Comparative Analysis of Maximized Efficiency and Power Factor of Power Converters for Photovoltaic System Application

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Abstract-The global electrical energy consumption is steadily rising. To meet the growing demand of electricity and reduction of greenhouse gas emission has prompted renewed interest in the renewable energy system. The cost of renewable energy technologies is on a falling trend and is expected to fall further as demand and production increases. Among various possibilities, the solar cell is an instinct source of energy, which is increasingly being studied, researched and for conversion of electrical energy. In this paper we have studied dc to ac conversion technique using boost inverter with solar energy stored via PV cells in a battery as input. In this way we have enabled to convert 12V dc to 120V ac for special home applications. The overall project has been verified by simulation with MATLAB simulation software. This technique supports the use of dc-ac boost inverter technique to feasible solution for solar home application.

Keywords
Boost Converter, Boost Inverter.

I. INTRODUCTION

Solar Cells supply electric energy renewable from primary resources. Solar cells are rarely used individually. Cells with similar characteristics are under peak sunlight (1 W/m^2) the maximum current delivered by a cell is approximately $30mA/cm^2$. Cells are therefore paralleled to obtain the desired current [1]. So, it can charge a battery up to 12 volt DC. For residential use, all equipment requires a pure sinusoidal 220V ac power supply. For this a static DC-AC converter is inserted between the solar cells and the distribution network. DC to AC conversion has been established as one of the most common operations in power electronics. The solar cell transforms the light energy into continuous electric energy. It represents a source with a good energy density. From an electric point of view, the solar cell is considered as a voltage source. This source is nevertheless imperfect. Therefore it is necessary to insert an inverter between the solar cell and the network in order to obtain the alternating electric source, assuming the transfer of light energy to the network. The typical voltage source inverter (VSI) uses the topology, which has a characteristic that the average output voltage is always lower than the input dc voltage [2]. Thus if an output voltage is higher than the input one, a boost dc-dc converter must be used between the dc source and inverters. Depending on power and voltage level involved, this solution can result in high volume, weight, and cost and reduce efficiency. The full bridge topology can however be used as a boost inverter that can greater an output ac voltage higher than the input dc voltage. A traditional design methodology is the use of buck inverter. One of the characteristics of the most classical inverter is that it produces an AC output instantaneous voltage always lower than the dc input voltage. Thus if an output voltage higher than the input one is needed, a boost dc-dc must be used between the dc source and the inverter [3]. This paper also describes a new P.W.M. strategy for a voltage source inverter. This modulation strategy reduces the energy losses and harmonics in the P.W.M. voltage inverter. The technique allows the P.W.M. voltage source inverter to become a new feasible solution for solar home application.

II. CONVENTIONAL METHOD

The conventional method comprises hard switching boost converter and full bridge inverter, its drawback are less efficiency (90.4%) at boost converter operation and less power factor (.88) and total harmonic Component (7.24%) for full bridge inverter operation, to overcome this issue are implemented by soft switching boost converter and boost inverter as the proposed method.

III.PROPOSED METHOD

The proposed method operates with soft switching DC-DC boost converter and boost inverter (DC-AC) as illustrated below.

IV.SOFT SWITCHING DC-DC BOOST CONVERTER

A converter topology with single switch and switching strategies to make the switch on at zero current and off at zero voltage at the given switching time with charging and discharging modes.

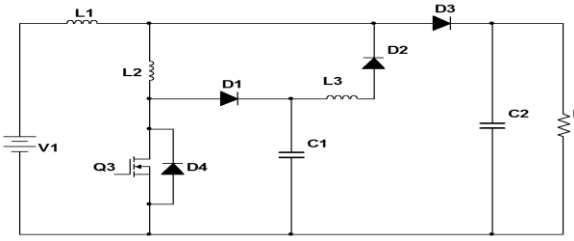

Fig .1 Soft Switching DC-DC Boost Converter

The circuit diagram of the proposed converter with soft switching scheme is shown in Figure .1. The switch S_1, L_1, D_3 and C_2 are the main boost converter components, while R represents the resistive load on the converter. Inductor L_2, L_3, D_1, D_2 and C_1 form the auxiliary circuit for accomplishing the soft switching of S_1. Inductors L_2 and L_3 are much smaller than L_1 and C_1 is much smaller than C_2. There are seven modes of operation. The duration of modes 1, 2, 5 and 6 being quite small i_{L1} and Vout are assumed constant at I_1 and V_1 for modes 1 and 2, and I_2 and V_2 for modes 5 and 6 respectively.

