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CUK-SEPIC Hybrid Converter

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Abstract: Electricity derived from renewable energy sources are unpredictable and intermittent in nature. Continuous power supply is a challenging task, obtained by maximum utilization of two or more resources resulting in a hybrid system. This work proposes a fused converter topology for a hybrid solar/wind system extracting maximum power. The hybrid configuration permits the sources to feed the load individually or simultaneously based on its availability. The proposed converter is the integration of Cuk and SEPIC converter. The characteristic feature of Cuk-SEPIC Hybrid converter is that it provides uninterrupted and constant voltage to dc micro grid applications. The suitability of proposed system at practical operation condition is demonstrated through simulation result using MATLAB/Simulink followed by an experimental validation
Keywords: cuk-sepic hybrid converter, Renewable Energy, Hybrid System

I. INTRODUCTION

Electricity is very much essential for our day to day activities. Nowadays, due to scarcity of fossil fuels, and discharge of greenhouse gasses, green energy such as solar, wind, biomass, geothermal, etc., comes into play. Research also has been focused on harvesting green energy. Green energy reduces the emission of greenhouse gasses, global warming and is pollution free. Among various green energies, Solar and wind energy have experienced a prompt growth in recent years.

They have unpredictable random behaviors, but complementary profiles. Hence there comes the necessity for a hybrid system for the extreme utilization of sources.

Hybrid systems are more beneficial and reliable than isolated systems of power generation. When there is failure in one system, the other source generates power and satisfies the demand. In the proposed work, a solar/wind hybrid power generation system model is simulated for household application.

Solar and wind systems along with fuel cells are proposed for residential applications. Solar and fuel cells are integrated for distributed generation applications. Power converters are essential for power management between sources and load. A boost converter is used in hybrid systems for continuous power supply.Multi input fused converters reduce the number of components, dimension and rate of the converter.

It also reduces the complexity of the system and supplies load either individually or together depending on the availability of resources. Multi input converter topology is proposed for diversification of energy in a hybrid system .CUK-SEPIC converter is used for producing continuous power for a hybrid system.

The main objective of the proposed work is to obtain continuous power, satisfying the load demand effectively. An integrated positive output Cuk-SEPIC converter topology fed by solar and wind energy systems is proposed to supply power continuously to the load based on the availability of the resource.

The advantages of cuk sepic hybrid converter compared to traditional approach are Two boost converters are replaced by single CUK-SEPIC fused converters, it provides Regulated DC output voltage at higher efficiency ,Continuous power generation, Reduce ripple currents ,Reduce switching losses, simple structure and reduced converter components, supports wide ranges of PV and wind input, low input current distortion, Improved conversion efficiency using P & O algorithm.

II. BLOCK DIAGRAM OF CUK-SEPIC HYBRID CONVERTER

The intensity of the sun does not exist throughout the day, likewise the wind speed will not be heavy for the whole day. Hence, for uninterrupted power supply a distinct source cannot be an enhanced option.

The hybrid combination harvests power from both sun and wind and stores the excess energy in the battery. So that the battery delivers the load even in the absence of sunlight or wind. Hybrid systems are employed for low cost and are more reliable.

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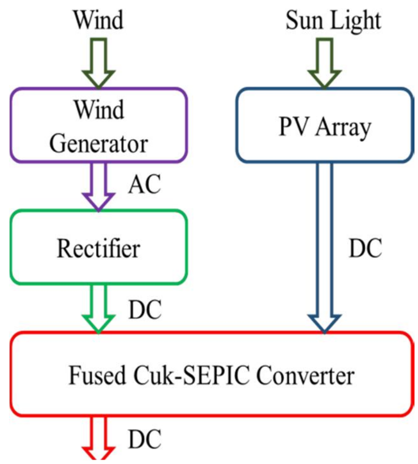

Fig1:Block Diagram of CUK SEPIC Hybrid Converter

The block diagram of the solar/wind hybrid system is presented in figure 1. Solar energy and wind energy are the inputs to the DC/DC converter. The proposed converter is the fusion of Cuk and SEPIC converters. It eliminates the need for a separate passive filter and provides uninterrupted power supply.

