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MPPT for Standalone PV Systems with the help of SEPIC Converter

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Abstract: *In this paper MPPT for standalone PV systems with the help of SEPIC converter is proposed. The boost converter not only boosts the relatively low PV voltage to high bus voltage but also offer a neutral point bus terminal for HB based inverters. The coupled inductor multiplier reduces the voltage stress on the all power switching devices as a result the low voltage rated power devices can be employed to reduce the conduction power losses. The PV model based MPPT Technique is starting from mathematical equations. A modeling of a novel model based MPPT Technique which doesn't require the direct measurement of solar insolation.*

Index Terms: *High boost converter, SEPIC converter, couple inductor multiplier, neutral point terminal, voltage stress, model based MPPT, insolation.*

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 grid connected to the inverter system, which is desired for low power and high efficiency applications.

In low power grid connected photovoltaic 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 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 spikes on the switch when switch is turn-off but also induce large energy losses. 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 (V_{mpp}) or current (I_{mpp}) at which the PV panel should be operate to acquire the maximum power output (P_{mpp}) 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 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 MPPT having a quality to be very attractive for module integrated converter (MIC) applications. The model based MPPT is easy to exact model the behavior of single panel. In this paper can be employ the implementation of a novel model based 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. In block diagram consisting of the PV panel, high step-up dc-dc converter, half-bridge inverter and model based MPPT technique block as show bellow. In block diagram a neutral point terminal connect to grid negative terminal to PV panel negative terminal

II. BLOCK DIAGRAM

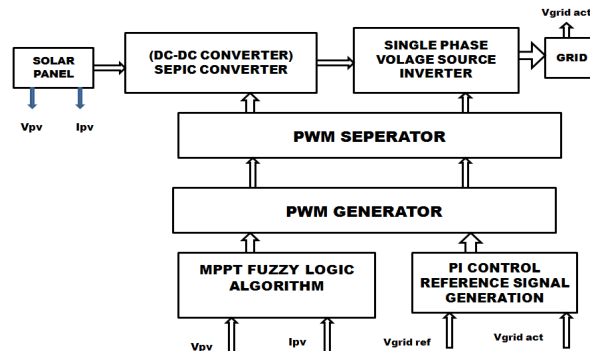


Fig.1 Block Diagram

- 1) *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.

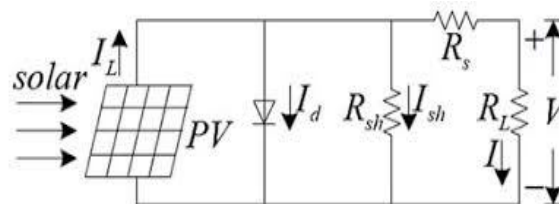


Fig.2 Equivalent circuit diagram

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

$$I = I_{pv\ cell} - I_{o\ cell} [\exp (qV / akT) - 1] \quad (1)$$

Where,

$I_{pv\ cell}$ —current generated by the incident light I_o —leakage current/reverse saturation of the diode q — electron charge ($1.60217646 \times 10^{-19}$ C)

K —Boltzmann constant (1.380650×10^{-23})

a —diode constant

$$I = I_{pv\ cell} - I_o \exp V + R_s I \quad V + a - 1 - V + R_s I \quad R_p \quad (2)$$

In this I_{pv} and I_o are photovoltaic and saturation currents and $V_t = N_s .Kt/q$ --thermal voltage the array with series connected N_s cells if the cells are connected in parallel the PV and saturation currents may express as $I_{pv} = I_{pv\ cell} . N_p \quad (3)$

$$I_o = I_o\ cell . N_p \quad (4)$$

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.

