International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Review of Switched Inductor DC-DC Converters

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A B S T R A C T

This paper presents a review of switched inductor used in DC-DC converter. In power electronics DC-DC converter is an essential aspect. Its voltage gain altering capabilities are used for power converter, as the different output voltage levels increases. So, in this paper discussed about switched inductor in various types of converters, such as Boost, Cuk, SEPIC converters. Also, it is discussed about different converter topologies technologies and methods.

Keywords: Switched inductor, DC-DC Converters.

1. Introduction

The converter is a circuit that uses inductive and capacitive filter elements to switch at high frequencies to produce a DC output of a different voltage from a DC input. A converter may be one or more task and give an output it differs from the input. There are four types of power converters: AC-DC converter it converts AC-DC using rectifier. DC-AC converter it converts DC-AC using of desired frequency and voltage using an inverter. DC-DC converter it converts constant current into variable current. AC-AC converter are called matrix converter it converts AC of a specific frequency.

2. Dc-dc converter

A DC-DC Converter is a piece of technology that changes the voltage level of a (DC) source. It is a specific kind of power converter for electricity. Very small to very high levels of energy are present. High frequency inductors, switches, transformers, and capacitors are used in DC converters to convert high frequency power to controlled DC voltages while reducing switching noise. When the input voltage and output current are altered, a closed loop keeps the output voltage constant. Both isolated and non-isolated models of DC-DC converter are available. An isolated converter eliminates the dc path that connects its input and output by using a transformer. Non-isolated DC converter patterns typically use ICs that are expressly designed for that use. A static "converter" circuit converts a constant DC input voltage right away. These are more efficient because choppers only require single stage of conversion. Smooth control, great efficiency, quick response, and regeneration are all features of the chopper system. Forced commutated thyristors, power BJTs, power MOSFETs, GTOs, and IGBTs are some examples of the power semiconductor components found in chopper circuits. A switch with an arrow could be used to represent these devices in general. The two different choppers that can step up and down.

2.1 USES OF DC-DC CONVERTER

DC converters are utilized in portable gadgets like laptops and phones that draw their power mostly from batteries. This electronic gadget has a few sub-circuits, each of which requires a different voltage level than what the battery or an external supply can provide. Battery voltage drops as the energy it has stored is used up. Instead of needing numerous batteries to do the same objective, switched converters provide a way to raise voltage from a battery voltage that has been partially reduced while also saving space. The output voltage is also adjusted by bulk DC-DC converter circuits. High efficiency LED power sources, charge pumps with double or triple output voltage, and the type of DC-DC converter that adjusts the current via the LEDs are a few of the assumptions.

3. SWITCHED INDUCTOR

A. ***Inductor*:** The majority of power electronic circuits include inductors, which are passive parts that when the power is applied, it absorbs power as dc power. An inductor's ability to resist variations in the amount of current flowing through it is a crucial property. Every time the current across the inductor varies, it either acquires energy or drains energy in order to maintain the current that passes through it. The inductor also goes by the titles coil, choke, and reactor.

B. ***Switched inductor:*** A switching DC/DC converter, also known as a regulator, is essentially a circuit that moves energy from input to the output using a power switch, an inductor, a diode, and a capacitor. To create the buck, boost, or buck-boost (inverter) kinds mentioned previously, these can be arranged in various ways. Buck converter, step-down. A switched-mode DC/DC converter works by regularly storing input energy and releasing it to the output at a changing voltage.

Three key benefits are provided by switch-mode DC/DC converters: Power conversion efficiency is significantly higher. The lower losses and smaller passive components caused by the increased switching frequency simplify thermal management. The energy held in an inductor in a shifting converter could be transformed into voltage levels that may be step-down, buck, boost, or buck-boost with reverse polarity (inverter). In contrast to a power converter, the straight converter must only output any energy that is lower than the input voltage. Switching DC/DC converters provides a number of advantages but also some disadvantages. They need energy management in the form of a control loop since they are noisier than a linear circuit. Fortunately, the control task is made simple by current switching-mode controller chips.