III. MPPT CONTROL

Maximum power point tracking (MPPT) is a technique that grid connected inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices, typically solar panels, though optical power transmission systems can benefit from similar technology. Solar cells have a complex relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency which can be analyzed based on the I-V curve. It is the purpose of the MPPT system to sample the output of the cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions. Perturb and observe is the most commonly used MPPT method due to its ease of implementation. In This method, the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This is called the perturb and observe method and is most common.

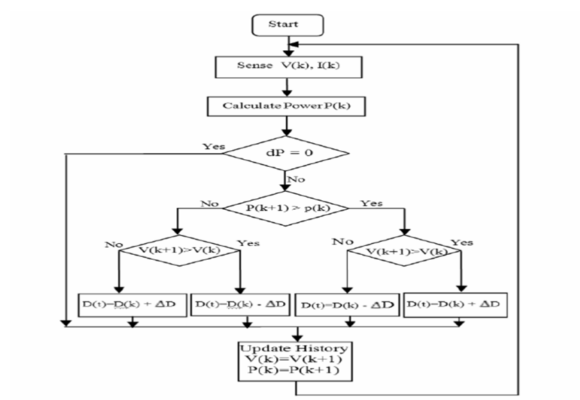

Fig2: P & O Algorithm flowchart

IV. CUK-SEPIC HYBRID CONVERTER

DC/DC converters act as switched regulators used to convert an irregular DC input to a controlled DC output. Cuk and SEPIC converters are types of DC/DC converter that helps to increase or decrease the input voltage. Both converters can perform boost and buck operations. Cuk converter has negative polarity, whereas SEPIC converter has positive polarity in the output. Fused converters shrink the number of components used in the circuit, which in turn lessens the cost of the converter. Moreover, it filters high frequency harmonics too. In the proposed work, Cuk and SEPIC converters are fused together to form a fused Cuk-SEPIC converter.

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The diodes of each converter are rearranged and the output inductor and capacitor are shared between the two converters. The equivalent circuit of the fused Cuk-SEPIC converter is exposed in figure 2. Based on the availability of resources, the proposed converter supplies the load.

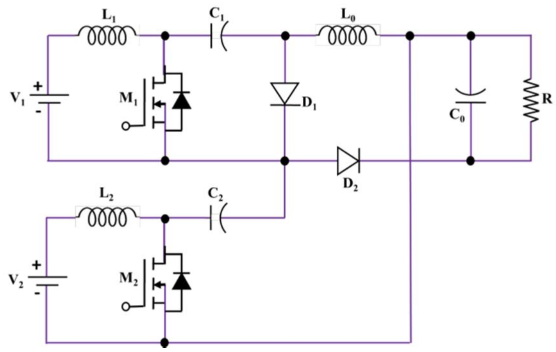

Fig 3:Circuit diagram of CUK SEPIC Hybrid converter

Let V 1 and V 2 be the DC output voltages from the solar and wind system respectively. MOSFET M 1 and M 2 act as switches to connect solar and wind systems. The various operating modes of fused Cuk- SEPIC converter are briefed below.

A. Operating Modes Of Cuk-Sepic Converter

1) *Mode 1:* Both sources are active, In this mode, both solar and wind systems are active for the generation of power. In this mode, switches M 1 and M 2 are ON and diodes D 1 and D 2 are in reverse biased condition. The supply voltages V 1 and V 2 charge the inductors L 1 and L 2 respectively. The capacitors C 1 and C 2 start discharging to charge inductor L 0 which in turn charges the capacitor C 0. The equivalent circuit when both sources are active is shown in figure 4.

