I. INTRODUCTION

Photovoltaic (PV) offers an environmentally friendly source of electricity since it is clean, pollution-free, and inexhaustible. However, the output from a PV solar cell alone is not good enough to input into an electricity bank or the main grid because its output is not constant in terms of voltage.

This raises a need to design a controller which can calculate and extract the maximum power point (MPP) at any instant from the solar cells.

Maximum Power Point Tracking, frequently referred to as MPPT is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of at that time.

MPPT is not a mechanical tracking system that "physically moves" the module to make thempoint more directly at the sun but it is a fully electronic system that varies the electrical operating point of the module so that modules can deliver maximum available power.

II. PROBLEM STATEMENT

Photovoltaic (PV) systems have become an important source of power for a wide range of applications. Unfortunately, PV generation systems have two major problems: the conversionefficiency of electric power generation is very low(9-17%), especially under low irradiation conditions, and the amount of electric power generated by solar arrays changes continuously with weather conditions. Moreover, the solar cell V-I characteristic is nonlinear and varies with irradiation and temperature.

III. PROJECT OBJECTIVES

The primary objective of this project is to design an MPPT controller for photovoltaicsystems.

In addition, this project has various objectives,which comprise of:

1) To design the optimum controller by simulation for the maximupower pointtracking.
2) To analyze simulation results of the maximum power point controller tracking.

A. Perturb and Observe Algorithm

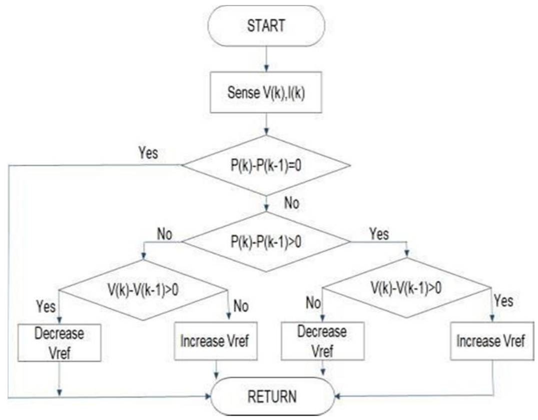


Fig.: Flowchart of P&O algorithm

The Perturb and Observe (P&O) algorithm isan extensively habituated system of Maximum Power Point Tracking(MPPT) used to control the power affair of a photovoltaic(PV) system.It's a simple and robust algorithm that's generally used in small-scale PV systems. The P&O algorithm works by continually conforming the operating voltage of the PV array and measuring the corresponding power affair. The algorithm starts by setting the voltage to an original value and also perturbingthe voltage slightly in one direction. However, the algorithm continues to undo MPPT the voltage in that direction, If the power affair increases. However, if the power affair diminishes, the algorithm changes direction andstarts perturbing the voltage in the contrarydirection. This process continues until the maximum power point is reached.

