

Simulation Analysis of Voltage-Lift Type Boost Converter for Solar Photovoltaic System

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Abstract: *Solar photovoltaic (SPV) systems are now widely used to generate electric power for homes, industries and commercial buildings. In photovoltaic based power system, power electronic interfaces are required for the efficient and reliable performance. This paper deals with photovoltaic based voltage-lift type boost converter for a standalone system. In this type of positive output dc-dc boost converters series voltage-lift technique is applied. Compared with the traditional boost converter, this converter can give dc-dc voltage with higher voltage conversion ratios. It is different from other existing dc-dc boost converters and is featured with the single-switch operation in simple structures. This voltage lift boost converter is connected with single phase full bridge inverter for AC system applications. In this paper simulation analysis of photovoltaic based traditional boost converter and voltage-lift type double and triple boost converter is done in MATLAB/Simulink environment. The simulation of boost converters integrated with single phase full bridge inverter and LC filter is also done. It is observed that with the use of voltage-lift type converter high voltage is obtained at the output stage and with the use of LC filter more sinusoidal AC output voltage is possible and the power quality of boost converter fed photovoltaic standalone system is highly improved.*

Keywords: Solar photovoltaic, boost converter, dc-dc, voltage-lift type, single phase full bridge inverter, passive filters

1. Introduction

In the recent years, with the growth in population, the demand for electrical energy has also increased. As a result, the research has been extended to generating power from solar energy. The key element required for producing electricity from sun is the solar panel or photovoltaic panel (PV panel). Photovoltaic (PV) sources are used today in many applications from satellite power systems to battery chargers and home appliances. PV is an important green energy source because it has the advantages of being pollution free, low maintenance, with no noise or wear due to the absence of moving parts. Usually, when a PV module is directly connected to a load, the operating point is rarely at the maximum power point or MPP. Thus tracking the maximum power point (MPP) of a photovoltaic (PV) array is usually an essential part of a PV system. A converter is therefore required to produce a constant voltage that is matched to the requirements of the load and supplied efficiently.

The voltage lift technique is a popular method that is widely applied in electronic circuit design. Because of the effect of parasitic elements, the output voltage and power transfer efficiency of DC-DC power converters are limited. The voltage lift technique opens a good way to improve circuit characteristics. After long-term research, this technique has been successfully applied for DC-DC power converters. These converters perform positive to positive DC-DC voltage increasing conversion with high power density, high efficiency and cheap topology in simple structure. They are different from other existing DC-DC step-up power converters and possess many advantages including a high output voltage with small ripples. Therefore, these converters will be widely used in computer peripheral equipment and

industrial applications, especially for high output voltage projects.

This paper presents an experimental study of PV system based Boost converter. We present in the first an operating principle of Traditional boost converter. The Boost converter with various voltage- lift is shown in the second part. In third part, the different experimental results obtained are presented.

2. Traditional Boost Converter

This paper mainly focused on a Photovoltaic system based voltage lift type boost converter. A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage. Boost converter is sometimes called a step-up converter since it “steps up” the source voltage. The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. When being charged it acts as a load and absorbs energy (somewhat like a resistor); when being discharged it acts as an energy source (somewhat like a battery). The voltage it produces during the discharge phase is related to the rate of change of current, and not to the original charging voltage, thus allowing different input and output voltages.

3. Voltage Lift-Type Boost Converter

The fig. 1 shows a step up or PWM boost converter. It consists of a dc input voltage source V_s , boost inductor L , controlled switch S , diode D , filter capacitor C , and the load resistance R . When the switch S is in the on state, the current in the boost inductor increases linearly and the diode D is off at that time. When the switch S is turned off, the energy

stored in the inductor is released through the diode to the output RC circuit.

