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1-Φ High Step-Up Converter with MB MPPT for Half-Bridge PV Inverter System

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Abstract: ***In this paper a 1-ϕ high step-up converter with model based mppt for half-bridge inverters is proposed. The high step-up converter not only boosts the relatively low photovoltaic voltage to high bus voltage but also offer a neutral point bus terminal for half –bridge-based inverters. The coupled inductor multiplier reduce the voltage stress on the all power devices as a result the low voltage rated power devices can be employed the reduce the conduction losses. The model based MPPT Technique is starting from set of equations. A modeling of a novel model based MPPT Technique which doesn't require the direct measurement of solar radiation.***

Index Terms:-High step-up converter, couple inductor multiplier, neutral point terminal, model based MPPT.

I. INTRODUCTION

A renewable energy source involves many aspects like efficiency, reliability, cost and safe connection to the electrical grid. Energy storage and development of advanced control and monitoring algorithms [1].The common renewable energy sources are photovoltaic (PV), wind energy, hydro electrical energy. Solar power is more attractive due to the several environmental protection regulation and predictable shortage of non renewable energy sources [2-3] as a result, so many research works has address the development and construction of solar power and small size photovoltaic (PV) grid connected to the inverter system, which is desired for low power and high efficiency applications.

In low power grid connected photovoltaic (PV) systems the transformer less configuration has become a wide spread tendency due to its high efficiency, smaller size and light weight and lower cost compare to the isolated counter parts [4]. In transformer less condition the traditional full bridge inverter with unipolar sinusoidal pulse width modulation is adopted, the common mode ground leakage current may appear on the stray capacitor between the photovoltaic panel and ground, which brings out the safety issue and reduce the efficiency of the inverter.

Most of the technologies like H5, H6 and HERIC inverters are suppress and eliminate the common mode leakage current caused by stray capacitance between photovoltaic (PV) panel and ground. But these inverters contain more switches so increase the conduction losses [5-10].

In fact the half-bridge inverter and neutral point clamped inverter can naturally eliminate the common mode leakage current because the grid neutral line is directly connected to the neutral point of the DC bus [11-12]. More importantly the DC bus voltage of the half-bridge inverters could be twice that of full bridge inverter topologies and the neutral point of the DC bus could be also required.

Normal boost converters are not suitable for the high step-up applications because the duty cycle of the normal boost converter with high step-up conversion is very large so in this some drawbacks like narrow turn-off period, large current ripple and high switching losses [13]. In order to achieve large voltage conversion ratio some of the switched capacitor based technologies are there .With these technologies the voltage conversion ratio of the converter is increased and voltage stress of the device are decrease, but it makes the switch suffer high transient current and large conduction losses [14].

It is easier for the isolated converter to achieve an extremely high voltage gain by adjusting the transformer turns ratio can be realized with optimal duty cycle, however one inductor and one transformer must be in this converter, which increase the circuit volume and reduce the power density.

In addition the driving circuit and sampling circuit in the isolated converter may increase system complexity, when comparing the non isolated converters. Actually the isolated high step-up conversion can be driven from their isolated counter parts [15-20].

Some high step-up converters with coupled inductor are introduced to achieve a large voltage conversion ratio [21-22] The voltage gain is extended and switch voltage stress is reduced by the transformer function of the couple inductor. Only one magnetic component is used which reduce the complexity and volume of the converter. However the leakage inductance of the coupled inductor may not only bring about high voltage spicks on the switch when switch is turn-off but also induce large energy losses.

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Combination of coupled inductor and switched capacitor concepts to improve a single-phase improved active clamp-coupled inductor based converter with extended voltage doubler cell is proposed [23], but unfortunately this converter can't offer a neutral point terminal for the half-bridge based transformer less inverter.