$$I_{pv} = (I_{pv}, n + Ki\Delta T) G Gn ; \Delta T = T - T_n \quad (5)$$

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

$$I_o = \exp [(1 T_n - 1T) (qEg) aK [T / T_n]^3 I_o, n \quad (6)$$

$$\text{Where } I_o, n = I_{sc, n} \exp [V_{oc, n} a / V_{tn} - 1] \quad (7)$$

The value of diode constant “a” may be arbitrarily chosen it usually $1 \leq a \leq 1.5$. This value is choosing depends on the other parameters of the I-V model of the panel [28]. Resistive effects in solar cells reduce the efficiency of the solar cell by dissipating power in the resistances. The most common parasitic resistances are series resistance and shunt resistance. The combination of the symmetrical and integrated high step-up converters to create a neutral point with high step-up p converter or improved boost converter the improved boost converter circuit diagram and equivalent circuit diagram as shown below. The "collection probability" describes the probability that a carrier generated by light absorption in a certain region of the device will be collected by the $p-n$ junction and therefore contribute to the light-generated current, but probability depends on the distance that a light-generated carrier must travel compared to the diffusion length. Collection probability also depends on the surface properties of the device. The collection probability of carriers generated in the depletion region is unity as the electron-hole pair are quickly swept apart by the electric field and are collected. Away from the junction, the collection probability drops. If the carrier is generated more than a diffusion length away from the junction, then the collection probability of this carrier is quite low. Similarly, if the carrier is generated closer to a region such as a surface with higher recombination than the junction, then the carrier will recombine. The short-circuit current and the open-circuit voltage are the maximum current and voltage respectively from a solar cell. However, at both of these operating points, the power from the solar cell is zero. The "fill factor", more commonly known by its abbreviation "FF", is a parameter which, in conjunction with V_{oc} and I_{sc} , determines the maximum power from a solar cell. The FF is defined as the ratio of the maximum power from the solar cell to the product of V_{oc} and I_{sc} . Graphically, the FF is a measure of the "squareness" of the solar cell and is also the area of the largest rectangle which will fit in the IV curve. The FF is illustrated below.

2) High boost Converter

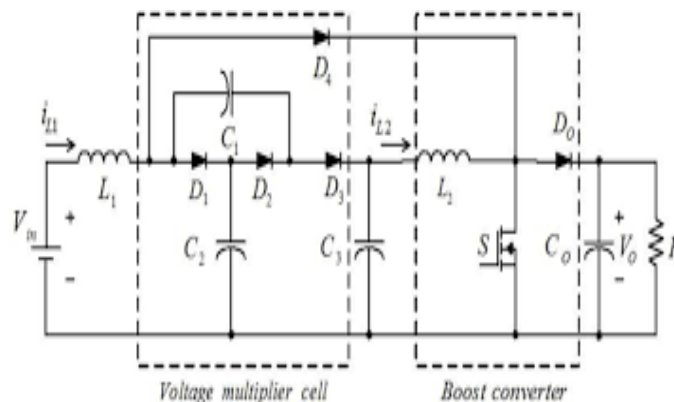


Fig.3 high step-up converter

Fig.3 high step-up converter In this block diagram high step up converter the clamp circuit includes a switch S_c and a capacitor C_c switched capacitors C_1 & C_2 , regenerative diodes D_1 & D_2 , L_1 inductor is coupling with L_2 inductor .the coupling is indicated as * and the turns ratio is $N=n_1/n_2$ the output load can be divide into two equal parts the voltage at R_{01} is V_1 similarly voltage at R_{02} is V_2 .Proposed system of the high boost converter is shown in fig.3

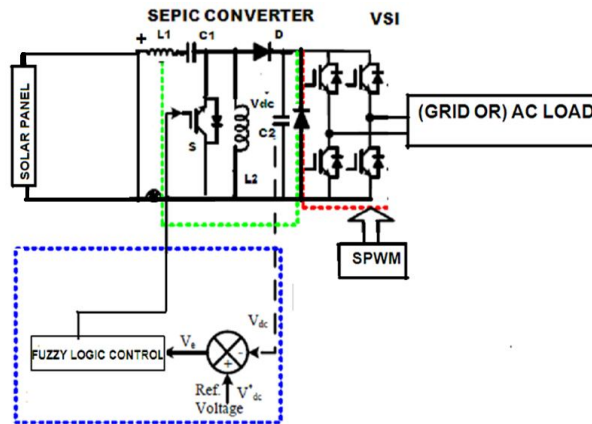


Fig.4 Proposed system circuit of high boost converter

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] L_1 and L_2 represent primary and secondary windings of the transformer, C_s is the parasitic capacitance of the terminal and clamping switch.