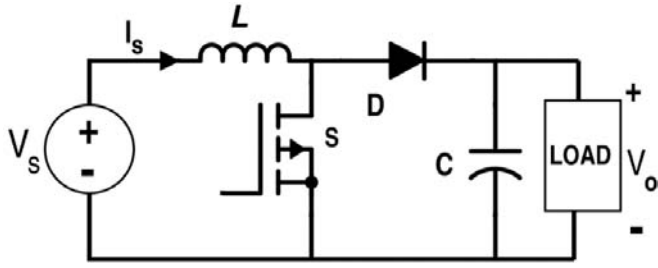


Figure 1: Circuit diagram of Boost converter

3.1 Double Lift Boost Converter

The Double-lift circuit shown in Fig. 2 is derived from the boost converter by adding the components ($D_1 - C_1 - L_1 - D_2$). The combination of ($D_1 - C_1 - L_1 - D_2$) can be regarded as a basic VL cell to enhance the voltage boost ability of the circuit. When switch S turns on, both D_1 and D_2 are on, and D_0 is off. When S turns off, both D_1 and D_2 is off, and D_0 is on. The capacitor C_1 performs characteristics to lift the output capacitor voltage V_{C_0} by the input voltage V_{in} .

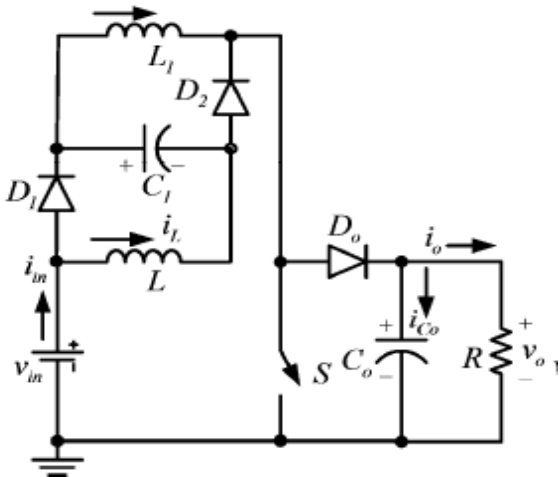


Figure 2: Double-lift circuit

3.2 Triple Lift Boost Converter

The triple-lift circuit shown in Fig. 4 is derived from the double lift circuit by adding the components ($D_3 - C_2 - D_4 - L_2$). The combination of $D_1 - C_1 - D_2 - L_1 - D_3 - C_2 - D_4 - L_2$ can be divided into two basic VL cells. The first VL cell is $D_1 - C_1 - D_2 - L_1$, and the second VL cell is $D_3 - C_2 - D_4 - L_2$. When S turns on, D_1, D_2, D_3 and D_4 are on, and D_0 is off. When S turns off, D_1, D_2, D_3 and D_4 are off, and D_0 is on. C_1 Both and C_2 perform characteristics to lift the output capacitor voltage V_{C_0} by V_{in} . L_1 Performs the function of a ladder joint to link the two capacitors C_1 and C_2 lift V_{C_0} .

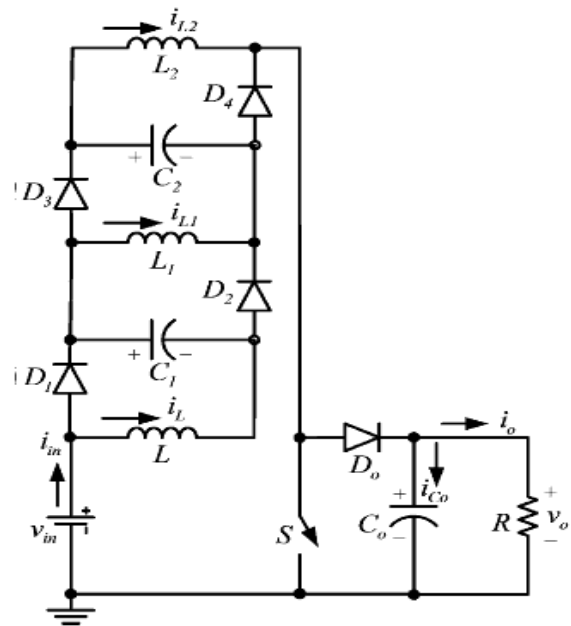


Figure 3: Triple-lift circuit

4. Inverter

An inverter is basically a device that converts electrical energy of DC form into that of AC. The purpose of DC-AC inverter is to take DC power from a battery source and converts it to AC. For example the household inverter receives DC supply from 12V or 24V battery and then inverter converts it to 240V AC with a desirable frequency of 50Hz or 60Hz. These DC-AC inverters have been widely used for grid connection of Wind Energy System or Photovoltaic System.

