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Maximum Power Point Tracking Using Indirect Adaptive Control Algorithm and Comparison with Other MPPT Technique

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***Abstract:** Solar photovoltaic (PV) systems, which generate electricity regarded to be a renewable energy source, have great potential. Compared with the traditional power resources, they develop increasingly swiftly. However, the issue is that the environment varies depending upon on generation of Solar panels. The fundamental problem with a PV system is that, according to varied conditions (i.e., irradiance, ambient temperature, etc.), the quantity of energy that photovoltaic systems generate varies. The continued monitoring of the maximum power point (MPP) is needed to maximize the output of a PV system. In this paper, the maximum power point tracking technique (MPPT$_S$) for a photovoltaic system to retrieve the maximum power from the solar arrays in adverse conditions, including changes in irradiation and temperature on the Voltage-current and Voltage-power characteristics of the photovoltaic array modulus is proposed. An indirect adaptive control technique and evaluated with various maximum power point tracking techniques is also stated.*
***Keywords:** photovoltaic, maximum power point, maximum power point tracking, indirect adaptive control.*

I. INTRODUCTION

The demand for electric energy has increased as the economy and industry have grown. In developing countries like India where the energy problems are very serious, the demand for traditional energy sources such as fossil fuels, oil, and gas has increased by the increase in power generation demand.[1] In the present condition to fulfill the demand for electrical power is becoming very hard for the power generation station because of the poor availability of fossil fuels and natural gas. [2] A long-term alternative for existing power generation methods is renewable energy sources. Different sources of renewable energy solar and wind energy are used to generate electricity. Because of its simple elegance and availability, solar energy might be considered the best alternative to electricity generation. [3] Solar energy can be produced for almost half the cost of traditional electricity generation. The photovoltaic effect is used in solar cells to convert light into an electric current. [4] A photovoltaic system is a power system that converts solar energy into usable electricity. [5]

A. Basic Principle

A procedure to collect maximum power from a PV system under all weather conditions is known as maximum power point tracking. According to the power transfer principle, to transfer more power to the load side, source impedance of PV module should match the load impedance i.e.

$$Z_L = Z_{PV}$$

II. PV SYSTEM WITH MAXIMUM POWER POINT TRACKING CONTROL

The process of maximum power point tracking is run perfectly only when the load and PV module is connected by the best tunable matching system. The main building block of maximum power point tracking concept as illustrated in fig

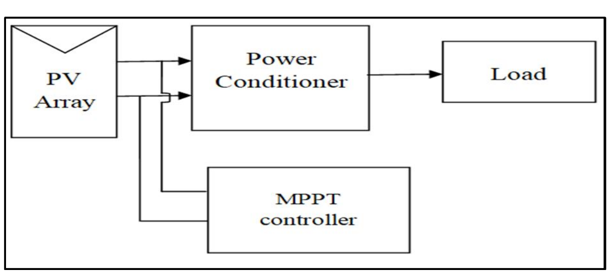

Fig.1 PV system with maximum power point tracking

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A. Fractional Open Circuit Voltage

This method is easy of all the maximum power point tracking methods and the method is easy to implement. This technique is established on good approximation.

The basic equation of this technique is

$$V_{mpp} = K \times V_{oc}$$

Where K is constant the value of K is around 0.7 To 0.8 this based on which type of power curve technology and solar cell is used in the system.

Every illumination level and irradiance level corresponds to the I-V curve. If the V_{oc} is measured so the V_{mpp} can also be found as a fraction of V_{oc}.

The main disadvantage is as already mentioned this technique is based on approximation so this method does not always exact MPP, it is only around the MPP region.

When change in illumination condition method needs to measure the V_{OC}. Each time to measure the open-circuit voltage this technique disconnects the Power curve module to load connection. This will cause very much power losses.