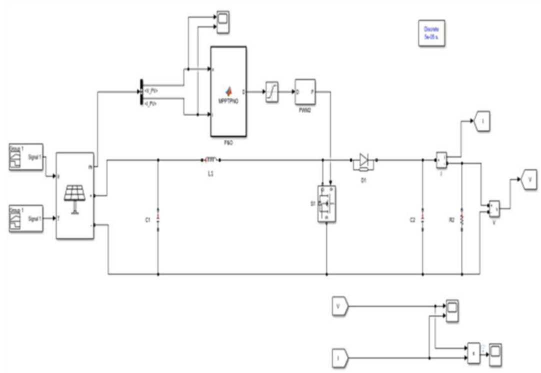


Fig.: Simulation of Perturb and Observe MPPT

IV. RESULTS

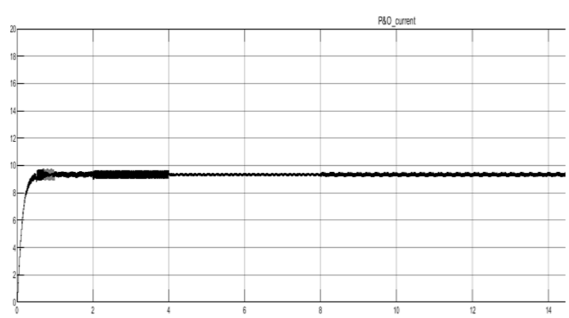


Figure: Output Current Form

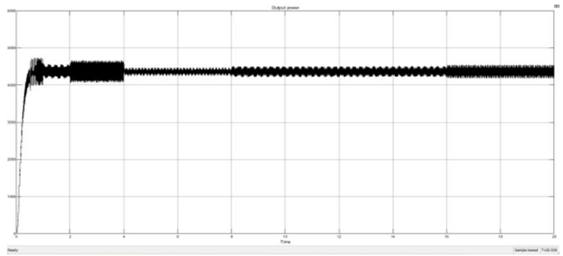


Figure: Output Voltage Form

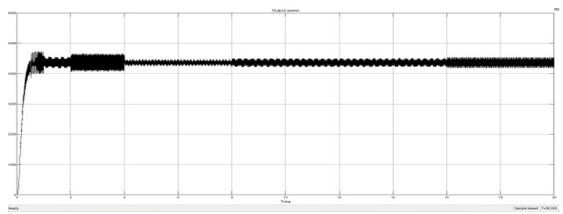


Figure: Output Power Form

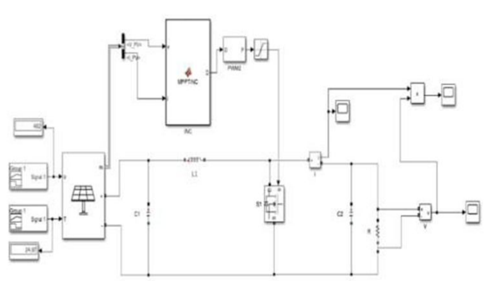
A. Conventional Incremental ConductanceAlgorithm

The incremental conductance algorithm detects theslope of the P–V curve, and the MPP is tracked bysearching the peak of the P–V curve. This algorithm uses the instantaneous conductance I/V and the incremental conductance dI/dV for MPPT.Depending on the relationship between the two values, as expressed in (1)–(3), the location of the operating point of the PV module in the P–V curve can be determined, i.e., (1) indicates the PV module operates at the MPP, whereas (2) and (3) indicate the PV module operates at the left and right side of the MPP in the P–V curve, respectively.

di/dv = -I/V—(1) di/dv > -I/V—(2) Di/dv < -I/V—(3)

The above equations are obtained from the conceptwhere the slope of the P–V curve at MPP is equal to zero, i.e.:
dp/dv=0—(4)
By rewriting (4), the following equation isobtained:
I+Vdi/dv=0 —(5)

In the conventional incremental conductance algorithm, (5) is used to detect the MPP, and the voltage and current of the PV module are measured by the MPPT controller. If (2) is satisfied, the duty cycle of the converter needs to be decreased, and vice versa if (3) is satisfied, whereas no change in the duty cycle if (5) is satisfied.



