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An Interleaved Boost DC-DC Converter for High Voltage AC and DC Applications

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ABSTRACT: This paper deals with a new high step-up interleaved dc-dc boost converter designed especially for regulating the dc interface between the source and for providing high voltage output. A high power efficient dc-dc converter is strongly desired and has found widespread applications. Examples include aerospace, sea and undersea vehicles, electric vehicles (EV), Hybrid Electric Vehicle (HEV), portable electronic devices like pagers, and microprocessor voltage regulation. Most of the applications need high output voltage for corresponding load requirement. If the input voltage is low and the output voltage needed should be higher than the input voltage, then boost converter is suitable to provide the needed high voltage output. This project proposes a new high step-up interleaved dc-dc boost converter designed especially for regulating the dc interface between the sources and for providing high voltage output. The configuration of the proposed converter is an interleaved boost converter with the auxiliary boost converter connected in parallel to the main boost converter. The converter achieves high step-up voltage with appropriate duty ratio and low voltage stress on the power switch. The operating principles with various modes are discussed. Simulation results are provided to illustrate the advantages of the proposed converter and controller scheme. It is simulated using MATLAB/SIMULINK in power system block set.

KEYWORDS: Interleaved, BEV (Battery Electric Vehicle) HEV (Hybrid Electric Vehicle), PEV (Photo Electric Vehicle).

I. INTRODUCTION

The interleaved PFC regulator is an interesting alternative and choice for high current applications. Interleaving permits a significant reduction in the magnetic energy storage inductors and the differential-mode EMI filter. Interleaving can also significantly reduce the switching losses. The main advantage of interleaving is that it effectively increases the switching frequency without increasing the switching losses. The obvious benefit is an increase in the power density without the penalty of reduced power-conversion efficiency. Dig shows the inductor current waveforms of a two cell interleaved boost converter operation at 50% duty cycle which results in a complete cancellation of input ripple current and also operation at 30% duty-cycle. Here the aggregated input ripple current is twice the individual cell switching frequency. Voltage boost is based on the two stages of operation. Comparing to the conventional circuit, the output voltage gain, output power is high and also the output ripple is low.

II. RELATED WORK

Interleaving the boost section of the conventional PFC is introduced and shown in Fig. 6. The main advantage of this topology is decreased high-frequency pulse width modulation (PWM) rectifier input current ripple caused by the switching action. Reducing input ripple decreases the required switching frequency to meet a current

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TDD limit imposed by the utility. Reducing PWM input ripple current also decreases the ac ripple current supplied by the dc-link capacitor, thereby reducing its stress. Another advantage is the reduced current rating of the active switches as the interleaving converter halves the input current. One disadvantage of the topology is the high conduction losses of the input bridge rectifier as well as increased number of semiconductor devices and associated gate control circuitry. This topology is preferred by the industry for on-board charging applications and is used for 3.3-kW level-2 chargers [1].

Some of the unidirectional ac–dc rectification stages are highlighted in the next sections.
A. PFC Unidirectional Chargers:
1) Symmetrical and Asymmetrical AC–DC Boost Converters:
The topology proposed is called symmetrical bridgeless boost rectifier and is shown in Fig. 1. Another topology called asymmetrical bridgeless boost rectifier is proposed in is shown in Fig. 2. They eliminate the input diode bridge to attain higher efficiencies at increased power levels [3].

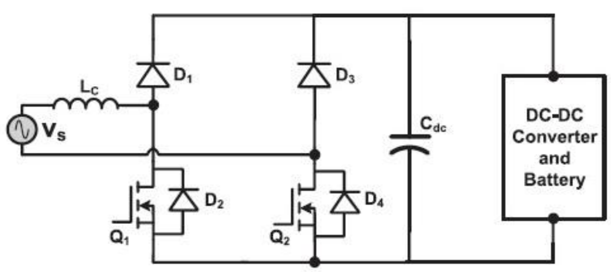

Fig. 1 Symmetrical bridgeless boost rectifier.

