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A NEW INTERLEAVED SWITCHED INDUCTOR BOOST CONVERTER FOR PV APPLICATIONS

SURESH KUMAR.R*1 and LOGESWARI.2
ASSISTANT PROFESSOR, DEPARTMENT OF EEE, ANNA UNIVERSITY REGIONAL CENTRE, COIMBATORE*1
ANNA UNIVERSITY REGIONAL CENTER, COIMBATORE2

ABSTRACT

This paper presents the formulation of a new interleaved switched inductor boost converter. Boost converter converts a low input voltage to a high voltage magnitude. Thus it attains a keen focus in renewable energy applications where only a small level of voltage is obtained from the renewable energy sources that should be boosted in order to meet the utility. In such case, the designed interleaved switched inductor boost converter combines the advantages of two methods- interleaving and switched inductor. The process of connecting two converters back to back is interleaving which has the advantages of decreased electrical stress, eliminating bulk inductors and filters. Switched inductor boost converter is formed by replacing the main inductor of boost converter with switched inductor. Switched inductor branch consists of two parts of inductor and three switching elements. It eliminates the loss due to partial shading.

Keywords—*Interleaving, switched inductor, boost converter, partial shading, continuous conduction, switch stress.*

I. INTRODUCTION

Conversion of power from one form to the other is an ultimate task in renewable energy applications in order to meet the power necessities of the utilities. Special switching components are used in this type of power conversions. Power converters comprised of four basic categories of components, semiconductor switches, gating and control systems, inductive components and capacitive components. The inductive and capacitive components are used to dynamically store the electrical energy for circuit power flow damping, filtering and transformation. Switch gating and control system is used to control the ON and OFF states of the switches so that the circuit operates in a stable, efficient and protective condition. Innovative improvements in the semiconductor switch designs have been the driving force for the advancements and implementations of power conversion stages in stand-alone or grid connected power conversion systems. A DC-DC converter converts fixed-voltage DC source into a variable DC source directly and is simply known as a DC converter.

A. BOOST CONVERTER

A boost converter is a DC-DC converter with an output voltage greater than its input voltage. It is a class of switched mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination, as shown in figure 1.1. Filters made of capacitors sometimes in combination with inductors are normally added to the output of the converter to reduce output voltage ripple.

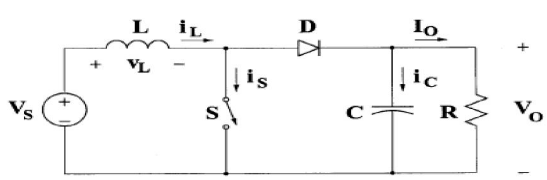

Figure 1.1 Boost Converter

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. In a boost converter, the output voltage is always higher than the input voltage. When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores the energy. Polarity of the left side of the inductor is positive. When the switch is opened, current will be reduced as the impedance is higher. Therefore, change or reduction in current will be opposed by the inductor. Thus the polarity will be reversed (means left side of

inductor will be negative now). As a result two sources will be in series causing a higher voltage to charge the capacitor through the diode D. The basic principle of a Boost converter consists of 2 distinct states.
(a) In the On-state, the switch S is closed, resulting in an increase in the inductor current.
(b) In the Off-state, the switch is open and the only path offered to inductor current is through the flyback diode D, the capacitor C and the load R. This result in transferring the energy accumulated during the On-state into the capacitor.
(c) The input current is the same as the inductor current as shown in figure 1.2. So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter. If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened.

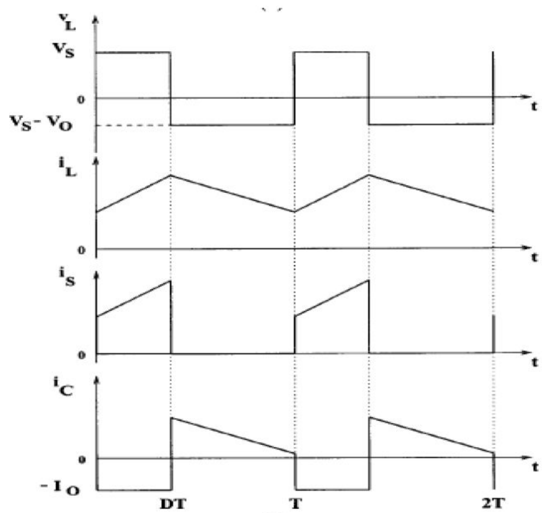

Figure 1.2 Waveforms of Boost Converter

B. SWITCHED INDUCTOR BOOST CONVERTER

In a simple boost converter when the inductor branch is replaced by a switched inductor branch then it as termed to be a switched inductor boost converter. A switched inductor branch is shown in figure 1.3.