In this paper an improved single phase high step-up converter with coupled inductor multiplier cell is proposed, this converter naturally create a neutral point terminal and its voltage gain is double then previous converters without increasing the duty cycle, which all the above mention advantages of the converter [23] has in this converter. A typical solar panel converts only 30 to 40 percent of the incident solar radiation into electricity. The maximum power point tracking technique is used to improve the efficiency of the solar panel. There are different techniques used to track the maximum power point. The choice of the algorithm depends on the time complexity the algorithm takes to track the maximum power point (MPP), implementation cost and the ease of implementation.

Perturb and Observe (P&O) in this the time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. However the method doesn't take account rapid change of irradiation level, to avoid this problem use incremental conductance method in this eliminate the error due to change in irradiance but increase the complexity. To automatically find the voltage (Vmpp) or current (Impp) at which the PV panel should be operate to acquire the maximum power output (Pmpp) under a given temperature and irradiance.

According to some MPPT Techniques, the Perturb& Observe Technique has well control PV output voltage compare with Hill climbing algorithm [24-25]. Each PV panel was connected with the own power electronic circuits hence know as module integrated converters (MIC) controllers, this module integrated converter (MIC) controllers allows eliminating the hot spots or panel level hot spots thus improving the system reliability [26].

But in this some drawbacks are there. Those are cost is high because of large number of power converters and another low efficiency of module integrated converters w.r.to large converters [27].

The model based (MB) MPPT having a quality to be very attractive for module integrated converter (MIC) applications. The model based (MB) MPPT is easy to exact model the behavior of single panel. In this paper can be employ the implementation of a novel model based (MB) MPPT , the maximum power point voltage can be estimate from the direct measurement of radiation and cell temperature, it is derived from the set of equations.

II. BLOCK DIAGRAM

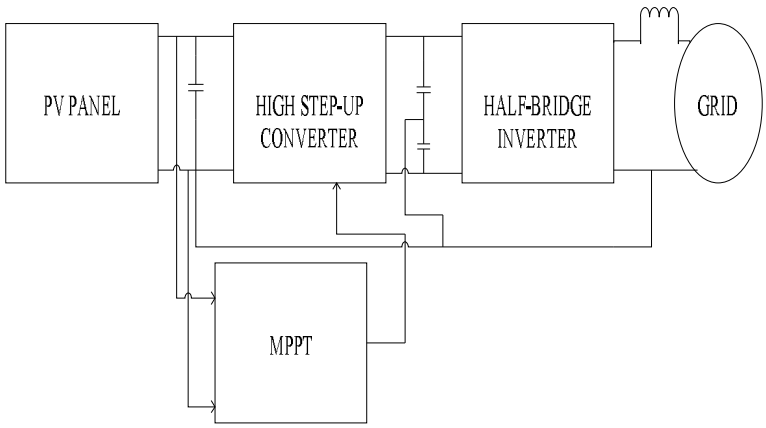

Fig.1 proposed block diagram

In this block diagram consisting of the PV panel, high step-up dc-dc converter, half-bridge inverter and model based (MB) MPPT technique block.

A. Modeling Of PV Device

In order to study the power electronic converter connected with PV systems one first need know how the model the PV device is affects to the converter, an elements that converts the sunlight into electricity the element device is PV cell, set of PV cells form a PV panel. These panels composed of series cells for large voltages, for large output current then composed in parallel. PV array may be either a panel or set of panels connected in series or parallel to create large PV system. This is the simple PV cell model.

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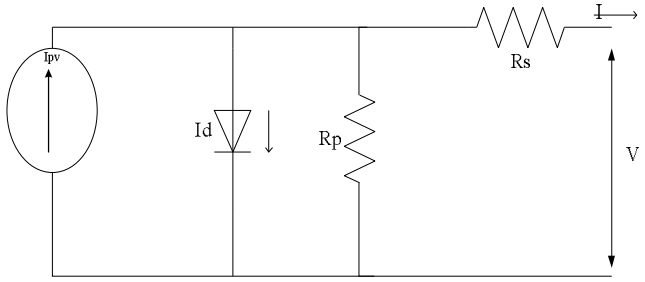