The inverters usually operate in a pulse width modulated (PWM) way and switch between different circuit topologies, which means that the inverter is a nonlinear, specifically piecewise smooth system. In addition to this, the control strategies used in the inverters are also similar to those in DC-DC converters. Both current-mode control and voltage-mode control are employed in practical applications. There are various types of PWM techniques and so we get different output and the choice of the inverter depends on cost, noise and efficiency. We will discuss only sinusoidal pulse width modulation technique below.

Sinusoidal Pulse Width Modulation: In this modulation technique are multiple numbers of output pulse per half cycle and pulses are of different width. The width of each pulse is varying in proportion to the amplitude of a sine wave evaluated at the center of the same pulse. The gating signals are generated by comparing a sinusoidal reference with a high frequency triangular signal.

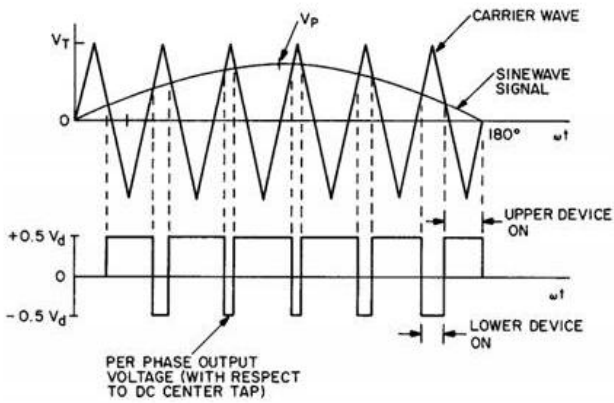


Figure 4: Sinusoidal Pulse Width Modulation

In this paper we take carrier frequency is 10 kHz, Modulation index is 0.9, modulation signal frequency for sine wave is 50 Hz.

5. Passive Filter

Harmonic elimination in inverters fed from a standalone photovoltaic power system is becoming very important in AC power applications. For standalone PV applications, generally PWM based single phase full bridge inverters are used for connecting the output from the PV panel to an isolated ac load. However PWM inverters inherently generate harmonics and produce a distorted output thereby reducing the power quality of the total system. A simple method to reduce output harmonic from a voltage source inverter is the use of a LC filter which is usually placed between the inverter and the load in a standalone PV system, is a second-order type of filter. A passive LC filter contains an inductor connected in parallel with a capacitor.

6. Simulation Analysis

Table 1: Simulation Parameters

S.No	Parameter	Values
1	Input voltage	21 V
2	Switching frequency	10 KHz
3	Duty Cycle	0.8333
4	Carrier frequency	10 KHz
5	Output frequency	50 Hz
6	Load	R= 200Ω ; L = 12mH

