ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 10 , October 2018

Modeling and Analysis of Two Phase Interleaved Boost DC to DC Converter for Renewable Energy Applications

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ABSTRACT: This paper investigates the benefits of two phase interleaved boost DC-DC converter is used for high power and high performance applications using directly inductors compared to the conventional uncoupled inductors. The advantages of the coupled inductors in interleaved boost converters include increased system efficiency, reduced core size, current ripple reduction. The focus is to develop useful design equations for the operation of the interleaved boost converters under continuous conduction mode (CCM). The effects of the directly coupled inductors has a key benefit of converter performance parameters such as inductor ripple current, input ripple current, which should be less than nominal value of the input current and achieving stable CCM operation. The inductors are modelled in MATLAB® Simulink to simulate and evaluate the performance of the DC-DC boost interleaved converter with proper design procedure of directly coupled inductors.

KEYWORDS: Interleaved Boost Converter, Ripple Cancellation, Continuous Current Mode, Coupled Inductors, MATLAB

I.INTRODUCTION

During the past several decades, power electronics research has focused on the development of multiphase parallel DC-DC converters to increase the power processing capability and to improve the reliability of the power electronic system. The advantages of constructing a power converter by means of interleaved parallel connected converters are ripple cancellation in both the input and output waveforms to maximum extent, and lower value of ripple amplitude and high ripple frequency in the resulting input and output waveforms. In addition, multiphase parallel connection of power converters reduces maintenance, increases reliability and fault tolerance. In general, the interleaving technique consists of phase shifting the control signals of several converter cells in parallel, operating at the same switching frequency. Maximum benefits of interleaving can be achieved at certain operating point.

Generally, for boost converter, a single inductor, single-switch topology and its variations exhibit a satisfactory performance in the majority of applications where the output voltage is greater than the input voltage. Nevertheless, in a number of applications, such as power-factor correction circuits and distributed power conversion systems, the performance of the boost converter can be improved by implementing a boost converter with multiple switches and multiple boost inductors. Interleaving technique can effectively reduce the filter capacitor size and weight. Boost power supplies are popular for creating higher dc voltages from low-voltage inputs. As the power demands from these supplies increase, however, a single power stage may be insufficient. Interleaving is also called multiphasing and is useful for reducing the filter components. It is equivalent to a parallel connection of 2 sets of switches, diodes and inductors connected to a common filter capacitor and load.

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II. SIGNIFICANCE OF THE SYSTEM

The Proposed system on Two Phase Interleaved Boost Converter using Coupled Inductor, in which the photo voltaic source voltage can be stepped up to Higher Voltage under continuous conduction mode. This system is to be applied for solar Photovoltaic Applications in Research Laboratories for study and research purposes. Other applications are in photovoltaic fuel cells, hybrid electric vehicles and low power applications. These can be used in power electronic equipments which require power factor correction (PFC).

III. LITERATURE SURVEY

Taufik Taufik et al. [1] describe the multiphase scheme of boost converter. When simulated, the converter met all of the goals except for the line and load regulations. The line regulation may be improved by changing the current sense resistor to make the converter more sensitive to any change in the voltage. The load regulation on the other hand may be improved by using higher quality output capacitors to be able to hold the voltage better and cleaner board layout to avoid crisscrossing of high frequency signals on the circuit board. Nandakumar Selvaraju et al. [2] explains a complete design procedure and comparison of the uncoupled, directly coupled and inverse coupled inductors of the interleaved boost converter is carried out. It analyses the design of interleaved boost converter with useful equations for Fuel cell applications. Ajit.N [3] simulated the interleaved boost converter in both the continuous conduction mode (CCM) and in the discontinuous conduction mode (DCM).The major differences that we see in the design when compared with the normal single stage boost converter are the same as that of CCM mode but when DCM design is compared to the CCM mode, the inductor value chosen is different, the formula for the duty cycle is different and also duty cycle depends on the load in DCM but not so in CCM. K. Latha Shenoy et al [4] designed and explained the interleaved boost converter for renewable application paper by state space analysis of Mathematical modelling. The input voltage of 100V is boosted to output voltage of 400V using interleaving technique. The operation is performed under open loop condition. The system is able to deliver the power to the load with higher efficiency. The efficiency of 98% is obtained using this technique.

