Analysis, Modeling and Implementation of Optimal DC-DC Converter for Photo Voltaic System

D.Vanitha[1*], S.Md. Thousif[2]
Assistant Professor[1*], UG students[2], EEE Department , SCSVMV University,
Enathur, Kancheepuram
Email.ID : *vanithadhanapal21@gmail.com*[1*],*thousif.spy5@gmail.com*[2]

Abstract : In the present scenario, scarcity of power supply is handled with the help of an alternative renewable energy source i.e., solar energy which is inexhaustible and available all over the country with free of cost. But the only challenge is poor conversion efficiency. In this paper, the improvement in output voltage of the PV panel is analyzed with various types of converters topology used in PV system. In this paper various converters are investigated and simulated using Simulink and their results are presented. At the end of investigation which help us to choose optimal converter for PV system can be analyzed. The investigation has the advantages like reduction in losses and performance of the PV system is also improved.

***Key words:** PV – Photo Voltaic, BC/BC – Buck/ Boost Converter, PWM – Pulse Width Modulation*

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I. INTRODUCTION

In many applications, high-efficiency, high-voltage step-up dc–dc converters are required as an interface between the available low voltage sources and the output loads, which are operated at much higher voltages[1]. Examples of such applications are as follows. Different distributed energy storage components such as batteries, fuel cells, and ultra capacitors are used in the power trains of hybrid electric vehicles (HEV), electric vehicles (EV), and fuel cell vehicles (FCV). In the present power train architectures of these vehicles, the voltage levels of the energy storage elements are usually low, whereas the motors of the vehicles are driven at much higher voltages. The dc–dc converter, used in this application, is required to boost the low voltage level of car battery to much higher voltage level during the start-up and normal operations Finally, few emerging applications, such as photovoltaic cells, also require high-gain dc voltage conversion [2] & [3]. It can be noted that in all these applications, the high-step-up dc–dc converters can be non isolated but they should operate at high efficiency while taking high currents from low-voltage dc sources at their inputs. In a conventional boost converter, the duty ratio increases as the output to input voltage ratio increases. However, the previously mentioned applications require high-voltage step-up and high-efficiency power conversion[4]. Therefore, the conventional boost converters will require extreme duty ratios to meet the high-voltage step-up requirements

II. Photovolatic Array

PV array's output current-voltage curve reflects PV array's dependence on environmental conditions such as ambient temperature and illumination level. Block diagram as shown in Figure.1.Typically, the illumination level ranges from 0 to 1100Wb/m2 and the temperature range is between 233 and 353 K. Normally, we select 1100 and 298 as the reference values for illumination level and temperature respectively. The relationship between PV array's output characteristics and environmental conditions could be illustrated from general simulation results of PV array. PV array's output power is increased as illumination level increases, while PV array's output power is improved with the decrease of the ambient temperature[5]. The equivalent circuit of a typical PV-cell is given below.(Figure.2)

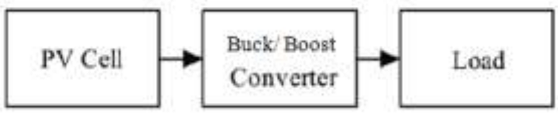

Fig. 1 Block diagram of Converter with PV system

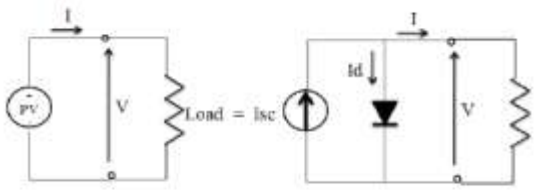

Fig . 2 Simple equivalent circuit of a PV-cell

Figure reflects a simple equivalent circuit of a photovoltaic cell. The current source which is driven by sunlight is connected with a real diode in parallel. In this case, PV cell presents a p-n junction characteristic of the real diode. The forward current could flow through the diode from p-side to n-side with little loss. However, if the current flows in reverse direction, only little reverse saturation current could get through. All the equations for modeling the PV array are analyzed based on this equivalent circuit which is shown in Figure. 3.

