A High Voltage Gain DC-DC Boost Converter for Solar Photovoltaic Applications

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Abstract— In this project the design of high gain dc-dc boost converter is used for the solar photovoltaic applications. When the dc input is taken from the solar system, it is provided as an input to the dc-dc boost converter. Since the voltage from the solar system will have many fluctuations and it can't be directly provided to the load system. So a high gain dc-dc boost converter is used for avoiding the fluctuations and for boosting the voltage. Two MOSFET switches were used in the converter for boosting the voltage. The desired output voltage can be obtained on the load side by using this converter. If there was any low voltage supply on the input side due to changes in weather condition, then the desired voltage cannot be obtained on the load side. At that condition, by varying the duty cycle of the MOSFET switches to less than 0.5 the boosting operation will takes place and the fixed voltage can be obtained on the load side. In this project if 12V is given as an input from the solar panel then it will get boosted to more than ten times and the output voltage of 196V was obtained on the load side.

Key words: Solar Photovoltaic Applications, MOSFET, HID, UPS

I. Introduction

Coal is used as a main source for producing electricity. Other sources like are also used for producing electricity. But more electricity generation is by using coal. Since these are decaying, so we move on from non-renewable energy source to the renewable energy source. The renewable energy sources are solar, wind, hydro, the solar energy is one of the main renewable or non-conventional energy source. Solar energy is the radiant light and heat from the Sun that has been exploited by humans since ancient times using a range of ever-evolving technologies.

Solar technologies are broadly characterized as either passive or active depending on the way they capture, convert and distribute sunlight. Active solar techniques use photovoltaic panels, pumps, and fans to convert sunlight into useful outputs. Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun. Active solar technologies increase the supply of energy and are considered supply side technologies, while passive solar technologies reduce the need for alternate resources and are generally considered demand side technologies.

The coupled inductor strategy lessens the parts in the circuit and expands the static pick up of the converter. Be that as it may, it brings the issue of spillage inductance which authorizes the utilization of clipping circuit. For the previously mentioned reasons, this paper proposes a current bolstered non-disconnected lift dc-dc converter topology embracing coupled inductor strategy. The displayed converter accomplishes high voltage pick up without extraordinary obligation proportion task and draws swell free constant information current. Dynamic clipping is utilized to reuse the vitality put away in the spillage inductance and to acknowledge zero voltage exchanging (ZVS) for semiconductor gadgets, in this manner stifling the turn-on voltage surge, decreasing exchanging misfortune and expanding productivity

The inexhaustible and reasonable vitality sources, for example, photovoltaic (PV) exhibits and power module stacks, deliver an unregulated low-level DC voltage. A high voltage pick up dcdc control interface is along these lines required as front end converter in framework associated frameworks and in different regions, for example, electric drives, electric vehicles(EVs), uninterruptable power supply (UPS), control supply for high power release (HID) lights, flying applications and so on . The traditional lift converter is typically not favored since its most extreme pick up is restricted to 3-4. Further, the converter must be worked at higher obligation proportion which builds switch voltage and current pressure, diode invert recuperation misfortunes, conduction misfortunes, brings down the converter proficiency and points of confinement the power level.

II. Existing System

A. Block Diagram

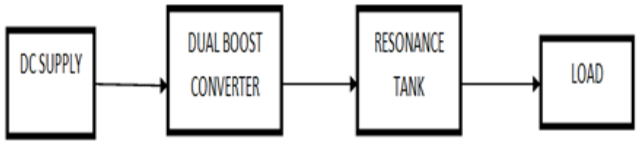


Fig. 1: Block Diagram

In an existing system, the dc supply is provided as an input to the dual boost converter. So that it will boost the dc voltage to obtain the desired output voltage. Then by using the resonant tank it was connected to the load. But the main drawback in this system was, if there is any change in the input side of the system (voltage increase or decrease), then it cannot be changed as it is an open loop system and the desired output voltage cannot be obtained. So that the sufficient voltage cannot be obtained on the load side. But in the proposed system, the fixed voltage can be obtained on the load side by using the closed loop system.

III. Proposed System

A. Block Diagram

In the proposed system, the solar panel is used for giving supply to the dual boost converter. The voltage from the solar panel will have many fluctuations, and it can be avoided by using the boost converter. It also increases the voltage to obtain the desired voltage on the load side. Then it is connected to the load through the resonant tank. By using the closed loop system, if there is any change in the temperature, the voltage from the solar panel will be decreased and it can be improved by using two MOSFET switches on the converter. By varying the duty cycle of the switches to less than 0.5, the boost operation will takes place and the voltage from the solar panel will be increased. It is the main advantage of this system. This operation will takes place by using the analog to digital converter. The analog signal will be sent from the load and it is given to microcontroller by converting it into digital signal. Then it is provided to the converter through the MOSFET driver as a closed loop system. A separate power supply is provided to the microcontroller. By using this arrangement, the fixed output voltage can be obtained on the load side. Then, the simulation and hardware results were obtained.