3) **Voltage Stress Analysis:** By ignoring the voltage ripple on the clamp capacitor the voltage stress of the main switch can be derived as follows $V_{c1} = NV_{in}$ (8)

$$V_{Lm, disc} \square arge = V_{Cc} - V_{in} = V_{out}N + 1 - V_{in} \quad (9) \quad M = V_{out}V_{in} = V_{out}(1 + V_{out}2V_{in} = 2 + N - D) \quad (10)$$

Voltage stress on switch is

$$V_{outN+1} = 0.5V_{outN+1} = V_{in}1 - D \quad (11)$$

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.

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

4) **Current Stress Analysis:** The peak current of the output diode D_{01} and regenerative diode Dr_2 is given by

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

The peak current of the output diode D_{02} and regenerative diode Dr_1 is obtained by $I_{D02-peak} = I_{Dr1-peak} = 2I_{out}D$ (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

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

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

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

$I_{clamp-S} = 2I_{out}(1 + N)1 - D$ (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 $T_c = T_p + K\Delta T$ (18)

When the temperature radiance level is very high $K\Delta T$ is very small. This equation set of a relationship among the T_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 $V_T, G, T_p = K T_1 T_p + K T_2 G$ (19) $I_{sc} G, T_p = G(K_{sc1} + K_{sc2} T_p)$ (20) $V_{ref} I, G, T_p = dV_{dII} = V_T(G, T_p) I_{sc} G, T_p - I + R_s I$ (21) Substitute equations (19) and (20) in (21) we get $V_{ref} I, G, T_p = dV_{dII} = (K T_1 T_p + K T_2) I G K_{sc1} + K_{sc2} T_p - I + R_s I$ (22) This equation has a unique solution in the operating voltage current range of panel therefore there is a single equilibrium point, the inverse model can't be obtaining a closed form therefore the light radiation intensity has to be estimated using a numerical procedure [30] $V(I, G, T_p) \rightarrow G_{est}(V, I, T_p) \dots\dots\dots 23)$

$$G_{est} V, I, T_p \cong I K_{sc1} + K_{sc2} T_p + eV + R_s I - K_0 c_1 - K_0 c_2 T_p K_0 c_4 T_p \dots 24)$$

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.