3.1 RESEARCH STATUS OF SWITCHED INDUCTOR DC-DC CONVERTER

The two categories of dc-dc converters exist: isolated and non-isolated dc-dc converters. In order to achieve high-voltage gain, this study suggests a two-phase switched-inductor DC-DC converter with a voltage multiplication stage. The converter is the perfect answer for applications that need high voltage gains, including incorporating photovoltaic energy sources into a microgrid or a direct current distribution bus. An interleaved switched-inductor boost stage connected to a voltage multiplier cells stage makes up the structure of the newly developed converter. Two switched-inductor phases are controlled by two out-of-phase controllable switches in an interleaved switched-inductor. One or more self-controlled input power sources can supply the switched-inductor stage [1].

The voltage-lift switched-inductor cell replaces a single inductor in the traditional multilayer boost converter. This method is a workable way to increase a low source voltage to a high voltage gain. This method is a workable way to increase a low source voltage to a high voltage gain. A suggested converter topology combines voltage-lift switched inductor cells with multilevel converters. As the initial stage in boosting a DC supply voltage, the voltage lift switched-inductor cell is employed [2].

Switched-inductor Boost converters work to reduce the impact of leaking inductors in coupled inductors-based converters (SL-Boost), This essay compares the ANC and Boost converters while discussing the properties of switched inductor (SL) cells. This work proposed the multicell switched-inductor on the basis of the analysis above active network convertors [3].

The DC-DC Switched Inductor Boost Converter (SLBC) is described in this research as a workable option for DC drive applications that use unconventional energy sources. The proposed SLBC derives from a normal boost converter by using a switched inductor in place of the original inductor. The two inductors are charged and discharged in parallel in SLBC. The strategy is to increase output volume. Combining a switched inductor with a traditional boost converter is called a SLBC. when compared to a conventional boost converter, the advantages are the transformer, uninterrupted input current, and a high conversion ratio without a high duty cycle [4].

The tapped inductor buck converter and the switched inductor buck converter can be compared. The dynamic model of the switched inductor buck converter created using the recently established tapped inductor switcher switched flow graph modelling approach is based on the determined equivalence conditions [5].

Buck DC-DC converter hybrid architectures using commutated inductors to increase the step-down ratio. Hybrid buck switched inductor dc-dc converters vs. traditional buck converters. The classical buck converter is contrasted with the hybrid switched inductor dc-dc converter in the continuous conduction mode, and the distinction between CCM and DCM is examined [6].

For photovoltaic applications, a switched inductor and voltage multiplier-based non-isolated high-gain switched inductor dc-dc multilevel CUK converter is described. The conversion ratio is raised as a result.

It is impossible to achieve high voltage gain while using a typical CUK converter. For solar applications where the voltage needs to be increased with negative polarity, this switching inductor multilevel CUK converter topology is appropriate. When high voltage gain is necessary, the proposed non-isolated, high gain switched inductor floating output DC-DC multilevel CUK converter is employed in photovoltaic applications. The voltage multiplier and switching inductor in the proposed converter are used to make it suitable for high voltage gain applications According on whether the minimum current flowing through the inductor L 3 is equal to zero, the proposed quadratic Buck-Boost Converter with Switched Inductor Network is separated into continuous conduction mode (CCM) and discontinuous conduction mode (DCM). The inductor peak current in the two modes is then calculated. Within a specified input voltage and load range, a comprehensive dynamic range inductor peak current analysis approach is put forth based on the quadratic Buck-Boost Converters with Switched Inductor Network. [7].

To address the issue with the DC-DC converter, the single-ended CUK converter has been replaced by a SEPIC converter. SEPIC converters can reduce ripple, produce harmonics, invert voltage, cause overheating, and other issues related to DC converters while still achieving the highest efficiency [8].

