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Mitigation of Voltage by Using PV-Connected Super-Lift Luo Converter under Variation of Temperature

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Abstract: This paper focuses on application a special type of DC-DC Converter called Super-Lift Luo Converter for load voltage mitigation due to variation in temperature. The converter is fed by a PV(Photovoltaic) System as input and its output is converted to AC Voltage by a Cascaded H-Bridge Inverter and this is integrated with grid and connected to load. In this work, the Super-Lift Luo Converter performance is studied.
Keywords: Super-Lift Luo Converter, Temperature, PV Module, Cascaded H-Bridge Converter

I. INTRODUCTION

The limitations of non-renewable energy sources gave rise to demand on power generation through renewable energy sources like solar, wind, tidal etc. Out of these, solar has significant advantage such as its availability, can be installed anywhere near house, industry etc. The recent application of such energy sources is that they are integrated to an electrical grid, such a power system is known as Grid Integrated PV system or Grid tied PV System [7].

The advantages associated with such system is that the overall reliability of the power system is increased and whenever there are faults in grid, the PV system can provide sufficient power without affecting the functionality of the load. Also, whenever PV system generates more power some of it is fed back into the grid or it can be stored in batteries to use at some other time.

PV Systems are dependent on Temperature and Irradiation, the temperature changes throughout the day and its variability are especially observed during monsoons, such variability may cause variation in PV output voltage and this voltage cannot be directly fed into the grid and it must be regulated regardless of any temperature variation. For this purpose, a DC-DC Converter controlled in closed loop fashion must be used [13]. The regulation of DC output voltage of PV System regardless of variation in temperature, was already obtained by a special type of converter called Luo converter whose duty cycle is controlled in closed loop fashion [1], [2]. This regulated DC Voltage is fed as an input to Cascaded H-Bridge Multi-Level Inverter whose AC output voltage is used for grid integration [6], [10], [12]. The MLI is switched by using Multicarrier Pulse Width Modulation [5].

This paper mainly focuses on how such system operates, its performance is studied and it was observed that under how voltage is mitigated or maintained constant when a DC-DC Converter called Super-Lift Luo Converter is utilized [3], [4]. The advantage associated with this converter is that the size as well as energy storage components were reduced.

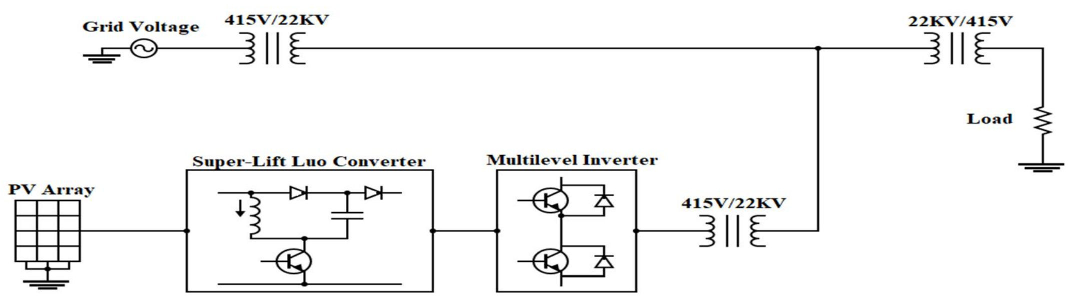

Figure 1: Block Diagram of Grid Integrated PV-Superlift Luo Converter-Multilevel Inverter System

The work is presented as follows: First, the design and modelling of PV Cell and Super-Lift Luo converter is studied. Then, the integration of such PV-Converter System to grid through a Cascaded H-Bridge Multilevel inverter is done and the performance is studied.

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II. DESIGN AND MODELLING OF PV CELL

The model of a PV Cell is as shown

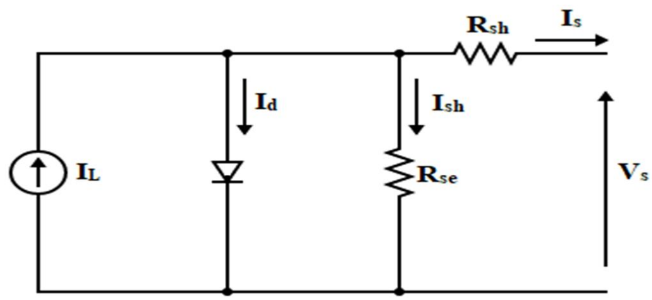

Figure 2: Model of PV Cell

The generated open circuit output voltage of a Solar PV System is given by following equation