Mathematically describes the I-V characteristics of the ideal PV cell is

$$I = Ipv\ cell - Io\ cell[\exp\left(\frac{qV}{akT}\right) - 1 \quad \text{.....(1)}$$

Where Ipv cell—current generated by the incident light

Io—leakage current/reverse saturation of the diode q—electron charge ($1.60217646\times 10^{-19}$)
K—Boltzmann constant (1.380650×10^{-23})
a—diode constant

$$I = Ipv\ cell - Io\left[\exp\left(\frac{V+RsI}{V+a}\right) - 1\right] - \frac{V+RsI}{Rp} \text{ ..... (2)}$$

In this Ipv and Io are photovoltaic and saturation currents and $Vt = \frac{Ns.Kt}{q}$ --thermal voltage the array with series connected Ns cells if the cells are connected in parallel the PV and saturation currents may express as

$$Ipv = Ipv\ cell.Np \quad \text{.....} \quad (3)$$

$$Io = Io\ cell.Np \quad \text{.....} \quad (4)$$

I-V characteristics of the PV array depend on the internal characteristics of the device (R_s, R_p) on the irradiance level and temperature.

$$Ipv = (Ipv,n + Ki\Delta T)\frac{G}{Gn}; \Delta T = T - Tn \quad \text{.....} \ (5)$$

From this equation the sun light generated current (I_{pv}) depends on solar irradiation and also influence by the temperature. T_n is nominal temperature and G is the irradiance on the device surface. And diode saturation current I_o is

$$Io = \exp\left[\left[\frac{1}{Tn} - \frac{1}{T}\right]\left[\frac{qEg}{aK}\right]\right][\frac{T}{Tn}]^3 I_{o,n} \text{.....} \ (6)$$

Where

$$I_{o,n} = \frac{I_{sc,n}}{\exp[\left(\frac{V_{oc,n}}{aV_{tn}}\right)-1]} \quad \text{.....} \ (7)$$

The value of diode constant "a" may be arbitrarily chosen it usually 1≤0≤1.5. This value is choosing depends on the other parameters of the I-V model of the panel [28]. This is simplicity of a single diode mode with this method for perfect for power electronic designers who are looking for an easy and effective model for the simulation of photovoltaic devices with power converters.

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B. High Step-Up Converter

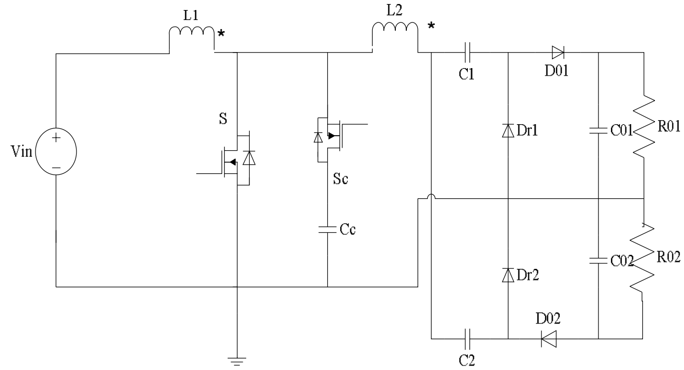

Fig.2 high step-up converter

In this block diagram high step up converter the clamp circuit includes a switch Sc and a capacitor Cc switched capacitors C1&C2, regenerative diodes D1&D2, L1 inductor is coupling with L2 inductor .the coupling is indicated as * and the turns ratio is N=$\frac{n1}{n2}$ the output load can be divide into two equal parts the voltage at R01 is V1 similarly voltage at R02 is V2.equalent circuit of the high step-up converter is