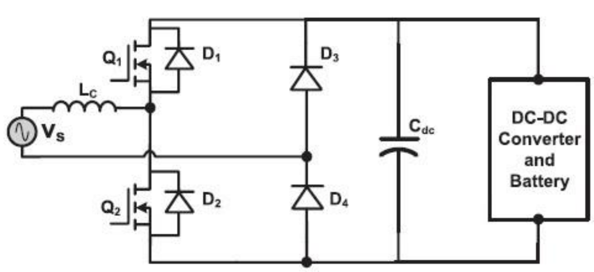

Fig 2. Asymmetrical bridgeless boost rectifier.

B. Four-Quadrant Bidirectional Chargers:
1) Conventional AC–DC Half-Bridge Converter: This type of converter diagram is illustrated in Fig. 3. It includes two dc-link capacitors, two switches, two diodes, and a coupling inductor for grid interconnection. Two sufficiently large capacitors share the dc-link voltage equally. The switches Q1 and Q2 cannot be ON at the same time to prevent any short circuit or shoot through. This requires a dead time when the switches are operated sequentially. When the switch Q1 is ON, either Q1 or D1 conducts depending on the direction of the charger current. Similarly, when the switch Q2 is ON, either Q2 or D2 conducts depending on the current direction. The topology is suitable to

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transfer power in four quadrants. A half-bridge converter requires bipolar switching because there are only two possible output voltage levels, +Vdc and −Vdc.

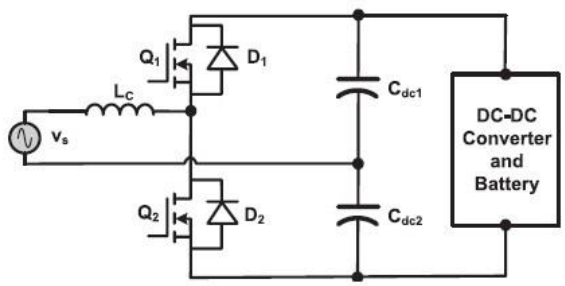

Fig.3 . AC–DC half-bridge converter diagram.

2) AC–DC Full-Bridge Converter: The full-bridge converter, shown in Fig. 4, is comprised of a dc-link capacitor, four transistors (either MOSFETs or IGBTs), four diodes, and a coupling inductor. Voltage of the capacitor is doubled in this configuration. The topology is suitable for four-quadrant operation. The full-bridge converter can operate in unipolar modulation and has three output voltage levels: +Vdc, −Vdc, and zero. Since there are three output voltage levels for the full bridge inverter, the number of switching's required for the same current THD level is effectively reduced with the full-bridge converter compared to half-bridge converter [7].

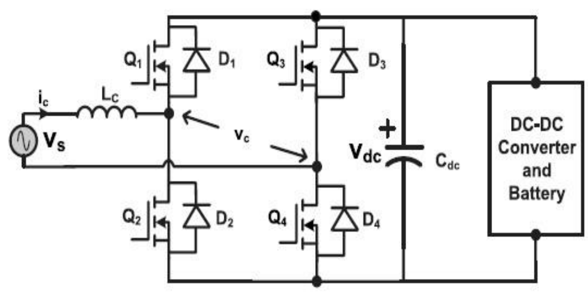

Fig.4 . AC–DC full-bridge converter diagram.

Overview:

It consists of a phase shifting of the control signals of several cells in parallel operating at the same switching frequency. As a consequence of the interleaving operation, the aggregated input current and output voltage waveforms exhibit lower ripple amplitude and smaller harmonic contents than a single boost converter. The cancellation of low-frequency harmonics allows, eventually, the reduction of size and losses of the filtering stages. In addition, switching and conduction losses through the switches are just a fraction of the input current and as a consequence EMI levels decrease significantly.

