iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: IX Month of publication: September 2023

DOI: https://doi.org/10.22214/ijraset.2023.55933

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue IX Sep 2023- Available at www.ijraset.com

Stabilization of Load Voltage under Fault Condition by Using Grid Integrated PV Fed Super Lift Luo Converter

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Abstract: This paper focuses on performance of a DC-DC Converter called Super-Lift Luo Converter for load voltage stabilization during faults as well as during variation of temperature. The converter which is fed by a PV System as input stabilizes the DC output voltage during variation of temperature which is fed to a multilevel inverter where it gets converted to AC Voltage and this converter also improves voltage quality on AC Side during fault condition. In this work, first a normal Luo Converter performance is analyzed under fault conditions and then the Super-Lift Luo Converter performance is studied.
Keywords: Luo converter, Super-Lift Luo Converter, Fault, Transients, Oscillations

I. INTRODUCTION

Power generation by utilizing renewable energy sources like solar, wind etc. have overcome the many setbacks and disadvantages associated with conventional energy sources. The majorly utilized renewable energy source is Solar PV System due to the advantages it provide like its available everywhere, 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 [8].

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.

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 [14].

The regulation of DC output voltage of PV System regardless of variation in temperature, was already obtained by using Luo converter and Super-Lift Luo Converter where the mitigation is provided by controlling duty cycle by utilizing a closed loop control [1] , [3].

his regulated DC Voltage is fed as an input to Cascaded H-Bridge Multi-Level Inverter whose AC output voltage is used for grid integration [7], [11], [13]. The MLI is switched by using Multicarrier Pulse Width Modulation [6].

This paper mainly focuses on how such system operates when a fault occurs on the transmission lines on grid side, its performance is studied and it was observed that under fault conditions due to the size and increased number of components in Luo converter transients were introduced into the PV System, this in turn led to increased settling time of Regulated DC Output voltage, Overshoots as well as Oscillations and Steady state error were also introduced into the DC Voltage [16]. These oscillations and less steady state accuracy made their way into the load. This resulted in oscillations as well reduction in load voltage.

To overcome such disadvantage a more advanced configuration or DC-DC Converter called Super-Lift Luo Converter is utilized [4], [5].

The advantage associated with this converter is that the size as well as energy storage components were reduced due to which no transients were introduced into PV System and PV System is protected [15].

Due to the absence of input transients the overshoots, oscillations, steady state error were all eliminated and DC Voltage is regulated at required. The response time is also reduced. This led to enhancement of Load voltage along with eradication of oscillations in the Load Voltage.

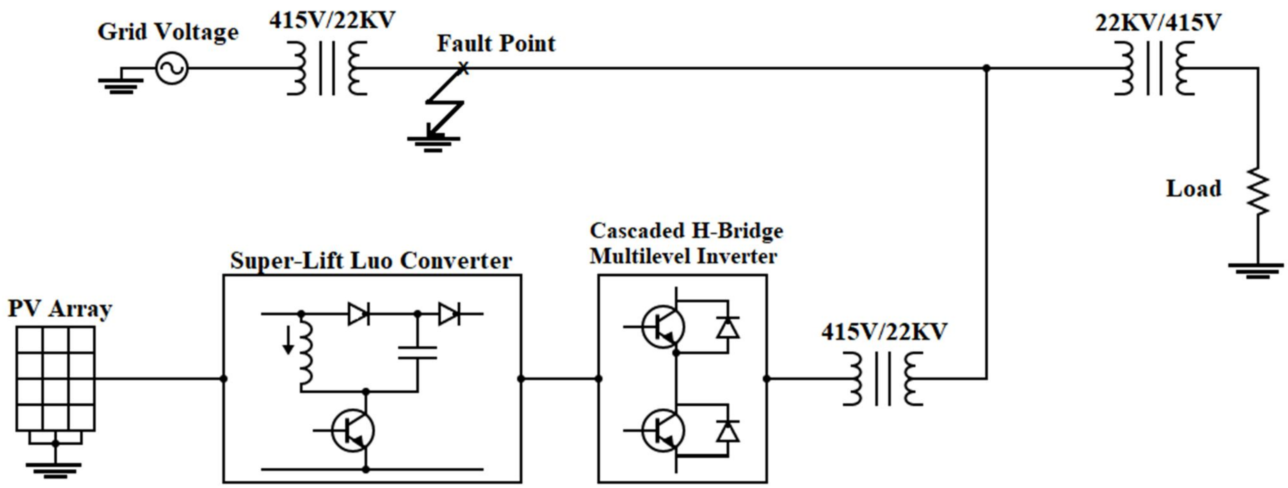

Figure 1: Block Diagram of Grid Integrated PV-Super lift Luo Converter-CHMLI System

Here, two conditions are considered they are i) Variation of temperature ii) Occurrence of fault and the Performance of Luo converter is studied under both these conditions occurring at the same time, its performance is compared with the performance of Super-Lift Luo Converter

II. DESIGN AND MODELLING OF PV CELL

The model of a PV Cell is as shown

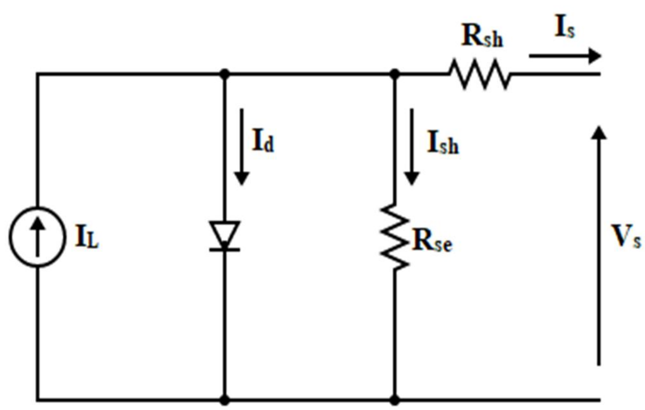

Figure 2: Model of PV Cell

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)