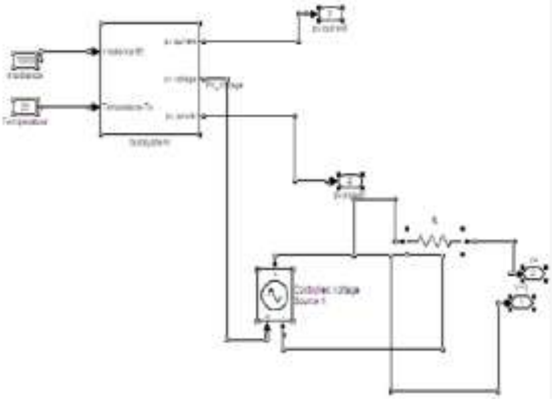

Fig. 3 MAT LAB model of single PV-cell

III. DC – DC CONVERETER TOPOLOGIES

Various DC-DC converters methodologies are implemented in solar/ PV systems are as follows

1. Conventional converter
2. Buck/Boost converter
3. Buck/Boost Coupled converter
4. Buck/Boost Interleave converter
5. LUO converter
6. Positive or Negative O/P converter
7. Super lift converter

All the above mentioned methods, this paper investigates the all types of converters and their simulation models.

1.Conventional converter

In order to obtain the low ripple, maximum voltage and power Buck-boost converter is shown in Figure. 4. Buck-boost converters are especially useful for PV maximum power tracking purposes, where the objective is to draw maximum possible power from solar panels at all times, regardless of the load. The output power is compared with the previous module output power and the duty cycle of the converter is adjusted continuously to track MPP. This process repeats until the output power reaches near to the maximum power point.

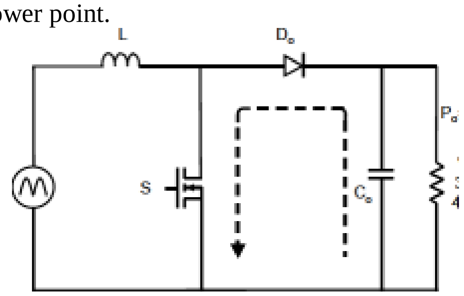

Fig . 4 Conventional DC DC converter

2. Buck/Boost converter

The challenge for this high-efficiency, high step-up DC-DC converter is to avoid extreme duty ratios so that conduction loss and switching loss can be dramatically reduced. The cascade structure Figure. 5 can be used to avoid the extreme duty ratios; however, the 400V startup voltage remains Problematic in terms of efficiency.

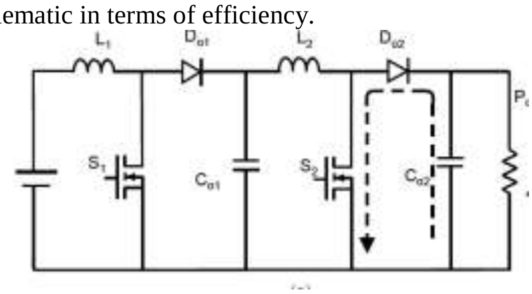

Fig . 5 Buck-Boost converter DC DC converter

It should be pointed out that isolation is not necessary for the AC-DC or DC –DC Front - end converter, since the isolation is provided by the consequent DC-DC stages. The DC-input front-end converter must provide approximately ten times the voltage gain.

3.Buck/Boost Coupled converter

In this paper, a boost–buck-type dc–dc converter (shown in Figure.6) is discussed with coupled inductor. Since the circuit runs either in boost or buck mode, it can be very efficient if the low conduction voltage drop power MOSFET and ultrafast reverse recovery diode are used. Since only the boost dc–dc converter or buck dc–dc converter operates with high-frequency switching all the time in the proposed system, the efficiency is improved. When the PV panel's voltage is lower than the required output voltage, it will operate in boost mode, in which S-boost will be switched ON and OFF and S-buck will be always ON, and the buck part of the circuit will act as an output filter. In this mode, the duty cycle of S-boost can be found as

$$\text{DUTY CYCLE(Sboost)} = 1 - \frac{V_{in}}{V_o}$$

When the PV panel's voltage is higher than the required output voltage, it will operate in buck mode, in which S-buck will be switched ON and OFF and Sboost will be always OFF, and the Sboost part of the circuit will act as an input filter. In this mode, the duty cycle of S-buck can be found as