Simulation Model

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B. Results

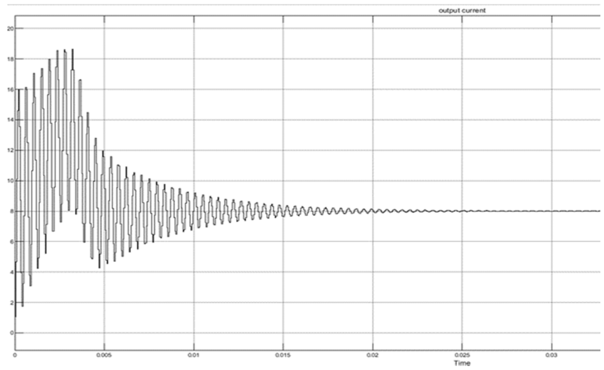

Figure: Output Current Form

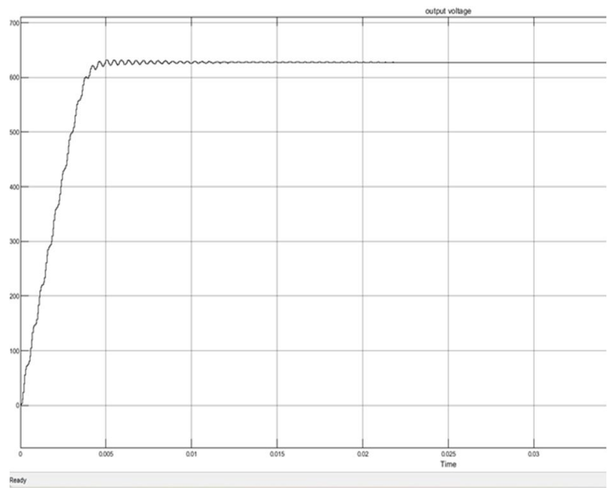

Figure: Output Voltage Form

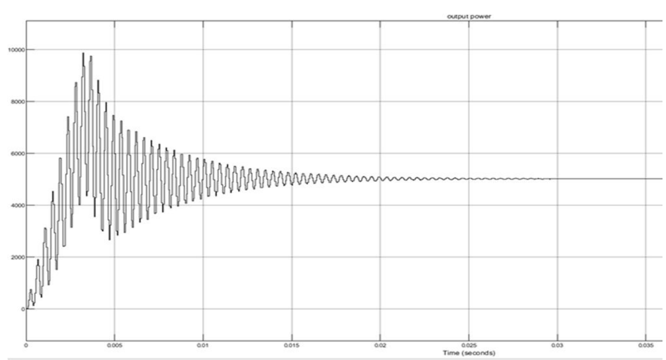

Figure: Output Power Form

V. FUZZY LOGIC

The fuzzy MPPT (FMPPT) is discovered to be more suitable for tracking MPP than standard algorithms in PV Systems due to the absence of accurate modeling of PV modules and uncertainty in the performance of PV systems due to fluctuating irradiance and temperature. FMPPT can handle uncertainty like unmodeled physical quantities, nonlinearity, and erratic fluctuations in the PV system's operational point. This MPPT technique increases the selection of the duty cycle's variable step size, which raises the photovoltaic system's performance.

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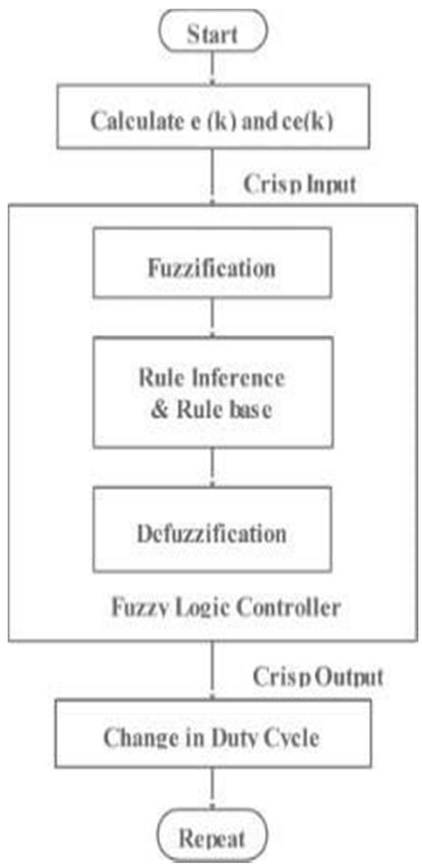
Fuzzification, rule inference, and defuzzification are the three functional building elements that make up the fuzzy controller [6, 7]. In the suggested system, the FLC's input variables are error (e) and error change (ce), and the FLC's output is changed in the duty cycle. The chosen input and the chosen output variable have an impact on the fuzzy MPPT algorithm's design considerations and effectiveness. The duty ratio command is often the output variable of the FMPPT algorithm, which is used to modify the PV module's operating point in order to increase poweroutput. The slope of the PV module's P-V curve and variations in this slope is the most often used input variables for FMPPT.