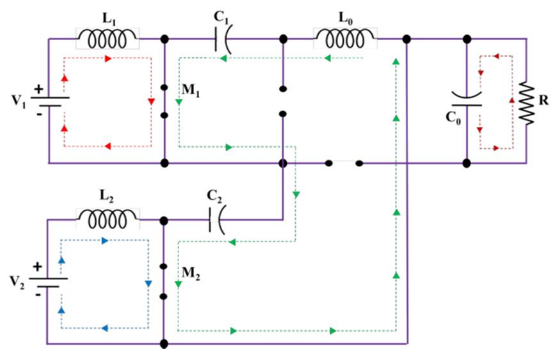

Fig 4 : Mode I Equivalent Circuit

2) *Mode 2:* Only solar source is active, In this mode, only the solar system is active for power generation. Here, switch M 1 is ON and switch M 2 is OFF. Diode D 2 is forward biased and D 1 in reverse biased conditions. The Inductor L 1 is charged by the solar voltage V 1 . The capacitor C 2 discharges through the diode D 2 and charges the inductor L 2 . Meanwhile, capacitor C 1 starts discharging and charges the inductor L 0. Figure 5 below shows the equivalent circuit during the presence of a solar source alone.

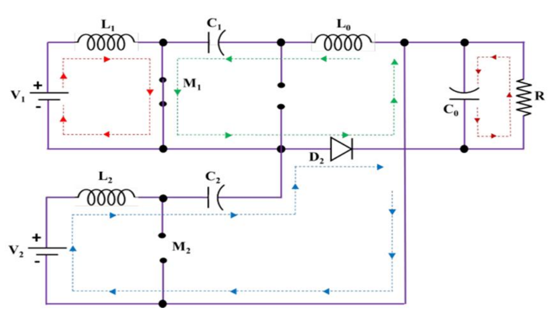

Fig 5: Mode II Equivalent Circuit

3) *Mode 3:* Only wind source is active, In this mode, only the wind system is active for power generation. In this mode, switch M 2 is ON while switch M 1 is OFF. Diode D 1 is forward biased and D 2 in reverse biased conditions. Here the inductor L 2 is charged by the wind voltage V 2. The capacitor C 1 discharges through the diode D 1, thereby charging the inductor L 1 . Meanwhile, the capacitor C 2 discharges and charges the inductor L 0 Figure 6 below shows the equivalent circuit during the presence of a wind source alone.

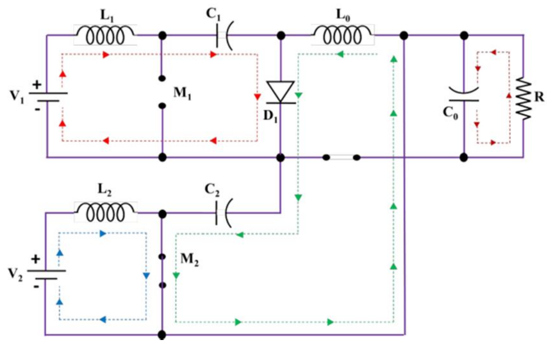

Fig 6: Mode III Equivalent Circuit

4) *Mode 4:* Both sources are inactive, In fourth mode, both the sources are not connected to the system for power generation. Here, switches M 1 and M 2 are OFF and diodes D 1 and D 2 are in forward biased condition. The inductor L 1 discharges through the diode D 1 due to which the capacitor C 1 is charged. Inductor L 2 discharges through the diode D 2, thereby charging the capacitor C 2. At the same time, inductor L 0 discharges to charge the capacitor C 0, thereby feeding the load R. The equivalent circuit during the absence of both solar and wind sources are shown in figure 7 below.