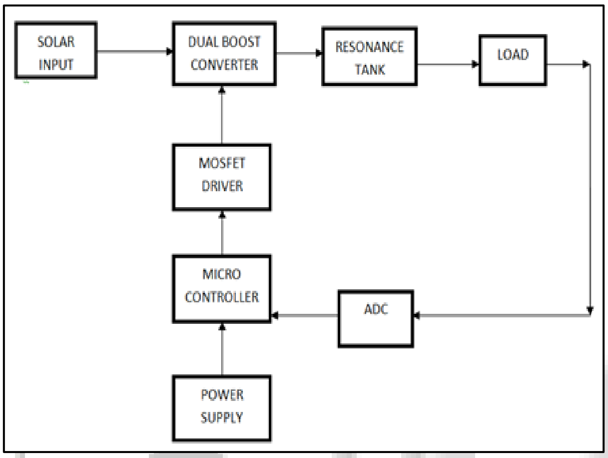


Fig. 2: Block Diagram

B. *Converter Circuit Diagram*

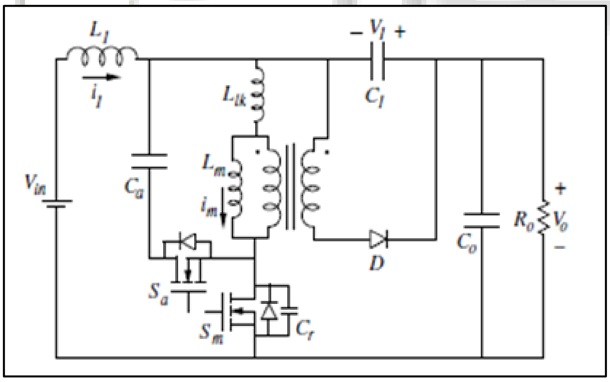


Fig. 3: Converter Circuit Diagram

The circuit conduct of the converter in light of the conduction conditions of Sm, Sa and their characteristic diodes amid one exchanging cycle are isolated into seven working modes. It can be unmistakably observed that the voltage crosswise over inductor is consistent and Vin=Vo-$V1$. The circuit conduct for every mode is broke down and the overseeing voltage and current conditions are inferred.

The circuit setup of the proposed support dc-dc converter is appeared .An info inductor $L1$, a coupled inductor with polarizing inductance Lm, control switch Sm, diode$D$, a middle of the road capacitor C_1 and a yield capacitor C_0 shape the power circuit as outlined in fig. The helper dynamic clasp circuit, appeared in figure, involving an assistant switch Sa and a clasp capacitor Ca, reuses the vitality put away in the unavoidable spillage inductance and limits the crest voltage worry of principle switch Sm. The switches Sm and Sa are worked in a correlative way, with dead-time between the rising and falling edges of their door activating signals. Both the principle switch Sm and assistant switch Sa are turned on at zero voltage exchanging (ZVS). This empowers to work the converter at higher exchanging recurrence, lessening the exchanging misfortunes and expanding the proficiency.

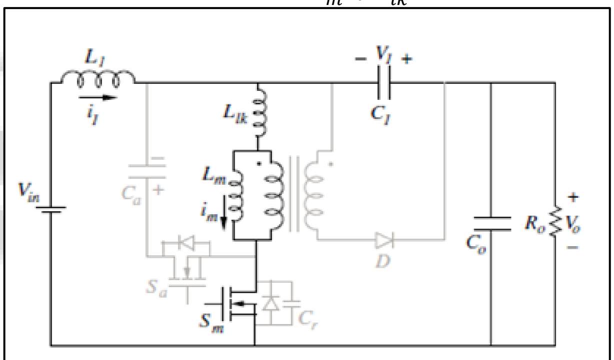
1) Switches Sm and Sa are perfect aside from their body diodes what's more, yield capacitors.
2) The capacitors C_0, C_1 and Ca are sufficiently vast to consider yield voltage Vo, middle of the road capacitor voltage $V1$ and brace capacitor voltage Va as steady.
3) The auxiliary to essential winding turns proportion is $n = ns/n$p.