$$e(k) = \frac{P_{pv}(k) - P_{pv}(k-1)}{V_{pv}(k) - V_{pv}(k-1)} \quad \text{\_\_\_\_(6)}$$

c(e) = e(k)-e(k-1)______(7)



By applying membership function values, the input variables e & ce and the output variable d are transformed into linguistic variables throughout thefuzzification process. These variables are expressed as NB (negative big), NS (negative small), ZE (zero), PS (positive small), and PB (positive big) in various fuzzy levels. In this work, triangle membership functions are taken into consideration, presuming that there is only one dominant fuzzy subset for each given input. Figure 7 displays the membership functions for e, ce, and d. Heuristic-defining rules are essential for modeling the FMPPT, and the fuzzy rule base—a collection of if-then rules—is utilized to handle fuzzified inputs. Based on experimental knowledgeof the issue or PV system characteristics, fuzzy rules are discovered.

The number of linguistic variables in the input Membership functions affects how many rules there are. In this study, there are 25 fuzzy control rules in the fuzzy rules. The composition operation carried out by a fuzzy inference system creates a logical choice based on fuzzy rules, from which a control output is produced. In this study, the Mamdani fuzzy inference approach with Max-Min composition operation was applied. Figure 8 depicts the three sections that make up the fuzzy rule database.

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1) Region-1

In this region, the PV curve's slope, or e(k), is negative. This suggests that the PV module's operating point is to the right of the MPP and thatthe duty ratio needs to be raised in order to followthe MPP. To determine the duty cycle increase's magnitude, utilize the ce(k). The operating point will be moving towards MPP from the right if e(k) is NS and ce(k) is positive. Tostop the system from oscillating at this point, the output is set to ZE.

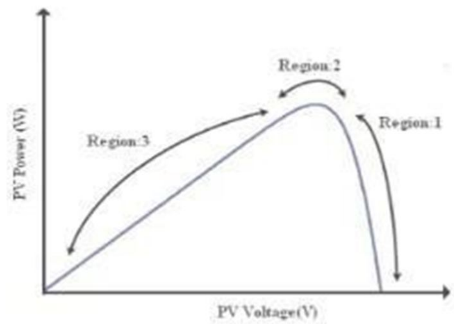

Figure P-V curve of PV module indicating different regions for fuzzy ruleset.

e\ce	NB	NS	ZE	PS	PB
NB	ZE	PB	PB	PB	PB
NS	PB	PS	PS	ZE	ZE
ZE	PS	ZE	ZE	ZE	NS
PS	ZE	ZE	NS	NS	NB
PB	PB	ZE	NS	NB	ZE

2) Region-2

E(k) is ZE in this area, indicating that the operating point is around MPP. Therefore, the guiding concept in such circumstances should be to retain the same obligation ratio.

The operational point is moving towards the MPP from the left if ce(k) is NB. Therefore, the duty ratio is reduced. The control rule should be PS to suppress the change in duty cycle magnitude in theopposite direction, preventing the operating point from shifting to the right side of the MPP.

3) Region-3

The operational point is found on the left side of the MPP when e(k) is positive. Therefore, the dutycycle needs to be reduced. The ce(k) is used to estimate how much of the duty ratio should be reduced.

The operational point is approaching the MPP fromthe left side when ce(k) is negative at this time. In order to avoid a reduction in duty cycle and oscillation of the system near the operational point,the controller should now set the output to ZE.