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III. DESIGN AND ANALYSIS OF LUO CONVERTER

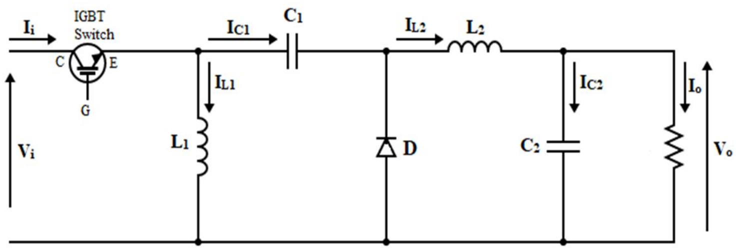

Figure 3: Circuit of Luo Converter

Mode-1: When switch is turned on, the current flows through inductor L1 and current is supplied by both source and capacitor (as it is initially charged to Vo when no switch was turned on) to the inductor L2.
Mode-2: When switch is turned off, since current direction cannot change instantaneously the current through L2 and C2 freewheels through diode D and capacitor C1 supplies current to L1

Analysis of Luo Converter:

The Output Voltage is given as , $V_O = \frac{D*V_I}{1-D}$

Output Current is , $I_O = \frac{1-D}{D} * I_I$

The Voltage gain is given as , $G = \frac{D}{1-D}$

Ripple in output voltage, $\Delta V_O = \frac{D*V_O}{8*G*f_S^2*C_2*L_2}$

Ripple in Inductor 1 current, $\Delta i_{L1} = \frac{D*V_I}{f_S*L_1}$

Ripple in Inductor 2 current, $\Delta i_{L2} = \frac{D*V_I}{f_S*L_2}$

Ripple in Capacitor 1 Voltage, $\Delta V_{C1} = \frac{(1-D)*I_I}{C_1*f_S}$

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

IV. 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

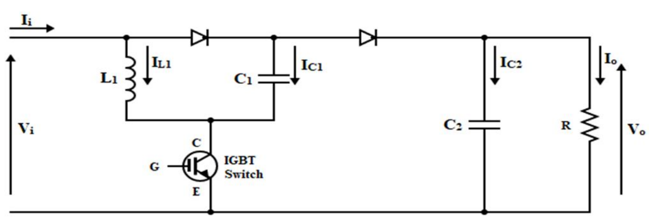

Figure 5: Circuit of Super-Lift Luo Converter

Mode-1: When switch is in ON State, 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

Mode-2: When switch is in OFF State, 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, $\Delta V_O = \frac{I_O*(1-D)}{f_S * C_2}$

V. PROPOSED WORK ON STABILIZATION OF LOAD VOLTAGE UNDER FAULT USING GRID INTEGRATION AND SIMULATION RESULTS

The Super-Lift Luo Converter similar to a Luo Converter maintains constant DC Output Voltage under variation of temperature, however the difference between both the converters occurs while stabilization of voltage under fault condition

The differences are

1) A Super-lift Luo converter always acts in boost mode of operation
2) Transients are not introduced into PV system due to reduced number as well as size of Inductors and Capacitors. Therefore, PV System is protected
3) Fast settling time as well as no overshoots and oscillations in the regulated DC Output.

A. *Simulation Results*

The above advantages can be better illustrated from the results obtained. The MATLAB/Simulink software has been utilized to simulate the results and the results are shown in two parts. Part 1 shows the results obtained from ordinary Luo Converter whereas Part 2 shows the results obtained from Super-Lift Luo Converter

