

Design and Implementation of Super Lift Converter for Photovoltaic System

Sarumathi S¹, Saminathan D², Sanjay vaidhyanath C. A³

Assistant Professor, Department of EEE, Sri Krishna College of Engineering and Technology, Coimbatore, Tamilnadu, India¹

Student, Sri Krishna College of Engineering and Technology, Coimbatore, Tamilnadu, India²

Student, Sri Krishna College of Engineering and Technology, Coimbatore, Tamilnadu, India³

ABSTRACT: The concept of generation of electric power from renewable energy sources, has gained momentum in recent days. The depletion of fossil fuel is one of the major factors that has led to the search of an alternative method for the production of electrical power. Increased energy consumption and environmental issues have increased the dependency on distribute energy sources such as solar, wind, biomass, and fuel cell for electrical power generation. Solar energy plays a vital role in electrical power generation. In this article Photovoltaic (PV) system is considered for the analysis with converters. Various methods adapted for lifting the voltage such as voltage lift technique and super lift technique in are discussed. The super lift converter is a DC/DC converter that boosts the input voltage to a higher level at different stages without parasitic effect, thereby increasing efficiency and reliability. Super-lift converters largely enhance the voltage transfer gain, which increases stage-by-stage in geometric progression. It effectively enhances the voltage transfer gain in power series. The main objective of the paper is to design and implement the super lift converter for Photovoltaic System. The simulation result of this PV system is obtained using MATLAB.

KEYWORDS: Photovoltaic cells, Voltage lift technique, Super lift technique, Voltage transfer gain.

I. INTRODUCTION

Power generation from conventional sources such as coal, water and nuclear fission is being carried out ever since the late nineteenth century. In current scenario, the rapid depletion of fossil fuel and increase in fuel cost makes fossil fuels unreliable for the source of power generation. In addition to this, there are adverse issues such as climate change, global warming, ozone depletion etc that make the conventional methods of power generation unreliable to the environment. Apart from this, the scarcity of the fossil fuels is one of the major reasons for switching on to renewable energy sources. The growing energy consumption, high demand and environmental issues have pushed to the verge of producing electricity from renewable energy resources. Energy sources which can be replenished by nature are called as renewable energy resources. Winds, solar, Biomass are some of the examples of renewable energy. The renewable energy sources such as wind, solar, fuel cells, small hydro, and wave energy tend to be exploited in recent decades [1].

The process of converting the DC voltage to a higher or a lower value is carried out by means of a DC-DC Converter or a chopper.[2] Choppers may broadly be classified into step-up and step down choppers. Step-up choppers lift the output voltage to a higher value, whereas step-down choppers bring down the value of the input voltage. In DC-DC Converter circuit design, voltage lift (VL) and super-lift (SL) technique are popular method widely used for boosting the voltage. In recent years these techniques have been successfully employed in DC-DC converters and have opened various opportunities to design high voltage gain converters. However in voltage lift technique the output voltage increases stage by stage in arithmetic progression and that in super-lift technique the output voltage increases in geometric progression. In power series, the voltage transfer gain is effectively enhanced due to this technique. The voltage-lift technique is a popular method that is widely applied in electronic circuit. This

technique gives a good way of improving circuit characteristics, and has been successfully applied for DC/DC [3] converters. In voltage lift technique, the voltage gets increased in arithmetic progression. This technique is employed in normal boost converters

In voltage lift technique, the magnitude of voltage that can be increased is less. Moreover the voltage lift is restricted due to the parasitic effect of the components connected. In order to overcome the parasitic effect, super lift converter is used. Super lift technique increases voltage in three steps. The voltage gets increased in geometric progression [4] and [5]. Many research works are carried out for the design of DC-DC converters to increase the power density and to boost the output to higher voltage. Attempts were made to implement the Voltage lift Technique in DC-DC Converters. A normal boost converter cannot boost the voltage to higher level due to the effect of parasitic elements. A super lift Technique is proposed by F.L.Luo [6] and [7]. Using this method the output voltage can be easily lifted by tens to hundreds of times. Therefore the magnitude of output voltage can be increased [8][9]. Based on required output voltage the technique such as self-lift, Re-lift, Multiple-lift are implemented by adding diodes and capacitors in each stage.