B. Fixed Voltage Techniques

This method is based on altering the PV array's operating voltage only on a seasonal basis. A fixed voltage algorithm is proposed that adjusts the reference voltage automatically to accommodate for changing environmental circumstances. Unlike other constant voltage MPP methods, this approach constructs the PV module so that its open-circuit voltage is measured without breaking the entire source from the load.

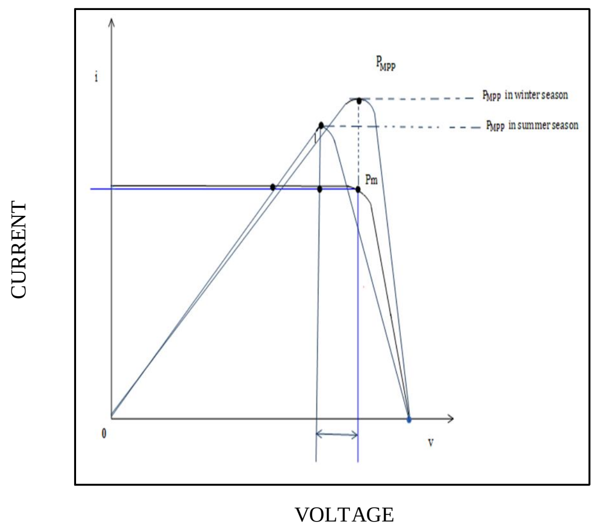

Fig. 2 Power and IV curve

The main drawback is if this method is used with minimum irradiance fluctuation in a single day, it is not very accurate. That maximum power will not be obtained.

C. Perturb & Observe Technique

This method is based on the rise of the power-voltage curve below the MPP and the drop beyond that point. Because of its simplicity, perturb and observe maximum power point tracking method is the most widely used.

In this method, a perturbation from the array voltage is provided to the PV module, resulting in an increment or decrement in power. An increase in voltage leads to an increase in power, which means the operating power point, is to the left of the maximum power point (Pmpp), and causing a voltage to fluctuate. To reach the maximum power point, the right side must be perturbed, the algorithm is implemented.

In contrast, a rise in voltage leads to a reduction in power, indicating that the operating power point is right to the maximum power point (Pmpp), causing a voltage to fluctuate. To reach the maximum power point, the left side must be perturbed.

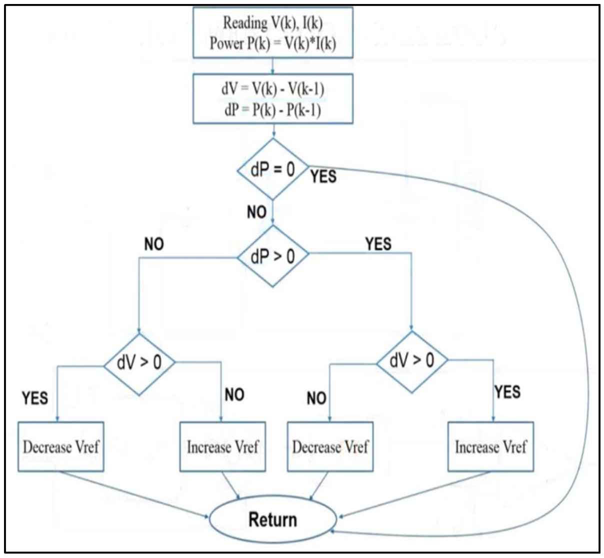

Fig. 3 flowchart for P and O

D. Increment Conductance Technique

In this method Conduction is a reciprocal of resistance i.e. ratio of current to voltage.

$$\text{CONDUCTION} = \frac{I}{V}$$

In general, this technique at every iteration measure increment in conduction changes compare with instantaneous conduction and decide the operation is left or right of maximum power point and takes next step toward maximum power point.

The system operates at the MPP at $\frac{\Delta I}{\Delta V} = -\frac{I}{V}$

The system operates at left the MPP $\frac{\Delta I}{\Delta V} > -\frac{I}{V}$

The system operates at left the MPP $\frac{\Delta I}{\Delta V} < -\frac{I}{V}$

Here $\frac{\Delta I}{\Delta V}$ is increment conduction & $\frac{I}{V}$ instantaneous conduction.