1) CASE-I: LUO CONVERTER IS USED

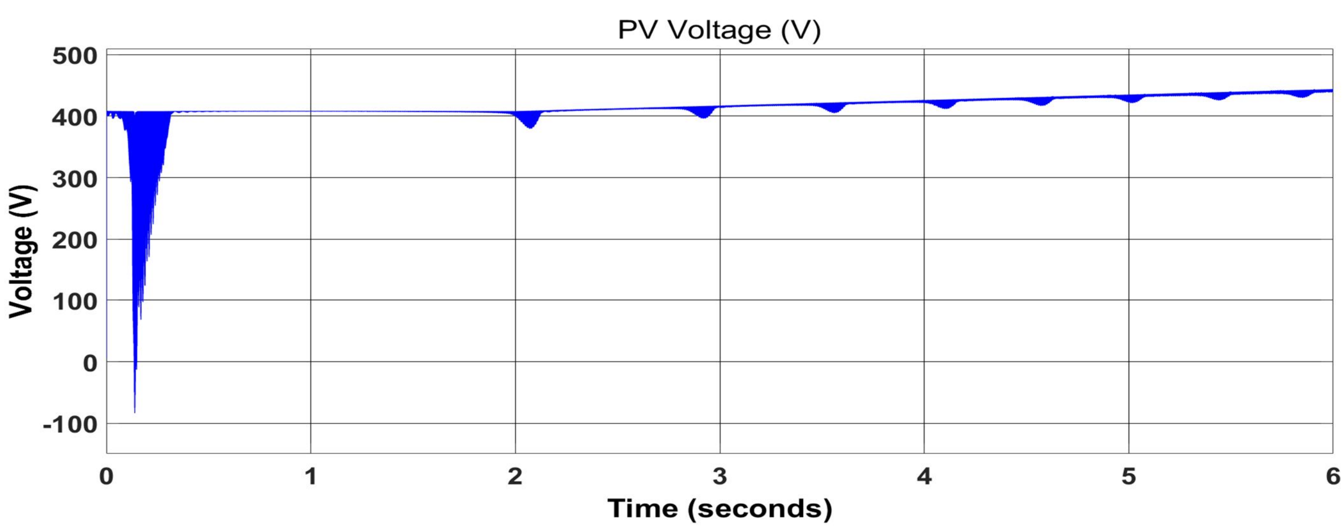

Figure 6: PV System Voltage

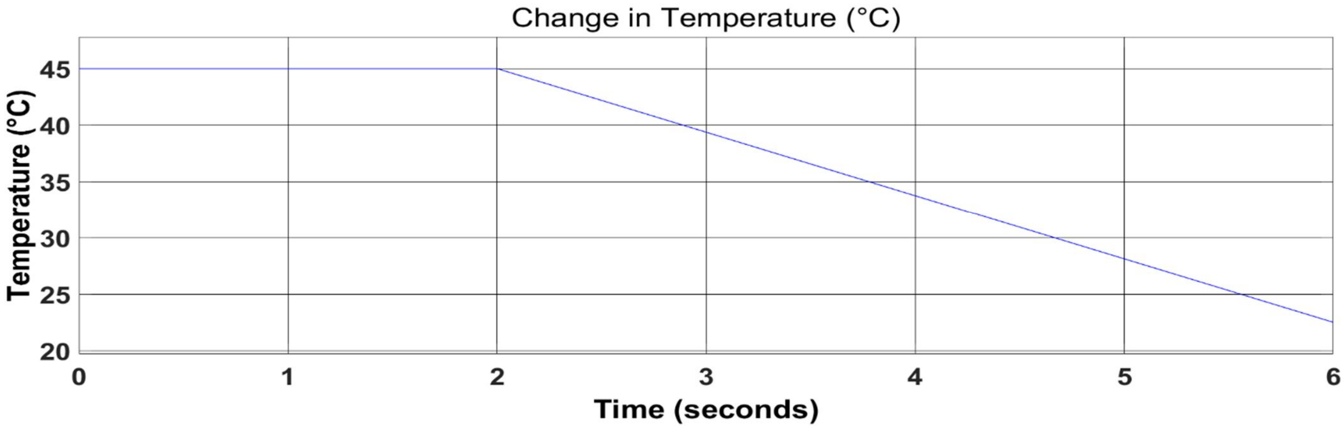

Figure 7: Change in Temperature

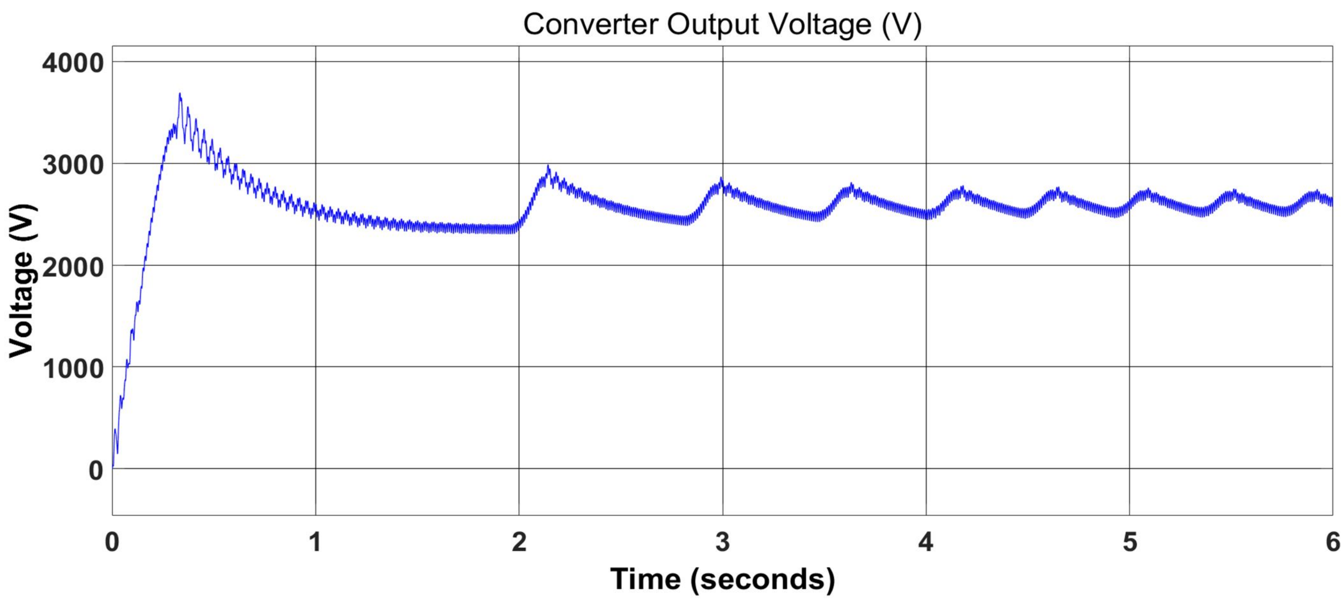

