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Research Paper

High Frequency Step -UP DC -DC Converter with High Efficiency for High Power Application and the Principle of its Control.

Engineering

KEYWORDS : high voltage gain, high step-up, boost converter

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ABSTRACT

A novel Boost converter is implemented in this project. The circuit configuration of the proposed converter is very simple. The proposed converter employs a coupled inductor with same winding turns in the primary and secondary sides. In step-up mode, the primary and secondary windings of the coupled inductor are operated in parallel charge and series discharge to achieve high step-up voltage gain. In step-down mode, the primary and secondary windings of the coupled inductor are operated in series charge and parallel discharge to achieve high step-down voltage gain. Thus, the proposed converter has higher voltage gain than the conventional boost converter. Under same electric specifications for the proposed converter and the conventional boost converter, the average value of the switch current in the proposed converter is less than the conventional boost converter. The operating principle and steady-state analysis are discussed in detail. Finally, a 5/12-V prototype circuit is implemented to verify the performance for the automobile dual-battery system.

INTRODUCTION

Energy consumption is tending to grow continuously. This demand is satisfied against a background of the depletion of conventional fossil resources. The renewable energy sources are becoming more and more popular. Global investments and R&D efforts are concentrating to reduce the renewable energy cost.

High gain boost converters are the key part of renewable energy systems. Boost converters are the converters with the dc output voltage greater than its input dc voltage. It is a class of switching mode power supply (SMPS) containing at least two semiconductors switches (a diode and a transistor) and at least one energy storage element. Filters made of capacitors (sometimes in combination with conductors) are normally added to the output of the converters to reduce output voltage ripple. This converter has the advantages of simplicity and high efficiency. This converter is transformer-less and thus has the desirable features of high efficiency, low cost and small size. Boost converters do not require isolation which is used in many applications. For example DC back energy systems for UPS, fuel cell systems, renewable

energy systems etc. To use boost converters it has the following requirements:-

1. High step up voltage gain.
2. High current handling capability.
3. High efficiency of a desired level of volume and weight.
4. Low input current ripple.

To provide high output voltage, the boost converter should operate at extremely duty cycle and then diode must sustain a short pulse current with high amplitude. By using extreme duty cycle may also lead to poor dynamic responses to line and load variations as well as results in serious reverse recovery problem. The basic boost converter is a very simple structure with a high step-up voltage gain, but the active switch of this converter will suffer a high voltage stress. The input current is large in the boost converter and hence low voltage rated MOSFET's with small Rds (ON) are necessary in order to reduce the dominating conduction loss. The switch in the boost converter should sustain high output voltage as well and therefore the device selection is faced with a contradiction. High step up boost converter topology have been presented to overcome the problem. Basically boost converter is a power converter with an output dc voltage greater than its input DC voltage. The operation of the boost converter is to boost up a certain input voltage to a higher level at the same time the boost converter steps down the current as a natural result of the energy conservation principle which implies that power being the product of voltage and current must be conserved.

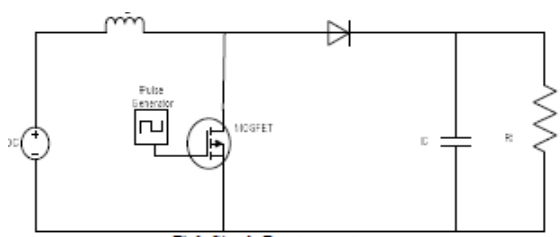
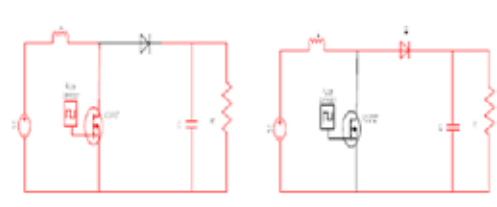