MODE 1: This mode begins with the turn on of S1, at zero current at t_0.The expressions are,

$$I_{L2}(t)=V_1/i_2 \quad (1)$$

$$V_{c1}(t_1)=[V_1-V_{C1}](t_0)][1-\cos w_1t]+V_{C1}(t_0) \quad (2)$$

$$i_{L3}=[V_{C1}(t_0)-V_1](\sin w_1t)/(w_1L_3) \quad (3)$$

where $w_1=1/\sqrt{(L_3c_1)}$

When D3 stops conducting and this mode comes to an end.

MODE 2: The initial conditions on L_3, L_2 and C_1 are V respectively, attained at the end of mode 1.The expressions are,

$$V_{C1}=-v_{C1(}t_{1)}[1-\cos w_2t]+i_{L2}(t_1)/(w_2c_1)\sin w_2-v_{C1}(t_0) \quad (4)$$

$$I_{L3}=v_{C1(}t_{1)/}w_2(L_2+L_3)\sin w_2t+i_{L3}(t_1)\cos w_2t \quad (5)$$

$$I_{L2}(t)=v_{C1}/w_2(L_{2+}L_3)\sin w_2t+i_{L3}(t_1)\cos w_2t+i_1 \quad (6)$$

Where,

$$w_2=1/\sqrt{((L_2+L_3)C_i)}$$

This mode comes to an end when v_{c1} reaches zero at t_2.

MODE 3: The initial conditions on are zero The expression for i_{L3} is

$$I_{L3}(t)=((-v_sL_2)/(L_1L_2 +L_2L_3+L_3L_1))(t) +i_{L3}(t_2) \quad (7)$$

This mode comes to an end at t_3 when i_{L3} reaches zero at t_3

MODE 4: In this mode current buildup in L_1 and L_2, and $V_{out}(t)$ are governed by the equations as follows.

$$I_{L1}(t)=i_{L2}(t)=V_s/(L_1 + L_2)+ i_1 \quad (8)$$

$$V_{out}(t)=V_1e^{(1/RC)} \quad (9)$$

This mode comes to an end when S_1 is turned off at zero voltage at t_4

MODE 5: This mode begins with the turn off of S_1 at zero voltage at t_4.The expressions are,

$$V_{c1} (t) =V_2 (1-\cos w_3t) + (i_2/w_2c_1) \sin w_3t \quad (10)$$

$$I_{L2} (t) = [V_2c_1\sin w_3t-i_2 (1-\cos w_3t)] +i_2 \quad (11)$$

$$I_{L3} (t) = (L_2/L_2+L_3) [-V_{2C1}w_3t + i_2 (1-\cos w_3t)] \quad (12)$$

Where,

$$w_3=1/\sqrt{((L_2L_3)/(L_2 +i_3))}c_1$$

This mode ends when i_{l2} reaches zero at t_6

MODE 6: In this mode i_{L3} reduces to zero. This mode comes to an end at t6 when i_{L3} become zero. The expression for i_{l3} and v_{c1} for this mode is

$$i_{L3}=((V_{C1}(t_5)-V_2)/L_3w_1)\sin w_1t+i_{L3}(t_5)\cos w_1t \quad (13)$$

$$V_{C1=}[V_{C1}(t_1)-V_2][\cos w_1t-1]((i_{L3}(t_5)/w_{1C1}))\sin w_1t \quad (14)$$

MODE 7: In this mode $i_{L2,}i_{L3}$ are zero. This mode comes to an end at t_7 when S_1 is turned on at zero current. This is the normal mode of the boost converter. The expressions are,

$$V_{out}(t)=e^{-at}[A \sin w_4t + B\sin w_4t]+V_s \quad (15)$$

$$i_{L1}(t)=(V_{out}(t)/R)+e^{-at}[((-BC_2+AC_2w_4t)\cos w_4t-(AC_2+BC_2w_4)\sin w_4t) \quad (16)$$

where,

$$\alpha= (1/2RC_2) \qquad w_4=1/\sqrt{(L_1C_2)}$$

$$A=L_2/ (w_4C_2)-V_2/(Rw_4C_2)+\alpha(V_2-V_5)/w_4$$

$$B=V_2-V_s$$

This are the modes of soft switched boost converter operation for zero current turn on and zero voltage turn off.