IV. METHODOLOGY

Higher Output Voltage can be achieved by a large inductor connect series with source. When the switch is on then inductor gets charged and when switch off the source and indicator both give supply to load. Though, it has many advantages, Its application is Limited. The main disadvantage is the production of high output ripples. Ripple current is a periodic non-sinusoidal waveform derived from an AC power source characterized by high amplitude narrow bandwidth pulses.

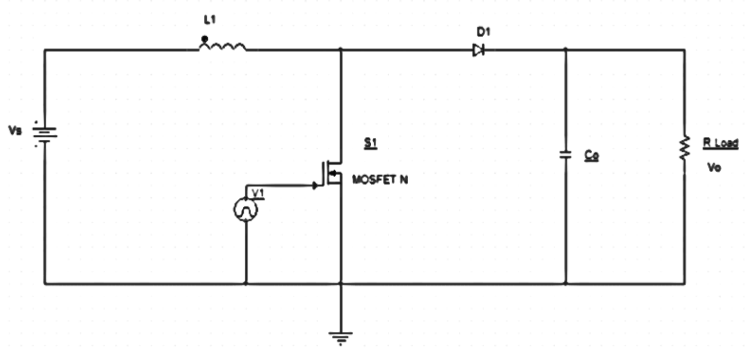

Fig.1: Conventional Boost Converter

The above Fig.1 is the Circuit Diagram of Conventional Single Stage Boost Converter having Single Inductor and Single Switch. The pulses coincide with peak or near peak amplitude of an accompanying sinusoidal voltage waveform. Ripple current results in increased dissipation in parasitic resistive portions of circuits like ESR of capacitors, DCR of transformers and inductors, internal resistance of storage batteries. The dissipation is proportional to the current squared times resistance (I^2R). The RMS value of ripple current can be many times the RMS of the load current. Ripple is undesirable in power supplies. Ripple current requires parasitic elements of components to

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International Journal of AdvancedResearch in Science, Engineering and Technology
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(components will be bigger, and quality will have to be higher). So to reduce ripple current, Interleaving technique is implemented. The below Fig.2 explains about the various blocks present in the prototype. The interleaved boost converter block in the block diagram is explained below.

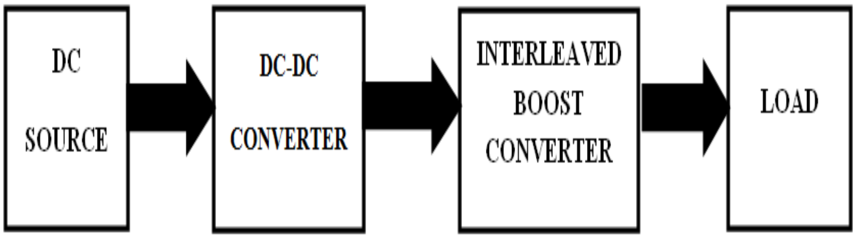

Fig.2: Block Diagram of Interleaved Boost Converter

Interleaving, also called multi-phasing, is a technique that is useful for reducing the size of filter components. This is equivalent to a parallel combination of two sets of switches, diodes, and inductors connected to a common filter capacitor and load. The switches are operated 180 degree out of phase, producing inductor currents that are also 1800 out of phase. The operating angle of switches is given by 3600/N, where N is the number of phases. Since N=2, the operating angle is 1800.Although IBC overcomes the drawbacks of conventional boost converters, its static and dynamic performances are poor. Hence, a new model consisting of coupled inductors in parallel are used. These coupled inductors reduce the ripple content in the inductor current on the input side by interleaving principles. The current entering the capacitor and load resistance is the sum of the inductor currents, which has a smaller peak-to-peak variation and a frequency twice as large as individual inductor currents. This results in a smaller peak-to-peak variation in capacitor current than would be achieved with a single buck converter, requiring less capacitance for the same output ripple voltage. The variation in current coming from the source is also reduced. In Boost Converters, output filter inductor influences several aspects of a power-supply's performance. With a larger inductance, there is smaller current ripple. This leads to higher efficiency, lower output voltage ripple, and lower EMI noise