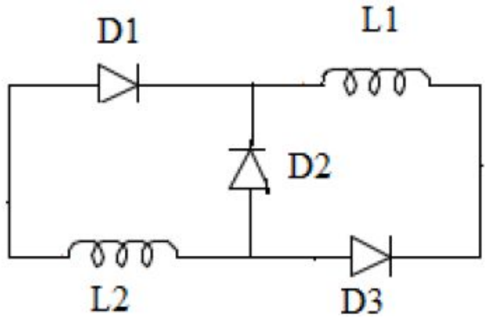

Figure 1.3 Switched Inductor Branch

This boost converter with high dc gain is used as a solution to the problem of partial shadowing in photovoltaic systems. Electrical characteristics of the PV module are affected by environmental conditions such as the temperature, the solar irradiation, dust accumulation and the shadow caused by birds, clouds, and dust. Shading of solar cells not only reduces the cell power, but it also changes the open circuit voltage, the short circuit current and the efficiency. Circuit diagram of switched inductor boost converter is shown in figure 1.4. It consists of two parts of inductors and three diodes. By replacing the inductor of the traditional dc-dc converter with the switched inductor, the emerged circuit is called switched inductor dc-dc boost converter (SIBC).

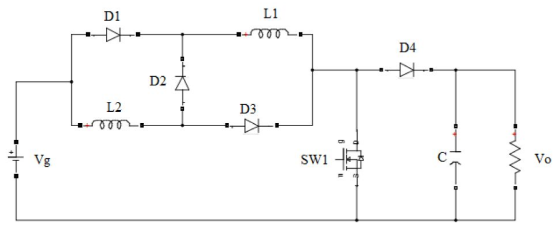

Figure 1.4 Switched Inductor Boost Converter

Mode 1 occurs when switch SW1 is ON, this causes diodes D1 and D3 to be ON and diodes D2 and D4 to be OFF. Thus the two branches of inductors are charging in parallel. Mode 2 occurs when switch SW1 is OFF, this causes diodes D1 and D3 to be OFF and diodes D2 and D4 are ON, and hence the two branches of inductors discharge in series. A switched inductor boost converter (SIBC) has very large dc-dc conversion ratio at low duty cycle far away from unity. The gain ratio of simple boost converter is low, also voltage stress across switch is same as output voltage. The advantage of multilevel boost converter is gain increases but stress is less as compared to other converter topology. In switched inductor multilevel converter gain ratio is high compared to multilevel converter and stress is also lower than multilevel boost converter for same duty cycle. The efficiency of switched inductor multilevel boost converter is high because of only one switch is used. Output voltage can be increased by increasing number of capacitors and diodes means multiplier stages without disturbing main circuit.

II. PROPOSED INTERLEAVED SWITCHED INDUCTOR BOOST CONVERTER

An interleaved switched inductor boost converter is designed by interleaving two switched inductor boost converters. Method of interleaving is the back to back connection of the components and the switching of these components are alternative.

Each switched inductor boost converter is controlled by individual switches connected with them and they operate sequentially. The circuit diagram of an interleaved switched inductor boost converter is given in the figure 2.1.

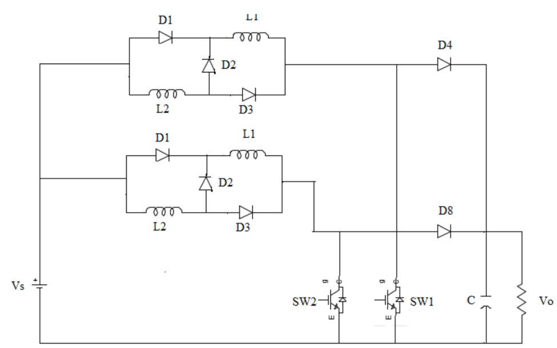

Figure 2.1 Interleaved Switched Inductor Boost Converter

The first and the second switched inductor branches are controlled by the two static switches SW1 and SW2 respectively. Vs is the source voltage that is the input provided to the circuit from any renewable energy sources or from any DC source. Vo is the output voltage and is obtained at the load side. Here, resistor is used to represent the load. Any type of load could be applied and the variations of output voltage accordingly can be verified by using the Simulink environment. This is the major property of the circuit in order that it could be able to provide output with respective input and load variations.