IV. Modes of Operation

A. *Mode 1:*

As appeared in Fig.4, the switch Sm is ON and Sa is in OFF state. Voltage crosswise over Llk and essential twisting of the coupled inductor breaks even with $Vo - V1$. Current through Lm, Llk and Sm is straightly expanding and is communicated as

$$i_m(t) = i_{lk}(t) = i_{sm}(t) = \frac{V_0 - V_1}{L_m + L_{lk}}(t - t_1) + i_{lk}(t_1)$$



(a) t_1-t_2

Fig. 4:

The optional side voltage
v_s=n(V_o-V_1)
where
k=L_m/(L_m+L_{lk})
so diode D is in OFF state. The voltage weight on switch S_a is given as
$v_{Sa} = V_{in} + V_a$
This mode closes at t=t_2 when the principle turn S_m kills.

B. *Mode 2:*

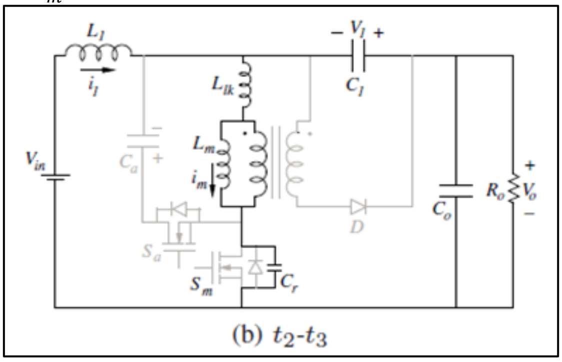
As appeared in Fig.5, this mode begins at time t=t_2 with S_m in OFF state. Assistant turn S_a is still OFF. The capacitor C_r is charged by the spillage inductor current i_{lk} (which moreover levels with the charging inductor current) from 0 to (V_{in}+V_a). Since C_r is little, it is charged directly and rapidly. The thunderous capacitor voltage v_{Cr} and inductor current are around communicated as

$$v_{c_r}(t) = \frac{i_{lk}(t_2)}{c_r}(t - t_2)$$

$$i_{lk}(t) = \frac{V_{in}}{L_m + L_{lk}}(t - t_2) + i_{lk}(t_2)$$

The polarizing inductor voltage is

$-kV_a < v_{L_m} < kV_{in}$



(b) t_2-t_3

Fig. 5:

auxiliary side voltage is

$$nkV_a < v_s < nkV_{in}$$

Subsequently diode D is OFF. This mode closes at $t=t_3$ when

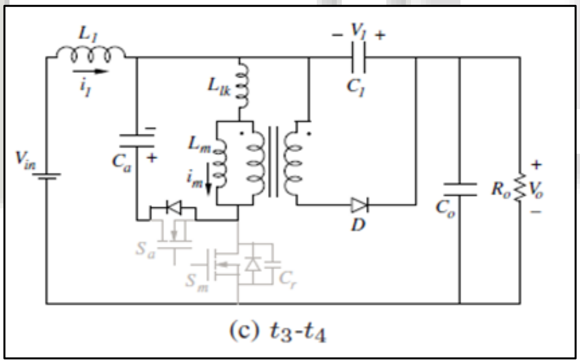
$$v_{c_r} = V_{in} + V_a$$

From (3) the time interim of this mode is given as

$$\Delta t_{23} = t_3 - t_2 = \frac{(V_{in}+V_a)C_r}{i_{lk}(t_2)}$$

C. Mode 3:

As appeared in Fig.6, at time $t=t3$, the voltage vCr squares with $(Vin+Va)$ and the body-diode of assistant switch Sa gets forward one-sided.



(c) t_3-t_4

Fig. 6:

Diode D is still OFF. Voltage over the essential winding is settled at V_a by the assistant capacitor C_a. The positive current i_{lk} charges C_a, the voltage crosswise over which is around given as

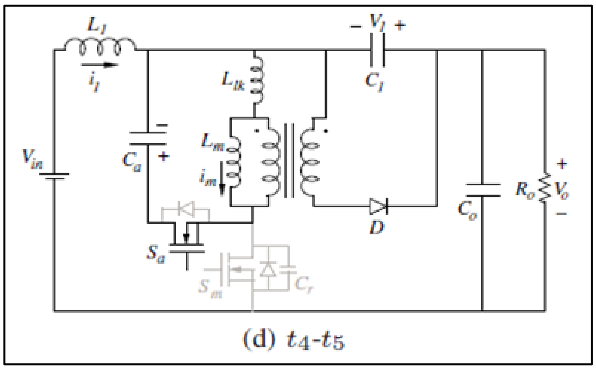
$$v_a(t) = \frac{i_{lk}(t_3)}{C_a} + v_a(t_3)$$

Subsequently voltage, vLm, showing up over the polarizing inductor diminishes as va increments as indicated by

$$v_{L_m} = -\frac{v_a L_m}{L_m + L_k}$$

D. Mode 4:

As appeared in Fig.7, at $t=t_4$, v_{Lm} has diminished to a level where the auxiliary voltage is adequate to forward predisposition D.