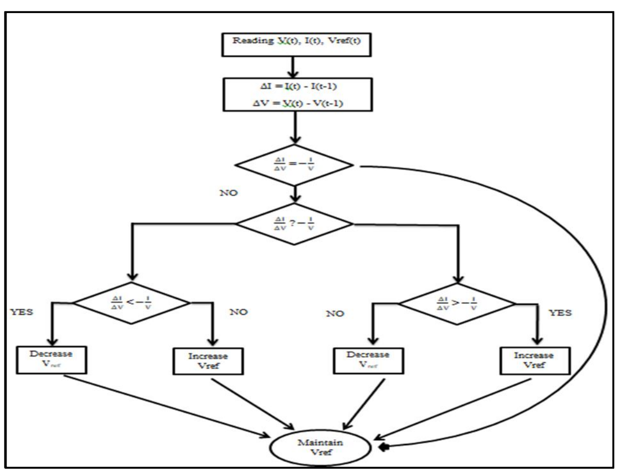

Fig. 4 flowchart for incremental conduction

Main disadvantage is that they can swiftly lose track of the maximum power point if the irradiance varies abruptly For cases with step changes they follow the maximum power point very well, since this shift is short and the curve doesn't really continuously changing. But, if irradiation varies along a slope, the start to fluctuate with the irradiation, illustrated in Fig. , thus those statuaries not get maximum power always around maximum power point region.

III. INDIRECT ADAPTIVE CONTROL

Adaptive control of nonlinear systems based on feedback linearization approaches. Indirect adaptive control approach is based on the online identification of the parameters of the unknown process using input-output data. These parameters are used to update the controller in such a way the transfer function of the regulated process evolves that of the model.

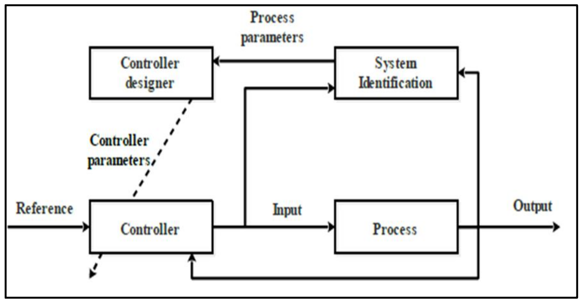

Fig. 5 indirect adaptive control technique

The proposed technique eliminates the drawbacks produced in previous methods from those generated due to irradiation variation and temperature variation.

A. PV Module

As the temperature increase, the efficiency of a photovoltaic module decreases. Only a part of the irradiance from the event is reborn as electric power.

The rate of increase in cell temperature is a result of the incoming light, which is referred to as short wave emission q_{sw}, long wave radiation qlw, heat converting to an environment q_{conv}, and power output pout.

It can be stated to:

$$C_{module}\frac{dTm}{dt} = q_{sw} - q_{lw} - q_{conv} - P_{out} \quad \text{eq.1}$$

B. Controller Reference Generation

Under all ambient circumstances, we do not get maximum power. As a result, the temperature of the module will be utilized as the regulated signal, which will be chosen to deliver the best power output at a received environmental temperature.

Run a designed module to determine the best output power at every input ambient temperature. For this method, two factors are considered i.e. ambient temperatures and ultraviolet wavelength λ_{UV}.

The factors levels will consider are following

1) Ultraviolet ray's range is λ_{UV} 300nm - 430nm
2) The ambient temp range is 25 °C - 30°C.

After selecting maximum power at every ambient temperature, algorithm will start to generate the best linear fit for this PV temperature and ambient temperature where maximum power can be generated.

C. System Identification

Regardless of the control technique, the process must be identified. This is the most difficult step, system identification gives verify quality of the data. The input-output of system data required for the system identification.