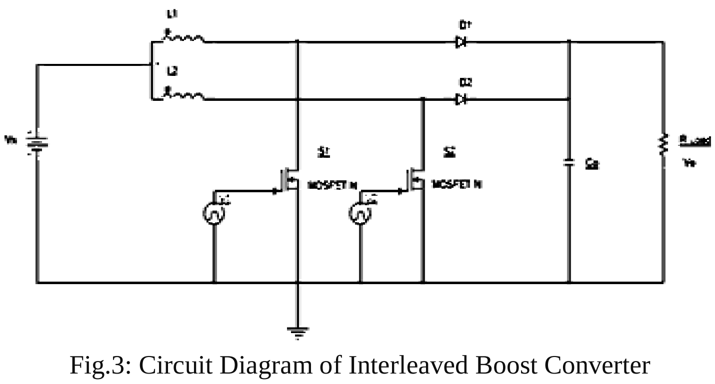

Fig.3: Circuit Diagram of Interleaved Boost Converter

The above Fig.3 is a connection diagram of the blocks present in the Fig.2.Coupled inductors used in this two-phase topology is to take advantage of the current-ripple cancellation from magnetic coupling between the phases. Normally, current-ripple cancellation happens only at the output of the multiphase buck converter when typical discrete inductors are used. When these inductors are magnetically coupled, the current-ripple cancellation is applied to all elements of the circuit: MOSFETs, inductor windings. Thus, the switching from all the phases affects each single phase, so the current ripple is reduced in amplitude and multiplied in frequency. Reduction in the RMS of the waveforms can improve the efficiency of the power converter or be traded for smaller magnetic, faster transient and, therefore, smaller output capacitance. Each inductor supplies one-half of the load current and output power, so the average inductor current is one-half of what it would be for a single buck converter. It comprises of N channel Power MOSFET, Silicon

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Diode, Coupled Inductor, Capacitor and Resistive Load. MOSFET is used rather than IGBT due to its suitability for Low power applications. It operates in Continuous Conduction Mode [CCM] in which the inductor current never reaches zero.

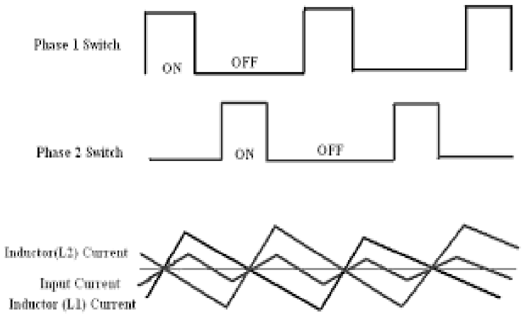

Fig.4: Operating Modes of MOSFET Switches

The above Fig.4 explains about the switching modes of operation of Interleaved Boost Converter Switches. Both the switches are operated alternately. When Switch 1 is ON, Inductor Current L1 increases while Inductor Current L2 decreases. The Peak-to-Peak variation in the Two Inductor Currents shows us the Output Current Ripples.

V. EXPERIMENTAL RESULTS

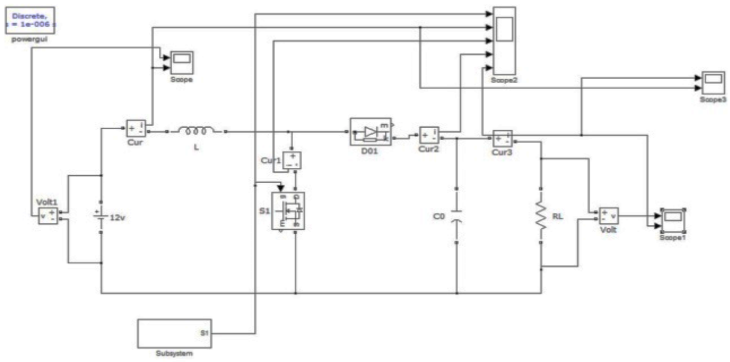
Fig.5: Simulation of Conventional Boost Converter