(d) t_4-t_5

Fig. 7:

Voltage crosswise over L_m is braced by the yield capacitor C_o to $v_{Lm}=-V_o/n$. Current i_{lk} and voltage v_a in the arrangement thunderous circuit, shaped by L_{lk} and C_a, are communicated as

$$i_{lk}(t) = i_{lk}(t_4)\cos w(-t_4) \frac{v_a(t_4) - \frac{V_1}{n}}{Z}\sin w(t - t_4)$$

$$v_a(t) = \frac{V_1}{n} + \left(v_a(t_4) - \frac{V_1}{n}\right)\cos w(t - t_4) + i_{lk}(t_4)Z\sin w(t - t_4)$$

The decreased current is denoted as,

$$i_m(t) = i_m(t_4) - \frac{V_0}{nL_m}(t - t_4)$$

The current in the diode is written as,

$$i_D(t) = \frac{-1}{n}\left(i_{lk}(t) - i_m(t)\right)$$

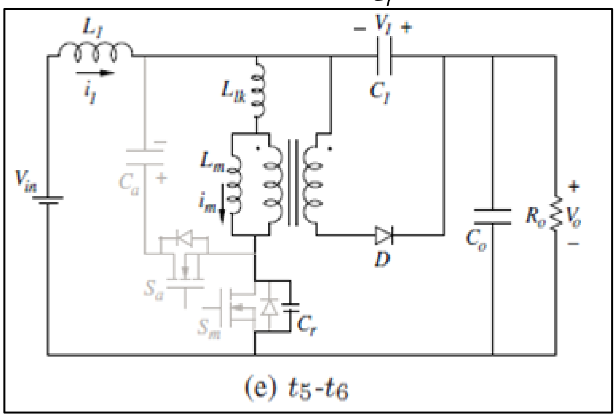
E. Mode 5:

At $t=t_5$, the switch S_a is in ON condition and the diode will be in conduction mode. The essential winding voltage is

$$v_{Lm} = -V_o/n$$

The charge from the capacitance will be fully discharged by the essential negative current and the voltage is

$$v_{c_r}(t) = (V_{in} + V_a) + \frac{i_{lk}(t_5)}{C_r}(t - t_5)$$



(e) t_5-t_6

Fig. 8:

For zero voltage switching operation, the stored energy from the inductor should be higher than the energy to be discharged,

$$\frac{1}{2}L_{lk}i_{lk}(t_5)^2 > \frac{1}{2}C_r(V_{in} + V_a)^2$$

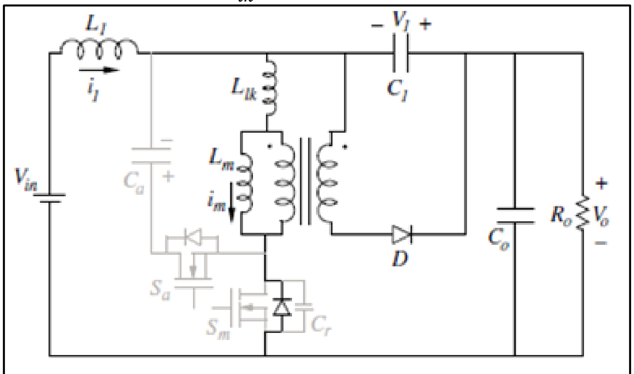
$$L_{lk} > \frac{C_r(V_{in} + V_a)^2}{i_{lk}(t_5)^2}$$

The time interval is

$\Delta t_{56} = t_6 - t_5 = \frac{-(V_{in}+V_a)C_r}{i_{lk}(t_5)}$

F. Mode 6:

As appeared in Fig.9, at time t=t_6, v_{Cr}=0 and body-diode of primary switch Sm begins directing. Diode D is still ON. Voltage over the essential winding is v_{L_m}=-V_o/n and over the spillage inductor is $v_{L_{lk}}$=V_{in}+V_o/n



(f) t_6-t_7

Fig. 9:

Consequently, current through the charging and spillage inductances is given as

$$i_m(t) = \frac{-V_0}{nL_m}(t - t_6) + i_m(t_6)$$

$$i_{lk}(t) = \frac{V_{in} + \frac{V_0}{n}}{L_{lk}}(t - t_6) + i_{lk}(t_6)$$

Current through D, is given as

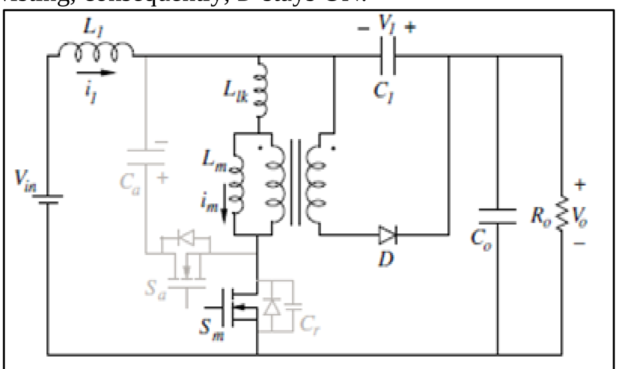
$$i_D(t) = \frac{-1}{n}\left(\frac{V_0}{nL_m} + \frac{V_{in} + \left(\frac{V_0}{n}\right)}{L_{lk}}\right)(t - t_6) + i_{lk}(t_6) - i_m(t_6)$$

what's more, the slant (negative) of the diode current is around d_{iD}

$$\frac{d_{i_D}}{dt} = -\frac{1}{n}\left(\frac{V_{in} + \frac{V_0}{n}}{L_{lk}}\right)$$

G. Mode 7:

As appeared in Fig.10, at time t=t_7, principle switch S_m is turned ON. The spillage inductance L_{lk} keeps the momentary exchange of charging current from optional to essential twisting, consequently, D stays ON.



(g) t_7-t_1

Fig. 10:

The circuit examination is same as in Mode 6. This mode closes at time t=t_1, when the current through the spillage inductor rises to the polarizing inductor current and the diode current achieves zero.

1) Voltage Gain

In view of the volt-sec adjust over the inductors Lm and $L1$, the voltage pick up of the proposed help converter can be communicated as

$$A_v = \frac{V_0}{V_{in}} = \frac{nD}{D'} + 1$$

Where D is the obligation proportion and $D' = 1 - D$. Considering the non-ideality of the inductors, the voltage pick up articulation can be spoken to as

$$A_v = \frac{kD + \frac{D'}{n}}{\frac{D'}{n} + \alpha_1\left(\frac{nkD^2}{D'} + (k+1)D + \frac{D'}{n}\right) + \alpha_2\left(n + \frac{1}{n} + \frac{nkD}{D'}\right)}$$

Where

$k = \frac{L_m}{L_m+L_{lk}}$

is coupling coefficient of coupled inductors,

$$\alpha_1 = r_1/ \ , \ \alpha_2 = r_2/R$$

is the heap protection, r_1 and r_2 are the ESR of inductors L_1 and L_m individually. Subsequently, the plot of voltage pick up as an element of obligation proportion under different turns proportion, coupling coefficients of coupled inductors.