After doing system identification we get a linearized function model of the PV system, compare that function model with the actual plant model to find the goodness of the linear model. It provides a figure that compares the actual model data to obtain the linear model.

D. Generating State-Space Model

To check the performance of system, necessary fact to provide physical constraints to system also from now on the constraints of the system we will be using are determined by the type of panel to be used in the simulation.By giving physical constraints to the MPC controller it becomes very easy for to MPC controller to achieve physical conditions of the PV module as well as decrease tuning time.

E. Model Predictive Control

Model predictive control (MPC) is a more advanced type of control system that can manage a system while also following a set of rules. The most important feature of MPC is its ability to optimize the current timeslot while also considering future timeslots. This is accomplished by optimizing a finite time, then implementing only the current timeslot and optimizing again. MPC is also capable to predict future actions and conduct control actions in response.

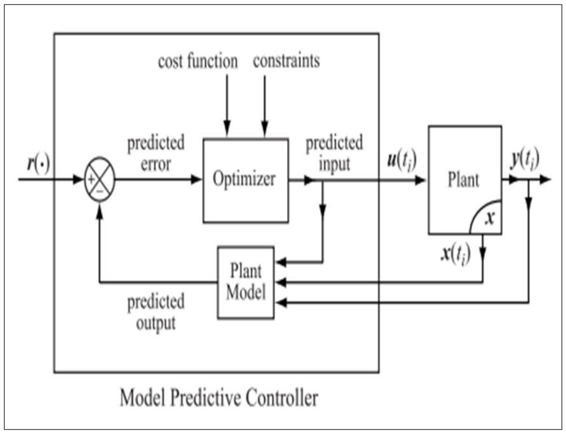

Fig. 6 MPC controller

A current measured output signal (mo), a reference signal (ref), and an optional measured disturbance signal (md) are fed into the MPC Controller block (md). The block solves a quadratic programming problem with a modified QP solver to find the optimal manipulated variable (mv).

Fig. 7 MPC controller block

IV. RESULTS AND DISCUSSION

Table 1.1 Characteristics of MPPT techniques

MPPT Tracking Technique	Efficiency	Tracking Speed	Cost	Complexity
Fractional Open Circuit Voltage	LOW	LOW	LOW	LOW
Fixed Voltage Techniques	MEDIUM	LOW	LOW	LOW
Perturb & Observe Technique	MEDIUM	MEDIUM	MEDIUM	MEDIUM
Increment Conductance Technique	MEDIUM	MEDIUM	MEDIUM	MEDIUM
Indirect adaptive control	HIGH	HIGH	HIGH	HIGH

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Simulation results and comparison of P & O, incremental conduction and indirect adaptive control techniques are shown below.