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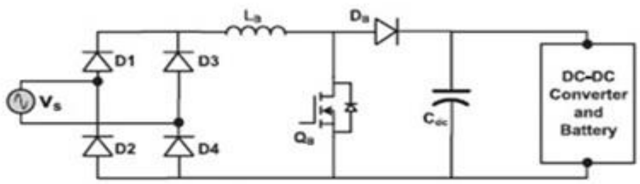

Fig 5 Conventional AC-DC Boost Converter

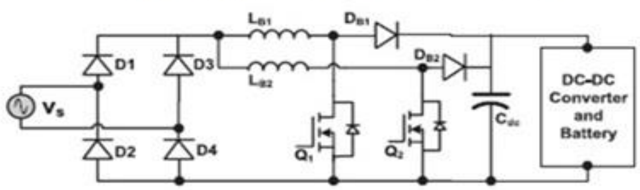

Fig.6 Interleaved AC-DC Boost Converter

III. MODE OF OPERATION

The states of operation of this converter are explained as follows. In order to simplify the calculation, it is assumed that the inductance value of both inductor are L1 and L2, where L1=L2=L, and the duty cycle of Q1 and Q2 denoted as D1 and D2, with D1=D2=D [4] [6].

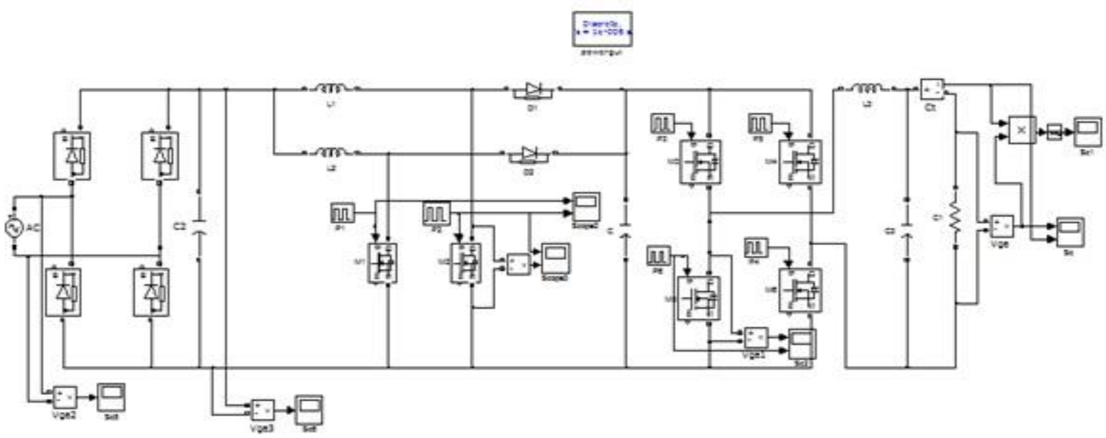

Fig.7. Interleaved Boost DC-DC Converter

1) <u>State A</u>:
   At time t0, Q1 is closed and Q2 is opened. The current of the inductor L1 starts to rise, while L2 continues to discharge. The rate of charge of iL1 is diL1/dt=Vi/L, while the rate of change of iL2 is diL2/dt = (Vi-Vo)/L.
2) <u>State B</u>:
   At time t1, Q1 and Q2 are opened. The inductors L1 and L2 discharge through the load. The rate of change of iL1 and iL2 are diL1/dt = diL2/dt = (Vi-Vo)/L.

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3) <u>State C</u>:
At time t2, Q2 is closed and Q1 is still opened. The current of the inductor L2 starts to rise, while L1 continues to discharge. The rate of charge of iL2 is diL2/dt=Vi/L, while the rate of change of iL1 is diL1/dt = (Vi-Vo)/L.

4) <u>State D</u>:
At time t3, Q2 is opened and Q1 is still opened. The situation is same as in state b. The inductors L1 and L2 discharge through the load. The rate of change of iL1 and iL2 are diL1/dt = diL2/dt = (Vi-Vo)/L.