$$V_{OC} = \frac{nkT}{q} \ln\left(\frac{I_L}{I_O} + 1\right)$$

Where, n = ideality factor of diode
k = Boltzmann constant (J/K)
T= Temperature (K)
I_L = Light generated current or Photovoltaic current (A)
I_o = Reverse saturation current of diode (A)
q = Charge of electron (Coulombs)
It can be seen that voltage increases linearly with temperature but the effect of variation reverse saturation current I_o with temperature is more than the linear dependency of voltage on temperature. So, the effect is decrease in voltage due to increase in temperature and vice versa.
The net output current of a PV system is given as

$$I_S = I_O - I_O\left(exp\left(\frac{q * V_S}{n * k * T}\right) - 1\right) - \frac{V + I * R_{SE}}{R_{SH}}$$

V_s = PV cell output voltage (V)
I_s = PV Cell output current (A)
R_{SE}=Series Resistance (Ω)
R_{SH}=Shunt Resistance (Ω)

III. DESIGN AND ANALYSIS OF PROPOSED SUPER-LIFT LUO CONVERTER

The demerits associated with normal luo converter are eliminated by using a super-lift luo converter. It is as shown

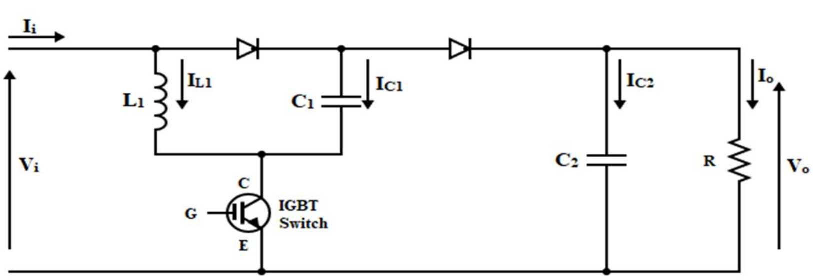

Figure 3: Circuit of Super-Lift Luo Converter

1) *Mode-1:* When switch is turned on, both Inductor L and Capacitor C1 are connected in parallel and diode D2 gets reverse biased. The Inductor and capacitor start to charge, while the output voltage is maintained constant by capacitor C2
2) *Mode-2:* When switch is turned off, the voltage across capacitor C1 cannot change instantaneously similarly the current through inductor L also remains constant. These current forward biases the diodes and connects the source to the load. The net effect is that load is supplied both by the source as well as by capacitor C1 with help of constant inductor current. The purpose of C2 is to maintain the output voltage constant

Analysis of Super-Lift Luo Converter:

Output Voltage, $V_O = \left(\frac{2-D}{1-D}\right) * V_i$

Gain factor for voltage transfer, $G = \frac{2-D}{1-D}$

Ripple in Inductor current, $\Delta i_L = \frac{V_O - 2*V_i*(1-D)}{f_S*L_1}$

Ripple in output voltage, $\Delta V_O = \frac{I_O*(1-D)}{f_S*C_2}$

Where,
V_i = Input Voltage (V)
I_i = Input Current (A)
D = Duty Cycle
f_s = Switching frequency (Hz)

IV. PROPOSED WORK

A. *Super-Lift Luo Converter*

The Super-Lift Luo converter performs same function as that of Luo converter i.e., when the temperature of PV System is varying in nature due to which the PV voltage also varies inversely proportional to temperature, in order to maintain a constant DC the super-lift Luo converter employs a closed loop control which takes the required DC voltage that is to be maintained to supply load irrespective of variation in temperature.

B. *Control Logic*

The Control logic that is implemented here consists of a PI Controller, to which, an error signal that is generated by difference between the reference signal and actual signal is given, the error signal is processed by the PI Controller and it generates an actuating signal which is in turn given to the 2-Level PWM Comparator which generates pulses of appropriate duty cycle depending on the input actuating signal.
The PI-Controller has P and I Controllers. P Controller reduces rise time and increases speed of response. The I-Controller eliminates Steady State Error.