V. SIMULATION RESULTS

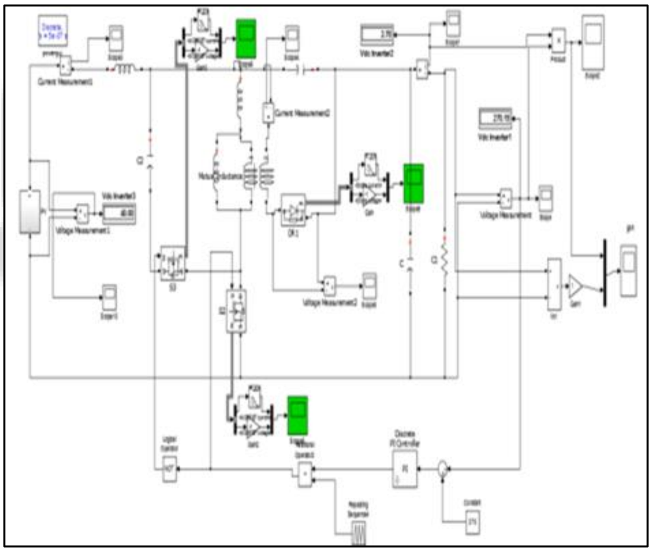


Fig. 11: Simulation Circuit Diagram

A. Input Voltage

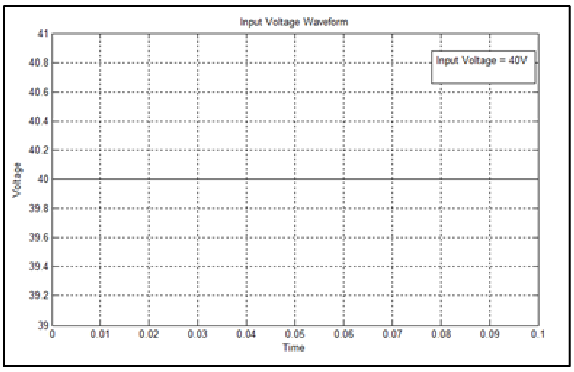


Fig. 12: Input Voltage

The input voltage of 40V from the solar panel is applied to the conventional boost converter and it can be boosted to more than ten times by using the converter. The DC input is provided from the solar panel. The input current waveform is plotted with current against time.

B. Input Current

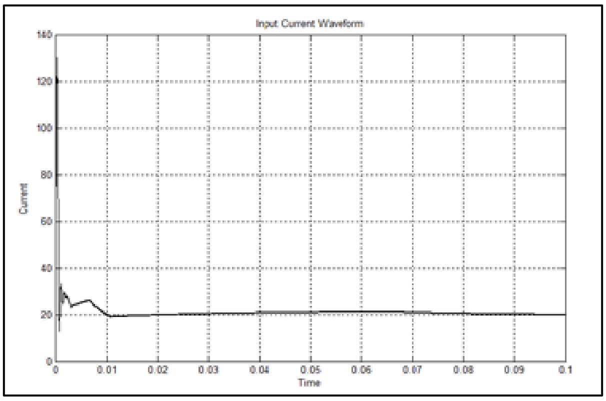


Fig. 13: Input Current

When the switch is in reverse biased condition, the diode D will be in OFF condition and the reverse/negative current will in the circuit through the capacitor. This current is said to be the reverse current of capacitor.

C. Reverse Current

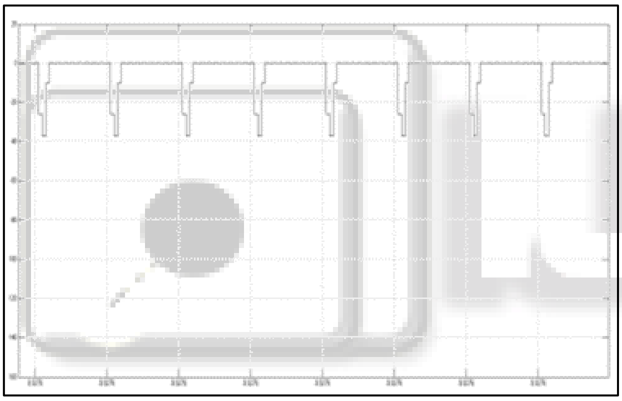


Fig. 14: Reverse Current

The transformer will be connected with the inductance on the primary side and capacitance on the secondary side in the with active clamp circuit. The transformer voltage is of greater than 400V.

D. Transformer Voltage

By giving the input voltage of 40V from the solar panel, the voltage can be boosted from the converter and the desired output voltage of 270V can be obtained. By using closed loop operation, if there is any changes on the input side, then by varying the duty cycle of the MOSFET switches, the output voltage can be obtained.

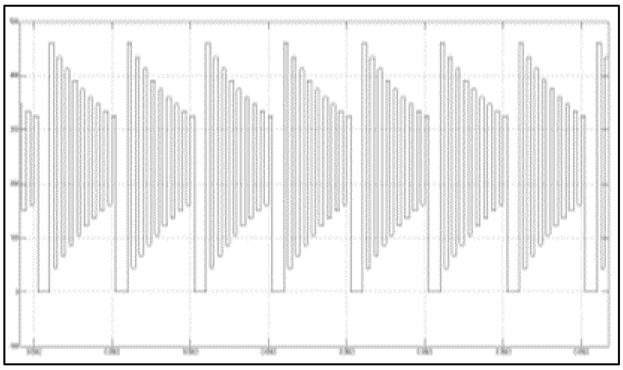


Fig. 15: Transformer Voltage

From the DC input of solar panel, the output of more than 2.5 can be obtained and by plotting the current Vs time, the output current waveform can be obtained.