V. BOOST INVERTER

Let us consider two dc-dc converters feeding a resistive load R as shown in Fig. 2(a).The two converters produces dc-biased sine wave output such that each source only produces a unipolar voltage. The modulation of each converter is 180 degrees out of phase with the other so that the voltage excursion across the load is maximized. Thus, the output voltage of the converters are described by

$$V_a=V_{dc}-V_m\sin wt \quad (17)$$

$$V_b=V_{dc}-V_m\sin wt \quad (18)$$

Thus, the output voltage is sinusoidal as given by

$$V_{O=}V_a-V_b=2V_m\sin wt \quad (19)$$

Thus, a dc bias voltage appears at each end of the load with respect to ground, but the differential dc voltage across the load is zero [6].

Principle of Boost Inverter

Each converter is a current bidirectional boost converter as shown in Fig 2(a). The boost inverter consists of two boost converters as shown in Fig 2(b). The output of the inverter can be controlled by one of the two methods: (1) Use a duty cycle D for converter A and a duty cycle of (1- D) for converter B. (2) Use a differential duty cycle for each converter such that each converter produces a dc-biased sine wave output. The second method is preferred and it uses controllers A and B to make the capacitors voltage v_a and v_b follow a sinusoidal reference voltage.

IV. PHOTO VOLTAIC CELL

Solar energy is a non-conventional type of energy. Solar energy has been harnessed by humans since ancient times using a variety of technologies. Only a small fraction of the available solar energy is used. Solar powered electrical generation relies on photovoltaic system and heat engines. Solar energy's uses are limited only by human creativity. To harvest the solar energy, the most common way is to use photovoltaic panels which will absorb photon energy from sun and convert it into electrical energy. Solar technologies are broadly classified as either passive solar or active solar depending on the way they detain, convert and distribute solar energy. The following figure.4 shows the basic structure of Photo Voltaic Cell [9]-[10].

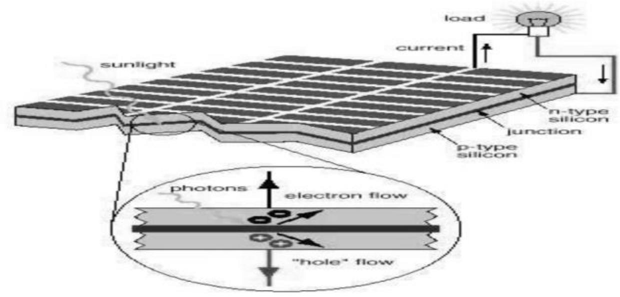

Fig 2: Basic Structure of PV Cell

From the solar radiation, Earth receives 174 Watts (W) of incoming solar radiation at the upper atmosphere. Approximately 30% is reflected back to space and only 89W is absorbed by oceans and land masses. The spectrum of solar light at the Earth's surface is generally spread across the visible and infrared region with a small part in the ultraviolet. The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 EJ per year.

4. Simulation Models

A. Simulation Model of PV System

The equivalent circuit of a PV cell is shown in Figure.5. It consists of an ideal current source in parallel with an ideal diode.