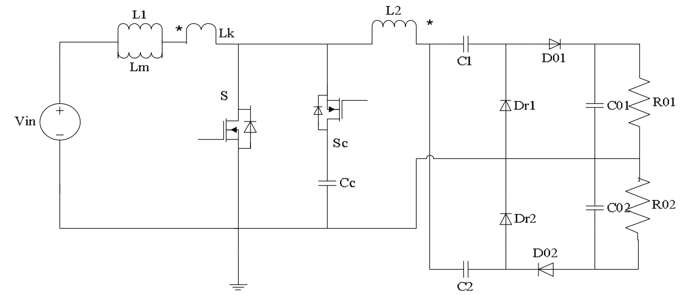

Fig.3 Equivalent circuit of high step-up converter

By combing and integrating two symmetric converters where single phase converters in the bus voltage doubler extended cell, this high step-up converter can be derived without adding the power switches and magnetic components . The coupled inductor can be considered as an ideal transformer a parallel magnetizing inductance and series leakage inductance [29] L1 and L2 represent primary and secondary windings of the transformer, Cs is the parasitic capacitance of the terminal and clamping switch.

C. Voltage Stress Analysis

By ignoring the voltage ripple on the clamp capacitor the voltage stress of the main switch can be derived as follows

$$V_{c1} = NV_{in} \quad \text{.......................................} \ (8)$$

$$V_{Lm,discharge} = V_{Cc} - V_{in} = \frac{V_{out1}}{N+1} - V_{in} \quad \text{.........} \ (9)$$

$$M = \frac{V_{out}}{V_{in}} = \frac{V_{out1}+V_{out2}}{V_{in}} = 2\frac{1+N}{1-D} \quad \text{................} \ (10)$$ Voltage stress on switch is

$$\frac{V_{out}}{N+1} = \frac{0.5V_{out}}{N+1} = \frac{V_{in}}{1-D} \quad \text{.............................} \ (11)$$

From (11) voltage stress on the main switch is equal to the clamp switch, it represent voltage stress of the main switch decrease when turns ratio increase, the voltage stress of the output diodes and regenerative diodes are equal to half of the input voltage.

$$V_{D01} = V_{D02} = V_{Dr1} = V_{Dr2} = 0.5V_{out} \text{..........} \ (12)$$

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D. Current Stress Analysis

The peak current of the output diode D_{01} and regenerative diode D_{r2} is given by

$$I_{D01-peak} = I_{Dr2-peak} = \frac{2I_{out}}{1-D} \quad \ldots\ldots\ldots\ldots\ldots \quad (13)$$

The peak current of the output diode D_{02} and regenerative diode D_{r1} is obtained by

$$I_{D02-peak} = I_{Dr1-peak} = \frac{2I_{out}}{D} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

Due to the ampere-second balance principal on the capacitor C_1 and C_2 is can be derived that that both of the average current through the primary and secondary windings of $L_1$and L_2 is zero. For the present current ripple through a magnetized inductance is neglected it can be concluded that a average current through the magnetizing inductance $L_m = I_{in}$ so the peak current of the main switch is given by

$$I_{stress-S} = 2I_{D02-peak}N + I_{in} + 2I_{D02-peak} \quad \ldots\ldots (15)$$

When power loss neglected, the peak current of the main switch is

$$I_{stress-S} = \frac{2I_{out}(2+2N-D-ND)}{D(1-D)} \quad \ldots\ldots\ldots\ldots\ldots \quad (16)$$

$$I_{clamp-S} = \frac{2I_{out}(1+N)}{1-D} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

The high step-up converter can be derived without any extra active switches and magnetic components. It is automatically create by combing the two integrated symmetrical converter and also automatically create a neutral point terminal naturally.

III. CONTROL TECHNIQUE

The novel model based MPPT technique which doesn't require the direct measurement of the solar radiation and this model based MPPT offer a better dynamic performance, in this starting from a new set of equations modeling of the model based MPPT technique, the measuring the temperature T_p of a point as possible as close to the cells. In particular it is much less affected by the wind speed and thermal transients.

