

Design and Simulation of DC-DC Boost Converter for Solar PV Application to Track Maximum Power

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Abstract – The solar energy conversion system is very interesting alternative or addition the electric system generation, due to the president cost reduction of the overall system and cleaner power generation. The switching mode power supply requirement is quickly increasing up in the today's world. In many technical applications it is required to convert a set voltage dc sources into a variable dc output voltage. This paper proposed to provide the design equations of DC-DC boost converter along with an example of boosting DC voltage from 25 to 100 for solar PV application. Because the output voltage from the solar panel is not constant and power from the panel is very low. Adding in or an extra voltage supply to a design is not always cost efficient. Results of simulation show that the switching converter will boost voltage from 25 volts to 100 volts with all data, tests and calculations.

Keywords: DC-DC boost converter, solar panel, battery management system.

I. Introduction

Renewable and sustainable energy sources such as photovoltaic (PV) and fuel cells (FC) require power electronic conditioning [1]. Recently, the installation of PV generation systems is quickly growing due to concerns related to atmosphere, global warming, energy defense, technology improvements and decreasing costs. PV generation scheme is considered as a clean and environmentally-friendly source of Energy Photovoltaic PV systems are one of the today's best growing renewable energy technology. The output of the FC or PV cells is typically an unregulated low-level DC voltage that needs to be stepped up to a regulated higher level, for many potential convenient applications, and boost converter stages are engaged for this purpose. For elevated efficiency, the SMPS switch must turn on and off quickly and have very less losses. The coming of a profitable semiconductor switch such as the boost converter represented a major milestone that made SMPSs possible. Switched systems such as SMPS are a challenge to design since its model depends on whether a switch is opened or closed. DC converters are broadly used for grip motor control in electric automobiles, trolley cars, marine hoxists, forklifts trucks, and mine haulers[1]. Many types of SMPS converters which change the output voltage as required for specific applications. There are four main types of converter in this non-isolating group, usually called the buck ,boost, buck-boost and cuk converters. The buck converter is use for voltage stand down , while the boost converter is use for voltage step-up. The buck-boost and Cuk converters be able to be second-hand for either step-

down or step-up, but are fundamentally voltage polarity reversers or 'inverters' as well. In a boost converter, the output voltage is greater than the input voltage – hence the name "boost". DC converters are used in DC voltage regulators; and also are used, with an inductor in combination, to generate a DC current source, particularly for the current source inverter. The switches are generally passive or Active type. Passive switches consists of a diode, while the active switches are like MOSFET transistor[2]. MOSFET transistors are an efficient and fast way to allow a pulse width modulation (PWM) signal to control. The frequency and duty cycle of the ON and OFF time of the "switch". More power is transferred from input to output when Duty cycle is high. Boost converters can rise the voltage and reduce the cell numbers. It can also make high voltages to operate cold cathode fluorescent tubes (CCFL) in devices such as LCD backlights and some flashlights. There are a range of uses for a DC-DC boost converter. Travelers need to carry such devices when they want to bring electronics from home and the supply of current in a foreign country differs from that which is here at their home. Sometimes only a plug converter is essential, but in other cases, plugging electronics directly into the power supply could damage the devices. A boost converter provides a bridge to allow travelers to entrance electricity safely. Such devices are also used with systems that require high voltage, ranging from dramatic lighting to scientific apparatus. Boost converter is also used in a Solar photovoltaic cells because the output voltage from the cells is very less and not a constant rated value, so by using boost converter the output voltage is taking fixed value or greater than the generated voltage by cells.[3]

Power for the boost converter can come from any appropriate DC sources, such as batteries, solar panels, rectifiers and DC generator.

II. General Boost Converter Configuration

The boost is a standard non-isolated power step topology, at times called a step-up power stage. Power supply designer select the boost power stage because the required output is always higher than the enter voltage .The obstruct diagram of boost converter is shown in Figure 1. In which the voltage source provides the input DC voltage to the switch control, and also to the magnetic field storage space element. The block which contain switch control direct the action of the switching factor, whereas the output rectifier and filter deliver an acceptable DC voltage to the output . The output capacitor supplies the whole load current for the rest of the switching cycle [4] .It is a type of switch mode power supply (SMPS) containing at least two semiconductors and at least one energy storage element, a capacitor, inductor or the two in grouping. This combination made a filters and it normally added to the output of the converter to reduce output voltage ripple .Figure 1 shows a simplified schematic of the boost power stage with a drive circuit block built-in. Power switch Q1 is n-channel MOSFET. The output diode is CR1. Inductor L and capacitor C make up the effective output filter. The capacitor corresponding series resistance (ESR), R_C , and the inductor dc resistance, R_L , are built-in in the analysis. Resistor R represents the load see by the power supply output.