Fig1. Simple Boost converter

The operation of the boost converter is to boost up a certain input voltage to a higher level at the same time the boost converter steps down the current as a natural result of the energy conservation principle which implies that power being the product of voltage and current must be conserved. The boost converter is based on the tendency of an inductor to resist changes in its current. When an inductor is charged, it behaves like a load as it absorbs energy. On the other hand, when it is discharged, it behaves as an energy source. The operation of the boost converter is explained when the switch is closed, the inductor is charged its current increases. When the switch is open, the only path offered to inductor current is through the diode D, the capacitor C and the load R. It indicates that energy generated during the ON state is transferred into the capacitor. The operation of boost converter is explained below. It includes two distinct stages:



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On-state: in which the switch is closed, and thus the inductor is charged, i.e., its current increases. Off-state: the switch is open and the only path offered to inductor current is through the diode D, the capacitor C and the load R. This result in transferring the energy accumulated into the capacitor during the on-state.

II. IMPROVED TOPOLOGY WITH ITS OPERATION

A. Circuit Topology

From basic topology we get voltage gain and in this topology we get increase in voltage gain. In fact, this converter uses two inductors of the same inductance level and the two switches being simultaneously used. When the switch is on, diode becomes forward biased, capacitor and inductor gets charged and then load discharges. When the switch is off, diode becomes forward biased and stored energy in an inductor gets transferred to the capacitor.

The operation as follows:-

Stage 1: This stage extends from t0 to t1 as shown in figure.4. In this interval, both the switches are turned on, and the equivalent circuit is shown in figure3. During this stage both the inductors are charged in parallel whereas capacitor C0 releases its energy to the load. Moreover capacitors C1 and C2 are charged from the DC source.

The voltage across *L1, L2, C1 and C2* are given by:

VL1 = VL2 = Vin = VC1 = VC2

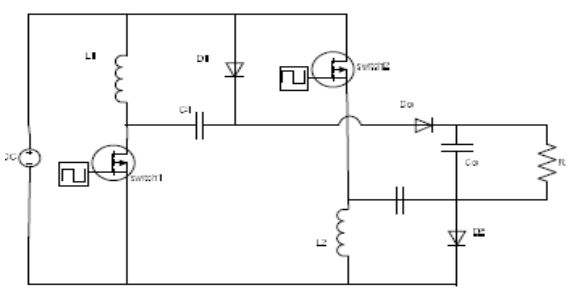


Fig. 3. Improved Circuit Topology

B. Circuit Operation

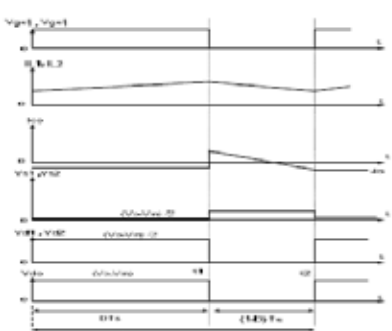


Fig. 4. Voltage and Current Waveforms for Improved Circuit Topology

Stage 2: This stage extends from t1 to t2 as shown in figure. In this stage both the switches are turned off and the equivalent circuit is shown in figure. Besides, L1, L2, C1 and C2 are connected to the DC source in order to transfer the stored energy to C0 and load. So, the voltage across L1 and L2 are given by:

$$V_{L1} = V_{L2} = \frac{V_{in} + V_{c1} + V_{c2} - V_o}{2} = \frac{3V_{in} - V_o}{2}$$

The two inductors are equal in values and have the same current. The voltage gain can be evaluated as:

$$\int_0^{DT_s} V_{in}\,dt + \int_{DT_s}^{T_s} \frac{3V_{in} - V_o}{2}\,dt = 0$$

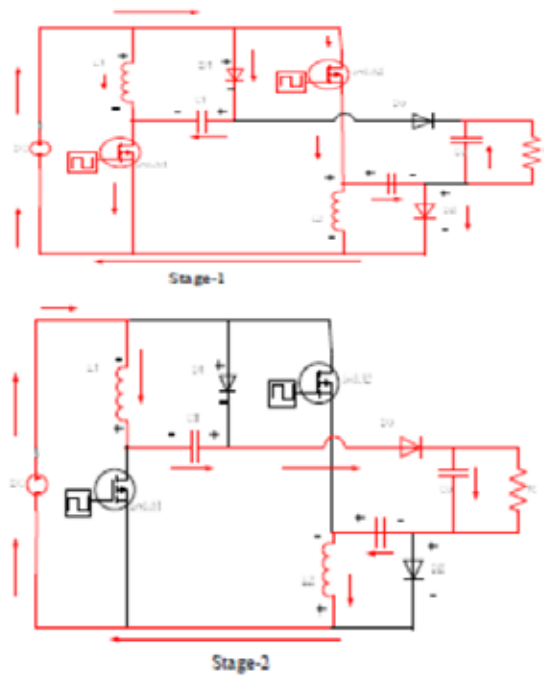


Fig.5. Equivalent circuit of stage-1 and stage-2 of Improved Topology The voltage gain is thus derived by rearranging the above equation, as follows:

The voltage gain is thus derived by rearranging the above equation, as follows:

$$\frac{V_o}{V_{in}} = \frac{3-D}{1-D}$$

where, D is the duty cycle.

The voltages of the switch are given by: $V_{S1} = V_{S2} = V_{D1} = V_{D2} = \frac{V_{in} - V_o}{2}$

Moreover, the diode voltage is: $V_{DO} = V_o - V_{in}$

II.TRADITIONAL TECHNIQUES

Bidirectional dc–dc converters are used to transfer the power between two dc sources in either direction. These converters are widely used in applications, such as hybrid electric vehicle energy systems, uninterrupted power supplies, fuel-cell hybrid power systems, photovoltaic hybrid power systems, , and battery chargers. Many bidirectional dc–dc converters have been researched. The bidirectional dc–dc fly back converters are more attractive due to simple structure and easy control. However, these converters suffer from high voltage stresses on the power devices due to the leakage inductor energy of the transformer. In order to recycle the leakage inductor energy and to minimize the voltage stress on the power devices, some literatures present the energy regeneration techniques to clamp the voltage stress on the power devices and to recycle the leakage inductor energy.

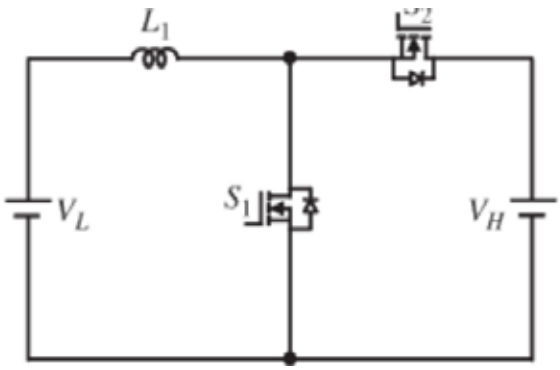


Fig .6Conventional bidirectional dc–dc boost/buck converter

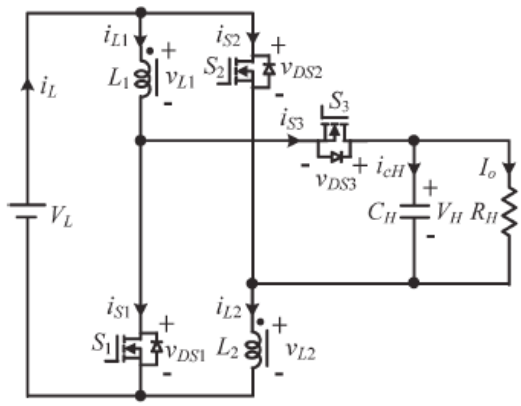


fig .7 Proposed bidirectional dc–dc converter.

Comparing to the proposed converter and the conventional boost converter, the proposed converter has the following advantages: 1) Higher step-up and step-down voltage gains and 2) lower average value of the switch current under same electric specifications. The following sections will describe the operating principles and steady-state analysis of the proposed high voltage gain boost converter. In order to analyze the steady-state characteristics of the proposed converter, some conditions are assumed: The ON-state resistance *RDS* (*ON*) of the switches and the equivalent series resistances of the coupled inductor and capacitors are ignored; the capacitor is sufficiently large and the voltages across the capacitor can be treated as constant.