IV. RESULT AND DISCUSSION

The simulation results for the proposed circuit are carried out in MATLAB/SIMULINK and are as per the following:

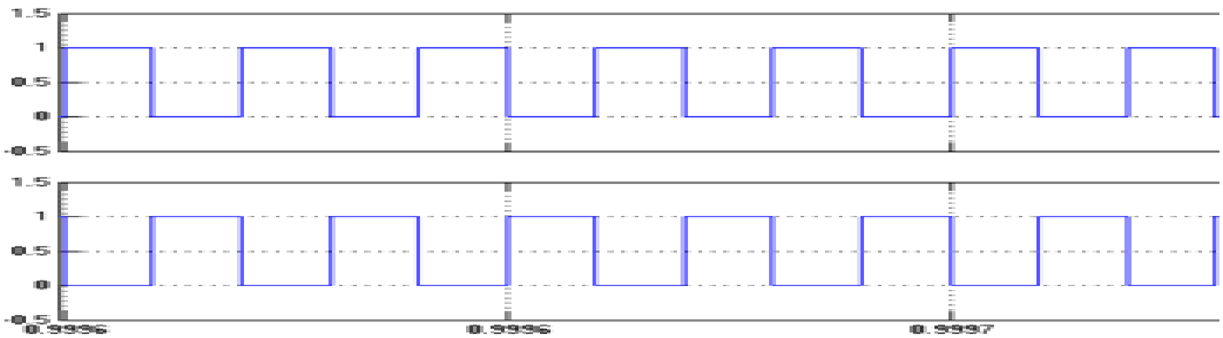

Fig.8 Switching pulse for M1, M2

The switching pulses for the MOSFET switch is shown above in fig.4. by the use of interleaving technique, the PWM pulses are given for the switch 1 and pulses are given to switch 2 after the switch 1 turn's off.

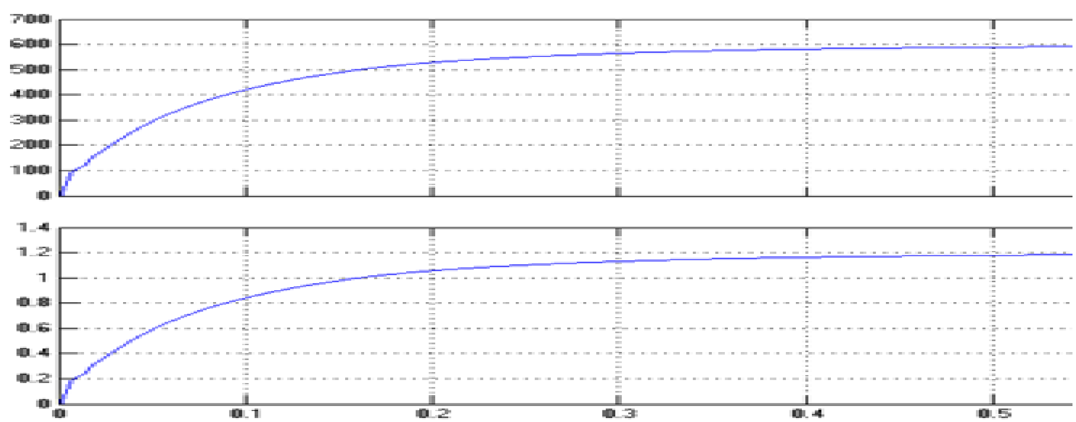

Fig.9 D.C Output Voltage (596.5V) and Output Current (1.2A)

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The DC output shown in fig.9 shows the DC output voltage (596.5V) and output current (1.2A). The input corresponding this given was about 120V A.C. Thus this proposed converter boosts up the voltage up to 5 times the input voltage.