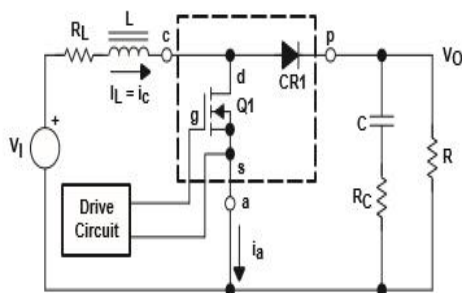


Fig.1: Basic diagram of boost converter

For the duration of usual operation of the boost power stage, Q1 is frequently switched on and off with the on and off times governed by the control circuit. This switching act generated a train of pulses at the junction of Q1, CR1, and L. Although inductor L is connected to output capacitor C only when CR1 conduct, an effective L/C output filter is produced. It filters the train of pulses to generate a dc output voltage, V_o .

II.1. Operating Modes of Boost Converter

The main principle that drives the boost converter is the tendency of an inductor to resist changes in current by

creating and destroying a magnetic field. In a boost converter, the operating modes of power converter is depends on inductor current..

II.2. Boost Steady-State constant Conduction Mode

In continuous inductor current mode, current flows frequently in the inductor during the entire switching cycle. When the switch is stopped, current flows throughout the inductor in clockwise path and the inductor stores some energy by generate a magnetic in steady-state operation. In the on position, Q1 is going on and D1 is off. In the off position, Q1 is off and D1 is going on. A easy linear circuit can represent each of the two states where the switches in the circuit are replaced by their equivalent circuit during each state. Figure 2 shows the linear circuit map for each state.

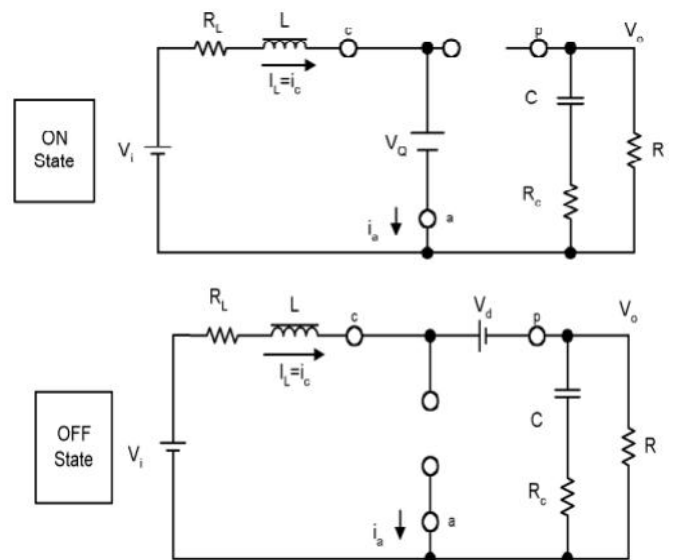


Fig 2: Boost power stage state in CCM mode

The duration of the on state is $D \times T_s = T_{ON}$, where D is the duty cycle set by the control circuit, articulated as a ratio of the switch on time to the time of one complete switching cycle, period of the off state is T_{OFF} . Waveforms of boost converter in CCM mode is shown in Figure 3.

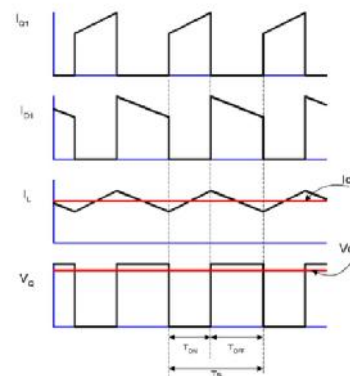


Fig 3: Waveforms of boost converter in CCM mode

The inductor-current raise can be calculated by this relationship

$$\begin{aligned} \text{i. } V_L &= L \times \left[\frac{di}{dt} \right]_L \\ \text{ii. } I_L &= V_L / L \times T \end{aligned}$$

The increasing inductor current at ON state

$$I_L (+) = (V_i - (V_Q + I_L \times R_L)) / L \times T_{ON}$$

The decreasing inductor current at off state

$$I_L (-) = ((V)_O + V_d + I_L \times R_L) / L \times T_{OFF}$$

II.3. Boost Steady-State Discontinuous Conduction Mode (DCM)

In discontinuous inductor current mode, inductor current is zero for a section of the switching cycle. It starts at zero, reaches peak value, and go reverse to zero during each switching cycle. The wave forms of boost converter in DCM is shown in Figure 4. From the charge and discharge of output capacitor, the yield current is given by:

$$I_O \times (T_{ON} + T_{OFF}) = I_{PK} / 2 \times T_{OFF} = I_{PK} = \left[\frac{2I}{1-D} \right]_O$$

Where D is duty cycle.