Parameters of PI Controller:
K_P =0.0001
K_I =0.004

C. *Multilevel Inverter*

The Regulated DC Output Voltage of Super-Lift Luo Converter is fed to a inverter which is employed to convert DC into appropriate AC for the purpose of Grid integration. Here, also the Cascaded H Bridge Inverter is utilized here due to the advantages associated with it over other Multilevel Inverters like Reduced THD, Reduced number of diodes, capacitors and Reduced size
Multi-Carrier Sinusoidal Pulse Width Modulation is employed here to generate higher levels of AC Voltage
Due to the absence of oscillations and overshoots the switching losses of MLI are reduced.
Here, cascaded h-bridge converter produces 5 levels of ac output voltage.

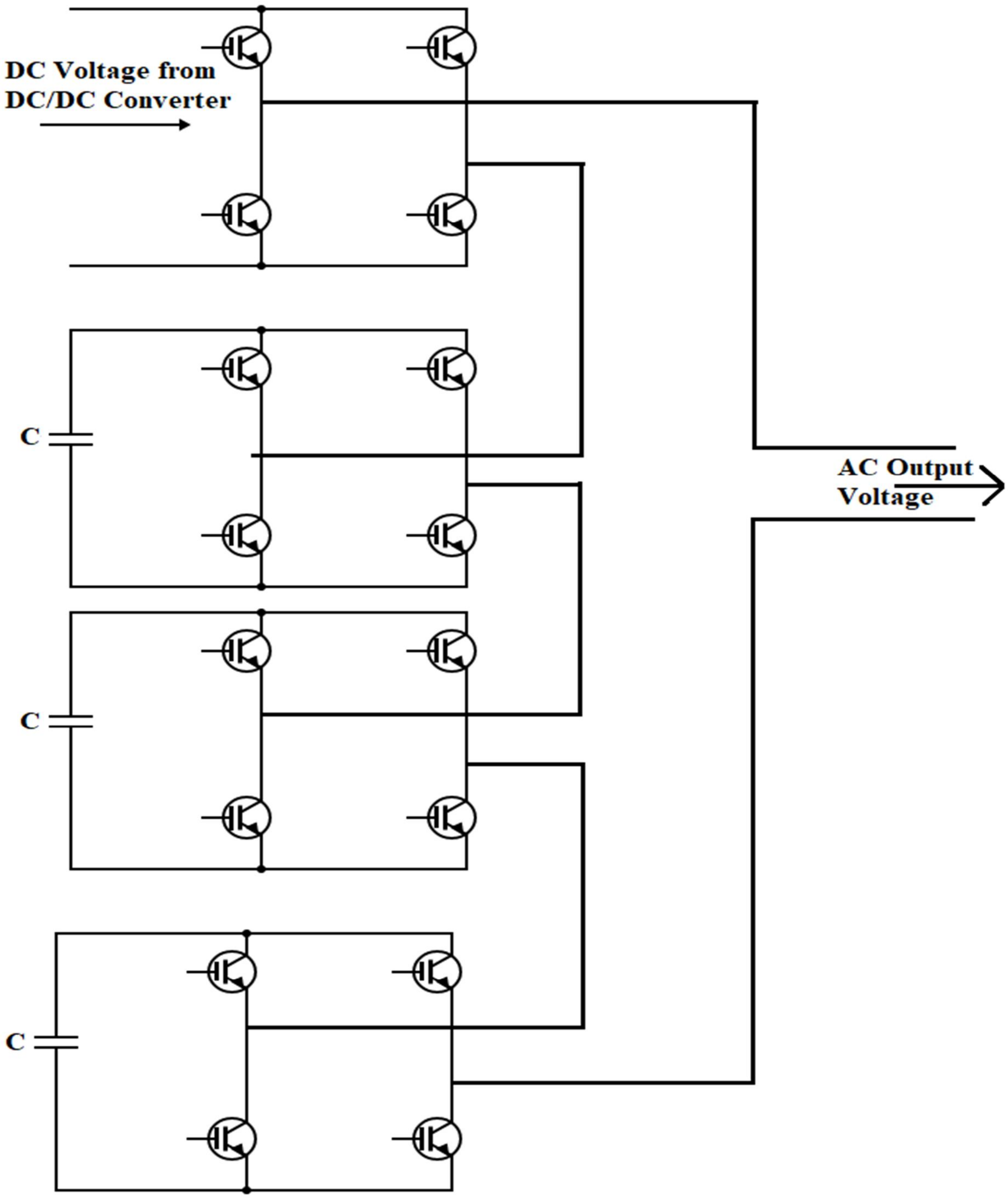

Figure 4: Circuit of Cascaded H-Bridge Multilevel Inverter

D. Grid Integration Design

The output of Multilevel inverter is connected to the grid through a LC Filter and a transformer.