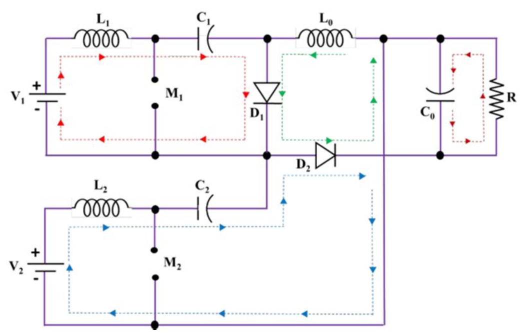

Fig 7: Mode IV Equivalent Circuit

V. DESIGN EQUATIONS

The DC output voltage can be calculated as follows:

Vpv–PV array voltage

Vw–Voltage occurs when wind source is available

D1–Duty ratio of switch

M1D2–Duty ratio of switch

M2Fs-Switching frequency

Ts–Switching period

The net change in the inductor current L1 is zero

(ΔiL1)closed=VpvL1∗D1∗Ts (1)

(ΔiL1)open=VpvL1∗(1−D1)∗Ts (2)

(ΔiL1)closed+(ΔiL1)open=0 (3)

$$V_{c1} = V_{pv}/(1 - D_1) \quad (4)$$

The net change in the inductor current L3 is zero

$$(\Delta i_{L3})_{closed} = \left(\frac{V_w}{L_3}\right) * D_2 * T_s \qquad (5)$$

$$(\Delta i_{L3})_{open} = \left(\frac{V_w - V_{c2} - V_{dc}}{L_3}\right) * D_2 * T_s \qquad (6)$$

$$(\Delta i_{L3})_{closed} + (\Delta i_{L3})_{open} = 0 \qquad (7)$$

$$V_{c2} = \left(\frac{V_w}{(1-D_2)}\right) - V_{dc} \qquad (8)$$

The average voltage across inductor L2 is zero

$$(V_{c1} + V_{c2}) * D_1 * T_s + (V_{c2}) * (D_2 - D_1) * T_s + (1 - D_2)(-V_{dc}) = 0 \qquad (9)$$

Substituting equation (4) and (8) in (9)

Then V_{dc} is given by

$$V_{dc} = \left(\frac{D_1}{1-D_1}\right) * V_{pv} + \left(\frac{D_2}{1-D_2}\right) * V_w \qquad (10)$$

Thus from the above equation it is observed that the DC link voltage Vdc is controlled by controlling duty cycles D1 and D2 simultaneously or individually.

Design of L and C components

The inductor values L1, L2, and L3 are given by:

$$L_1 = V_{pv} * \left(\frac{D_1}{\Delta i_{L1} * F_s}\right) \qquad (11)$$

$$L_2 = (1 - D_1) * \left(\frac{R}{2 * F_s}\right) \qquad (12)$$

$$L_3 = V_w * \left(\frac{D_2}{\Delta i_{L3} * F_s}\right) \qquad (13)$$

The capacitors C1, C2, and C3 are given by:

VI. SIMULATION DIAGRAM AND RESULTS

The simulation model of Hybrid Cuk-SEPIC converter based solar/wind hybrid system is presented in figure. The solar and wind sources are connected to the hybrid Cuk-SEPIC converter. A battery is connected at the output of the converter to store excess energy. The converter provides continuous power to the load either with the help of solar source or wind source or battery based on the availability.

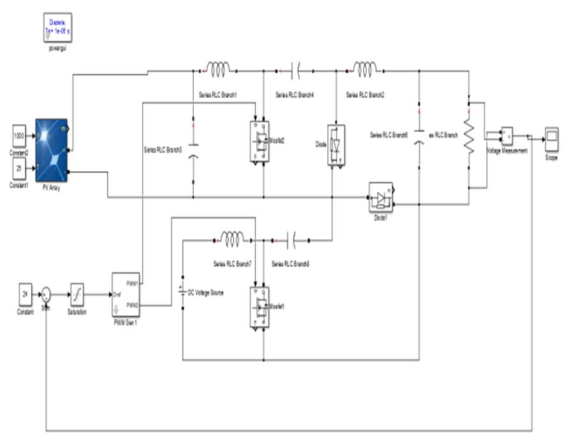

Fig 8: Simulation diagram of CUK SEPIC Hybrid Converter

The solar module produces an output voltage of 630V and current of 1.8A as shown in figure .Likewise the wind module produces an output voltage of 400V and current of 11A as shown in figure. The output from solar and wind modules are fed to the Hybrid Cuk-SEPIC converter. The proposed fused Cuk-SEPIC converter produces an output of 530V and 2.4A