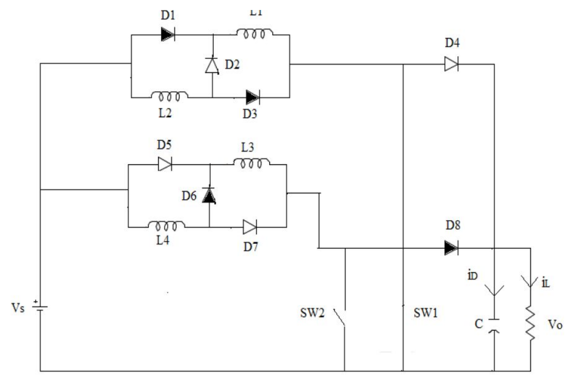

Figure 2.2 Mode 1 operation

The two parts of inductor are charged in parallel and discharge in series according to the state of the switches. When the switch SW1 connecting the first switched inductor branch to the load is ON, the two parts of the inductor are charged in series. The parts of the inductor branch L1 and L2 belong to the first switched inductor branch and the inductor branches L3 and L4 belong to the second switched inductor branch. When switch SW1 is closed, the current passes through diodes D1 and D3 in the first switched inductor branch. As the switch SW1 is closed in this mode, the first switched inductor branch acts as charging profile. Here the two parts of inductor gets charged and they store energy in their magnetic field. In this case, the load is supplied by the capacitor.

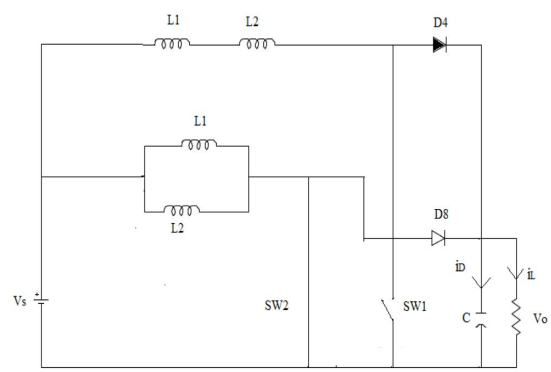

Figure 2.3 Mode 2 operation

The circuit representing operation of the circuit when the switch SW1 is in OFF state and the switch SW2 is in ON state is given in figure 2.3. Switched inductor branch is replaced by their respective charging and discharging profiles. When switch SW2 is ON the current is supplied via diodes D5 and D7. The two parts of inductors L3 and L4 are charged in parallel with respect to the input voltage applied to the circuit. Similar inductor voltage and current equations are obtained as that of the first switched inductor pair when the switch SW1 was ON state. Neither the charging voltage is sign changed as that of in ac input systems.

III. RESULT AND DISCUSSION

Main applications of boost converters are in the renewable energy systems in which the generated output is small to supply the utilities. Hence the generated powers by such systems have to be boosted or stepped up in order to meet the need. Since based on this consideration the interleaved switched inductor boost converter is designed and simulated using MATLAB and its results are displayed below. The output voltage of designed system in Simulink is given in figure 3.1. The output voltage obtained here is 300V which is used to run a DC motor, heavy duty machines and so on.

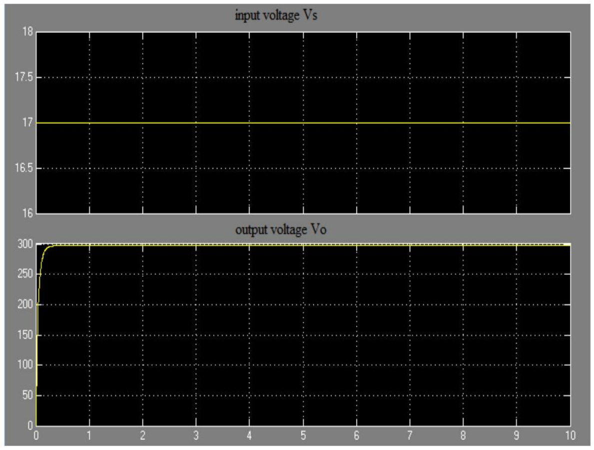

Figure 3.1 Input and Output voltage waveforms

In order to supply grid systems or grid-integrated systems this need to be converted into another form say AC as most of the systems used are of this type. In order to provide regulated voltage to the systems charge controllers and power conditioning systems are used.

TABLE 3.1: Parameters of Interleaved Switched Inductor Boost Converter

PARAMETER	SYMBOL	VALUE	UNIT
Input Voltage	Vs	17	V
Output Voltage	Vo	300	V
Line Current	IL	3.52	Amps
Output power	Po	60	W
Inductor value	L	8.17	mH
Capacitor value	C	5.453	F

IV. CONCLUSION

This paper presents a new interleaved switched inductor boost converter designed especially for solar energy systems. The new converter integrated PV system can be applied to stand-alone system or grid-connected system. Hence the designed interleaved switched inductor boost converter provides high efficiency with appropriate duty ratio and low stress on the power switches. It has very high DC-DC conversion ratio. It is suitable for ac modules besides it can offer a solution for the problem of shading and grid connection applications for low dc voltage of the available PV modules. Additionally the energy stored in the two parts of inductors are relatively large than that of the usual system as the inductor section has two branches which charge in parallel and discharge in series.

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