The purpose of LC Filter is that, the output voltage of multilevel inverter is not purely sinusoidal, i.e., it contains harmonics so a LC Filter is connected to eliminate such harmonics.

The purpose of transformer is it will step up the voltage so that current flowing through transmission line reduces and the power loss is also reduced.

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V. SIMULATION RESULTS

The MATLAB/Simulink software has been utilized to simulate the results and the results obtained from Super-Lift Luo Converter are as shown

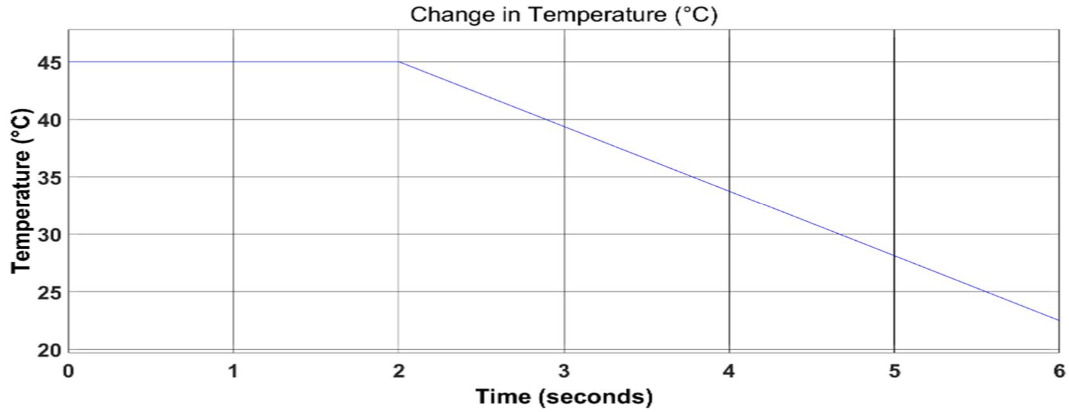

Figure 5: Change in Temperature

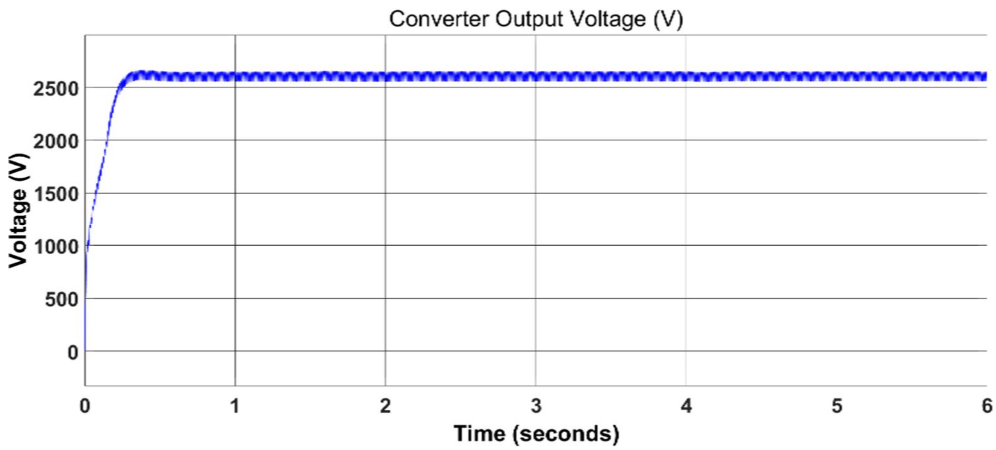

Figure 6: Converter Output Voltage

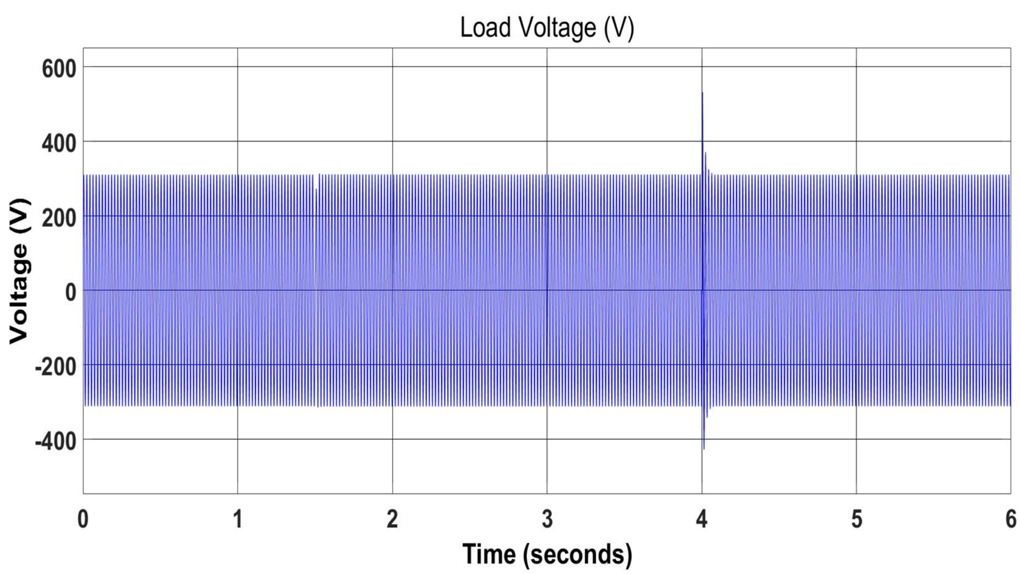

Figure 7: Load Voltage