The coefficient $K_{\Delta T}$can be introduced to write down the following equation

$$T_c = T_p + K_{\Delta T}G \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (18)$$

When the temperature radiance level is very high $K_{\Delta T}$ is very small. This equation set of a relationship among theT_c, the solar radiation and temperature of rear surface in the panel. These mean parameters of the model can be considered as function of solar radiation G and of T_p which can easily measured

$$V_T(G,T_p) = K_{T1}T_p + K_{T2}G \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

$$I_{sc}(G,T_p) = G(K_{sc1} + K_{sc2}T_p) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

$$V_{ref}(I,G,T_p) = \frac{dV}{dI}I = \frac{V_T(G,T_p)I}{I_{sc}(G,T_P)-I} + R_sI \quad \ldots\ldots\ldots\ldots \quad (21)$$

Substitute equations (19) and (20) in (21) we get

$$V_{ref}(I,G,T_p) = \frac{dV}{dI}I = \frac{(K_{T1}T_P+K_{T2})I}{G(K_{sc1}+K_{sc2}T_p)-I} + R_sI \quad \ldots\ldots (22)$$

This equation has a unique solution in the operating voltage current range of panel therefore there is a single equilibrium point, the

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inverse model can't be obtaining a closed form therefore the light radiation intensity has to be estimated using a numerical procedure [30]

$$V(I, G, T_p) \rightarrow G_{est}(V, I, T_p) \quad \text{..... (23)}$$

$$G_{est}(V, I, T_p) \cong \frac{I}{K_{sc1}+K_{sc2}T_p} + e^{\frac{V+R_sI-K_{0c1}-K_{oc2}T_p}{K_{0c4}T_p}} \quad \text{...(24)}$$

By neglect the temperature difference between frame and PV panel leads to in accurate results in the prediction of V-I characteristics especially for open circuit. The cells are employed as solar radiation sensors; just the effective solar radiation that contributes to the energy conversion is measured. So the panel operates so as it were clean, but with lower irradiance level.

K_{sc1}	2.263mAm^2/W
K_{sc2}	9.603μAKm^2/W
K_{oc1}	80.65V
K_{oc2}	-169.9mV/K
K_{oc3}	-869.5μVm^2/W
K_{oc4}	6.597mV/K
K_{T1}	7.032mV/K
K_{T2}	216.6μVm^2/W

