International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 04 | Apr 2020 www.irjet.net p-ISSN: 2395-0072

A HIGH STEP UP DC-DC CONVERTER USING ISOLATED COUPLED INDUCTOR

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Abstract - *This paper presents a novel high step up DC-DC boost converter which offers an optimum option for DC voltage supply applications. The proposed converter is based on modified conventional Switched Inductor Boost Converter (SIBC) topology in which isolated coupled inductor is used instead of normal inductors. Modified SIBC charges the inductor primaries in parallel and discharges them in series. This offers higher DC voltage at the output in comparison with conventional switched inductor boost converter. The proposed topology provides a boosted output voltage according to turn's ratio of the inductor secondary. It offers high voltage gain with reduced switching losses and provision for voltage multiplication at the output using voltage multiplier strings. Proposed converter is designed and simulated for an input voltage of 30V, boosted output voltage of 120V and power rating of 100W.*

Key Words: **High Gain, DC-DC Converter, Isolated Coupled Inductor, Switched Inductor Boost (SIB), Voltage Multiplication, Constant DC Output**

1. INTRODUCTION

The DC-DC converters are widely used for regulated switch mode DC power supply applications. These converters accept unregulated DC voltage as input, which may be obtained from PV array or any other renewable resources. Therefore it will be fluctuating due to changes in atmospheric conditions. The average DC output voltage can be controlled to the desired value although the input voltage is changing. Conventional DC-DC boost converter only needs an inductor, switch, diode and output capacitor. The converter can therefore operate in the two different modes depending on its energy storage capacity and the relative length of the switching period. [2]

Renewable energy sources such as solar energy are widely used to produce electrical energy [5]. However, their problem of low output voltage than needed for connecting to a grid can be solved by using high gain dc-dc converters.

Several switches need to be employed to achieve high voltage gain and to lower the switch stress voltage to boost this low voltage. However, the converter cost is increased and the control method is more complicated in comparison to the single switch DC-DC converters. The boost converter is the most common converter used to step up the dc voltage. High dc gain can be theoretically achieved by using this converter.

Almost all the electronic devices are powered from a DC power source; be it a battery or a DC power supply. Electronic devices require not only a DC power source but also a source giving a well filtered and regulated DC voltage. Therefore, to meet these demands, the power supply has become more and more sophisticated.

The paper propose, a novel high gain DC-DC converter using isolated coupled inductor adopting Switched Inductor Boost Converter (SIBC) concept which offers a reasonable solution for constant DC power supply applications. The proposed converter is designed from conventional boost converter where the inductors are replaced by isolated coupled inductor. The approach is to have higher output voltage in comparison with conventional boost converter using appropriate duty cycle with high gain. The coupled inductor technique provides solution to achieve high voltage gain, low voltage stress on the active switch, high efficiency without sacrificing high duty ratio.

The proposed topology is constructed using single switch, two coupled inductors and diode capacitor strings for voltage multiplication.

The organization of paper is as follows: Brief introduction about the need and scope of the concept. Basic Boost Converter and SIBC topology is discussed in section 2 and 3 respectively. Operation modes and Conversion ratio of proposed converter is in section 4. Simulation results of proposed converter presented in Section 5. Finally, conclusion is provided in section 6.

2. BOOST CONVERTER

A basic DC-DC boost converter provides an output voltage V_o higher than the input voltage V_{IN}. The circuit diagram of a conventional DC-DC boost converter is shown in Fig. 1. It consists of an inductor, diode and a switch. IGBT is used as switch in this circuit diagram.

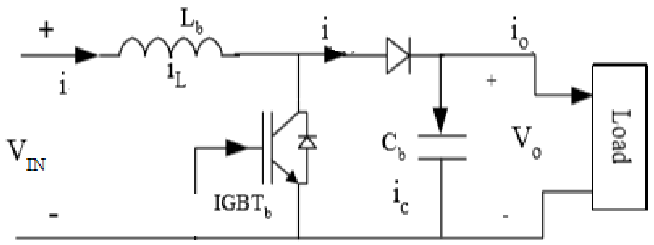

Fig . 1: Basic Boost Converter

Basic DC-DC boost converter operates in two modes; when switch is turn ON and another when switch is turned OFF. When switch is turned ON, inductor gets charged by input voltage V_{IN} through switch ($IGBT_b$). When Switch is turned OFF, inductor discharges through the load, diode and input voltage.