(A) Photovoltaic array fed boost inverter circuit

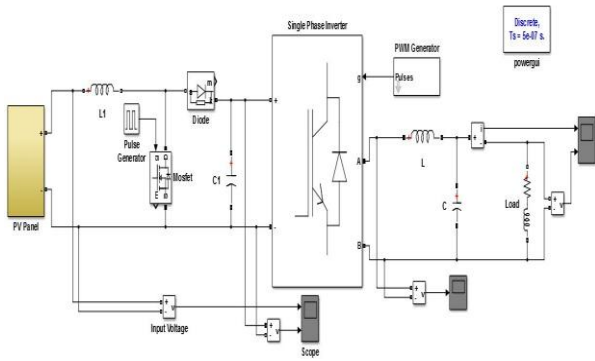


Figure 5: Simulink model of PV fed boost inverter circuit

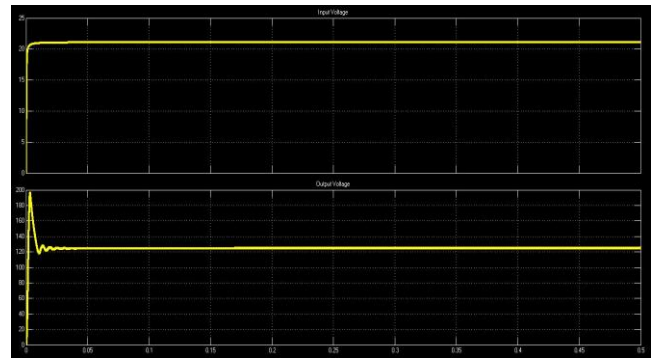


Figure 6: Input and output voltage of boost converter

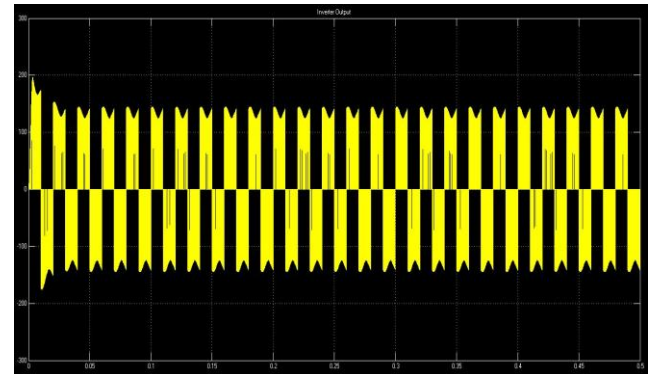


Figure 7: Inverter output voltage

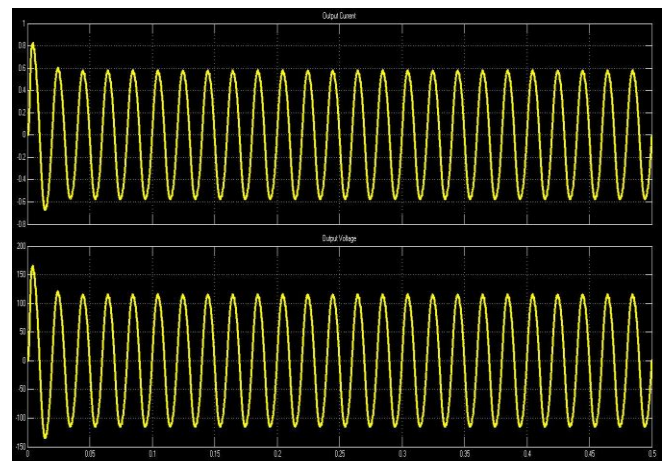


Figure 8: Output current and voltage from PV fed boost inverter with LC filter

(B) Photovoltaic array fed double lift boost inverter

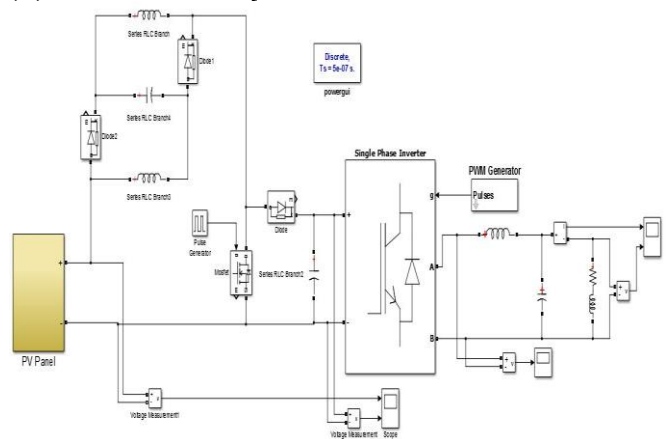


Figure 9: Simulink Model of photovoltaic array fed double lift boost inverter

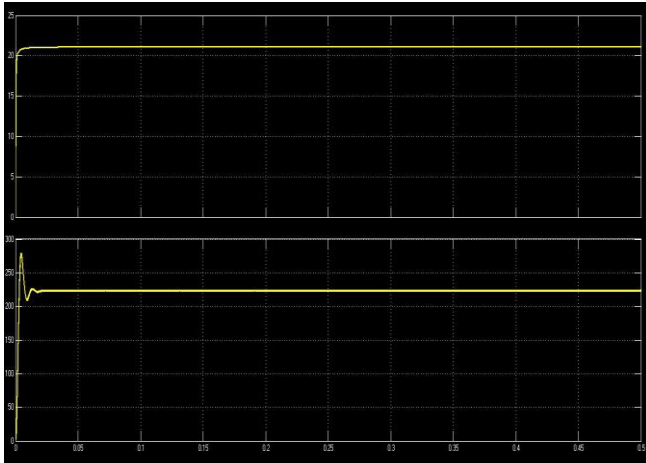


Figure 10: Input and output voltage of photovoltaic array double lift boost converter