IV. SIMULATIONRESULTS

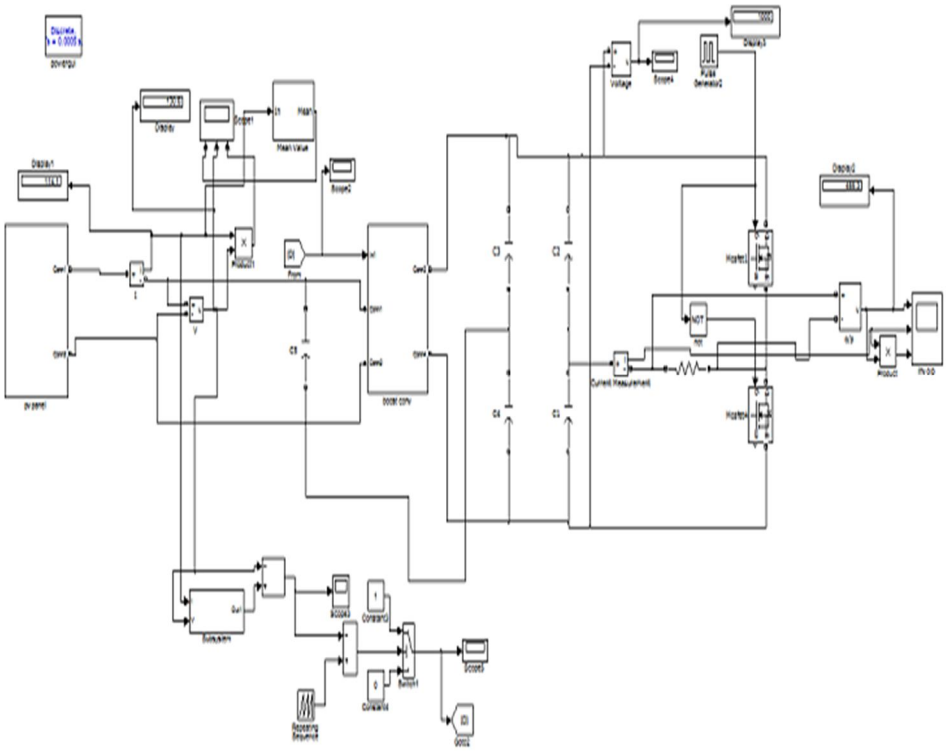

Fig.4 SIMULINK model of proposed system

This is the SIMULINK model of proposed model input of the high step-up converter connecting with half bridge inverter with model based MPPT technique is developed by the MATLAB/SIMULINK.

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Input voltage of converter	130.6V
C1	1.05µF
C2	1.05µF
Cr1	1.05µF
Cr2	1.05µF
L1	32mH
L2	1mH
Cc	0.15mF

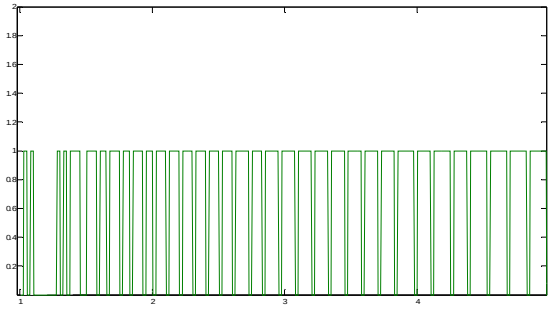

Fig.5 pulse from MPPT to give a high step-up converter

The model based MPPT technique is the surface temperature (Tp) is taken 320k it is applied to gate pulse of the boost converter.

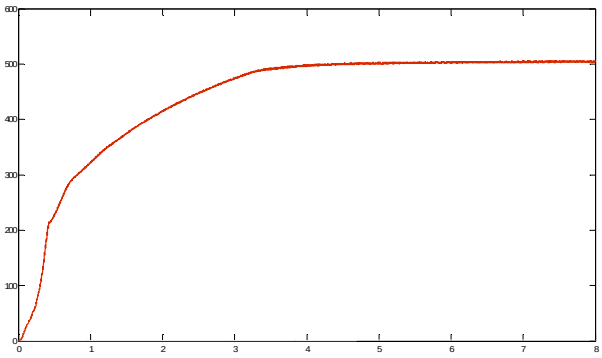

Fig.6 high step-up converter output voltage (Vout1)

The high step up converter with coupled inductor multiplier is naturally creating a neutral point terminal it divides the output. The simulation output wave form is the half of the output voltage of the high step up converter.

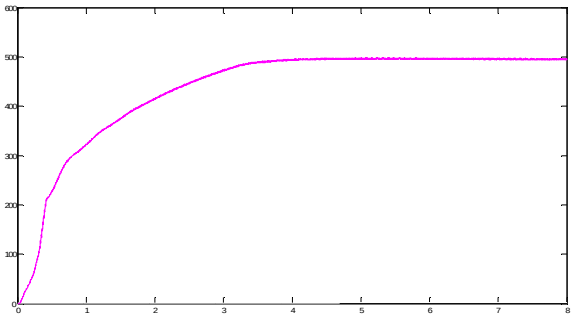

Fig.7 high step-up converter output voltage (Vout2)

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This simulation output voltage waveform is the another half of the output voltage taken at the high step-up converter Vout2.