Gain is given by,

$$\frac{V_O}{V_{IN}} = \frac{1}{1-D} \qquad (1)$$

Where D is the duty ratio.

3. CONVENTIONAL SWITCHED INDUCTOR BOOST CONVERTER

A basic switched inductor branch is shown in Fig. 2. Switched inductor module consist of two inductors L_1, L_2 and three uncontrolled devices i.e. diodes D_1, D_2 and D_3.

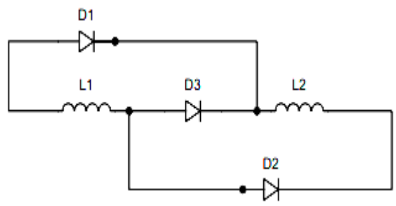

Fig. 2: Switched Inductor Branch

DC- DC Switched Inductor boost converter (SIBC) circuit is depicted in Fig. 3. [3] SIBC topology is obtained by replacing inductor in a basic boost converter with switched inductor branch .Capacitor C is connected at the output side across the load as in a conventional boost converter.

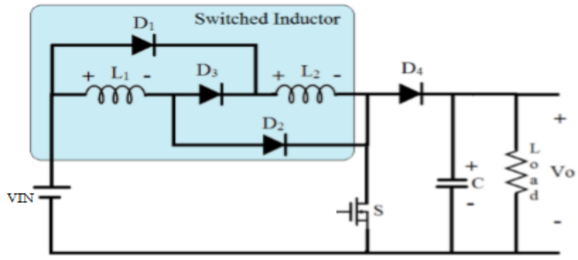

Fig. 3: Switched Inductor Boost Converter [3]

SIBC also operates in two modes; when switch S is turned ON and when switch S is turned OFF.

When switch S is turned ON, L_1 and L_2 gets charged from input voltage V_{IN} via diodes D_1 and D_2 respectively in parallel. Capacitor is discharged through load resistor. D_3 and D_4 are reversed biased here. Fig. 4 depicts the operation when switch S is turned ON.

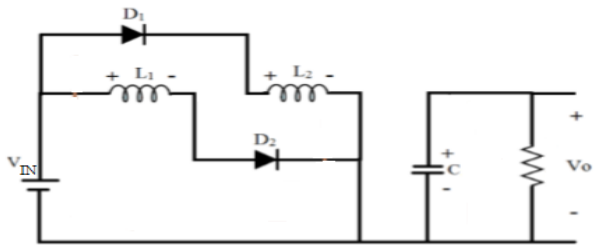

Fig – 4: SIBC When Switch ON [3]

When switch S is turned OFF, L_1 ,L_2 is discharged in series through D_3 and D_4. Diodes D_1 and D_2 are reversed biased in this mode. Fig. 5 shows the operation when switch S is turned OFF.

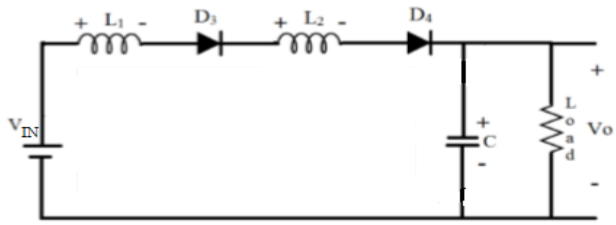

Fig – 5: SIBC When Switch OFF [3]

Thus voltage gain for a SIBC can be derived as [3],

$$\frac{V_O}{V_{IN}} = \frac{1+D}{1-D} \qquad (2)$$

This is always higher than a basic boost converter.

4. MODES OF OPERATION OF PROPOSED CONVERTER

Proposed converter can be described in a simple block diagram as shown in Fig. 6. Converter takes DC voltage as input and a constant boosted voltage is obtained at the output by means of a controller as feedback. Output voltage of the converter is compared with a reference voltage and the error voltage is given to a controller to maintain a constant voltage at the output.

