DC-DC Switched Inductor Boost Converter for DC Drives Applications

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Abstract— *This paper presents a DC-DC Switched Inductor Boost Converter (SIBC) which offers a viable solution for DC drives applications which practices non-conventional energy sources. The proposed SIBC is derivation of conventional boost converter by means of substituting inductor with switched inductor. In SIBC, the two inductors are charged parallelely and discharged in series. The methodology is to achieve higher output voltage in comparison with conventional boost converter which uses appropriate duty cycle. The key merits of proposed topology are: an continuous input current, a large conversion ratio without use of extreme duty cycle and transformer. The design of proposed SIBC is planned using single switch, two inductor, four diodes, and single capacitors. With the help of performance equations, the components in the proposed converter are designed. The proposed SIBC converter has rated power 100W, output voltage 160V with input supply voltage 20V. The circuit of proposed SIBC is simulated in MATLAB and simulation result will define the validity of the theoretical design.*

Keywords — *DC-DC; Switched inductor Boost converter (SIBC); Single Switch, DC drives, Non Conventional Energy Sources*

I. Introduction

As world-wide demand for electrical energy stands to grow, the need for alternative energy sources which curtail impact on the environment came into picture [1]-[10]. Conventional energy sources especially fossil fuels are exhausting day by day; hence it is imperative to have substitutes to satisfy the global energy demand. Non-conventional Energy resources are prominent nowadays. Generally photovoltaic and wind systems are the source of energy in standalone systems [11]-[23]. Batteries plays vital role because power is supplied in an irregular way by the renewable source. In lieu of this problem a power conversion system is essential so as to have good output power quality.

Practice of Quadratic boost converter, cascaded boost converters and isolated converter were habitually done to attain the required high voltage gain [24]-[25] However, the difficulties of large ripple current and comparatively higher losses evidenced as interference to acquire high efficiency and high gain.

Numerous DC-DC topologies are attained to yield high voltage by using several diode, capacitor and inductor arrangement [26]-[44]. In Isolated topologies transformers or coupled inductor with suitable turn ratio (isolated topologies) were used to attain the necessary voltage gain. As the losses in transformer are function of switching frequency, it restricted the maximum operating frequency and resulted in increased converter size moreover making the converter circuit bulky and expensive.

In this paper, Switched Inductor Boost Converter (SIBC) is presented. This converter topology is a reasonable solution for DC Drives which uses non-conventional energy sources. The proposed SIBC is designed from conventional boost converter and switched inductor. The approach is to have higher output voltage in comparison with conventional boost converter using appropriate duty cycle. The proposed topology is constructed using single switch, two inductor, four diodes, and single capacitors. The proposed SIBC converter is designed for rated power 100W, output voltage 160V with input supply voltage 20V.

The organization of paper is as follows: Brief introduction of recent DC-DC converter is presented in section I. Conventional boost and proposed SIBC is discussed in section 2 and 3 respectively. Operation and Conversion ratio of proposed SIBC is in section 4. Simulation results of proposed SIBC are in Section 5. Finally, conclusion is provided in section 6.

II. CONVENTIONAL DC DC BOOST CONVERTER

In DC-DC Boost Converter, the output voltage V_o is higher than the input voltage V_{in}. The circuit diagram of DC-DC boost converter is shown in Figure 1. Boost converter circuit is designed using Single inductor, single diode and single switch. The operational modes of boost converter can be categorized into two modes, one when switch S is turn ON and another when switch S is turned OFF. When switch S is turned ON, inductor is charged by input voltage Vin through switch S. Figure 2 picturises the mode of operation when switch S is turned ON. In practical boost converter circuits, the value of internal resistances of switch and diodes are finite. When Switch S is turned OFF, inductor is discharged through load, diode and input voltage.

Figure 3 shows the mode of operation when switch S is turned OFF.