Less passive components are used while the same number of semiconductor devices are used. A brand-new switched inductor configuration called the switched inductor double switch DC-DC converter is suggested (SL-DS-DC). In addition, this proposed converter has such a larger gain than the most current converter that was reported [9].

The type-I and type-II topologies of the high-step-up DC-DC converter using a switching inductor and voltage multiplier cell are elaborated in this work. These suggested topologies have the advantages of less voltage stress on semiconductor devices, a low device count, high power conversion efficiency, a high switch utilisation factor, and a high diode load factor. It has been developed and studied to use two non-isolated converters based on switching inductors and voltage multiplier cells [10].

3.2 SL BOOST DC-DC CONVERTER

A voltage-lift switched-inductor cell charges the capacitor C_V and the inductors L_1 and L_2 in parallel when the stage is ON. Inductors and capacitors are discharged in series when the stage is OFF to produce a large voltage gain. A DC-DC boost converter is being suggested. The voltage-lift switched-inductor cell is made up of two inductors, L_1 and L_2, two diodes, D_1 and D_2, and a charge pump capacitor, according to the voltage-lift switched-inductor with two-level boost converter scheme. Another is the two-level voltage multiplier cell, which is made up of three capacitors (C_1, C_2, and C_3) and three diodes (D_3, D_4, and D_5). The first component is connected to the second component, the output load R, and the low voltage source V_i, from which the electrical energy is transferred [2].

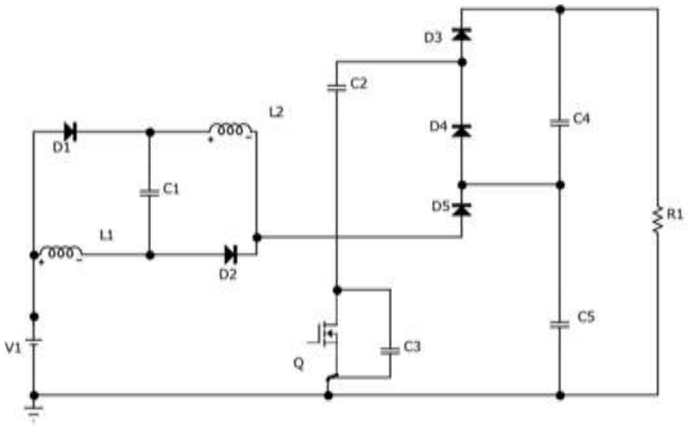

Figure 1: Topology of N-level Boost converter

Throughout the period of switching ON. V_{in} is equal to the corresponding voltage across both inductors. Consequently, the equations are

$$V_{L1}=V_{L2}=V_{in} \quad ...(1)$$

The output voltage for a two-level converter is expressed as

$$V_0 = 4\frac{Vin}{(1-D)} \quad ...(2)$$

3.3 SWITCHED-INDUCTOR CELL

The SL-cell illustrated in the dotted box can be used to replace the inductor L in a conventional Boost converter. Two inductors, L1 and L2, that have the same inductance, make up the SL-cell. Diodes D1, D2, and D3 are three. D1 and D2 conduct, D3 shuts off, and two inductors are linked in parallel while the switch is conducting. D1 and D2 are reverse-biased, and D3 is run during the off-state. The two inductors are then connected in series.

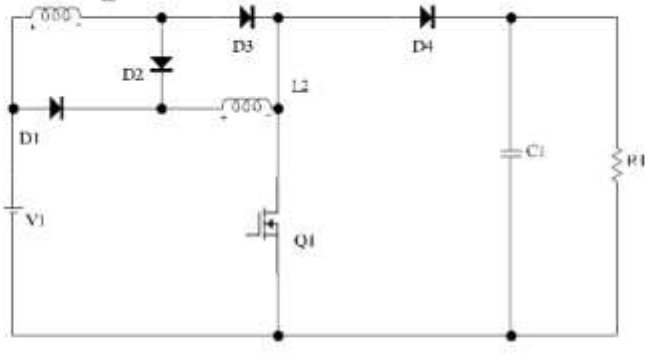

Figure 2: switched inductor boost converter cell

The voltage gain is calculated using,

$$G = \frac{V_0}{V_i} = \frac{3+5D}{1+D} \quad ...(3)$$

The following benefits of the SL-Boost converter over the conventional Boost converter:

1. Because the average inductor current is low, a single inductor can be smaller.

2. The inductors of the converter that have the same inductance can be merged into a single magnetic core and operate under the same conditions, which helps to minimise the size of magnetic components.
3. Compared to a Boost converter, the voltage conversion ratio is larger.

The SL-Boost, however, has a few drawbacks as well:

1. The 10 times voltage gain ratio is difficult to handle since the voltage gain is constrained.
2. The output voltage is the voltage across the power switch while it is in the off-state, and the conduction loss will grow with a high voltage stress switch with a big Rd (on).
3. The output voltage is the voltage applied across the output diode when it is in the off-state. Therefore, the reverse-recovery issue could get worse [3].

3.4 SWITCHED INDUCTOR BOOST CONVERTER (SLBC)

Switched inductor network is connected in series with voltage source in suggested DBC. Two inductors and three unregulated devices, D_1, D_2, and D_3, make up a switched inductor network. Single controlled power switch S and one uncontrolled switch, or diodes D_4, are needed for SLBC. Additionally, a capacitor is needed on the converter's output side. Gate pulses are produced by the pulse generator block for switch S [4].

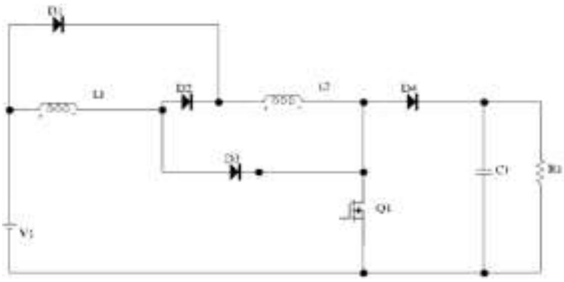

Figure 3: switched inductor boost converter

If the voltage across the switch and diode is disregarded,

V = 0

$$\frac{V_0}{V_{in}} = \frac{1+D}{(1-D)} \quad \dots(4)$$

3.5 SWITCHED INDUCTOR CUK CONVERTER

The suggested three-level, non-isolated, switched-inductor, multilevel CUK converter's power circuit schematic Because a switching inductor and a voltage multiplier are combined, this type of converter offers significant voltage gain. The proposed N-level switched inductor dc-dc multilevel CUK converter uses 2N capacitors, 2N+2 diodes, three inductors, one switch, and a single input supply [8].