The above Fig.5 is the Simulation Circuit Diagram of Conventional Single Stage Boost Converter. It consists of Single MOSFET Switch, Single Inductor, Silicon Diode, Capacitor and Resistor Load and various Current and Voltage Measurement Blocks. Fig.6 shows the input Voltage and Current are measured and displayed in the Scope.

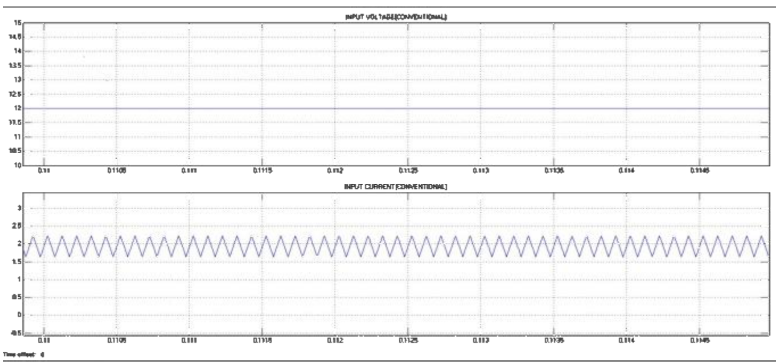
Fig.6: Input Waveforms of Conventional Boost Converter

ISSN: 2350-0328
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The following Fig.7 shows the Output Current and Inductor Current Waveforms from Scope 3.This Figure shows that Output Ripple is reduced comparatively to Input Ripple.

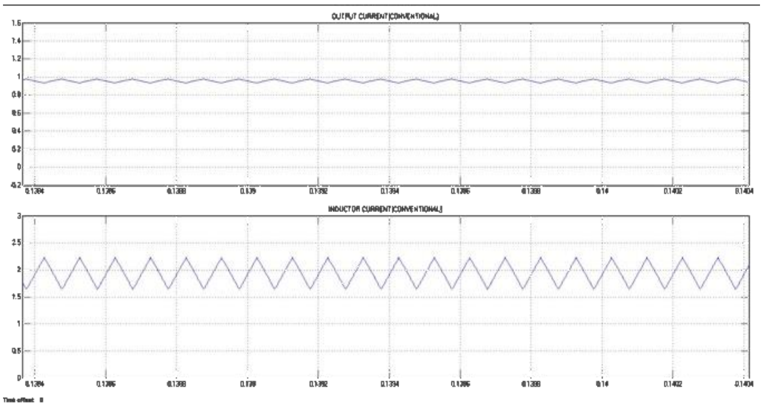

Fig.7: Output Current and Inductor Current Waveforms of Conventional Boost Converter

But the above simulation results do not produce the expected results, in order to run an efficient system. So to overcome the drawbacks, as mentioned above Interleaved Boost Converter is used. The Simulation Circuit for Interleaved Boost Converter is shown in **Fig.8**. It consists of Two MOSFET Switches, Two Inductors Coupled together, Capacitor, Two Silicon Diode and Resistor Load.