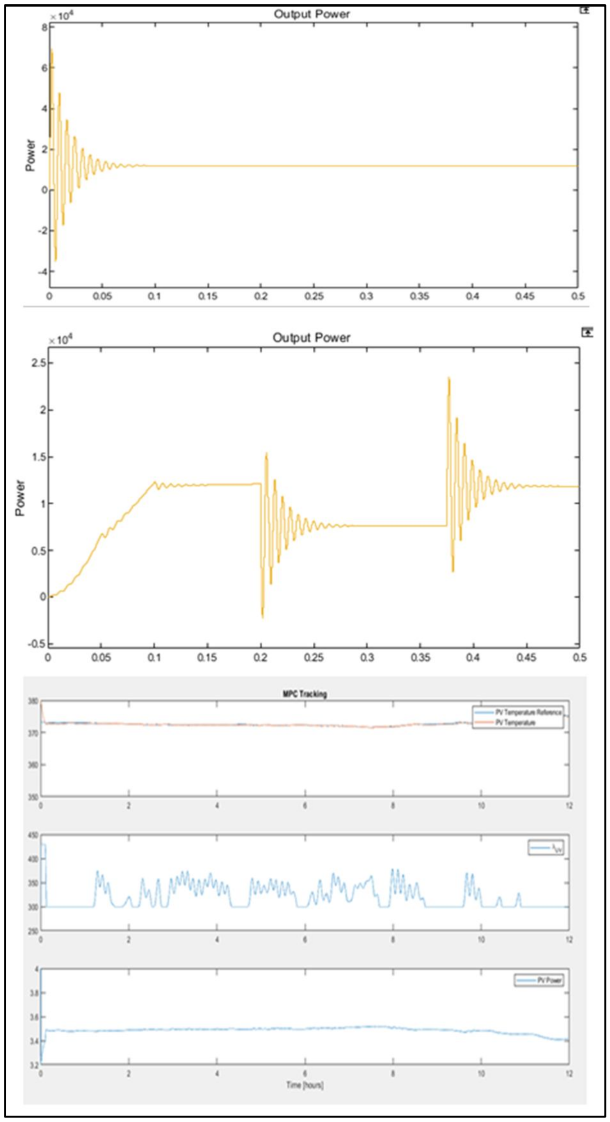

Fig. 8 simulation results of Top- P and O technique. Middle- Incremental conduction. Bottom- IAC technique

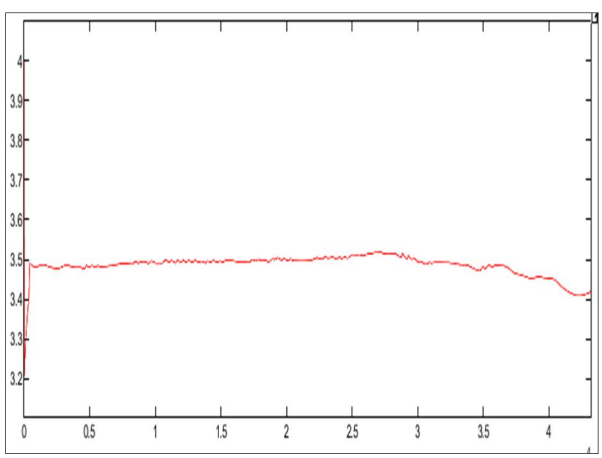

Fig. 9 Output power of photovoltaic cell of IAC

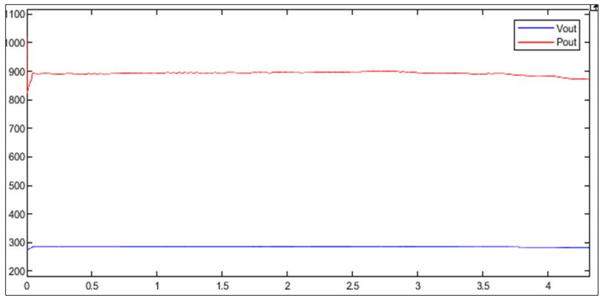

Fig. 10 Output power and voltage of a photovoltaic cell of IAC

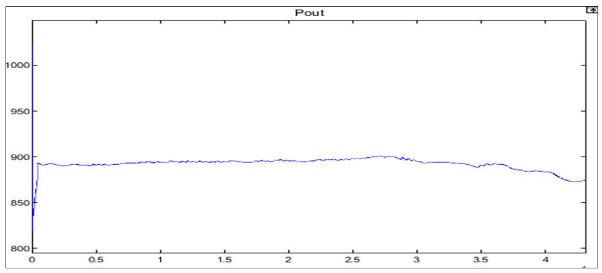

Fig. 11 Output power of photovoltaic array of IAC

V. CONCLUSION

In this paper new method is proposed for maximum power point tracking system to PV system named as indirect adaptive control technique, this is most advanced method among all the previous MPPT technique and better than tradition electricity generation method and also presented comparison IAC with other MPPT technique. The results show that this strategy is robust and effective in terms of performance improvement, stability, and accuracy. This also shows great increase in efficiency of photovoltaic modules.