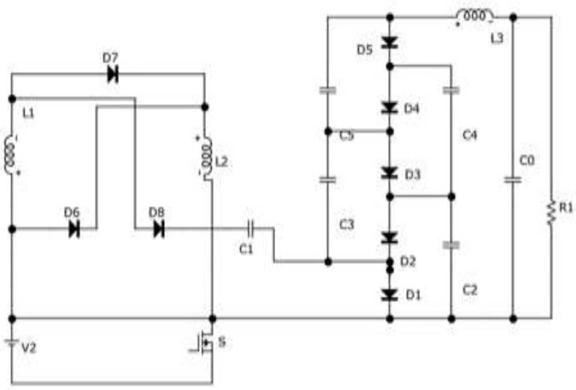

Figure 4: power circuit of CUK converter

Different possibilities exist for the three-level non-isolated high gain switched inductor dc-dc multilevel CUK converter's operation depending on whether switch S_1 is conducting or not. Both inductors L1 and L_2 are charged in parallel by input supply voltage Vin through the corresponding diodes D_6 and D_8 when switch S_1 is conducting (on). Vin and the voltage across capacitor C_2 are used to charge capacitor C_1 when diode D_2 is forward biased. Similar to this, through diode D_4, capacitors C_1 and C_3 are charged by V_{in} and voltage across C_2 and C_4. Finally, by switch S_1, input supply voltage V_{in} and the capacitors C_1, C_3, and C_5 charge the inductor L_3. explain the circumstances in which S_1 conducts. Both diodes D_6 and D_8 are reverse biased when switch S_1 is not conducting (turned Off) due to energy stored in inductors L_1 and L_2. Both inductors L_1 and L_2 are discharged in series at the same time through the forward biased D_7. When diodes D_7 and D_1 are forward biased, inductors L_1 and L_2 charge capacitor C_1 by passing through them via diodes D_7 and D_1. Capacitor C_2 is charged by diodes D_7 and D_3, which are forward biased, capacitors C_1, C_3, and the voltage across L_1 and L_2. When D_7 and D_5 are forward biased, voltage applied across L_1 and L_2 charges capacitors C_2 and C_4 as well as capacitors C_1, C_3, and C_5.

The same time L_1 and L_2 are charged in parallel by input supply voltage Vin when switch S_1 is operating.

$V_{L1}=V_{in}$ … (5)

$V_{L2}=V_{in}$ … (6)

Expression (7), where D is the duty cycle, R is the load value, and f is the switching frequency, can be used to compute the three inductors.

$$L = \frac{(1-D)R}{2f} \quad \ldots.(7)$$

3.5 POWER FACTOR CORRECTION (SL) SEPIC CONVERTER

The suggested PFC converter is created by splitting the rectifier diode D_0 into two equal diodes (D, D_5) and the inductor L_o into two equal inductors (L_2, L_3). These components are then rearranged to create a switched inductor circuit consisting of SW_1, L_o, and D_o. During each period of the switching cycle, the intermediate inductor interconnections switch from a series connection to a parallel connection. The SEPIC converter with switching inductor is intended to function in CCM. During a changeover period, the voltage is constant [10].

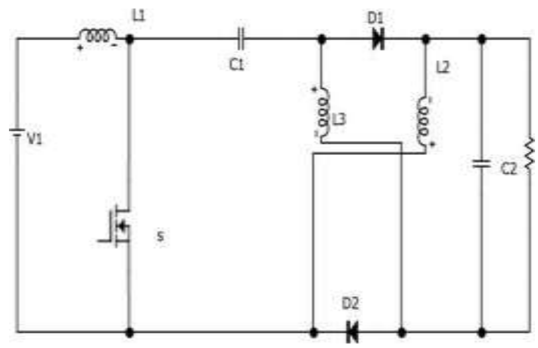

Figure 5: (SL) SEPIC converter

The output voltage is denoted by (8),

$$\Delta V_0 = \Delta V_c . \Delta iESR \quad \ldots (8)$$

4. COMPARISON OF (SL) DC-DC CONVERTERS

	[2]	**[3]**	**[4]**	**[8]**	**[10]**
No. of. switch	1	1	1	1	1
No. of. diodes	5	4	4	9	2
No. of. inductors	2	2	2	3	3
No. of. capacitors	5	1	1	6	2
Total components	13	8	8	19	8
Duty ratio	0.5	0.5	0.5	0.75	0.5
Input voltage	12v	40v	20v	12v	12v
Output voltage	95.5	400v	160v	-225v	48v

5. CONCLUSION

This paper provides a survey of the literature on the switched inductor dc-dc converter topologies that have been covered in a number of periodicals. A switching DC/DC converter, sometimes referred to as a regulator, is essentially a circuit that transfers energy utilising a power switch, an inductor, a diode, and a capacitor from the input to the output. In order for a switched-mode DC/DC converter to function, energy from the input is periodically stored and released to the output at a fluctuating voltage. In this paper briefly explain about switched inductor with different converters such as Boost, CUK, SEPIC.

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