Figure 8: Converter Output Voltage

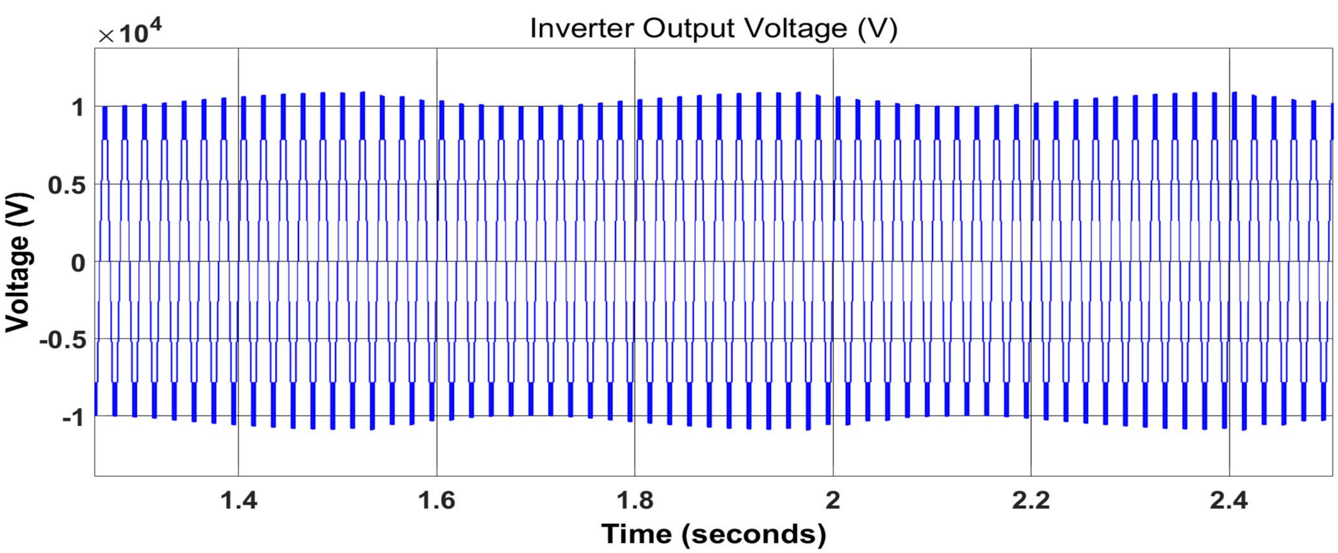

Figure 9: Inverter Output Voltage

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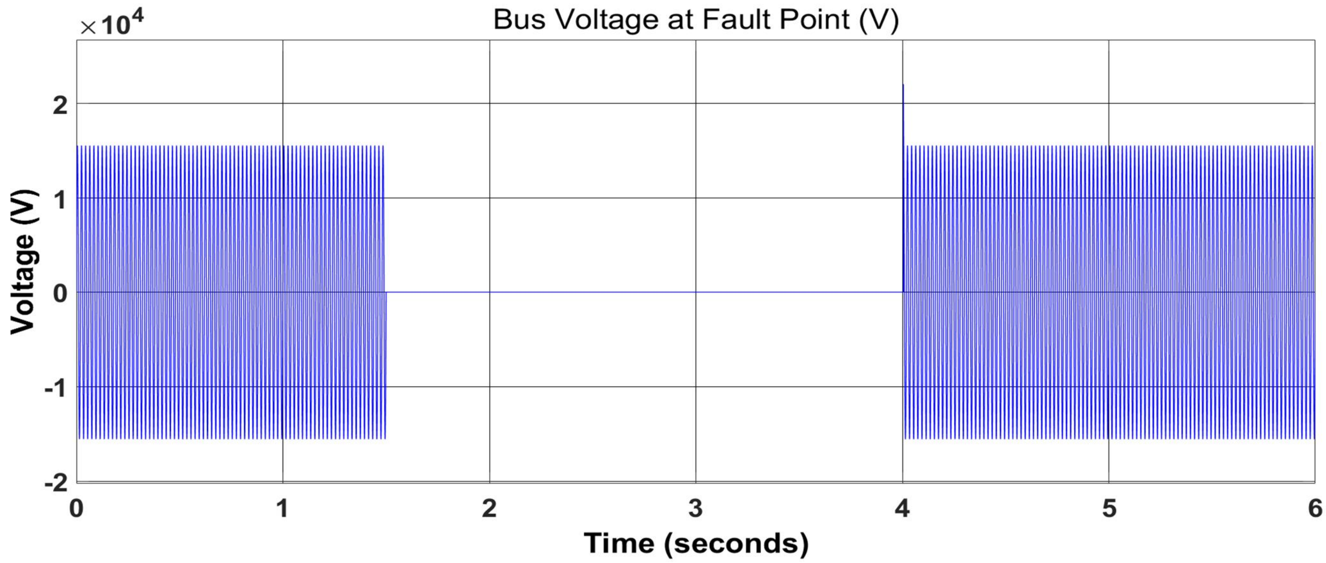