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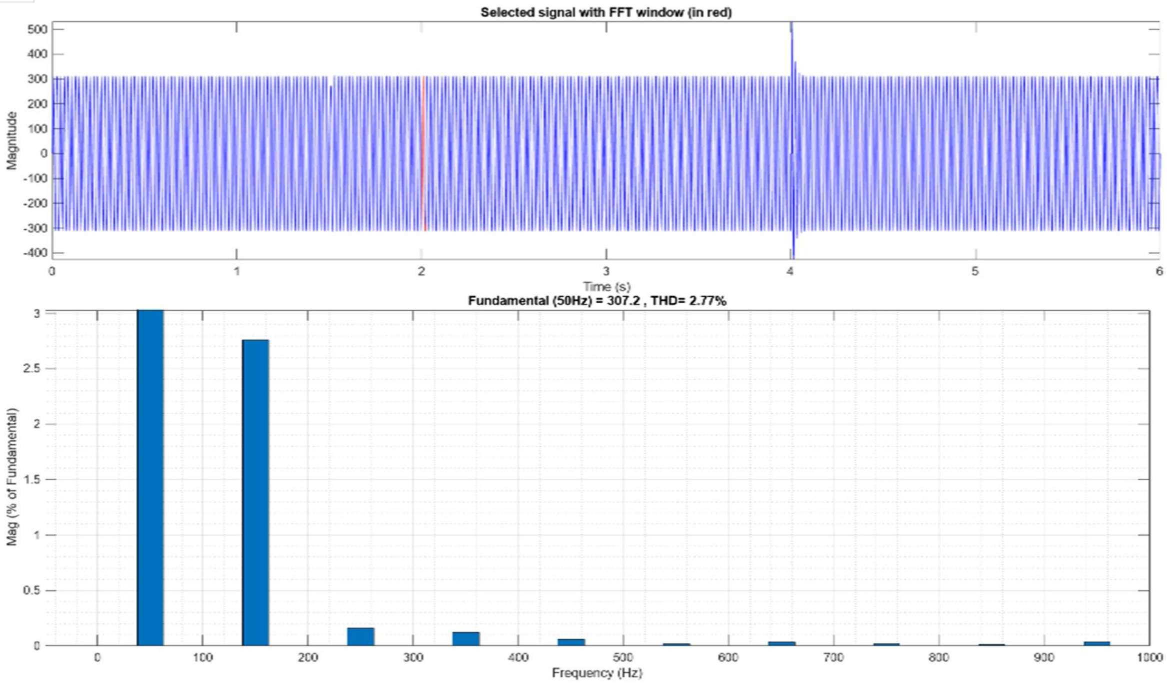

Figure 8: %THD in Load Voltage

VI. PARAMETERS

Parameters	Super-Lift Luo Converter
Inductor L1 (H)	0.025
Capacitor C1 (F)	0.0002
Capacitor C2 (F)	0.0002
Switching frequency of converter fs (Hz)	1000
Grid Frequency f (Hz)	50
Transformer Rating	415V/22KV
Load Resistance (Ω)	1000

VII. OBSERVATIONS

	Luo Converter	Super-Lift Luo Converter
%THD	3.8%	2.77%

VIII. CONCLUSION

Hence, from above simulation results it can be inferred that it was proposed to use a Super-Lift Luo Converter which employs reduced number components, reduced size of components its effect is the regulated output DC voltage performance is improved. Due to the improvement in Performance of DC Output Voltage the Load Voltage was also improved and %THD is reduced.