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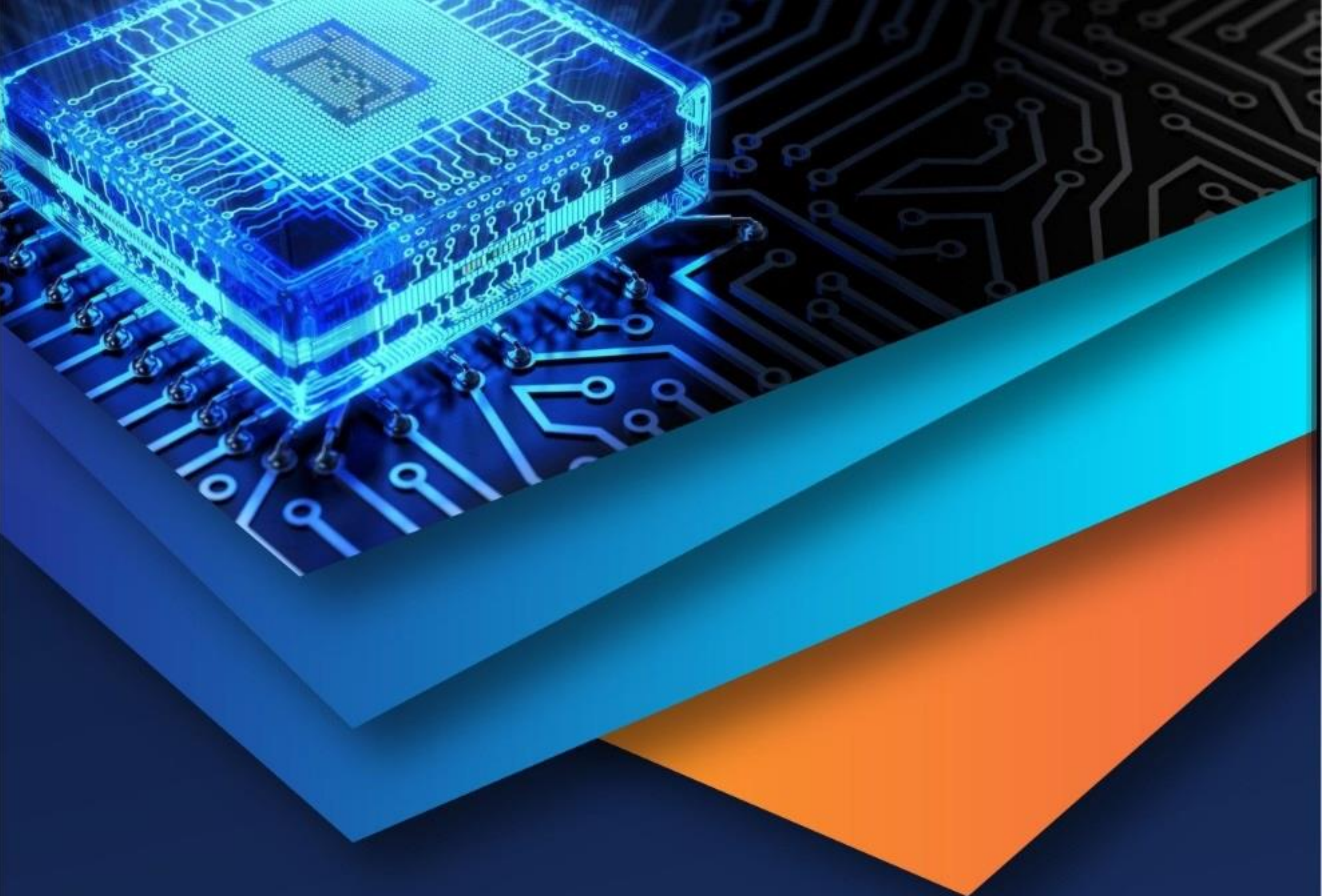

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