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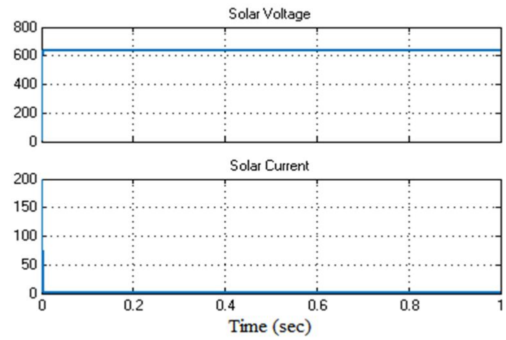
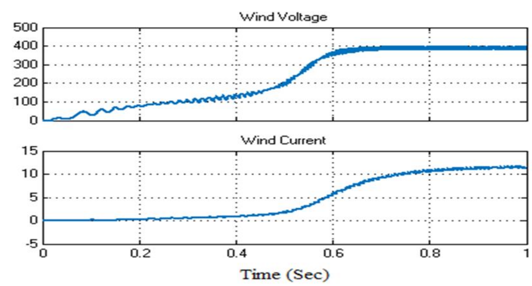


Fig9: Solar Voltage and Current



Wind Voltage and Current

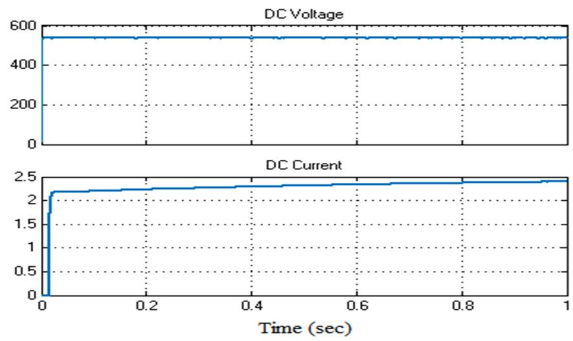


Fig 10: Hybrid Cuk-SEPIC Converter Output

VII. HARDWARE IMPLEMENTATION

The hardware prototype of the Hybrid Cuk-SEPIC converter based solar/wind hybrid system is displayed in figure. For hardware implementation, DC generator is used instead of solar panel and wind turbine. The inductor and capacitor values used in Hybrid Cuk-SEPIC converter are taken as 20mH and 470μF respectively. A lamp is considered as the load. The lamp keeps on glowing continuously receiving power either from solar panel or DC generator or battery. Thus continuous power is generated by the proposed Cuk-SEPIC Hybrid converter.

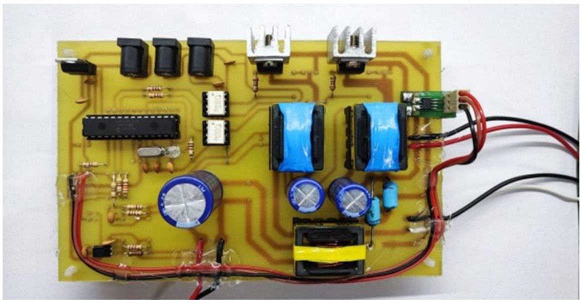


Fig 11 :Hardware Prototype

VIII. CONCLUSION

A Cuk-SEPIC Hybrid converter topology has been proposed for solar/wind hybrid energy systems. Two separate DC/DC converters are integrated together, so that the count of components, size and complexity of the system is reduced. The proposed converter allows both the solar and wind sources to feed the load separately or combined together based on the accessibility. The battery supplies the load in the absence of solar and wind sources. Thus, uninterrupted power is attained due to the proposed HybridCuk-SEPIC converter topology. Hardware implementation has been done to verify the performance of the proposed Cuk-SEPIC converter. The proposed system finds its applications in domestic purposes like street lighting, traffic signals, pump irrigation systems and various communication and monitoring systems. The proposed hybrid system is applied for remote area power generation and rural electrification.