II.PHOTOVOLTAIC SYSTEM

Photovoltaic offer consumers the ability to generate electricity in a clean, quiet and reliable way. Photovoltaic systems are comprised of photovoltaic cells, devices that convert light energy directly into electricity. Because the source of light is usually the sun, they are often called solar cells. The word photovoltaic comes from “photo,” meaning light, and “voltaic,” which refers to producing electricity. Therefore, the photovoltaic process is “producing electricity directly from sunlight.” Photovoltaic are often referred to as PV. PV cells convert sunlight directly into electricity without creating any air or water pollution. A PV cell is composed of a P-type semiconductor and a N-type semiconductor, forming a junction. When sunlight is irradiated on the cell, it produces photons. These photons move from N-type material to P-type material thereby, allowing the flow of current. This phenomenon is called as **Photovoltaic effect** [10]. The overall efficiency of the module will depend on the cell efficiency, placement within the module and the laminating materials used. The standard testing condition defined at total irradiance of 1000W per.sq.m. and an ambient temperature of 25 degree Celsius is used to define the module ratings [11]. The equivalent circuit of PV cell is presented in Fig 1.(a). A solar cell consists of P-type semiconductor and N-type semiconductor similar to a diode

A PV cell is a simple PN junction which is fabricated in a layer of semiconductor material. When it is illuminated by sunlight of photons with the energy equal or slightly greater than the band gap energy of semiconductor material [12], it is absorbed and the valence electrons are knocked out from the atoms in the material, and create electron-hole pairs. These photo generated carries are swept apart by the internal electric fields of this cell and if the cell is connected by external circuit, they contribute to flow of current. The detailed modeling of super lift converter based Solar PV system is used in boosting voltage levels [13],[14] and [15].The simulink model of a PV system is shown Figs 1. (b)

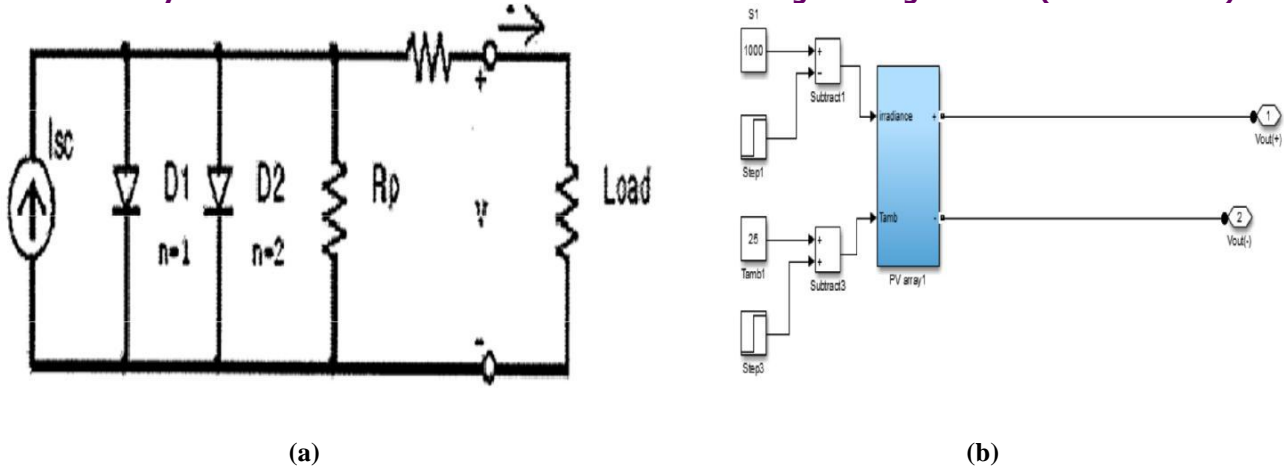


Fig-1. (a) Equivalent circuit of a solar cell (b) Simulink model of a solar panel

SUPER LIFT CONVERTER

The converter which makes use of the super lift technique is called super lift converter. There are three major types of lifts in a super lift converter. They are

- Self-lift (or) Elementary lift
- Re-lift
- Triple lift (or) Super lift

Voltage lift through super lift converter possesses the following advantages,

- A. Effect of parasitic components is eliminated
- B. Voltage can be raised to ten times to that of the input
- C. Three stages of conversion, facilitating easy availability of output voltage at desired level
- D. Highly efficient and reliable