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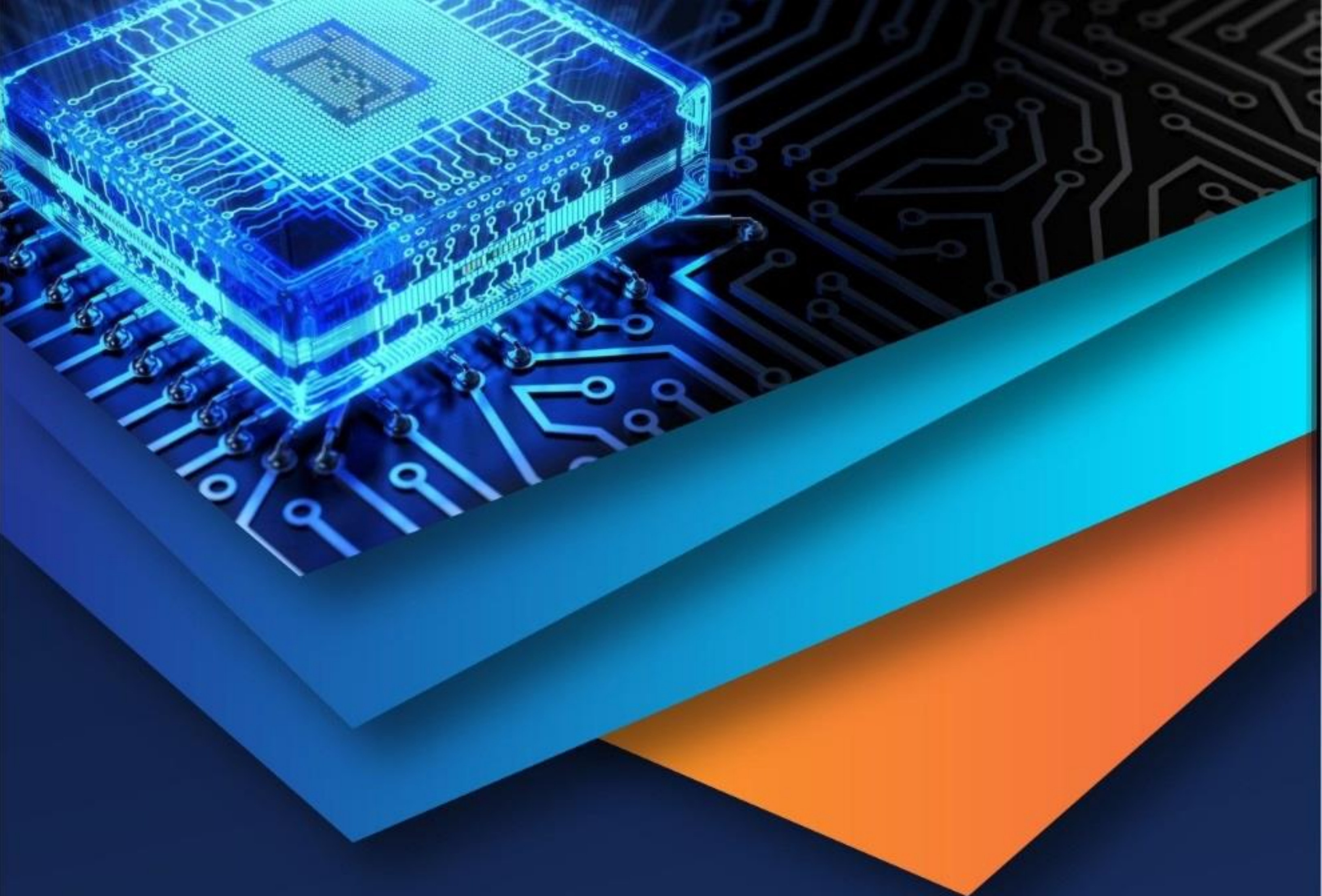

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