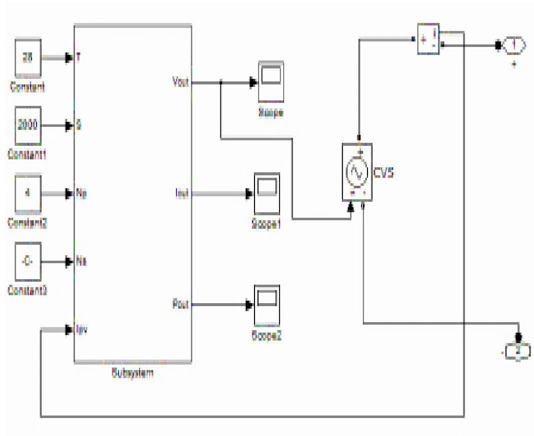

Fig 3: Simulation Diagram of PV Panel

The current source represents the current generated by photons, and its output is constant under constant temperature and constant incident radiation of light. There are two key parameters frequently used to characterize a PV cell one is the photon generated current. The photon generated current will flow out of the cell as a short-circuit current (Isc) thus, $I_{pv}=I_{SC}$. When there is no connection to the PV cell (open circuit) the photon generated current is shunted internally by the intrinsic p-n junction diode. This gives the open circuit voltage (V). It is seen that the temperature changes affect mainly the PV output current .The PV cell output equal voltage is a function of the photocurrent that mainly determined by load current depending on the solar irradiation level.

System Description

The boost dc–ac converter includes dc supply voltage V_{in} , input inductors L_1, L_2 and L_3, power switches S_1– S_5 , transfer capacitor C_1– C_3, free-wheeling diode D_1– D_5 and load resistance R. The principal purpose of the controllers A and B is to make the capacitor voltages V_1 and V_2 follow as as possible a sinusoidal reference.