The duty cycle of the DC-DC converter changes asa result of FLC. Defuzzification transforms the linguistic value of the output into a clear output value. An aggregated output fuzzy set is used as the input to the defuzzification process, and the output is a single number. There are a lot of defuzzification methods that have been suggested in the literature. The Centre of Gravity (COG) or centroid defuzzification method is the approach that is most frequently utilised [8]. The centre of gravity (centroid) is identified by the defuzzifier inthis manner, and the FLC output is based on that value. The centroid of a continuous aggregated fuzzy collection is provided by:

___(8)

Where d is a crisp value, Wi is a weighting factor,and di is a value that corresponds to d's membership function

The FLC's output is the shift in duty cycle (d),which is written as

d(k) = d(k-1)+s.Δd_______(9)

Where s is the fuzzy MPPT controller's outputscaling factor.

$$\Delta d = \frac{\sum_{i=1}^{n} W_i \Delta d_i}{\sum_{i=1}^{n} W_i}$$

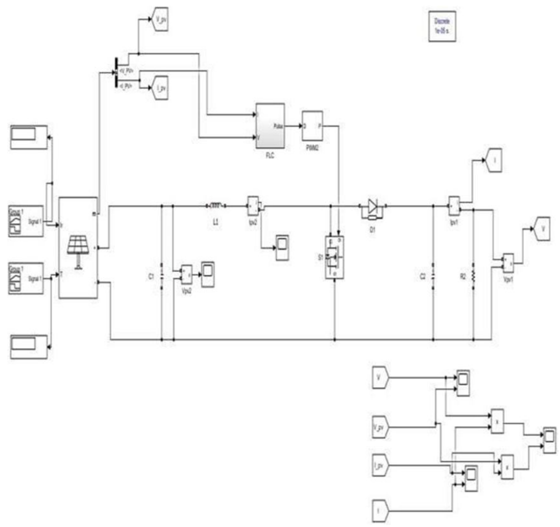

Figure: The figure above shows simulation modelof fuzzy technique.

VI. FUZZY RESULTS

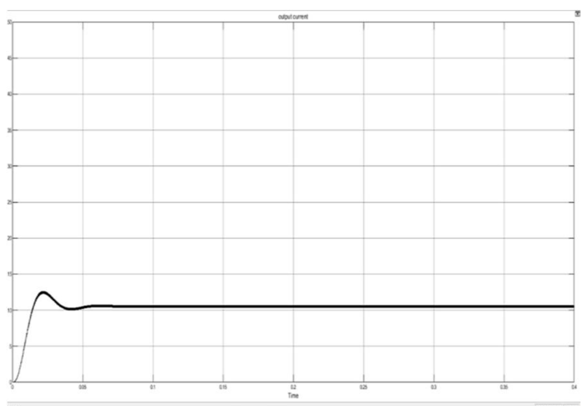

Figure: Output Current form

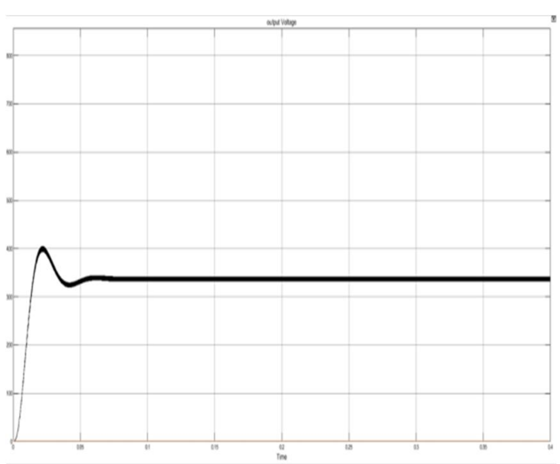

Figure: Output Voltage form

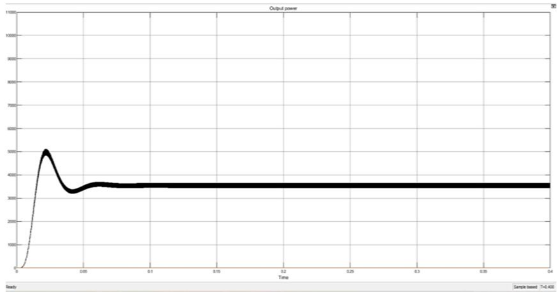

Figure: Output Power form

A. Result

TECHNIQUE	INPUT		OUTPUT POWER (kilo watts)
	TEMPERATURE (degrees)	IRRADIANCE (W/m^2)	
Perturb and Observe	25	400	4.3
Incremental Conductance	25	400	5.02
Fuzzy Logic	25	400	5.75