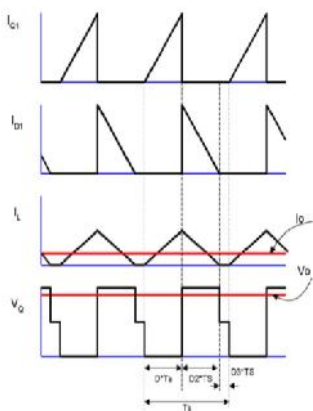


Fig. 4.: The waveforms of boost converter in DCM is

The duration of the off state is $T_{OFF} = D^2 \times T_S$. The idle time is the remainder of the switching cycle and is given as $T_S - T_{ON} - T_{OFF} = D^3 \times T_S$. These times are exposed with the waveforms in Figure 4

II.4. Design Calculations

a.b.a-Selection of inductor: The inductor acts as the magnetic field storage element . Selection of inductor should be done on the basis so that it allows the maximum ripple current at minimum duty cycle D. Boost inductor value can find out by the following equation

$$L = (V_{in} \times (V_{out} - V_{in})) / (I_L \times F_S \times V_{out})$$

a.b.b Selection of capacitor: The diode and the capacitor are used to execute the function of the output rectifier and filter block. The value of capacitor should be chosen in such a way so that its ESR should be minimum. Lower ESR will also minimize the ripple in output voltage .. This minimum value is necessary to stabilize the input voltage due to the peak current requirement of a switching power supply. The value can be increased if the input voltage is noisy.

$$C = (I_{Omax} \times D_{max}) / (f_s \times V_{O})$$

Where, $I_{O(max)}$ is the maximum output current and D_{Omax} is the maximum duty cycle. For alternating inductor current mode process, to determine the amount of capacitance required, the following equation is used assuming all the output voltage ripple is due to the capacitor's capacitance.

$$C = D / (R_{(0 \times f)} \times (V/V_0))$$

a.b.c-Power Switch: The function of the power switch is to control the flow of energy from the input power source to the output voltage. In a boost power stage, the power switch (Q1 in Figure 1) connects the input to the output filter when the switch is turned on and disconnects when the switch is off. The power switch must conduct the current in the inductor while on and block the full output voltage when off. The type of power switch considered in this report is a power MOSFET.[5]

The power dissipated by the power switch, Q1, is specified by:

$$P_{D(Q1)} = (I_O / (1-D)) \times R_{DS(ON)} \times D + 1/2 \times V_O \times (I_O / (1-D)) \times (t_r + t_f) \times f_s + Q_{GATE} \times V_{GS} \times f_s$$

Where t_r and t_f are the MOSFET turn-on and turn-off switching times Q_{Gate} is the MOSFET gate-to-source capacitance.

II.4. Output Diode

The output diode conducts when the power switch turns off and provide a path for the inductor current. Main criteria for select the rectifier include: quick switching, breakdown voltage, current rating, low forward-voltage drop to minimize power dissipation, and appropriate packaging. The voltage drop across the diode in a conducting state is primarily responsible for the losses in the diode. The power degenerate by the output rectifier is given by:

$$P_{D(Diode)} = V_D \times I_O$$

Where V_D is the forward voltage fall of the output rectifier.

II.5. Critical inductance

The required value of critical inductance is minimum for CCM. Because the inductor current never become zero for CCM mode. The value of critical inductance is given by this equation

$$L_{crit} = \frac{R_o \times D(1 - D)}{2f_s}$$

2.2.6-Duty cycle: The value of duty cycle is given by corresponding output voltage. Equation of duty cycle is given below.

$$D = 1 - \left(\frac{V_{in}}{V_o}\right)$$

III. Design of Simulink Models

A SIMULINK MODEL OF SOLAR PV WITH RESISTIVE LOAD.

As shown in the Figure 5, designed circuit is simulated in the matlab Simscape. In this stimulant model solar panel which contain 36 solar cell is connected to the resistive load at output terminal. The output power of solar panel is nearly 28 to 29W

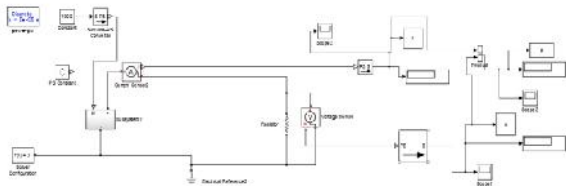


Fig: 5 Simulink model of solar PV for resistive load

The waveform of the output voltage and output power from the solar panel without boost converter is shown in Figure 6 and Figure .7.