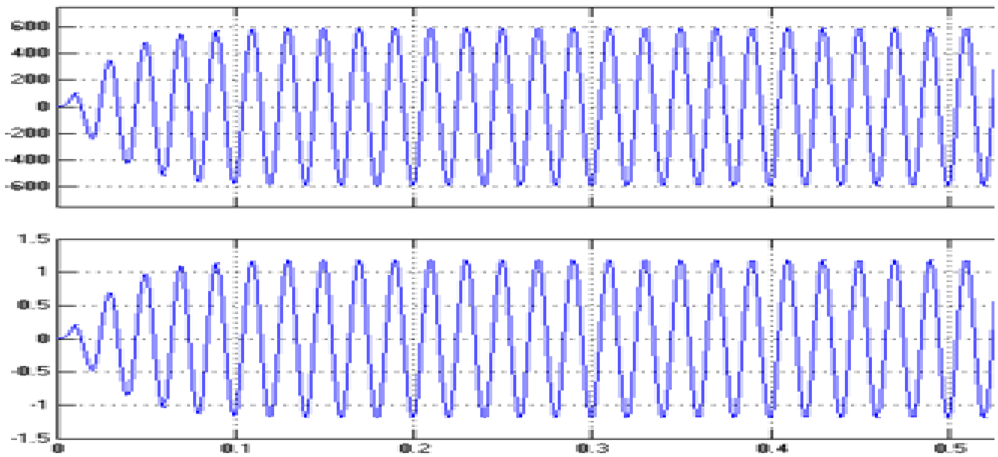

Fig.10 A.C Output Voltage (596V) and Output Current (1.2A)

The Output shown in fig.10 shows the AC Output Voltage (596.5V) and Output Current (1.2A). The input corresponding this given was about 120V A.C. Thus this proposed converter boosts up the voltage up to 5 times the input voltage.

Input voltage versus output voltage characteristics of the circuit is given by the table,

INPUT VOLTAGE	OUTPUT VOLTAGE
12	52
48	234
120	600
240	1200

Table.1 Output Voltage Corresponding to Input Voltage

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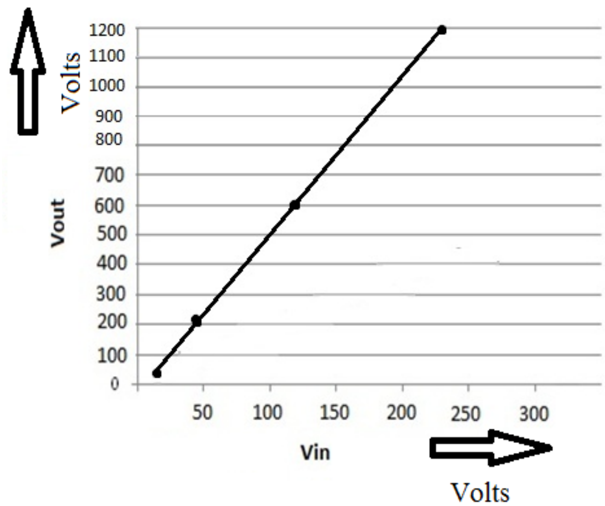

Fig.11 Input Vs Output Voltage Graph

We can clearly see from the graph in fig 9, the variation of output voltage with respect to the input.

V. CONCLUSION

Interleaved DC-DC boost converter for high voltage applications is modeled and simulated using MATLAB SIMULINK. The system is simulated using PWM technique. The presented paper has the basic idea of the interleaved boost DC-DC boost converter which are effectively provides a high voltage gain from a low voltage source.

In this two boost converters are successfully combined to achieve high step up voltage gain. All the low voltage sources that come from renewable source also can be effectively boosted to a high voltage. By using the interleaved boost converter, the output voltage gain will be thrice the input voltage.

The proposed converter is analyzed under different states operating conditions and the analysis is carried out towards simulation and the proposed converter is simulated and a basic understanding of the proposed converter has been achieved.

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