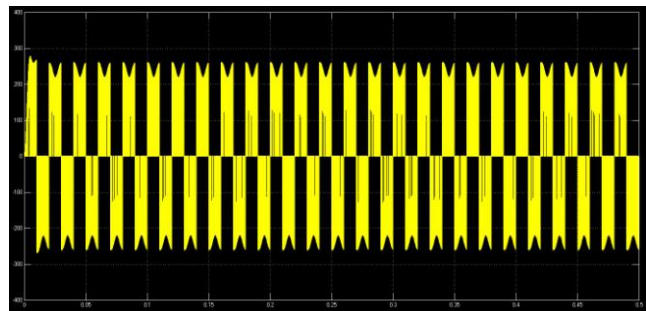


Figure 11: Inverter output voltage

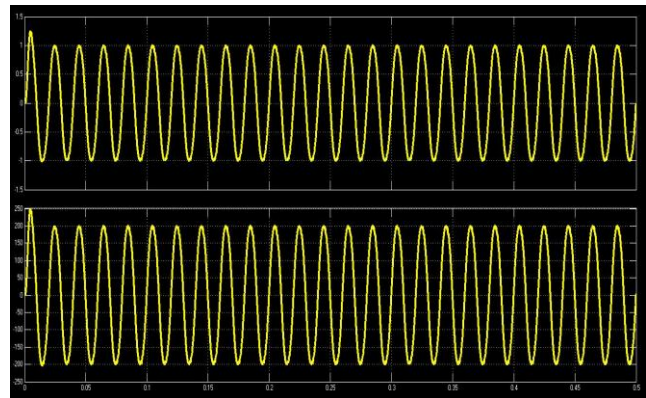


Figure 12: Result of output current and voltage from filter in PV inverter circuit

(C) Photovoltaic array fed triple boost inverter

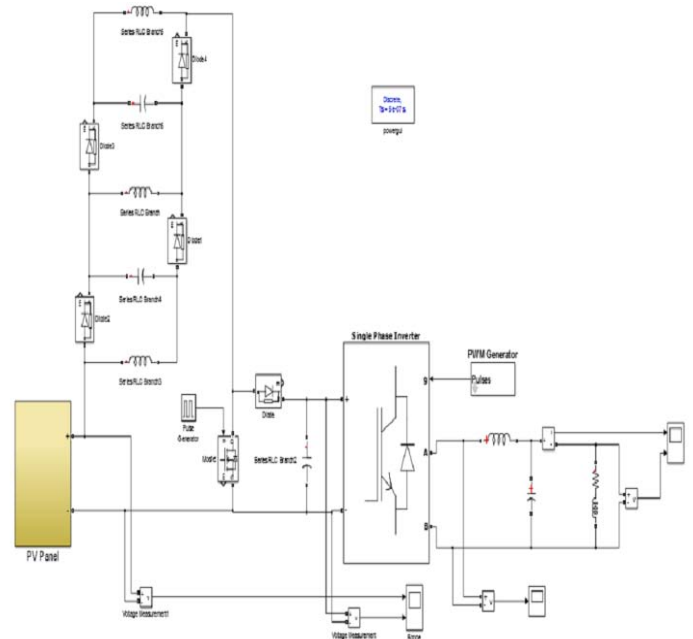


Figure 13: Simulink model of photovoltaic array fed triple boost inverter

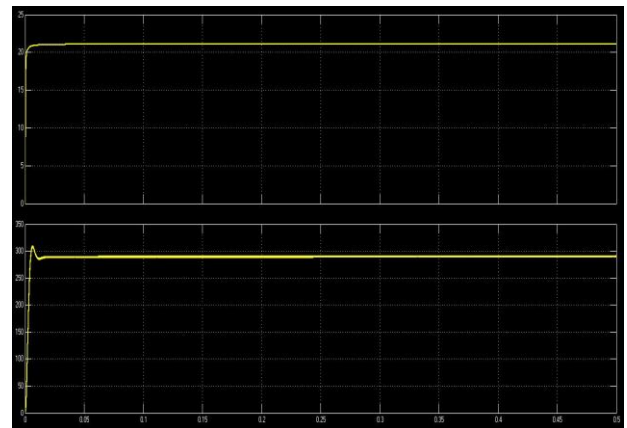


Figure 14: Input and output voltage of photovoltaic array fed triple lift boost converter