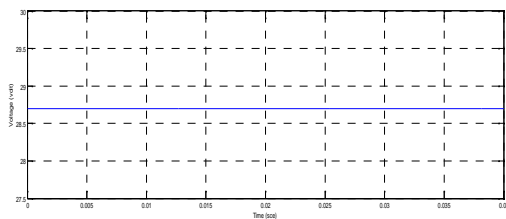


Fig:6 Waveform of output voltage of solar PV for resistive load

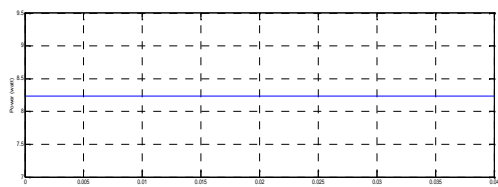


Fig:7 Waveform of output power of solar PV for resistive load

III.1 Simulink Modal of 25-100v DC_DC Boost Converter for Solar PV Application

Given below is a circuit diagram in Figure 8 used for MATLAB simulation of 25-100 volt boost converter. The purpose of this circuit is to increase the power of the solar panel. .By using 25-100 V DC-DC boost converter with the help of simulink and simscape library the power from the solar panel is increase up 97 to 98 percent shown in fig 5. In the simulink model solar panel which contain 36 solar cell is connected to the dc –dc boost converter. A Solar PV module is mathematically modeled and connected at the DC input of the DC –DC converter under standard test condition of 1000W/sq.m and with a temperature of 25K[6]. The n- channel mosfet is used to switch control, the gate to source voltage is given by the PWM technique. The resistive load is connected to the output terminal.

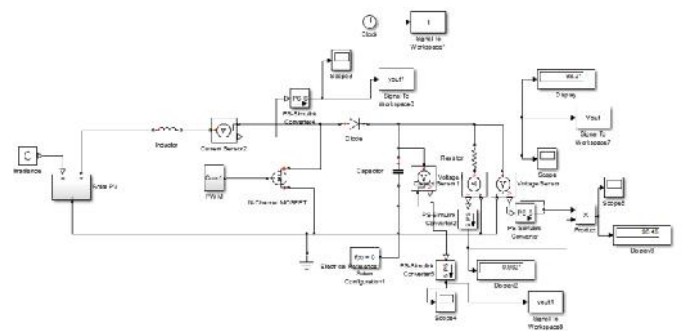


Fig:8 Simulink model of 24-48V Boost converter

Given below in Figure 9 is increased the 97 to 98% output power of the solar panel by using 25-100V DC-DC boost converter with a maximum output ripple of 1%.

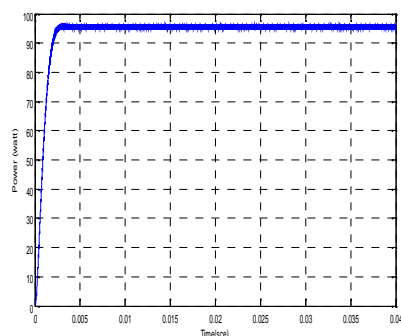


Fig:9 Waveform of output voltage of boost converter for solar PV

The waveform of the output voltage of boost converter in which 25V is input voltage and output voltage is 98V are shown in Figure 10.

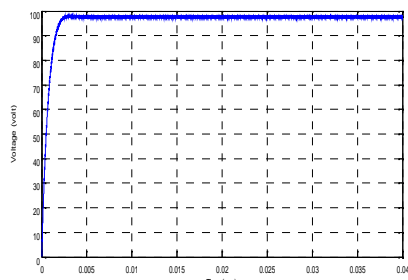


Fig:10 waveform of output power of boost converter for solar PV

IV. Design Parameter of 25-100V Boost Converter and Solar PV

Serial No.	Name of parameter	Value of parameter
1.	Input voltage	24V
2.	Output voltage	48V
3.	Output resistance	10
4.	Output capacitor	0.0005 μ F
5.	Inductor	0.0025 H
6.	Critical Inductor	0.000625 H
7.	Duty cycle	0.5
8.	Temperature	25K
9.	Open circuit voltage	28 V
10.	Short circuit current	4.16 A
11.	Output power	98W

V. Result

Based on the above analysis the step up DC – DC converter is have to obtain the more voltage gain for the required voltage rating for the solar power application with proper design of all the parameter of the circuit diagram. It is clearly observed from waveform that the boost converter steps up the voltage from 25V to 100 volt in accordance with the parameters derived.

VI. Conclusion

All of the specifications stated beforehand have been met by this boost converter design. By using MATLAB all calculated parameters were performed and corresponding waveforms were obtained. The output voltage across the

capacitor is nearly 100V with a maximum output ripple of 1% and power efficiency up to (98%). So the procedure obtain in this paper can be easily adopted for boost converter. it is therefore feasible for common solar DC-DC conversion application.

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