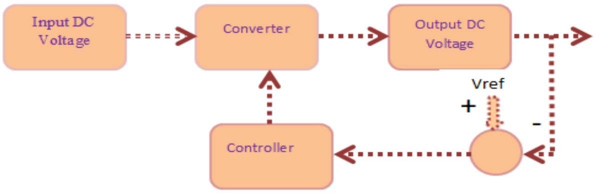

Fig. 6: Block Diagram Of Proposed Converter

Proposed converter topology is shown in Fig. 7.It is obtained by replacing inductors of switched inductor module with a coupled inductor. Thus output voltage gets boosted according to the turn's ratio of the secondary of coupled inductor. Voltage multiplication blocks are provided by means of a diode capacitor string.

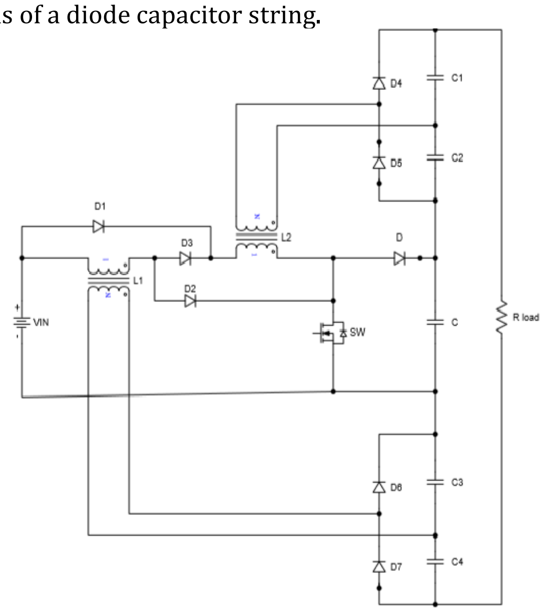

Fig. 7: Proposed Converter Topology

It has two modes of operation; when switch is turned ON and when switch is turned OFF.

4.1 Mode 1-Switch ON

During this mode switch SW is closed. The primaries of switched inductors L_1 & L_2 are charged in parallel through conducting diodes D_1 & D_2. At the same time voltage will be induced in the secondary sides of inductors by voltage transformation. Diodes D_4, D_6 are forward biased and D_5, D_7 are reverse biased. The capacitors C_1 & C_3 charges through D_4 & D_6 respectively. All other capacitors C, C_2 & C_4 discharges and feed the load. Mode-1 operation of the proposed converter is depicted in Fig. 8.

Here,

$$V_{L1}=V_{L2}=V_{IN} \qquad (3)$$

Where V_{L1} and V_{L2} are inductor voltages of L_1 and L_2 at the primary side.

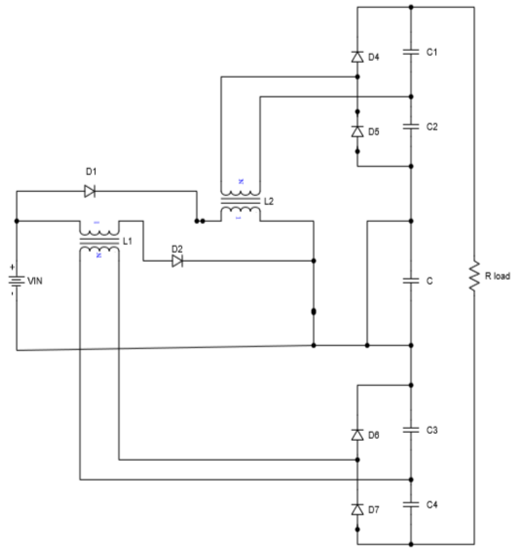

Fig. 8: Proposed Converter When Switch is Closed

4.2 Mode 2-Switch OFF

In this mode of operation switch SW is in open position. The primaries of switched inductors L_1 & L_2 discharges in series through diode D and capacitor C. At the same time the secondary sides of inductors discharges through the forward biased diodes D_5 and D_7 and the capacitors C_2 & C_4 charges respectively. All other capacitors C, C_1 & C_3 discharges and feed the load. Mode-2 operation of the proposed converter is depicted in Fig. 9.

Therefore during all the charging and discharging phases the load will be supplied with full voltage.

Here,

$$V_{L1}+V_{L2} = -(V_o-V_{IN}) = V_L \qquad (4)$$

$$V_{L1}=V_{L2} = -\frac{V_o-V_{IN}}{2} \qquad (5)$$

Where V_{L1} and V_{L2} are inductor voltages of L_1 and L_2 at the primary side. V_L is the total inductor voltage when inductor primaries are in series.