If voltage across diode and switch is ignored then, $V_d = 0$

$$\frac{V_o}{V_{in}} = \frac{1}{(1-D)} \text{ where, D is Duty cycle} \qquad (1)$$

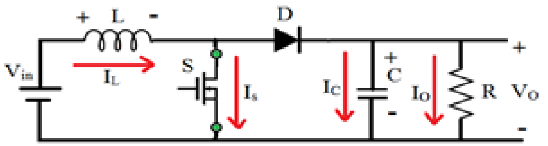

Fig 1. Circuit diagram of DC-DC Boost Converter

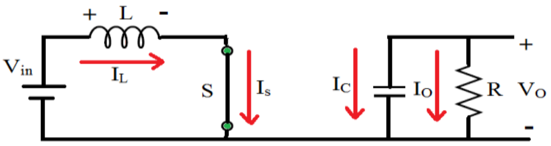

Fig 2. Equivalent Circuit of Boost Converter when switch is ON

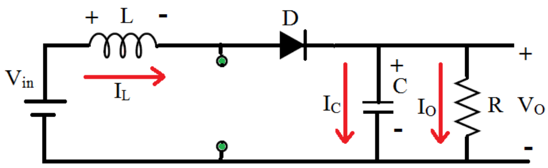

Fig 3. Equivalent Circuit of Boost Converter when switch is OFF

III. DC-DC SWITCHED INDUCTOR BOOST CONVERTER (SIBC)

DC-DC Switched Inductor boost converter (SIBC) circuit is depicted in Figure 4. In proposed DBC, switched inductor network is in series with voltage source. Switched inductor network constitutes two inductor and three uncontrolled devices i.e D_1, D_2 and D_3. For SIBC, Single controlled power switch S with one uncontrolled switch i.e diodes D_4 is required. Also, capacitor at the output side of converter is required. Pulse generator block generates gate pulse for switch S.

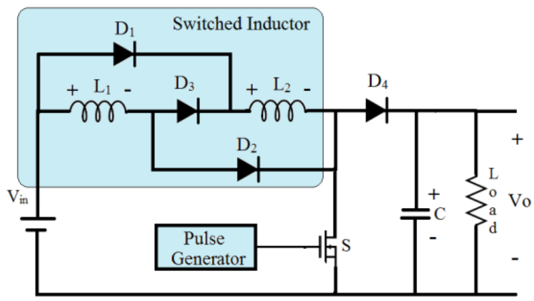

Fig 4. Circuit of DC DC switched Inductor boost converter

IV. OPERATION MODES OF PROPOSED SIBC

The operation of proposed SIBC is divided into two modes, when control switch S is ON and another when switch S is OFF.

When switch S is turned ON, inductor L_1 and L_2 is charged in parallel by input voltage V_{in} through Diode D_2 and D_1 respectively. Capacitor C is discharged through load. Diode D_3 and D_4 are reversed biased. Figure 5 describes operation when switch S is turned ON.

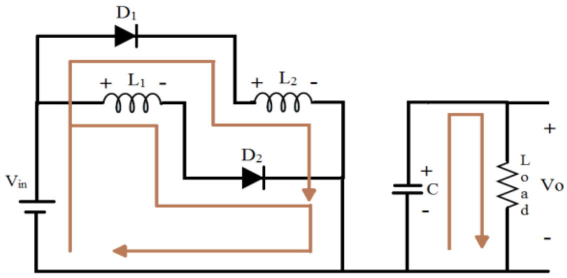

Fig 5. Equivalent Circuit and current direction of SIBC when switch is ON

When switch S is turned OFF, inductor L1, L2 and voltage source is discharged in series thorough Diode D3 and D4. Here diode D1 and D2 are reversed biased. Figure 6 explain the operation when switch S is turned OFF.

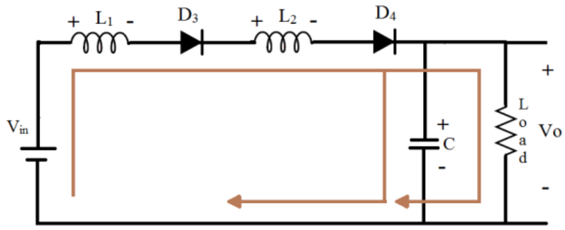

Fig 6. Equivalent Circuit and current direction of SIBC when switch is OFF

If voltage across diode and switch is ignored then, $V_d = 0$

$$\frac{V_o}{V_{in}} = \frac{1+D}{(1-D)} \text{ where, D is duty Cycle} \qquad (2)$$

Thus, the voltage gain of the SIBC is higher than the conventional boost converter.