Figure 10: Bus Voltage at Fault Point

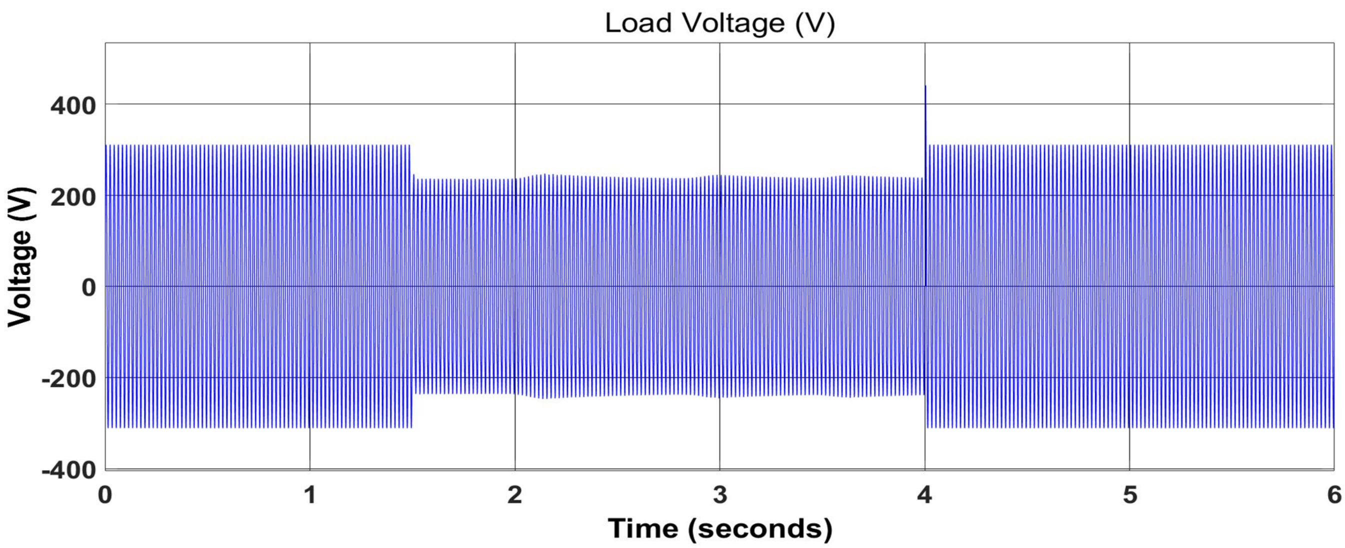

Figure 11: Load Voltage

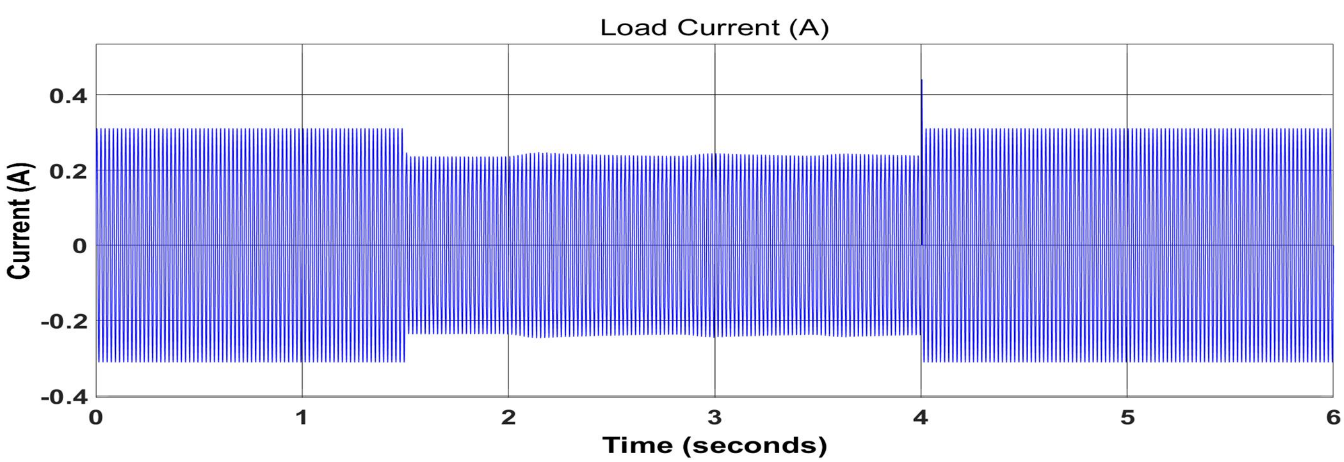

Figure 12: Load Current

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2) CASE-II: SUPER-LIFT LUO CONVERTER IS USED