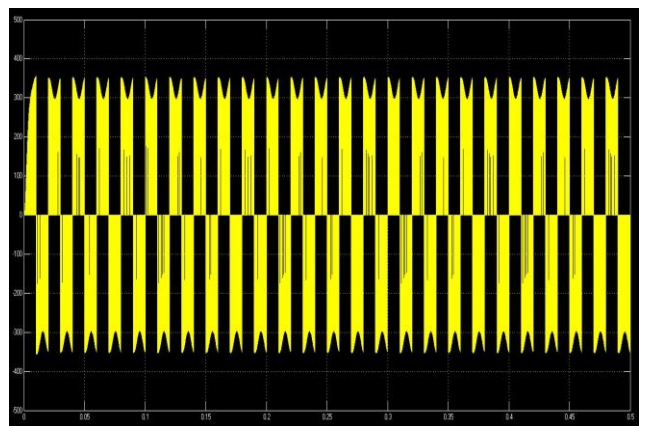


Figure 15: Inverter output voltage

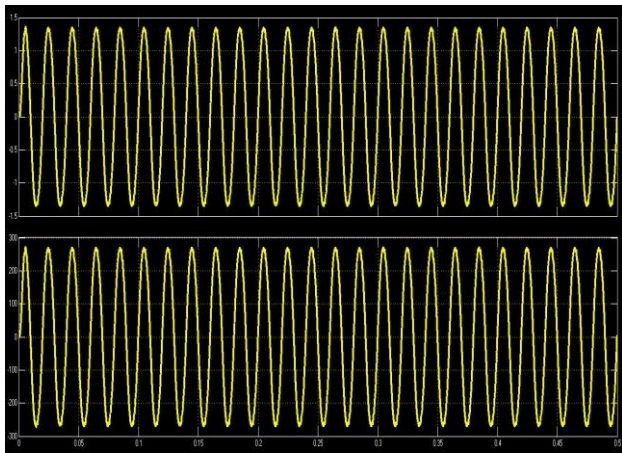


Figure 16: Result of output current and voltage from filter in PV inverter circuit

The output waveform of boost converter with double lift and triple lift is shown in figure. On the x-axis is time t and on the y-axis is output voltage V . The input given to the boost converter is 21 V and output voltage is 286 V

Table 2: For Traditional boost converter

S. No	Converter	Input voltage	Output voltage
1	Traditional Boost Converter	21 V	125 V
2	Double lift boost converter	21 V	224 V
3	Triple lift boost converter	21 V	286 V

Table 3: For boost converter with inverter

S. No	Converter	DC Input voltage	Output voltage	Output current
1	Traditional Boost Converter	21 V	84 V	0.4199 A
2	Double lift boost converter	21 V	147.5 V	0.7372 A
3	Triple lift boost converter	21 V	197.2 V	0.9856 A

7. Conclusion

In solar photovoltaic power systems, efficient dc-dc and dc-ac converters play a vital role for the reliable performance of the complete system. In this paper photovoltaic based voltage-lift technique in traditional dc-dc boost converter is discussed. These converters could be widely used in the areas where strong dc-dc voltage boost abilities are required. From the simulation analysis it is seen that the voltage-lift type boost converters can greatly increase the voltage conversion ratios without resorting to higher values of duty ratio. Since most of the practical application lies in AC system, along with this high step up type converter other power electronics interfaces like single phase full bridge inverter with passive filters are also required. With the use of double and triple voltage-lift type converter high voltage is obtained at the output stage and with the use of inverter and LC filter more sinusoidal AC output voltage is obtained and the power quality of boost converter fed photovoltaic standalone system is highly improved. Single-switch transformer less structure is adopted in this dc-dc converter topology, thus it has simple structure and operation principles may be more practicable compared with traditional cascade and transformer-type converters.

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