V. SIMULATION RESULTS

The proposed topology of Switched Inductor Boost Converter (SIBC) is simulated in MATLAB using the parameter listed in Table 1.

TABLE I

No	Parameter	Value
1	Input voltage	20 V
2	Output voltage	160V
3	Output power	100W
4	Inductor, Capacitors	700uH, 220uF
5	Switching frequency	50 KHz

Switch S is fired with the help of pulse generator. The waveforms for output voltage, output current and input voltage are shown in Figure 7. The voltage ripple and current ripple in output voltage is illustrated in Figure 8. It is observed from waveform that voltage ripple is 0.05V. Output power waveform is shown in Figure 9.

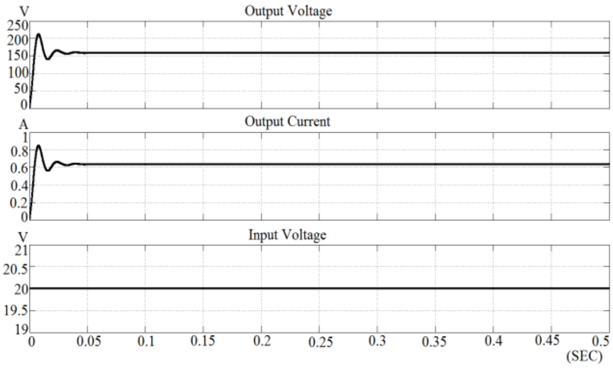

Fig 7. Output voltage, output current and Input voltage waveform

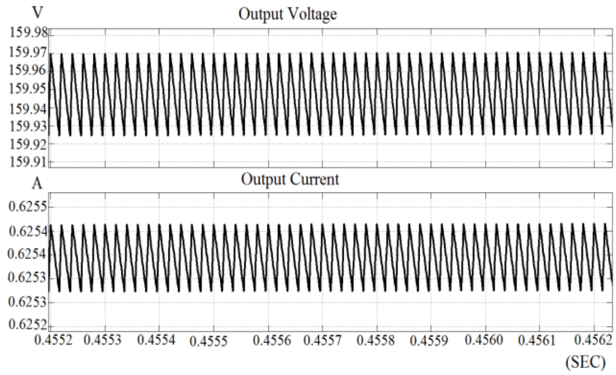

Fig 8. Voltage and current ripple in output voltage

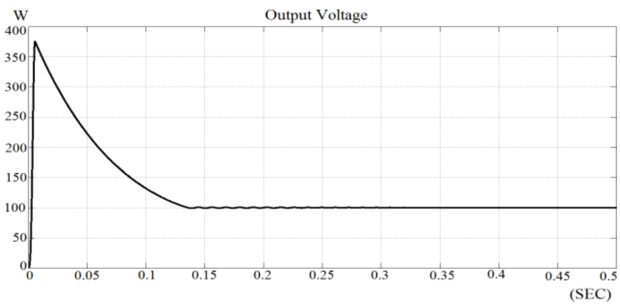

Fig 9. Output power of Converter

VI. CONCLUSIONS

DC-DC Switched Inductor Boost Converter (SIBC) is presented for DC Drives applications using non-conventional energy sources. Comparing with conventional boost converter, SIBC has higher voltage gain. The proposed SIBC is combination of conventional boost converter and switched inductor. Uninterrupted input current, a high conversion ratio without extreme duty cycle and transformer are the benefits when compared with conventional boost converter. In proposed topology use of single switch, two inductor, four diodes, and single capacitors are done while in conventional boost converter single switch, single inductor, single diodes, and single capacitors are used.The proposed SIBC is simulated in MATLAB and simulation result verifies the validity of the theoretical design.

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