E. Output Voltage

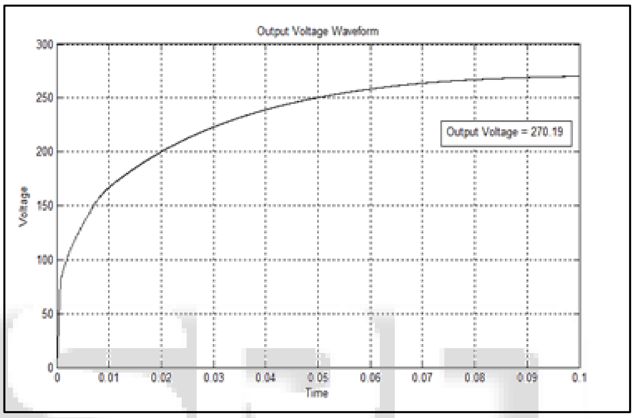


Fig. 16: Output Voltage

F. Output Current

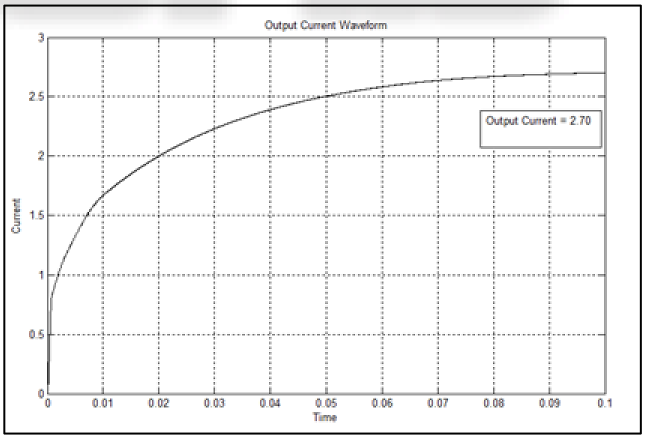


Fig. 17: Output Current

G. Gain Waveform

The gain voltage is defined as the ratio of output voltage to the input voltage and efficiency is the ratio of output power to the input power. From this conventional DC-DC boost converter, the gain voltage of above 700 can be obtained.

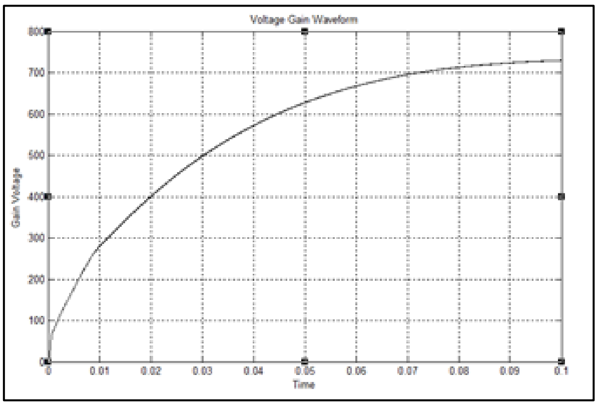


Fig. 18: Gain Waveform

VI. Hardware Results

A. Solar DC Input

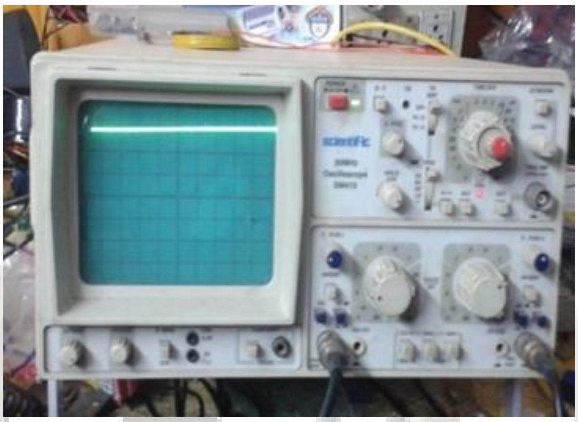


Fig. 19: DC input

The DC input of 12V is provided from solar to the conventional boost converter for avoiding the fluctuations and to make the voltage constant. By using the converter, the voltage can be boosted into more than ten times.

B. Pulse input to Switches

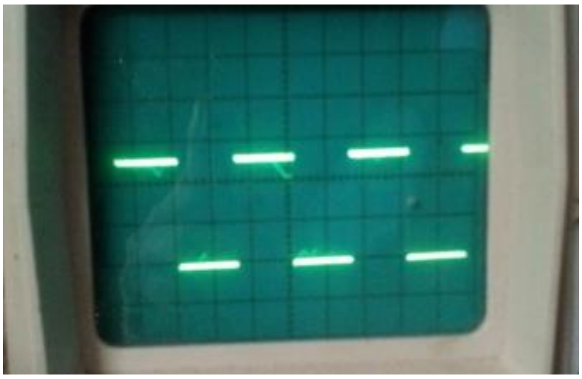


Fig. 20: Pulse input to Switches

When the supply is provided, the pulse transformer will get started and the pulse will be provided to the MOSFET switches. If the desired voltage is not obtained, then by varying the duty cycle to below 0.5, the fixed voltage can be obtained on the output side.