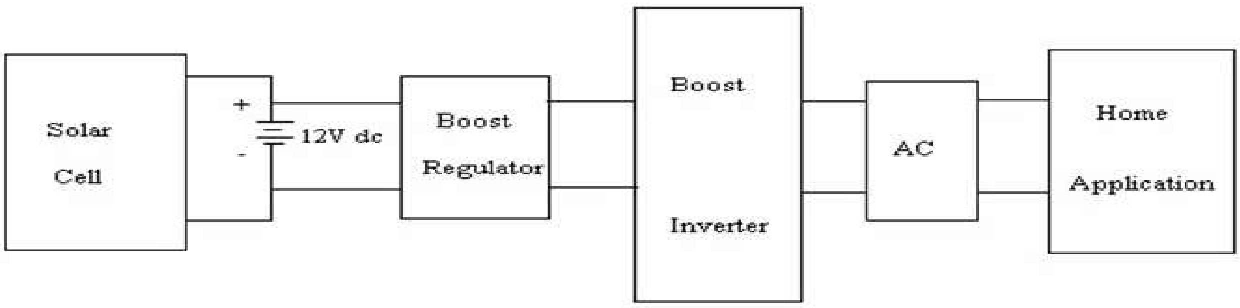

Fig 4: The Conversion Structure from Solar Cell to Load

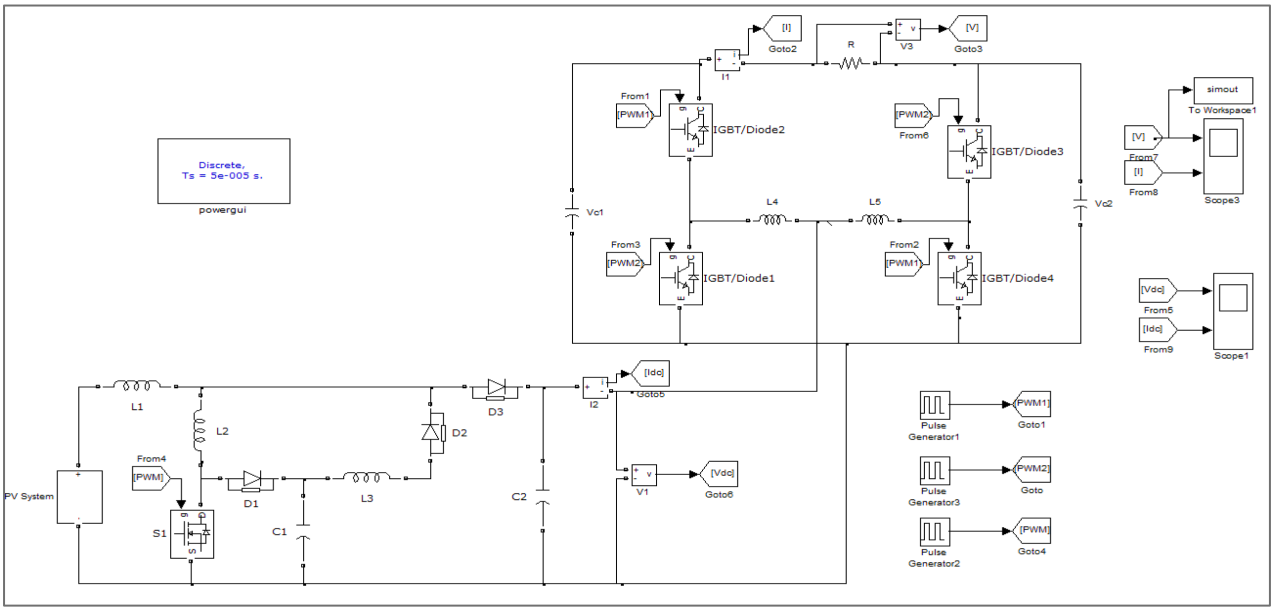

Fig 5: Simulation Diagram of Proposed System

V.SIMULATION RESULT

The simulation parameter of power electronic devices and passive devices as in MATLAB simulation

Parameters Valve of Boost Converter

- $V_{input(Solar)}$=12V
- S=IGBT Switch of Boost Converter
- D_1 –D_3=Freewheeling Diode
- L_1=1µH,
- L_2=L_3=10µH,
- C_1=1mF,
- C_2=10pF**,**

Parameters Valve of Boost Inverter

- S_1-S_2 =IGBT Switches Of Boost Inverter
- Q_1-Q_4=IGBT Switches Of Boost Inverter
- D_1-D_6=Freewheeling Diodes
- L_1,L_2=10µH
- C_1,C_2=220µF
- R_{LOAD}=200Ω
- V_{output}(Boost Converter)=56v
- V_{output}(Boost Inverter)=120V

Simulation Diagram of Boost Inverter

The simulation diagram of the proposed boost inverter has DC outputof boost converter fed boost inverter circuit which input voltage ranging of 56V. The low voltage of boost converter has boosted upto voltage 120V and also DC-AC conversion takes place. Resistive load is used in this boost inverter circuit.

From the simulation diagram of boost inverter circuit, the output voltage obtained from the boost inverter circuit is AC

voltage. Fig.3 shows the output voltage waveform of the boost inverter. The voltage and current parameter are shown in x axis and time in y axis respectively.

From the simulation diagram of boost inverter circuit, the output voltage obtained from the boost inverter circuit is AC voltage. The sinusoidal voltage is produced that the two boost converter are operated 180^0 out of phase. The load is connected differentially across the converters. Fig.10 shows the output voltage waveform of the proposed system. The voltage and current parameters shown in x axis and time in y axis respectively.The overall simulation diagram of the proposed solar power generation system is shown in the Fig.4. The DC output from solar panel which fed to boost converter circuit to boost up the voltage and then low voltage of boost converter circuit applied to boost inverter circuit to obtain 120V AC .Resistive load is used as per application purpose. Its voltage and current waveform is shown in fig.4

The simulation diagram of the proposed boost converter and boost converter for improving the power conditioning system. It consist of solar as DC input voltage ranging 12V is fed to boost converter and boost inverter to boost up the voltage level upto step up to 120v .Here capacitor acts as a filter and resistor acts as resistive load.