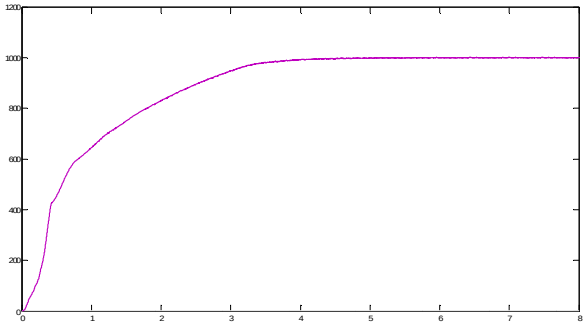

Fig.8 half bridge inverter input voltage

The high step-up converter output is connected with the input of the half bridge inverter its total voltage is combination of the two output voltages of the high step up converter.

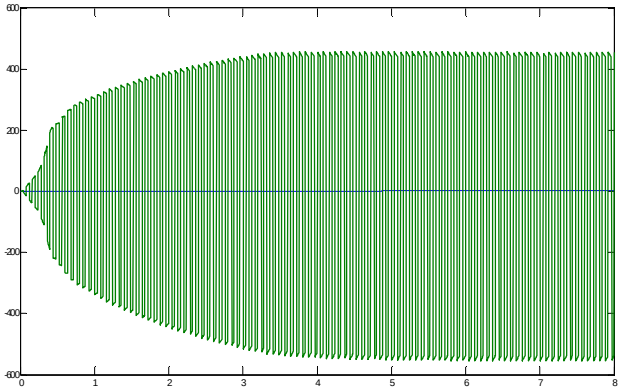

Fig.9 half bridge inverter output voltage

The half-bridge inverter output voltage is half of the output voltage when the switch S1 is on takes a positive half cycle. When the switch S2 is on negative half cycle voltage obtained.

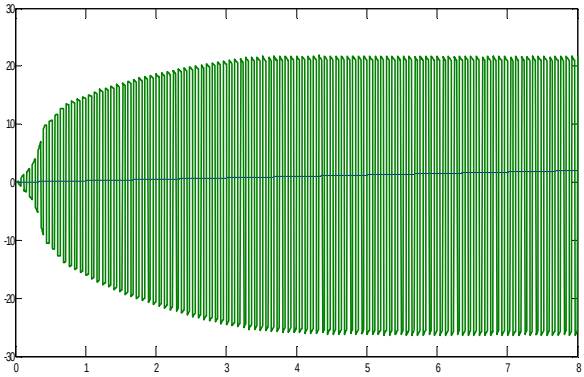

Fig.10 half bridge inverter output current

This simulation of output current wave form is taken from the general load of half bridge inverter its current is depend on the load

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conditions.

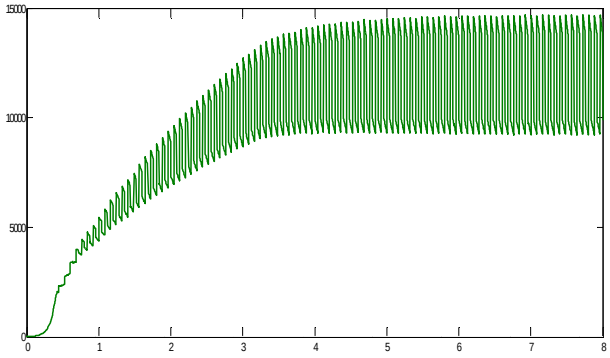

Fig.11 half bridge inverter out power

The simulation result is the product of the output current and output voltage to gain the output power of the half bridge inverter.

V. CONCLUSION

In the proposed system the high step-up converter is naturally create a neutral point for half bridge inverter, the high step-up converter is not only increase the voltage it relatively low PV voltage to high bus terminal voltage without addition of the extra active switches and magnetic components. And also the main advantages by combination of the two integrated high step-up converters to create a neutral point terminal, which meets the input voltage of the half bridge inverter, the coupled inductor multiplier in the converter is extended the voltage gain and reduce the voltage stress on the switches and also improve the efficiency, the model base MPPT technique can be used to how to avoid a direct measurement of the cell temperature ,furthermore the model based MPPT can also estimate the solar radiation with an adequate accuracy. This aspect increases the robustness, thus making the method competitive w.r.to other systems