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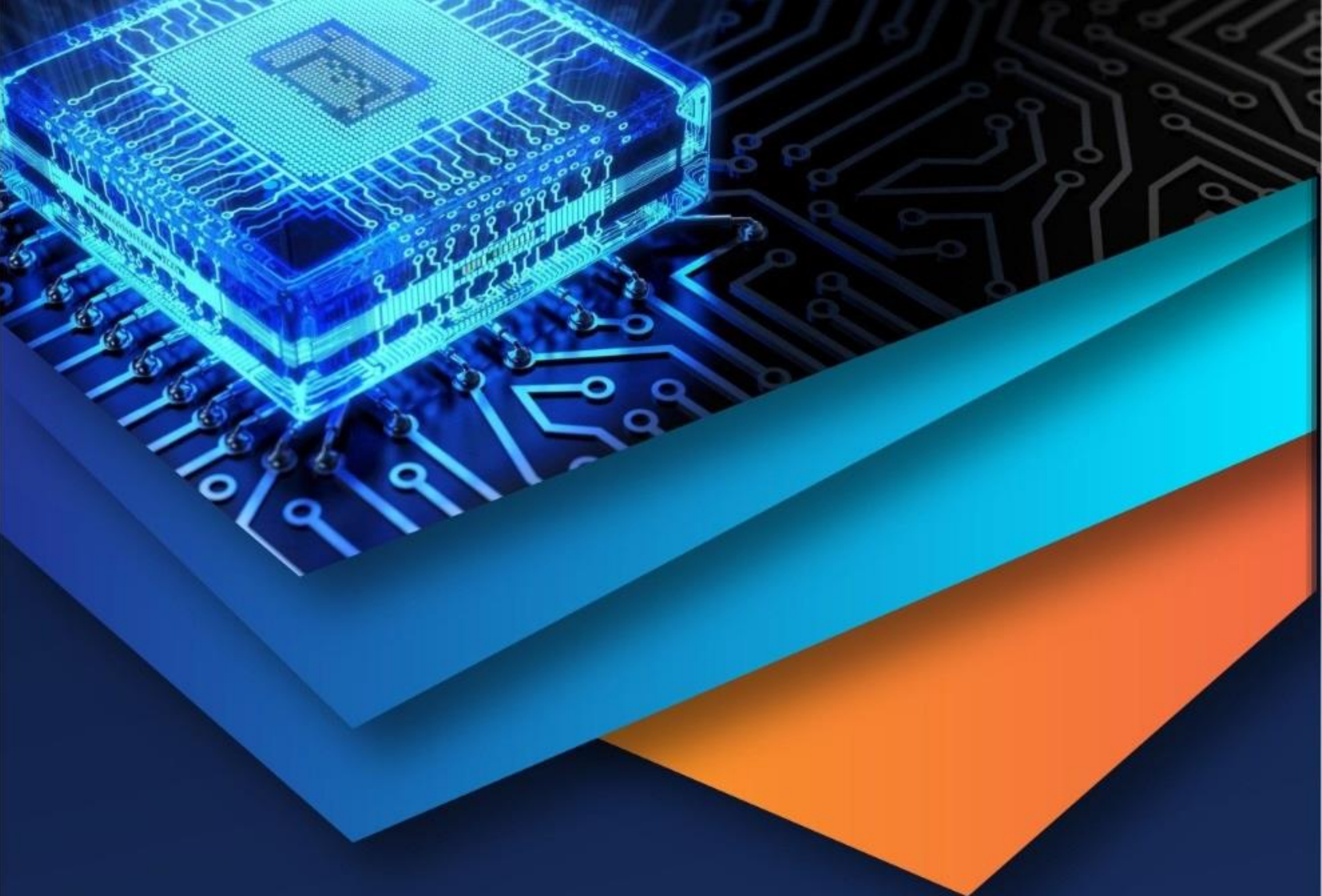

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