III.PROPOSED METHOD

The proposed Boost converter pulse width modulation (PWM) technique is used to control the switches *S*1 and *S*2 simultaneously. The switch *S*3 is the synchronous rectifier. Since the primary and secondary winding turns of the coupled inductor is same, the inductance of the coupled inductor in the primary and secondary sides are expressed as

$$L_1 = L_2 = L \quad \text{---------- (1)}$$

Thus, the mutual inductance *M* of the coupled inductor is given by

$$M = k\sqrt{L_1 L_2} = kL \quad \text{---------- (2)}$$

Where *k* is the coupling coefficient of the coupled inductor. The voltages across the primary and secondary windings of the coupled inductor are as follows:

$$v_{L1} = L_1\frac{di_{L1}}{dt} + M\frac{di_{L2}}{dt} = L\frac{di_{L1}}{dt} + kL\frac{di_{L2}}{dt} \quad \text{--------- (3)}$$

$$v_{L2} = M\frac{di_{L1}}{dt} + L_2\frac{di_{L2}}{dt} = kL\frac{di_{L1}}{dt} + L\frac{di_{L2}}{dt} \quad \text{---------- (4)}$$

For the proposed converter in step-up mode is operated in boundary conduction mode (BCM), the voltage gain of CCM operation is equal to the voltage gain of DCM operation the boundary normalized inductor time constant $\tau_{LH,B}$ can be derived as follows:

$$\tau_{LH,B} = \frac{D(1-D)^2}{2(1+k)(1+D)} \quad \text{---------- (20)}$$

The curve of τ *LH, B* is plotted in Fig. 6. If τ_{LH} is larger than τ_{LH}, *B*, the proposed converter in step-up mode is operated in CCM

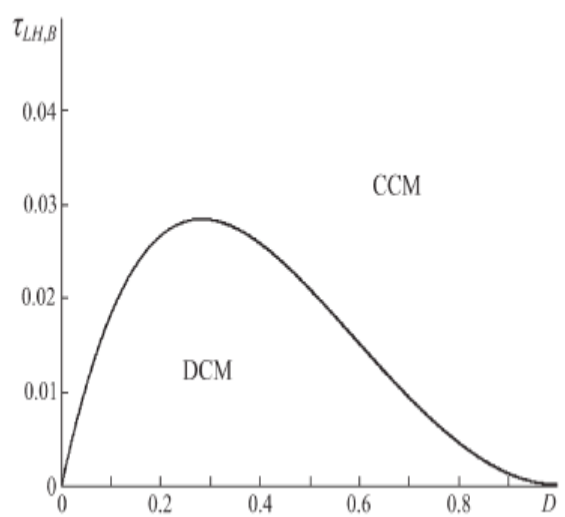


fig .8 Boundary condition of the proposed boost converter (assuming *k* = 1).

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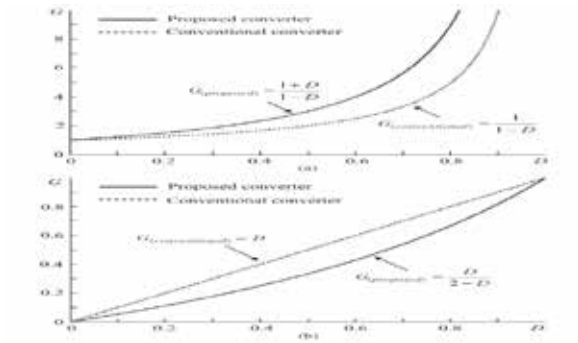


Fig .9 Voltage gain of the proposed boost converter and conventional boost converter in ccm operation

IV.MATLAB/SIMULINK RESULTS:

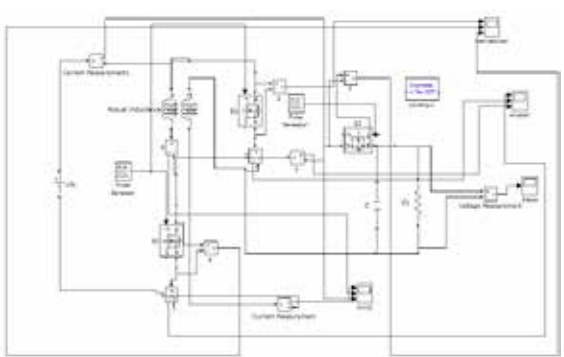
The improved converter topology has been modeled using simulation. The simulation has been conducted to verify the performance of high step-up DC-DC converter. The circuit with the components indicated in fig.3 are given in Table I and used for evaluating the circuit performance. In the simulation, MOSFET is used as the switching device.

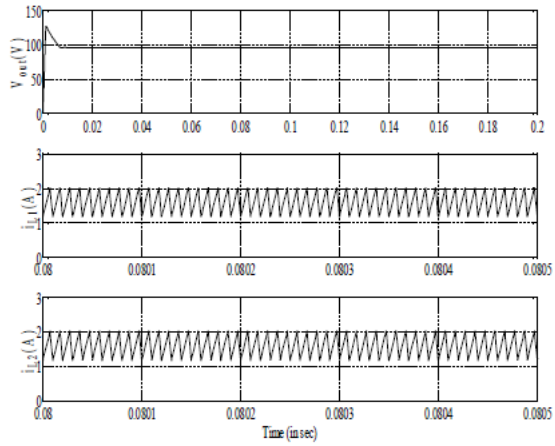
TABLE I: Circuit Parameters for Analysis

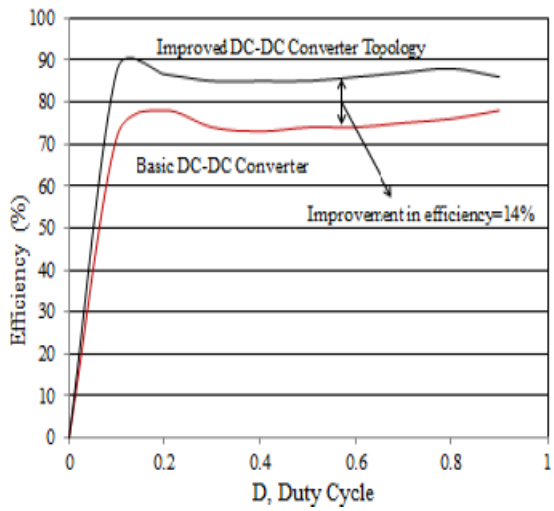
Parameters	Values
Inductor (L1)	60 µH
Inductor (L2)	60 µH
Capacitor (C1)	80µF
Capacitor (C2)	80 µF
Output Capacitance (Co)	100 µF

A. High Step up DC-DC Converter Performance

The improved converter is tested for 12V Input and 100V output is obtained. The switching frequencies of switches are kept at 100 kHz switching frequency. Due to high Frequency operation, the size of inductors L1 and L2 are reduced. The average value of inductor currents iL1 and iL2 are obtained as 1.5A. The decrease in the input current at a high duty cycle holds a greater significance. The improved converter can be operated at a high duty cycle without an enormous amount of input current. The output is maintained its constant value of 100V for various loading conditions.







(a) Output voltage, inductor current through L1 and inductor current through L2 at 100kHz, 12-100V operation, (b) Efficiency curves of basic and improved topology for different values of duty cycle

VI.CONCLUSION

This projects researches a novel high voltage gain boost converter. The circuit configuration of the proposed converter is very simple. The proposed converter has higher voltage gain and lower average value of the switch current than the conventional boost converter. From the experimental results, it is seen that the experimental waveforms agree with the operating principle and steady-state analysis. At full-load condition, the measured efficiency is high up to 90% which is higher than the conventional boost converter.

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