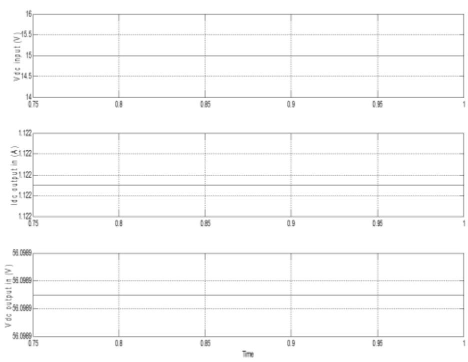

Fig 6: Output Waveform of Boost Converter

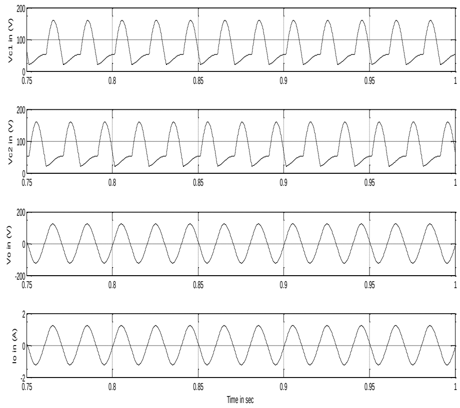

Fig 7: Output Waveform of Boost Inverter

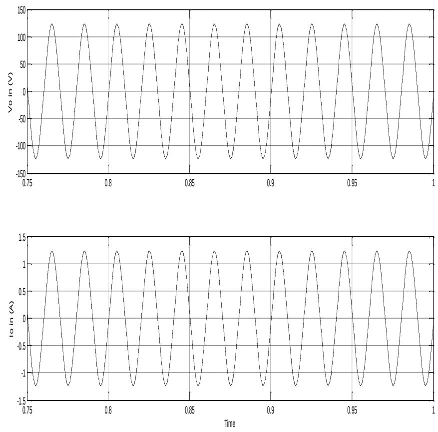

Fig 8: Output Waveform of Proposed System

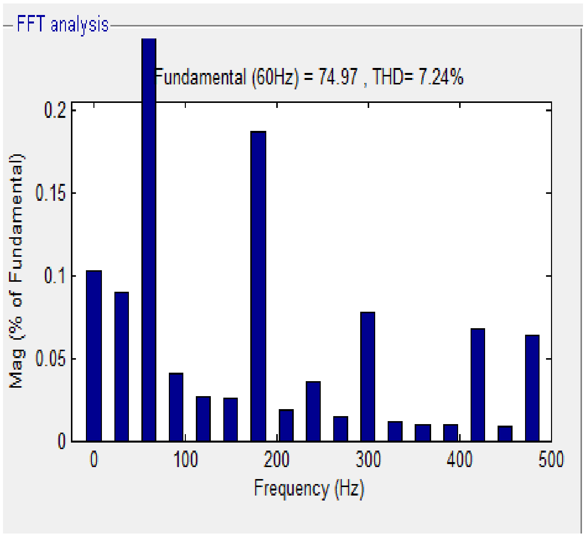

Fig 9: Total Harmonic Distortion of Conventional Method

The Total Harmonic Distortion of Conventional Method is reduced to 7.24% is shown in fig.9.

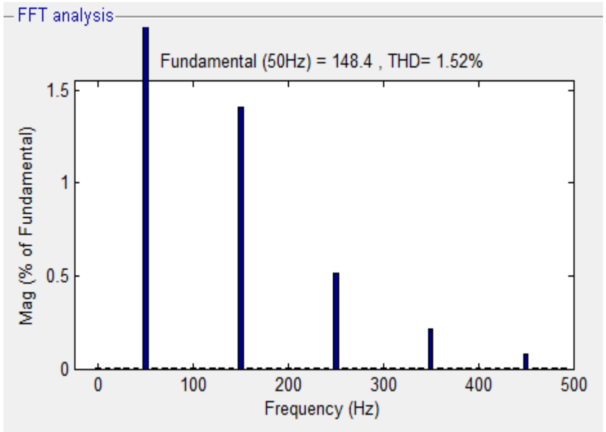

Fig 10: Total Harmonic Distortion of Proposed Method

The Total Harmonic Distortion of Proposed Method is reduced to 1.52% is shown in fig.10.

VI.CONCLUSION

In this paper we tried to implement a new type dc to ac inverter. We use IGBTs as active switches which operate at fixed frequency. Here we use different linear and nonlinear loads. Our simulation result is not completely coping with the proposed theory. Because in ours simulation we used the ideal conception. The new inverter is applicable in solar home application and UPS design when the ac voltage is larger than the dc link voltageis needed, with no need of second power conversion stages. There is a vast scope for future work about this project. Here we use SPWM to control the IGBTs which operate at high frequency and pulse width change automatically. We may use other modulation techniques to obtain the IGBTs gate. At the transistor period of the gate pulses (direct and complementary pulse) we should employ proper lock circuit. We know, at the timing ofswitching the power is lost as heat. It is possible the output will be smooth and ripple free at lower switching frequency. Then the loss will be decreased and component works more perfectly.

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