$$\text{DUTY CYCLE(Sbuck)} = \frac{V_o}{V_{in}}$$

Where

V_o – output voltage
V_{in} – input voltage

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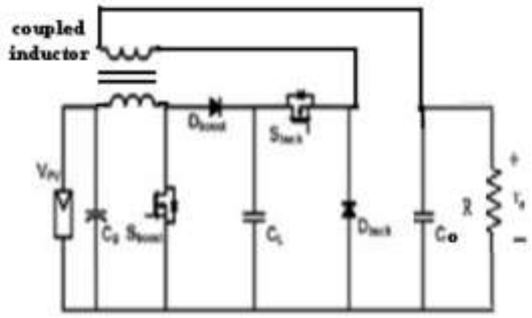

Fig.6. Boost–Buck converter with coupled inductor

If the PV panel's voltage is higher than the peak output voltage, it will always run at buck mode.However if the PV panel's voltage is lower than the peak output voltage, the voltage across the capacitor *CL* in boost/buck PV converter varies with the output voltage as shown in Figure. 7. However, if PV panel's voltage is higher than peak output voltage, *CL*'s voltage will be the same as the PV panel's voltage.

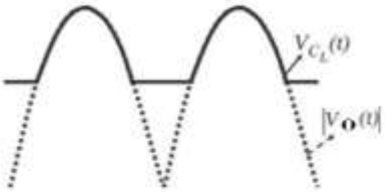

Fig.7. capacitor C_L's voltage

4. Buck/Boost Interleave converter

Figure. 8 shows the coupled interleaved DC-DC boost converter topology. For the subject DC DC converter project, converters were primarily operated and analyzed in CCM mode so that both inductor currents (*i1* and *i2*) were always positive. The primary benefit of CCM over Discontinuous Conduction Mode (DCM) of operation is the minimization of circuit ringing, inductor and input ripple current, and voltage ripple effects and their associated mitigation.

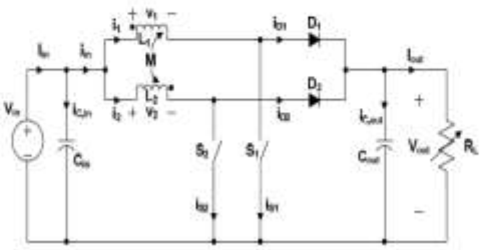

Fig. 8 Interleaved DC-DC Boost Converter

A set of steady state interleaved boost converter waveforms, for CCM operation with a duty ratio greater than 0.5, are shown in Figure 3 in which input current (Iin), inductor voltages (V1, V2), inductor currents (I1, I2), and S1 and S2 gate drive signals are represented. For CCM operation, the voltage gain is the same as that given for a simple boost converter described by Equation (1),

$$(V_{out}/V_{in} = 1/(1-D))$$

Where D is the duty cycle

5. LUO converter

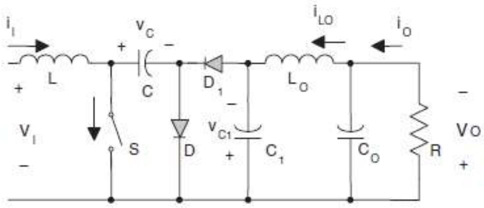

Fig. 9 LUO Boost Converter

All self-lift converters introduced here are derived from developed converters such as Luo-converters[6], Cuk-converters, and single-ended primary inductance converters (SEPICs) are discussed in 5. Since all circuits are simple, usually only one more capacitor and diode required that the output voltage be higher by an input voltage as shown in Figure.9 . The output voltage is calculated by the formula

$$V_O = (\frac{k}{1-k} + 1)V_{in} = \frac{1}{1-k}V_{in}$$

Where K is the duty cycle

Self-lift Cuk converters and their equivalent circuits during switch-on and switch-off period are shown in Figure 10 and Figure 11. It is derived from the Cuk converter.During switch-on period, *S* and *D*1 are on, *D* is off. During switchoff period, *D* is on, *S* and *D*1 are off.