V_o is the output voltage and V_{IN} is the input voltage.

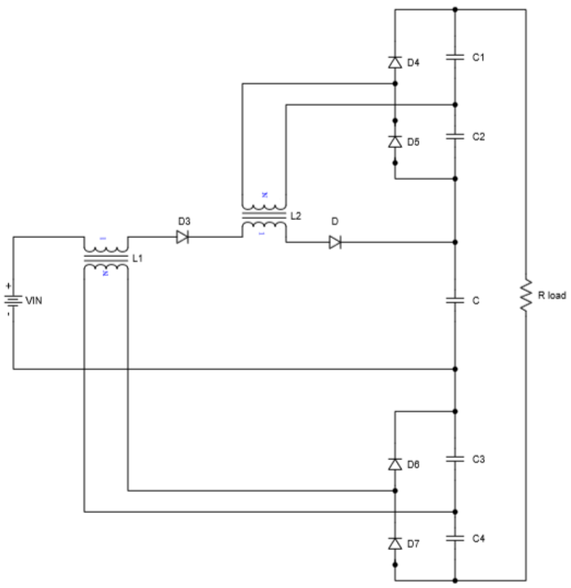

Fig. 9: Proposed Converter When Switch is Open

Overall gain for the proposed converter can be obtained as,

$$\frac{V_O}{V_{IN}} = \frac{1+D}{1-D} + 2\frac{N_2}{N_1} \times D \qquad (6)$$

Where D is the duty cycle
N1 and N2 are turns ratio of primary and secondary coils of coupled inductor respectively.

5. SIMULATION RESULTS

The proposed converter topology is simulated in MATLAB using the parameter listed in Table I.

Table -I: Simulation Parameters

No	Parameter	Value
1	Input Voltage	30V
2	Output Voltage	120V
3	Switching Frequency	20KHz
4	C1,C2,C3,C4	1.354mF
5	C	1.354mF
6	R load	144Ω

These parameters are calculated based on the design procedure of switched inductor boost converter. The proposed converter circuit is simulated with and without feedback circuit. Feedback circuit helps to regulate the boosted voltage to a constant value. Simple voltage regulation loop concept using error amplifier is adopted to maintain this constant voltage .The boosted voltage is regulated to a value of 120V.
Simulation diagram of proposed converter with feedback controller is shown in Fig. 10.

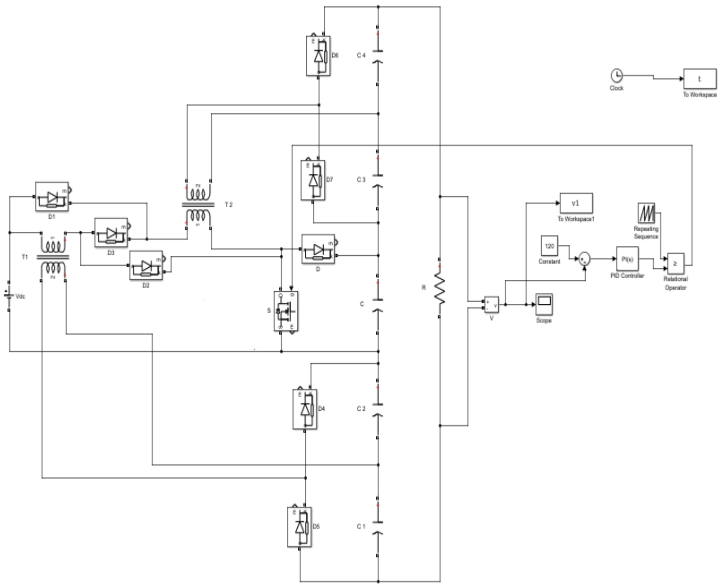

Fig. 10: Simulation Diagram Of Proposed Converter

Fig.11 shows the voltage and current waveforms of the proposed converter. Input voltage is plotted first.VP1/VP2 is the primary inductor voltages of both coupled inductors. Similarly IP1/IP2 is the primary inductor currents of both coupled inductors.