C. Hardware Picture

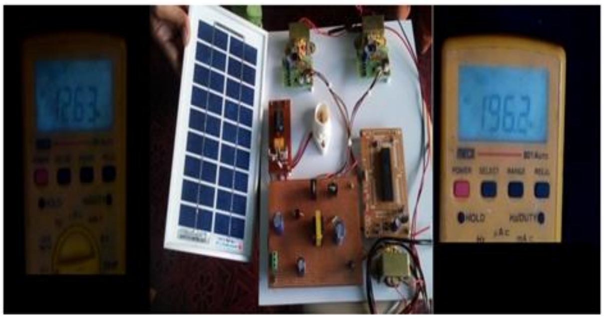


Fig. 21: Hardware

This proposed system has the main components like

- Solar panel,
- DC-DC boost converter,
- Two pulse transformers for two MOSFET switches,
- Micro-controller and
- RL load

D. Solar Input

Solar panel is used as an input to this closed loop system. The solar panel of 3W and 12V are used and it can be boosted to more than ten times.

E. Microcontroller

The PIC micro-controller “PIC 16F84A” is used in this system. The PIC16F84A belongs to the mid-range family of the PIC microcontroller devices. The program memory contains 1K words, which translates to 1024 instructions, since each 14-bit program memory word is the same width as each device instruction. The data memory (RAM) contains 68 bytes. Data EEPROM is 64 bytes. There are also 13 I/O pins that are user-configured on a pin-to-pin basis.

F. DC-DC Boost Converter

A High voltage gain DC-DC conventional boost converter is used in this system. It is the main part of this system. This conventional boost converter has totally seven modes of operation. The converter consists of capacitors, inductors, linear transformer, two MOSFET switches and RL load.

G. RL Load

The RL load is used in this system. It consists of a transformer and rectifier with a capacitor. If there is any deviation on the load side then it can rectified by using the closed loop system.

H. Pulse Transformer with Driver

Two pulse transformers are used for two MOSFET switches and if the input voltage is changed due to the deviation in temperature, then the desired output voltage cannot be obtained. At that condition, by using this pulse transformer the duty cycle of the MOSFET switches can be varied to below 0.5, so that the boost operation will takes place.

I. DC Output

By using this type of conventional boost converter the voltage get boosted into more than ten times of 196.2V and DC output of straight line can be obtained,

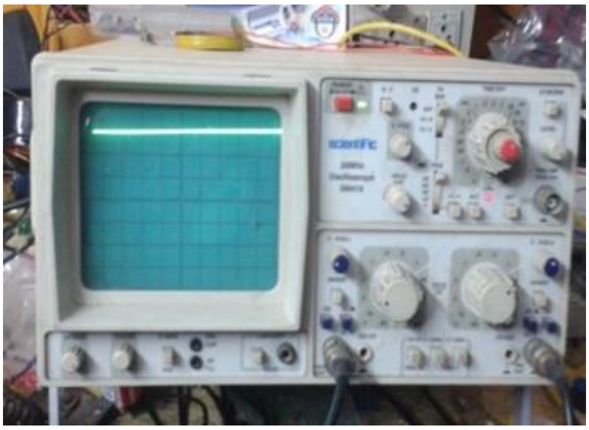


Fig. 22: DC output

J. Comparison of Input and Output

The input voltage of 12.63V is provided as an input from the solar panel, then by using the conventional boost DC-DC converter, the voltage can be boosted to more than ten times of 196.2V can be obtained.

VII. INFERENCE TABLE

Parameters	Range
Input Voltage	12.63V
Input current	20A
Reverse current	-38A
Output Voltage	196.2V

VIII. CONCLUSION

The proposed high gain dc-dc boost converter has many advantages of zero-voltage switching (ZVS), circulating current will be reduced, low conduction loss and size of the inductor were reduced. By using this converter, the desired output voltage can be obtained on the load by varying the duty cycle of the switches. So that the load efficiency can be increased. The energy stored in the inductor during starting can be recycled and input current flow will not be discrete. The closed cycle of operation will takes place by using PI controller for varying the modes to obtain the fixed output voltage on the load side.

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