The voltage gain based on which converts work can be defined as shown below,

$$G = \frac{V_{out}}{V_{in}} = \frac{1}{1 - \frac{1}{n}}$$

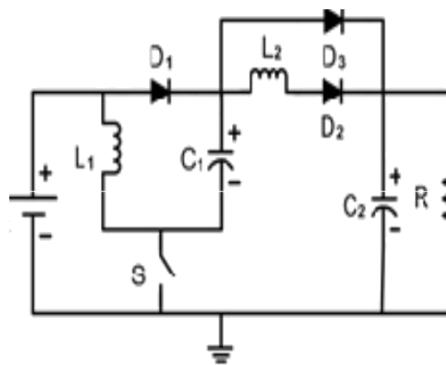
Where,

$$\begin{aligned} [1] &= \dots \\ [2] &= \dots \end{aligned}$$

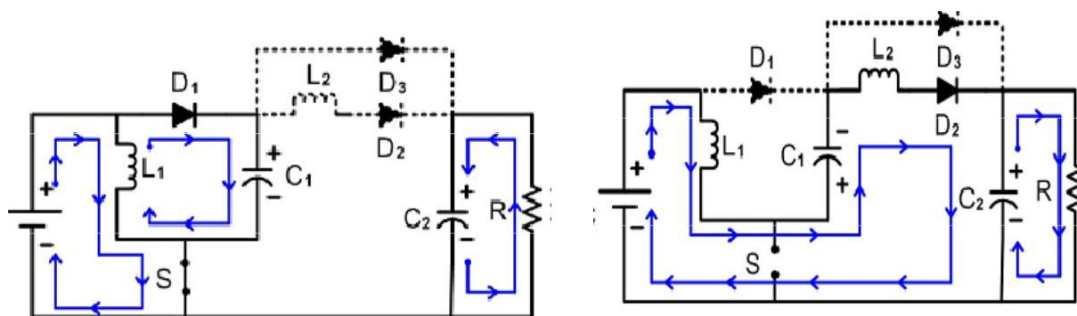
The elementary circuit for super lift converter shown in Fig.2.(a). Luo converters were developed from the prototypes using VL technique. These converters perform DC-DC voltage increasing conversion with high power density, high efficiency, and cheap topology in simple structure. They are different from output voltage with small ripple. This introduces positive output super lift technique that implements the output voltage increasing in stage by stage along the geometric progression. Super lift technique converters overcome the effects of the parasitic components that are present in the circuit that limits the output voltage. In order to increase the efficiency further Super-Lift technique is implemented which increases the output voltage in geometric progression. The circuit consists of a MOSFET switch S, Inductor L1, Diodes D1, D2, Capacitors C1, C2 and load. The various mode in which the super lift converter operates are enlisted below.

The equivalent circuit of super lift converter in Mode 1 are shown in Fig.2.(b). In mode 1 the switch S is turned ON during the period 0 to ΔT . When the switch is closed, the source voltage causes the current to flow through the inductor L_1 and capacitor C_1 . Since capacitor C_1 has zero impedance to current the capacitor C_1 charges faster than inductor thus forward biasing the diode D_1 . Thus charge gets stored in inductor L_1 and Capacitor C_1 . Also during this period the load current is maintained constant by the discharging capacitor C_2 . Thus the energy stored in the capacitor C_2 during the previous cycle is transferred to the load.

The equivalent circuit of super lift converter in Mode 2 are shown in Fig.2.(c). In mode 2, the switch S is turned off during the period ΔT to T. In this mode when the switch is open the energy that is stored in the inductor L_1 and the capacitor C_1 discharges across inductor L_2 and the nodal points of the capacitor C_2 thus boosting the output voltage. The load current is supplied by the inductor. The modeling of super lift converter is shown in Fig.2.(d).

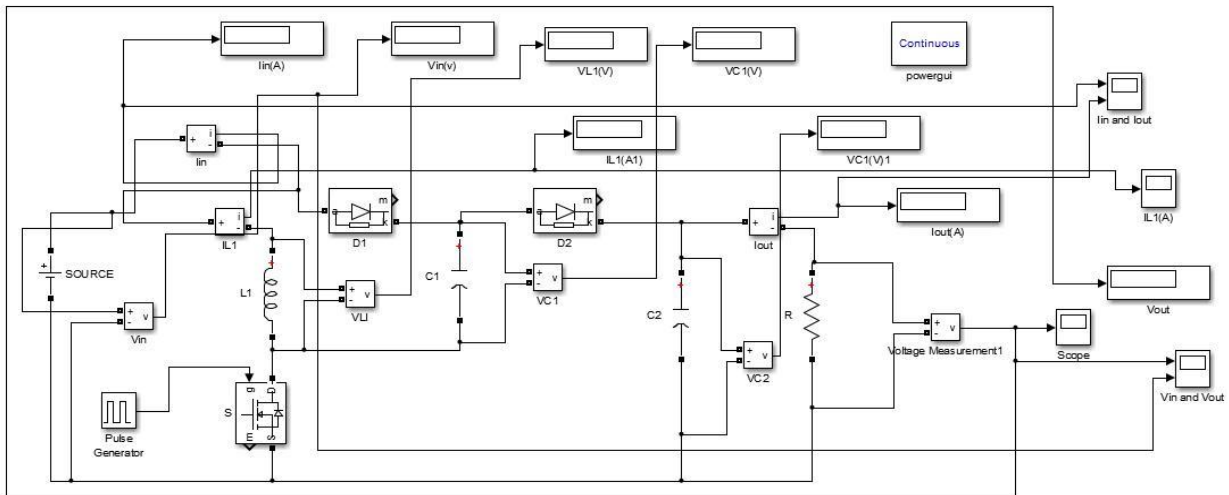


(a)