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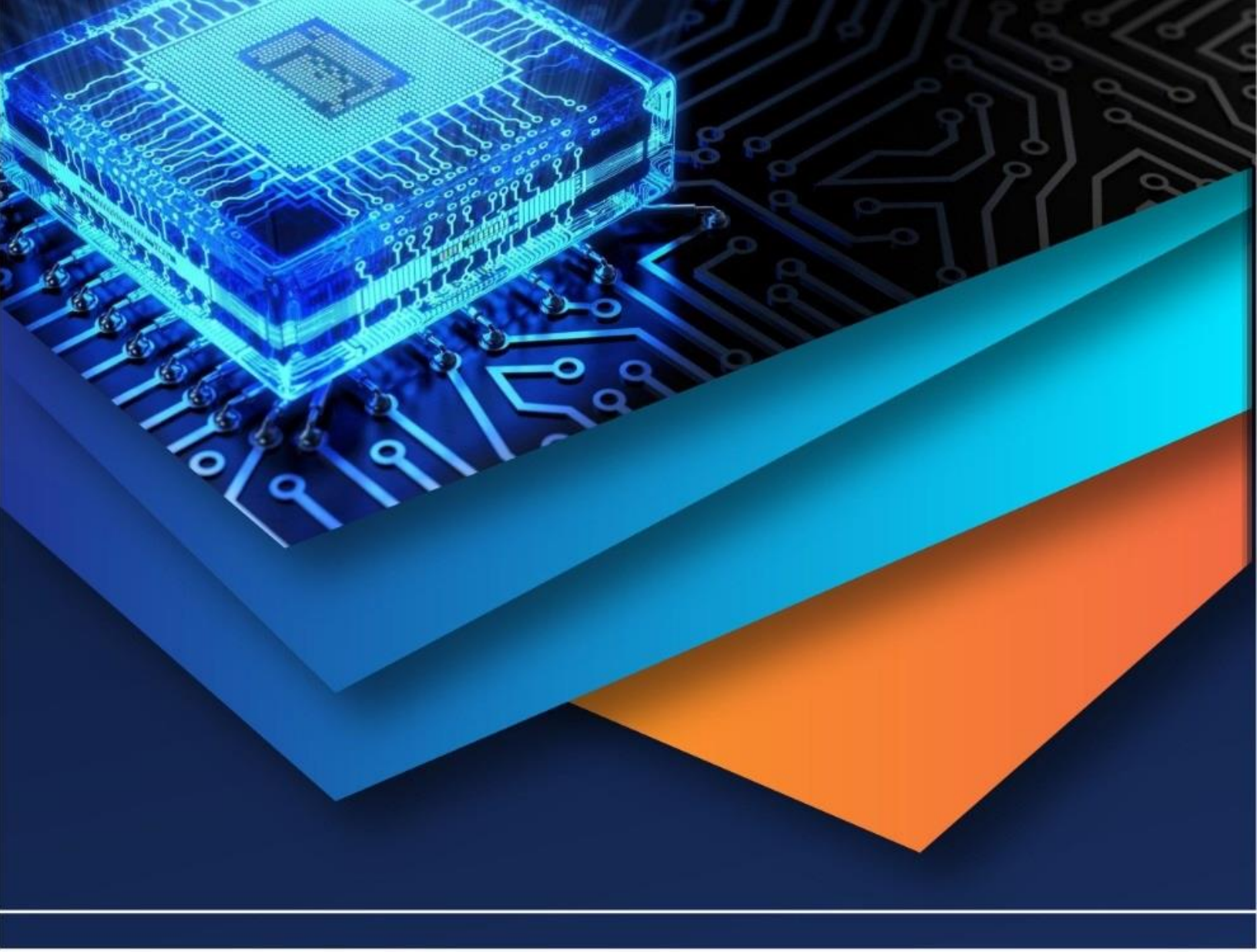

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