IV. SIMULATION RESULTS

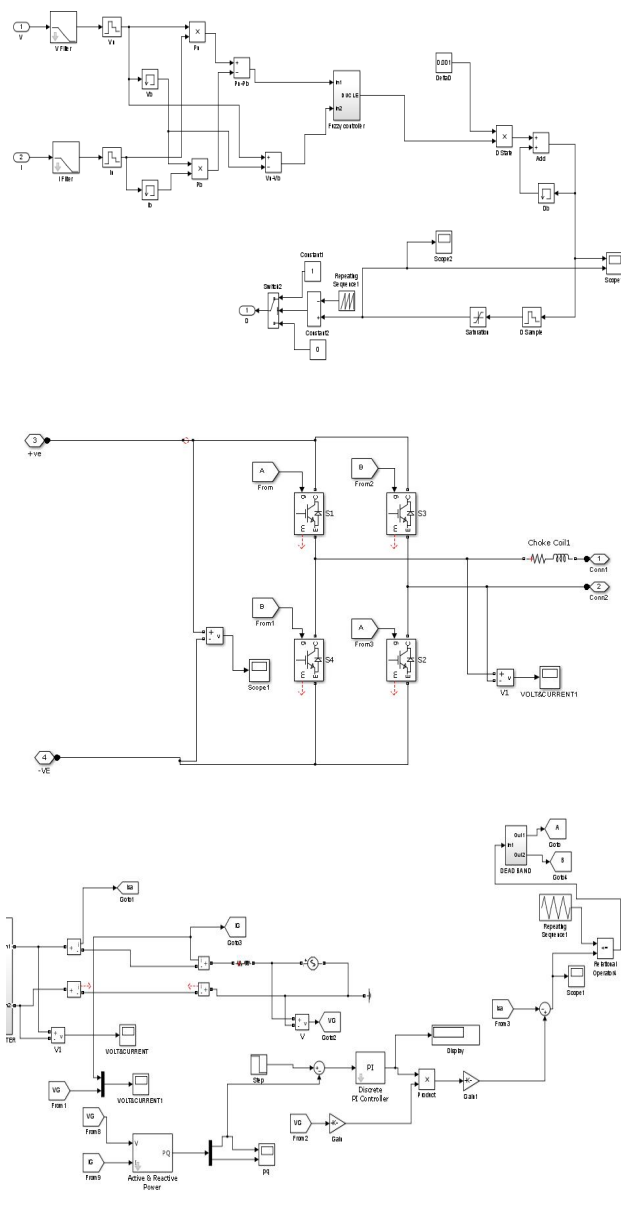


Fig.4 SIMULINK model of proposed system

This is the proposed topology 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.

Input voltage of converter	130.6V
C1	1.05 μ F
C2	1.05 μ F
Cr1,Cr2	1.05 μ F
L1	32mH
L2	1mH
Cc	0.15mF
Vout1	504V
Vout2	495V
Inverter output	455V