(b)

(c)



(d)

Fig-2: (a) Elementary circuit of a super lift converter, (b) Equivalent circuit of super lift converter in Mode 1, (c) Equivalent circuit of super lift converter in Mode 2, (d) Simulink model of a Super lift converter

IV.RESULTS AND DISCUSSIONS

The elementary circuit along with its equivalent circuits during switch-on and switch-off period is shown in Fig. 4. The voltage across capacitor C1 is charged to V_{in} during switch-on period. The current flowing through inductor $L1$ is I_{L1} and increases with input voltage V_{in} during switch-on period KT . The inductor current I_{L1} decreases with voltage (V_o-2V_{in}) during switch-off period $(1-K)T$. The formula for finding the parameter value of super lift converter as shown from Equation 1- 6.

The ripple of the inductor current I_{L1} is,

$$\Delta I_1 = \frac{V_{in} \cdot K}{L_1} = \frac{V_{in} \cdot K}{L_1} \quad \dots(1)$$

$$= \frac{V_{in} \cdot K}{L_1} \quad \dots(2)$$

The voltage transfer gain,

$$= \frac{V_o}{V_{in}} = \frac{V_o}{V_{in}} \quad \dots(3)$$

The input current is equal to $(I_o + I_{L1})$,

$$\bullet \quad +$$

$$\circ \quad +$$

$$= (1 -)$$

If inductance L1 is large enough then I_{L1} is nearly equal to its average current I_{L1} Therefore

$$\begin{aligned}
 &= \dots = \dots + \frac{1 - \dots}{\dots} = \dots \\
 &= \frac{1 - \dots}{\dots} \\
 &= \dots + (1 - \dots) = \dots + (1 - \dots) = (2 - \dots) \dots(4) \\
 &\quad \frac{1 - \dots}{\dots} \\
 &= \frac{\dots}{2 - \dots} = \frac{\dots}{2}
 \end{aligned}$$

The variation ratio of inductor current ,

$$\begin{aligned}
 &= \frac{\Delta / \dots}{\dots} = \frac{(\dots)}{(\dots)} = \frac{(\dots)}{(\dots)} \dots(5)
 \end{aligned}$$

The ripple voltage of output ,

$$\begin{aligned}
 \Delta &= \frac{\Delta}{2} = \frac{(1 - \dots)(1 - \dots)}{2}
 \end{aligned}$$

Therefore, the variation ratio of output voltage ,

$$\begin{aligned}
 &= \dots = \dots \dots(6)
 \end{aligned}$$

The components value for super lift converter are tabulated in Table-1.

Table – 1 : Components Value for Super Lift Converter

Parameter	Value
Inductor (L1)	10 mH
Capacitors (C1=C2)	2 μF

The super lift converter design is validated using MATLAB Software. The simulation parameters are $V_{in}=12V$, $L1= 10 \text{ mH}$, all the capacitors i.e. $C1=C2=2 \text{ μF}$ and $R=30k\Omega$ for $k=0.5$ and $f=100kHz$. The output of the elementary circuit of super lift converter is shown in Fig.3.(a). The input voltage is 12V DC. The output voltage increases as the input. The output voltage is 34.11V DC.