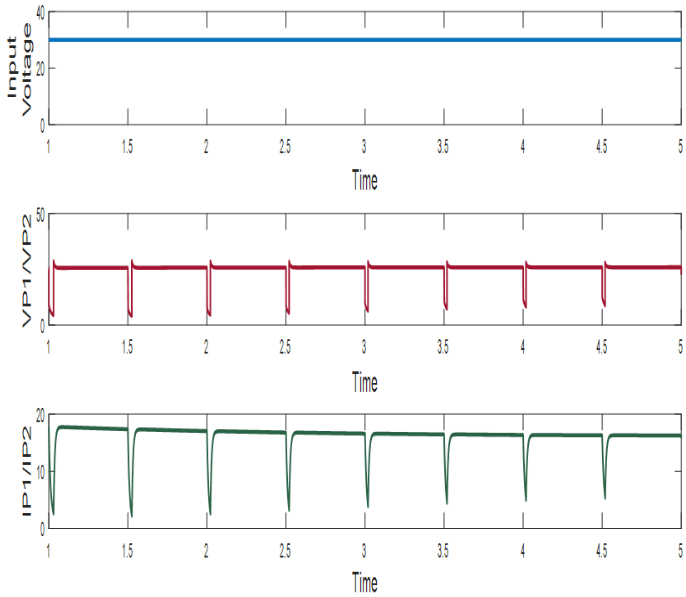

Fig. 11: Voltage And Current Waveforms of Proposed Converter

Fig.12 shows the pulse generation waveforms of the proposed converter. Converter output is compared with repetitive sequence which is the first plot. Pulse generated after comparison for the switch is plotted second. Final plot shows the regulated output voltage obtained.

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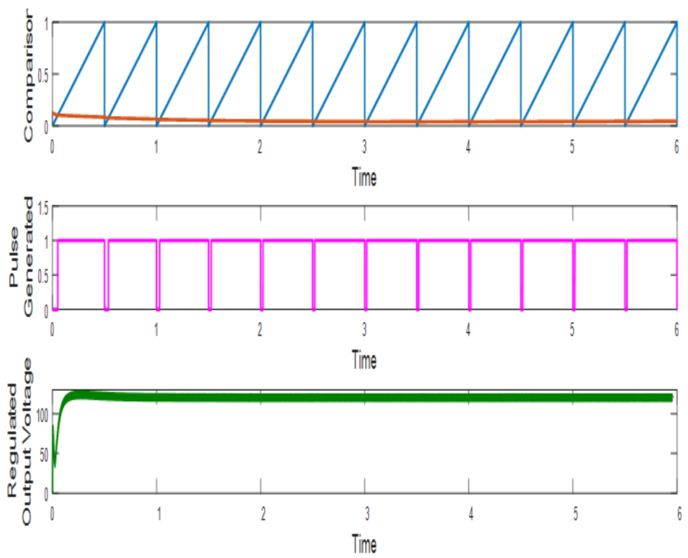

Fig. 12: Waveforms Of Pulse Generation Of Proposed Converter

Regulated output voltage obtained is plotted separately in Fig. 13.

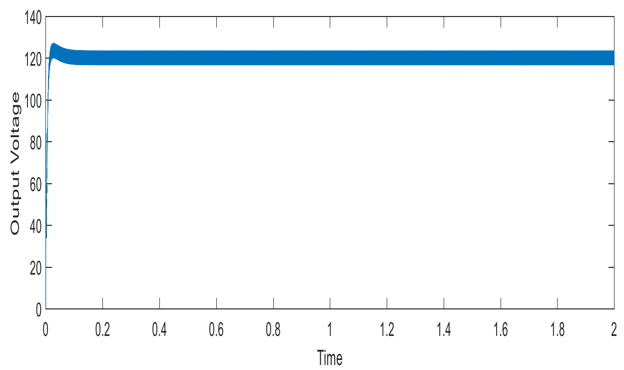

Fig. 13: Regulated Output Voltage Of Proposed Converter

6. CONCLUSIONS

A novel high gain dc-dc boost converter has been proposed. This novel high gain dc dc converter using isolated coupled inductor can be used for constant DC power supply applications. Comparing with conventional boost converter, this proposed converter topology has higher voltage gain. The proposed converter is combination of conventional boost converter and switched inductor, where inductors replaced by isolated coupled inductors. Detailed analysis on the design and performance of the proposed topology showed high gain by using coupled inductor with reasonably good efficiency. The proposed converter is simulated in MATLAB/ SIMULINK and the results verify the validity of the theoretical design.

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