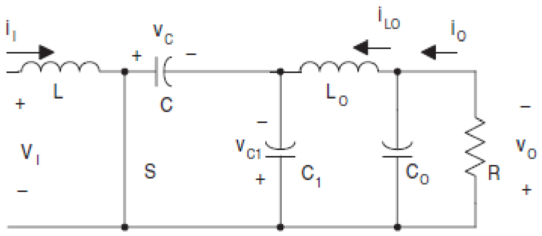

Fig. 10. Switch on

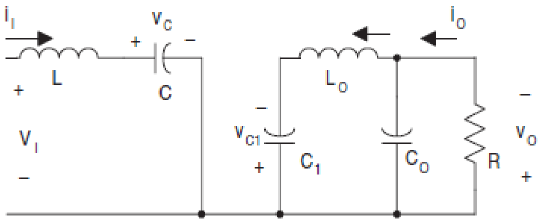

Fig. 11. Switch off

The voltage transfer gain of the self-lift Cuk converter is the same as the original boost converter. However, the output current of the self-lift Cuk converter is continuous with small ripple. The output voltage of the self-lift Cuk converter is higher than the corresponding Cuk converter by an input voltage. It retains one of the merits of the Cuk converter. They both have continuous input and output current in CCM. As for component stress, it can be seen that the self-lift converter has a smaller voltage and current stresses than the original Cuk converter.

6. Positive /Negative O/P Luo converter

When switch S is on, the source current $iI = iL1 + iL2$. Inductor $L1$ absorbs energy from the source. In the mean time inductor $L2$ absorbs energy from source and capacitor C, both currents $iL1$ and $iL2$ increase. When switch S is off, source current $iI = 0$. Current $iL1$ flows through the free-wheeling diode D to charge capacitor C. Inductor $L1$ transfers its stored energy to capacitor C. In the mean time current $iL2$ flows through the (CO – R) circuit and freewheeling diode D to keep itself continuous[7]. Both currents $iL1$ and $iL2$ decrease. In order to analyze the circuit working procession, the equivalent circuits in switch-on and -off states are shown in Figures 12, 13 and 14.Actually, the variations of currents $iL1$ and $iL2$ are small so that $iL1 \approx IL1$ and $iL2 \approx IL2$.

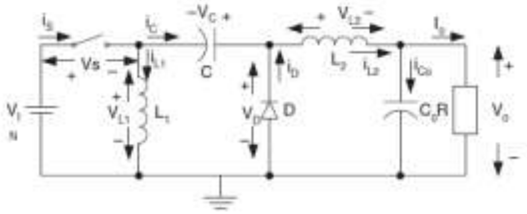

Fig. 12. Positive O/P Luo converter

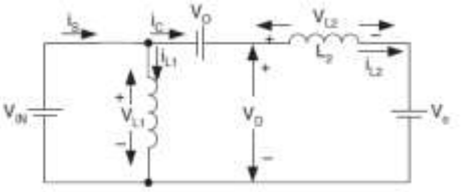

Fig. 13. Switch on

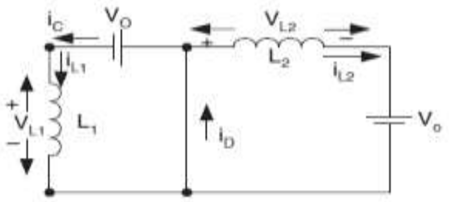

Fig. 14. Switch off

The charge on capacitor C increases during switch off:

$$Q+ = (1 - k)T\, IL1.$$

It decreases during switch-on:

$$Q- = kTIL2$$

In a whole period investigation, $Q+ = Q-$. Thus,
Since capacitor CO performs as a low-pass filter, the output current

$$IL2 = IO$$

These two Equations are available for all positive output Luo-Converters.

7. Super lift converter

The section introduces positive output super lift Luo-converters which is shown in Figure. 15. In order to differentiate these converters from existing VL converters, these converters are called *positive output super-lift Luo-converters*. The elementary circuit and its equivalent circuits during switch-on and –off are shown in Figure 15. The voltage across capacitor $C1$ is charged to Vin.