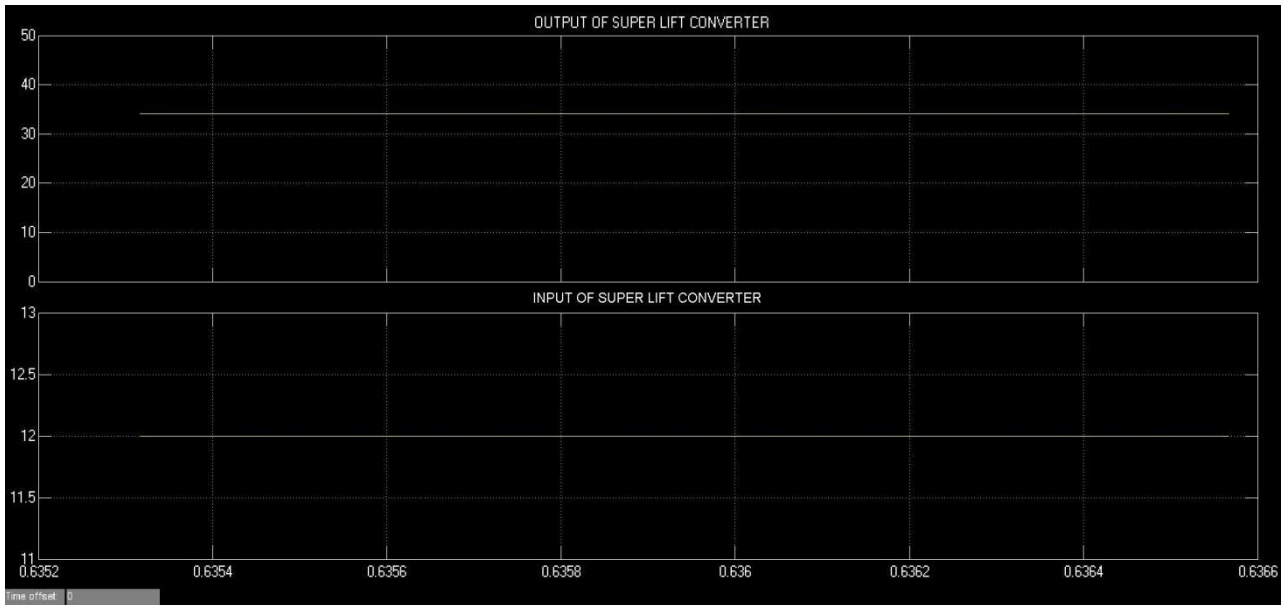


Fig.3: (a) Simulink model output of a Super lift converter ,(b) Simulink model output of a Soar PV system

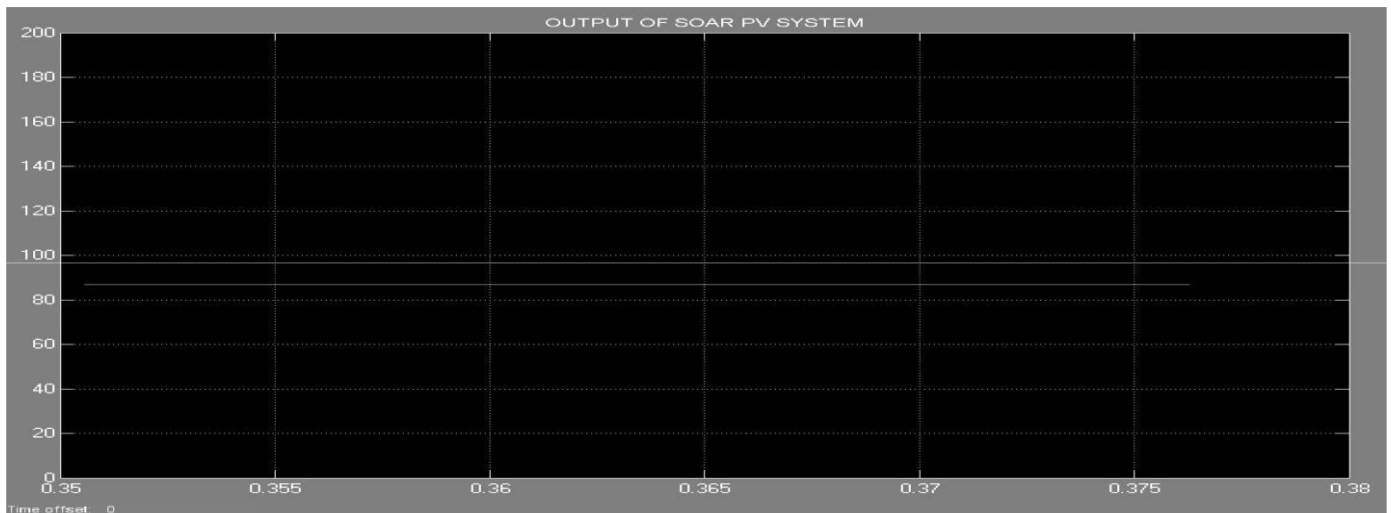


Fig.3.(b).solar PV system is designed for 100V DC. The output of the solar PV system is shown in

V.CONCLUSION

An attempt has been made in this article to design and Implementation of Super lift converter for Photovoltaic System. Design and simulation of PV system based Super lift converter have been carried out successfully using MATLAB/Simulink model. The simulation results of super lift converter based solar PV system are analyzed. Since the super lift technique progress the voltage gain in geometric progression, the boosted output voltage from super lift converter shows the improved results over the conventional converters. The simulation result ensures that the required output voltage can be obtained by different lifting techniques.

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