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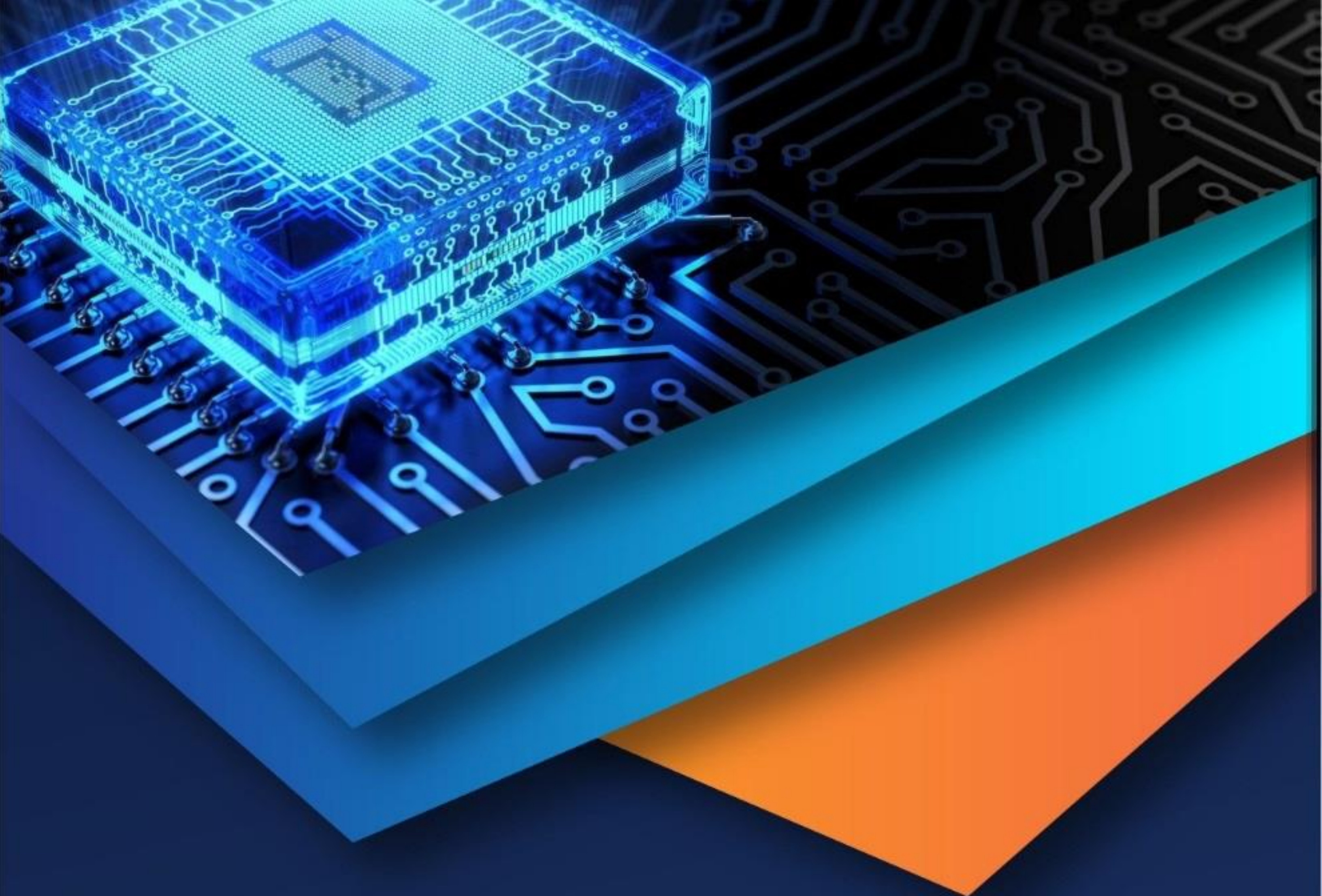

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