The current $iL1$ flowing through inductor $L1$ increases with voltage Vin during switch-on period kT and decreases with voltage $-(VO - 2Vin)$ during switch off period $(1 - k)T$. Therefore, the ripple of the inductor current $iL1$ is

$$\Delta i_{L1} = \frac{V_{in}}{L_1} kT = \frac{V_O - 2V_{in}}{L_1}(1-k)T$$

$$V_O = \frac{2-k}{1-k} V_{in}$$

The voltage transfer gain is

$$G = \frac{V_O}{V_{in}} = \frac{2-k}{1-k}$$

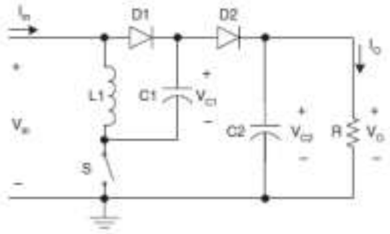

Fig. 15. Super lift converter (positive output)

IV. SIMULATION RESULTS

The simulation results of various converters are presented in this section. For the same input dc voltage of 15volts is applied to system, as shown in Figure.16.the corresponding output voltage of the conventional converter is shown in Figure.17. and its value is 190 volts. The converter with coupled inductor is shown in Figure. 18. And its corresponding output voltage is 360 volts. The interleave inductor voltage is shown in Figure. 19. And its value is 140 volts. The luo converter output voltage is shown in Figure. 20. And its value is 240 volts.

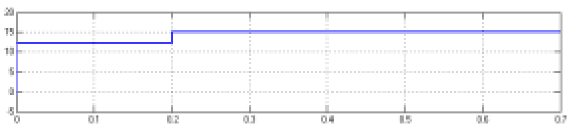

Fig.16. Input dc voltage

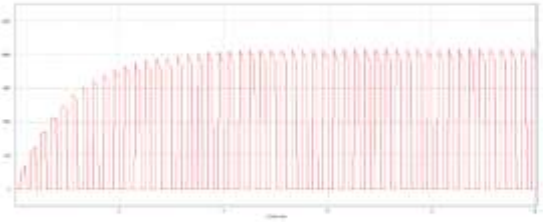

Fig.17. Output voltage of conventional converter

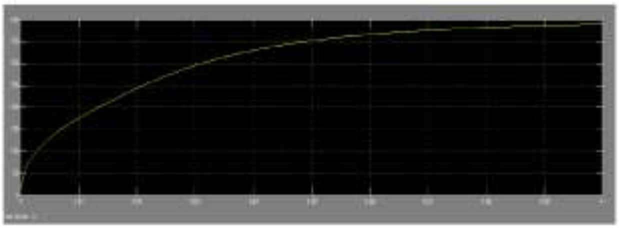

Fig. 18. Output voltage of coupled inductor

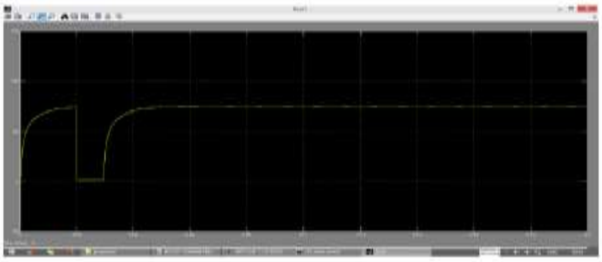

Fig.19. Output voltage of Interleave inductor

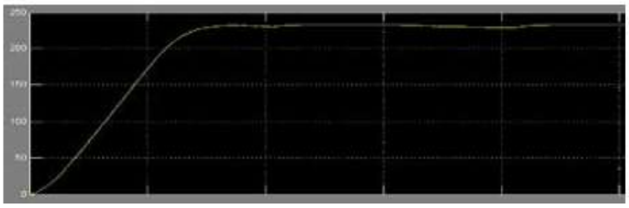

Fig.20 . Output voltage of LUO inductor

Based on the simulation results compared with all converters output voltage of coupled inductor is more than the rest of converters with the same input voltage. And also to built coupled inductor quit simple and less components compared with luo and super lift techniques. Simulations results are compared and tabulated in Table- I

Table – I Simulation results comparison

Converter Type	Input Voltage (volts)	Output Voltage (volts)
Conventional	15	200
Coupled inductor	15	360
Interleaved inductor	15	140
Luo – Lift converter	15	240

V. CONCLUTION

The various DC-DC converter circuits have been investigated, modeled and simulated for PV system. Finally voltage gain compared with all types of converter techniques and modeled with Simulink and high efficiency has been achieved with help of coupled boost converter. Compared to all converters coupled inductor based DC-DC converter is more suitable for PV system.

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