A. Input Voltage To The Sepic Converter

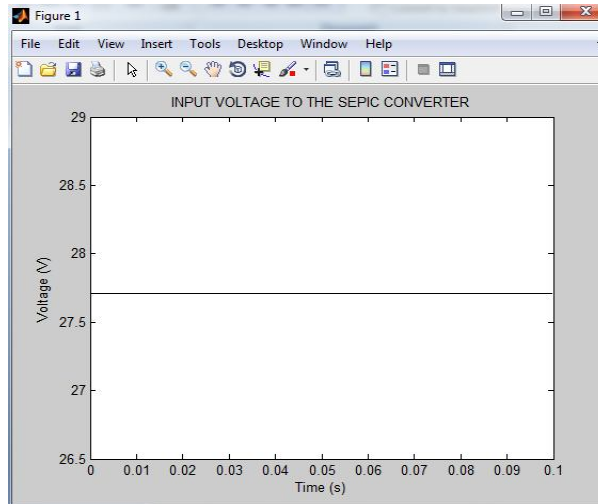


Fig.5 Input Voltage to the SEPIC Converter

B. Fuzzy Logic Triangular Membership Function

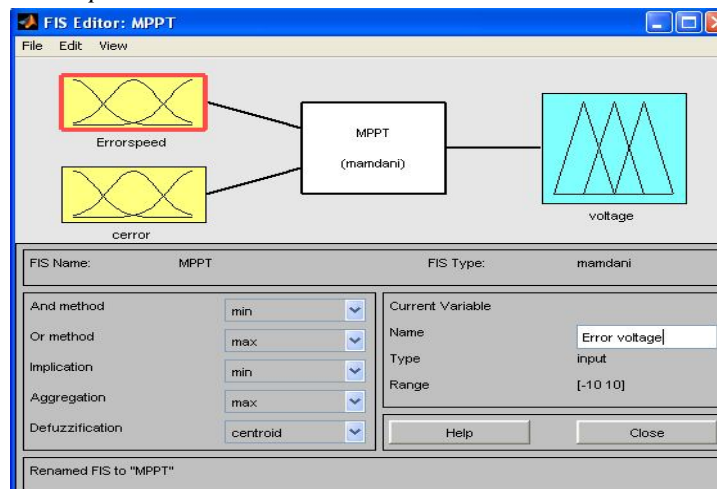


Fig.6 Fuzzy Logic Triangular Membership Function

C. Pwm Pulse To The Sepic Converter

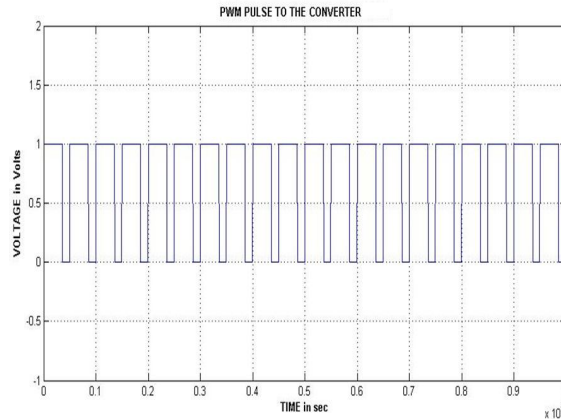


Fig.7 Fuzzy Logic Triangular Membership Function

D. Sepic Converter Output Voltage

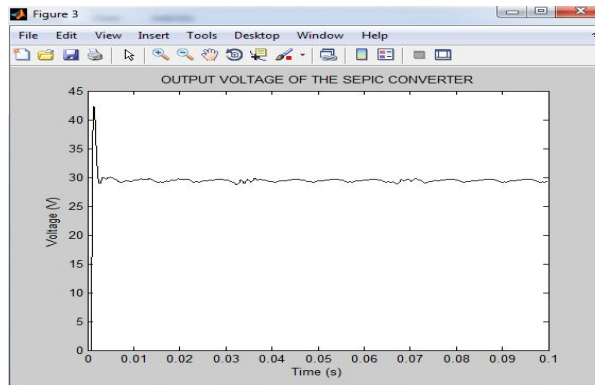
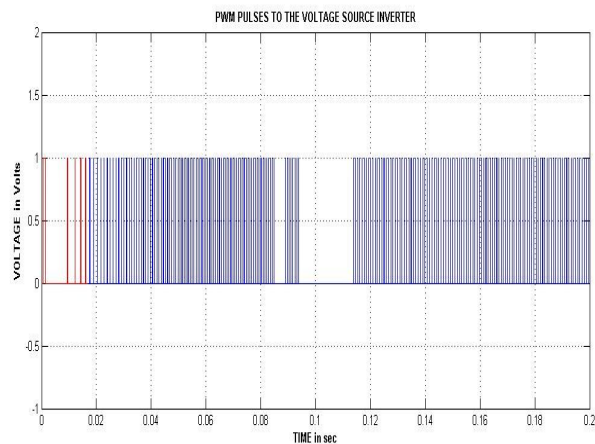


Fig.8 SEPIC Converter Output Voltage

E. Pwm Pulse To The Single Phase Inverter

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



F. Inverter Output Voltage With Filter

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 input voltage from the panel is 130V and half of the boost converter output is 504V.

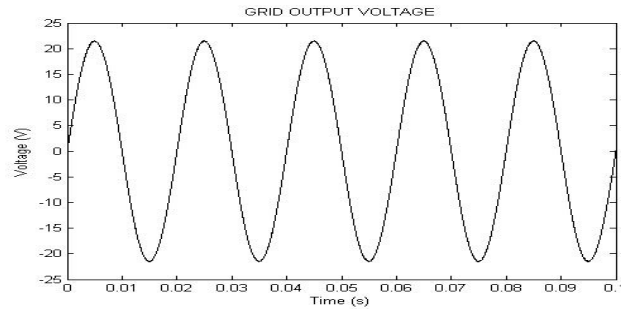


Fig.9 Inverter Output Voltage With Filter

G. Inverter Voltage Thd Waveform Using Fft Analysis

This simulation output voltage waveform is another half of the output voltage taken at the high step-up converter V_{out2} . is equal to 495.1V

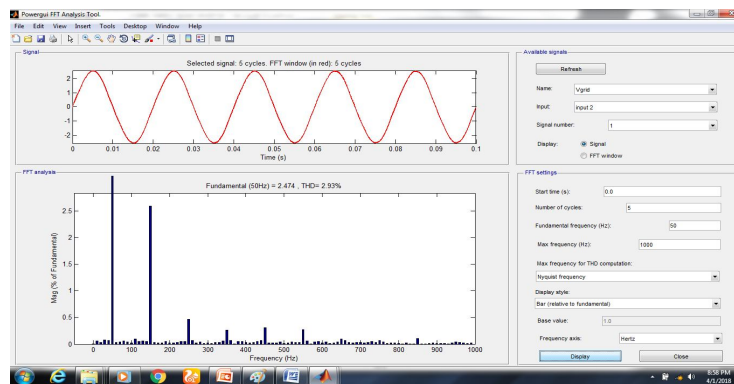


Fig.10 Inverter Voltage THD Waveform Using FFT Analysis

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 is 1000V. 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 the output voltage is 455V. This simulation of output current wave form is taken from the general load of half bridge inverter its current is depend on the load conditions is 23A. 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 boost 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.t other systems

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