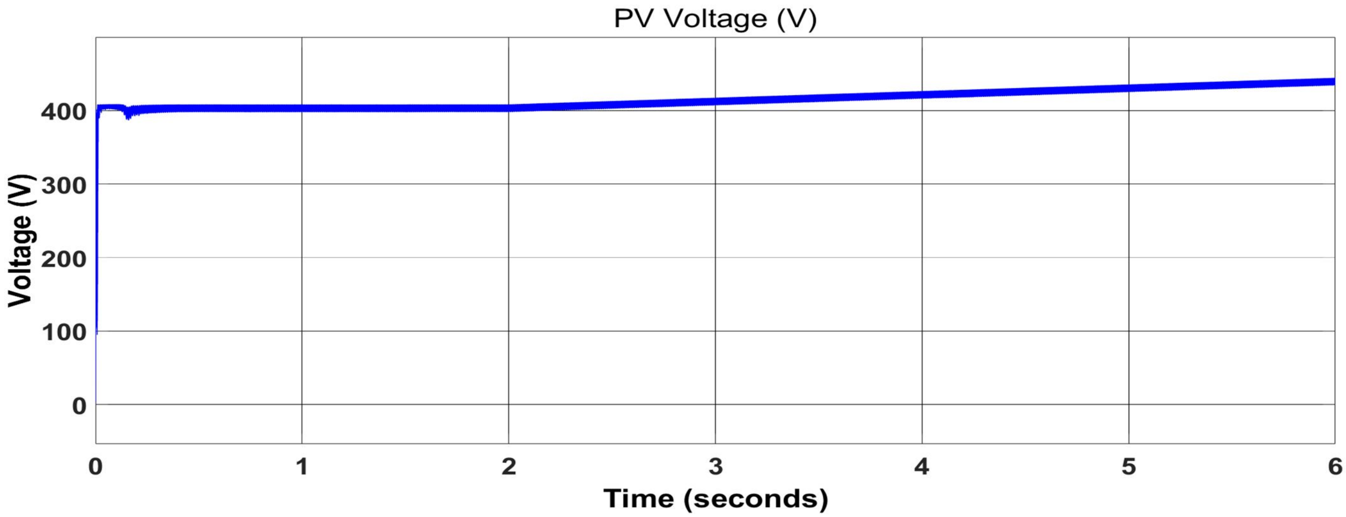

Figure 13: PV System Voltage

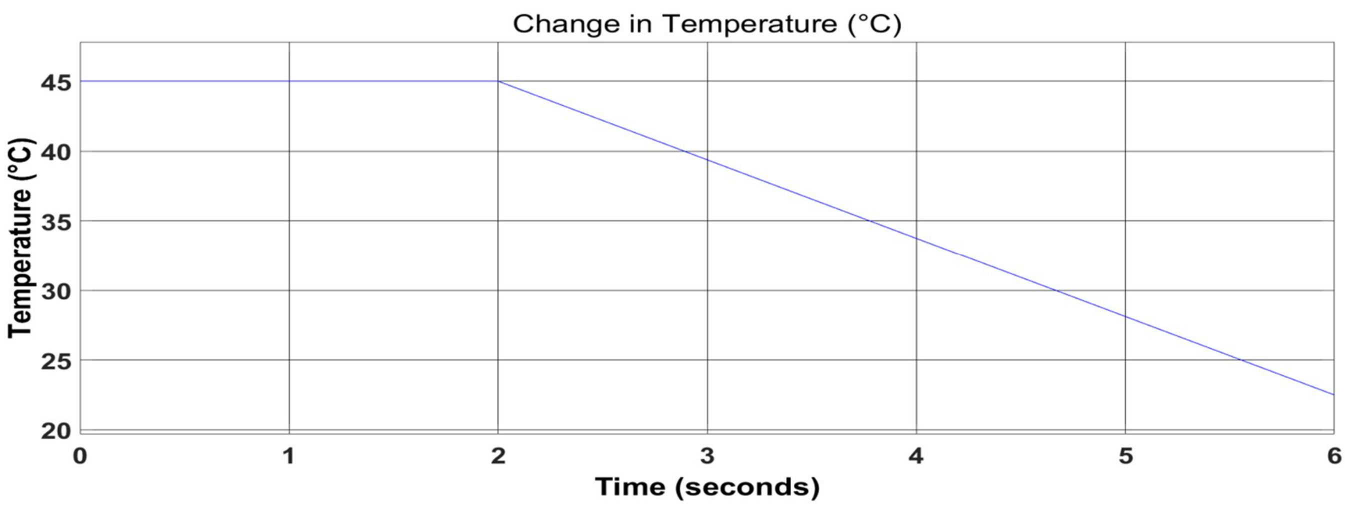

Figure 14: Change in Temperature

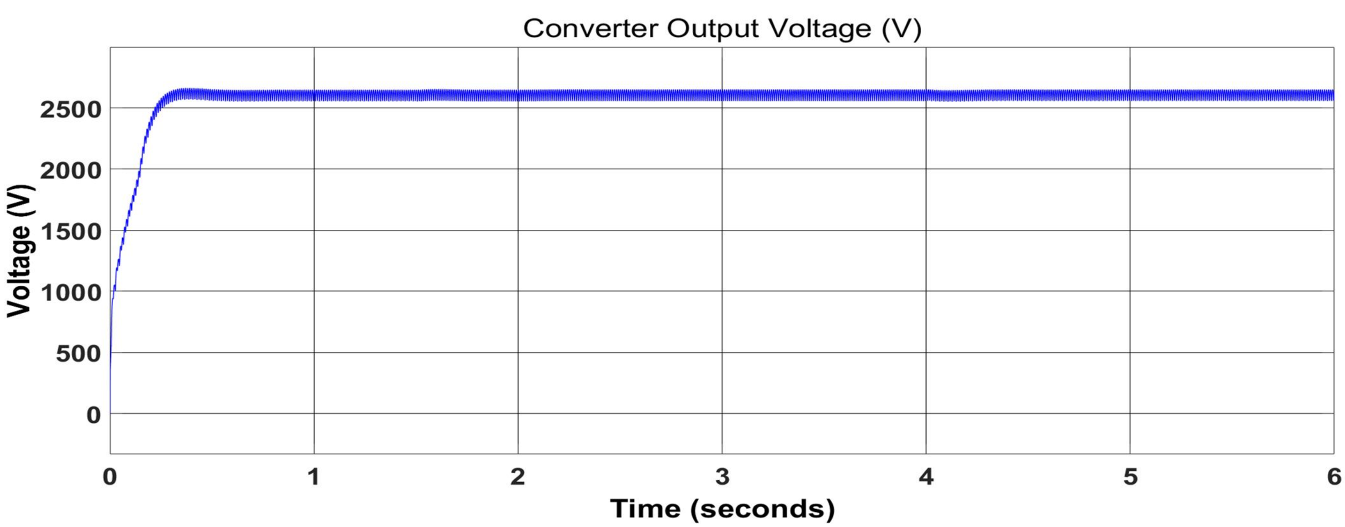

Figure 15: Converter Output Voltage

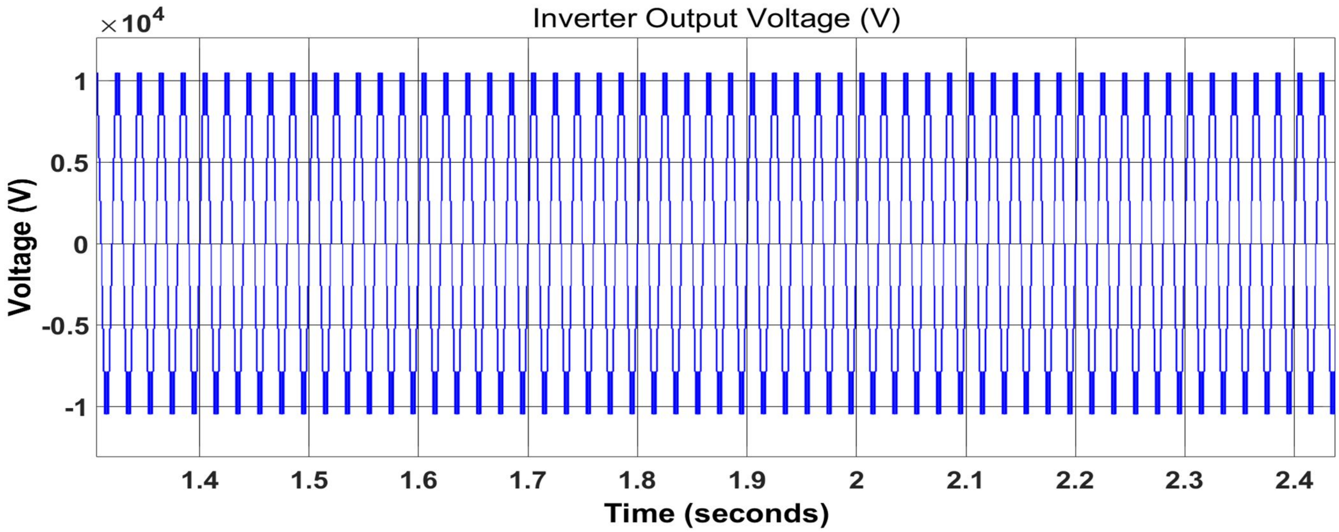

Figure 16: Inverter Output Voltage

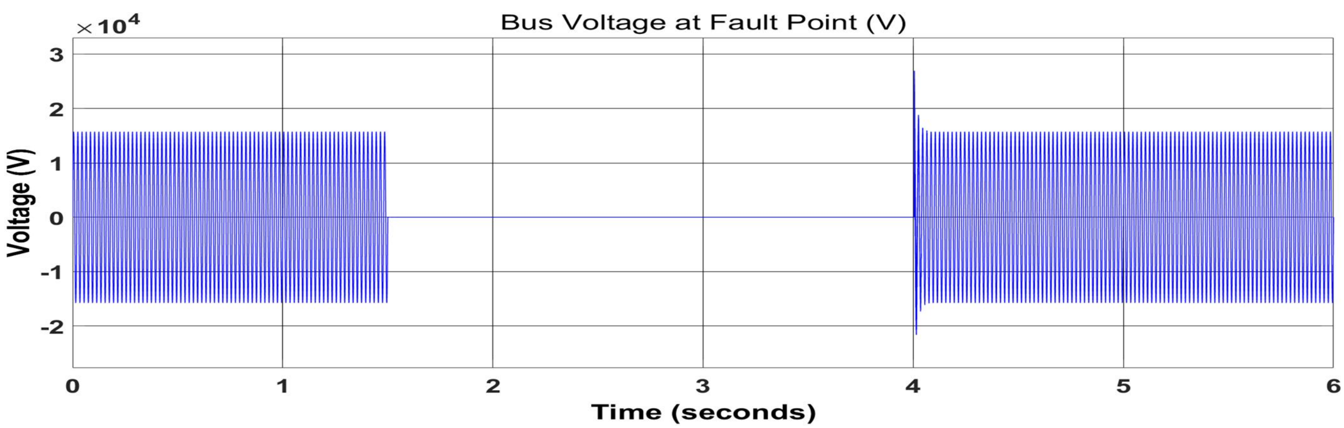

Figure 17: Bus Voltage at Fault Point

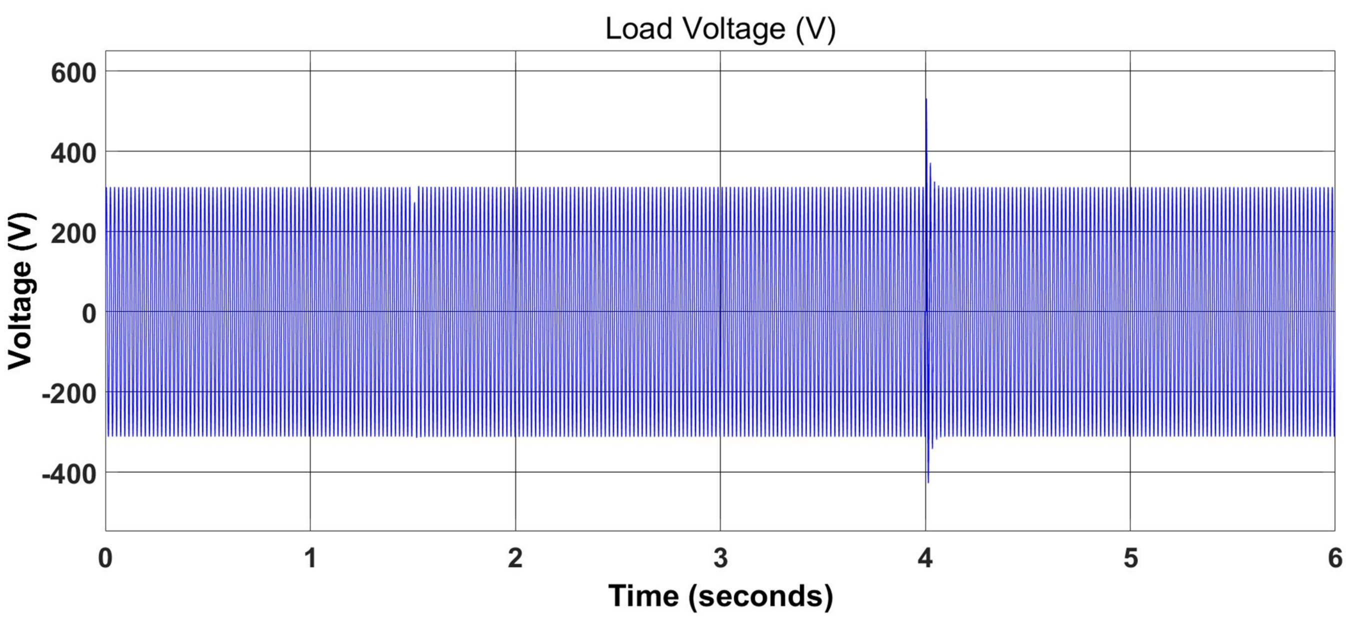

Figure 18: Load Voltage

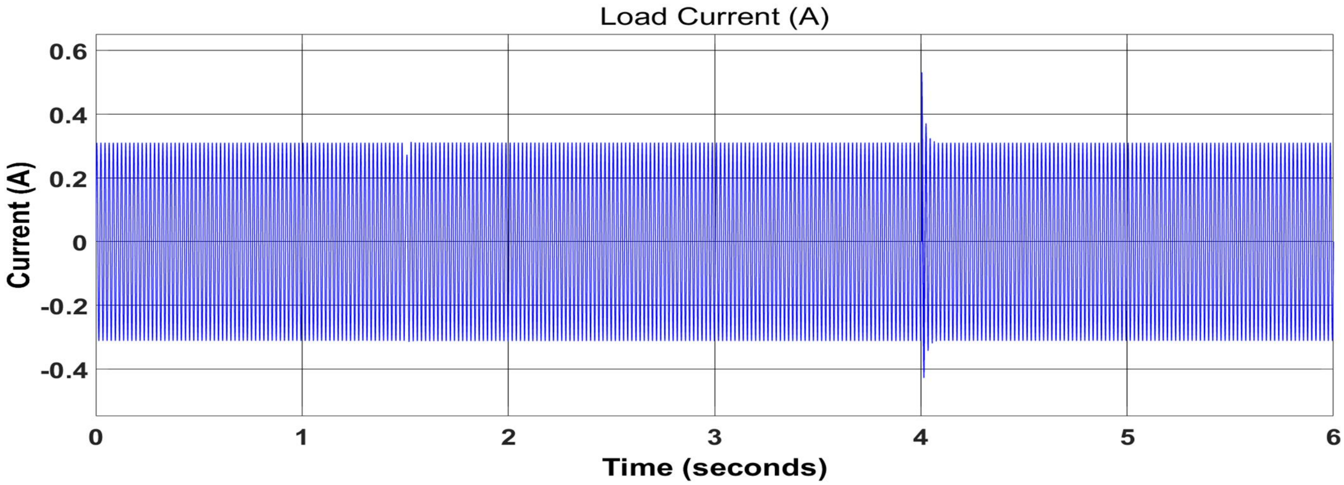

Figure 19: Load Current

VI. PARAMETERS

Parameters	Luo Converter	Super-Lift Luo Converter
Inductor L1 (H)	233.7 mH	25 mH
Capacitor C1 (F)	0.2 mF	0.2 mF
Inductor L2 (H)	146.1 mH	-
Capacitor C2 (F)	0.2 mF	0.2 mF
Switching frequency of converter fs (Hz)	1KHz	1KHz
Grid Frequency f (Hz)	50	50
Transformer Rating	220V/11KV	415V/22KV
Load Resistance (Ω)	1KΩ	1KΩ

VII. OBSERVATIONS

	Luo Converter	Super-Lift Luo Converter
% Peak Overshoot in Regulated DC Voltage	44.23%	1.92%
Settling time (secs)	4.45	0.52

VIII. CONCLUSION

Hence, from above simulation results it can be inferred that when Luo converter is used voltage is regulated but when a fault has occurred in grid a huge transients were introduced into PV System and also the output regulated DC voltage experienced slow response, high settling time, oscillations , steady state error, less accuracy as well as overshoots these oscillations and steady state error have made their way to load voltage where the effect is that the load voltage is reduced as well as it became oscillatory. So, 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 as well as PV system is protected from transients under fault conditions. Due to the improvement in Performance of DC Output Voltage the Load Voltage was also improved and %THD is very much reduced, oscillations and overshoots eliminated and steady state error also eliminated.

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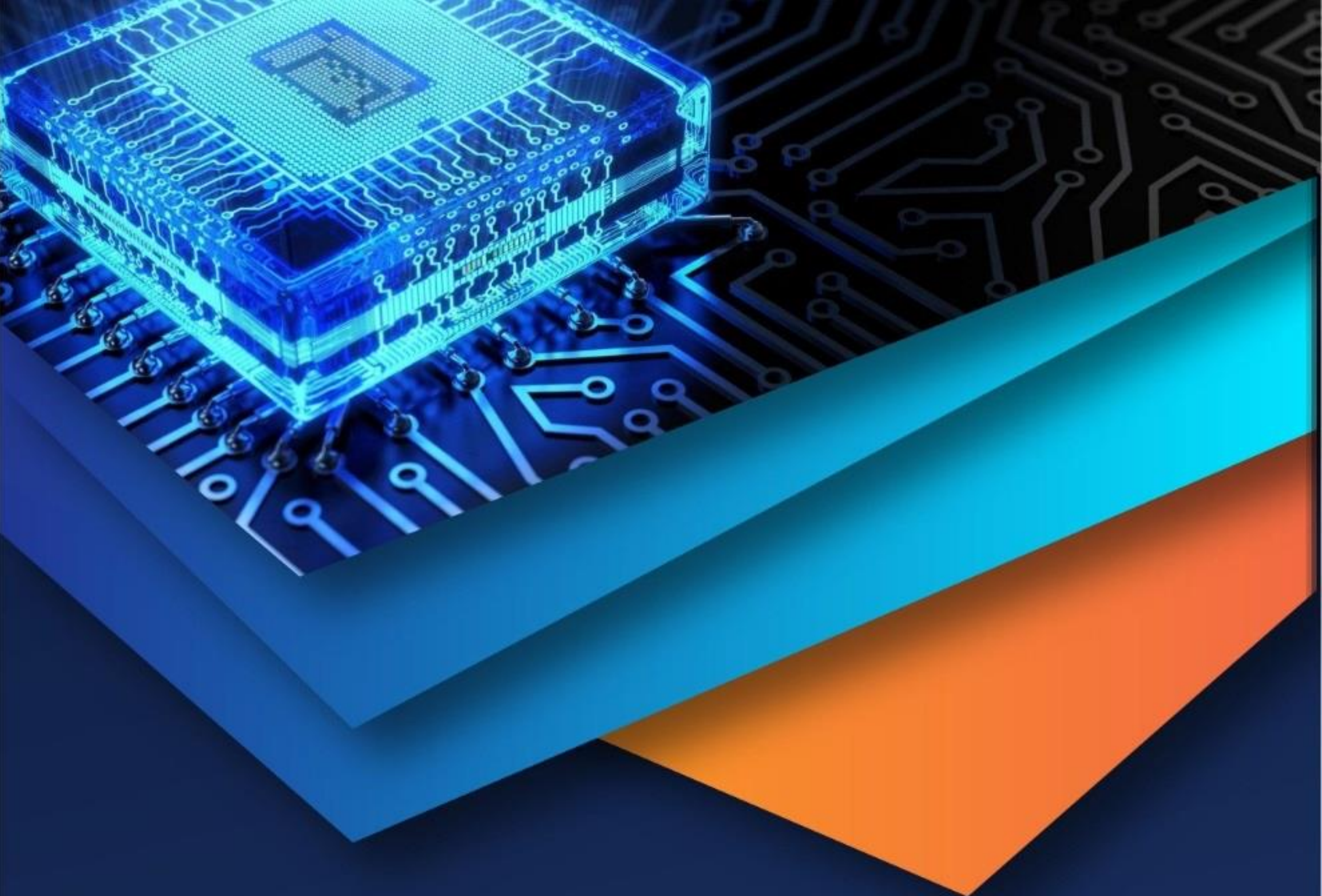

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