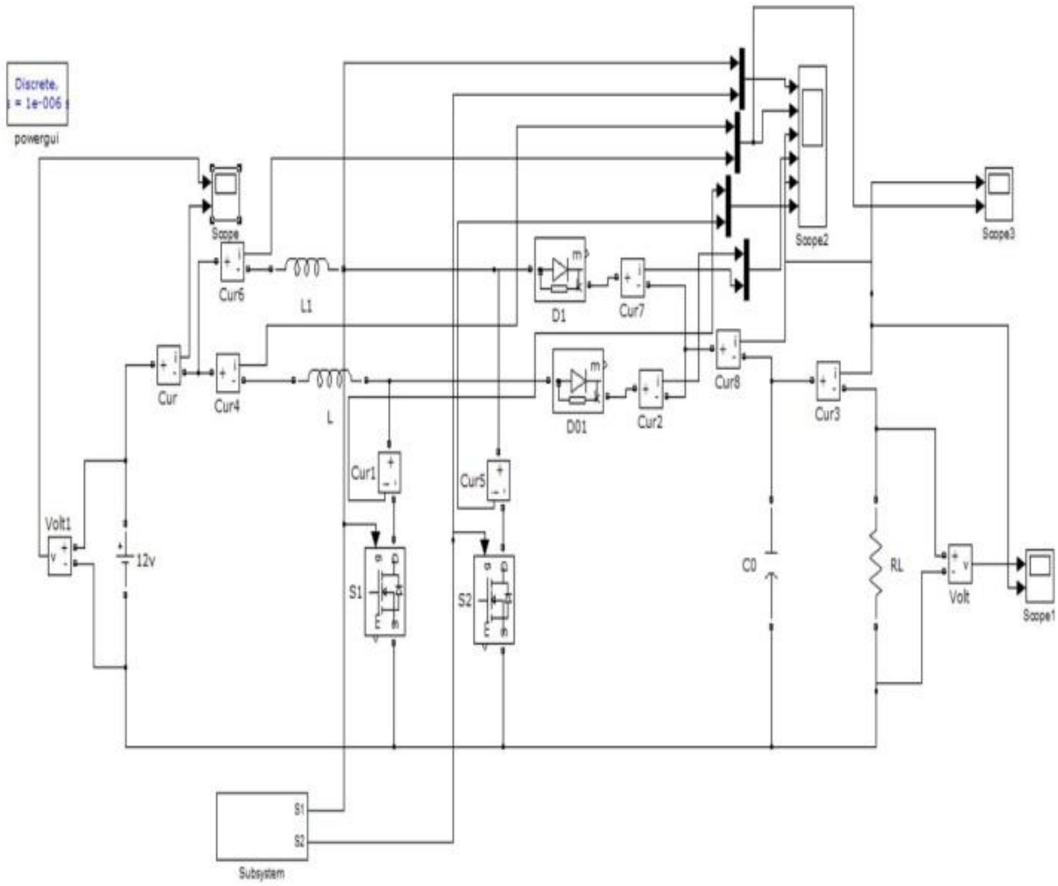

Fig.8: Simulation of Interleaved Boost Converter

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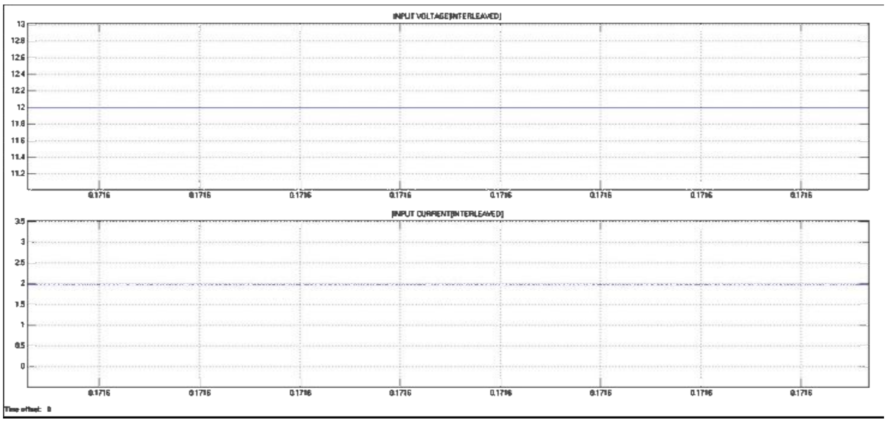

Fig.9: Input waveforms of Interleaved boost converter

Fig.9 shows the Input Waveforms of Interleaved Boost Converter. From Fig.10, Output Voltage and Current Waveforms are displayed. In order to display the Output Ripples, Fig.11 explains the Output Current and Inductor Ripple Current of Two Inductors.

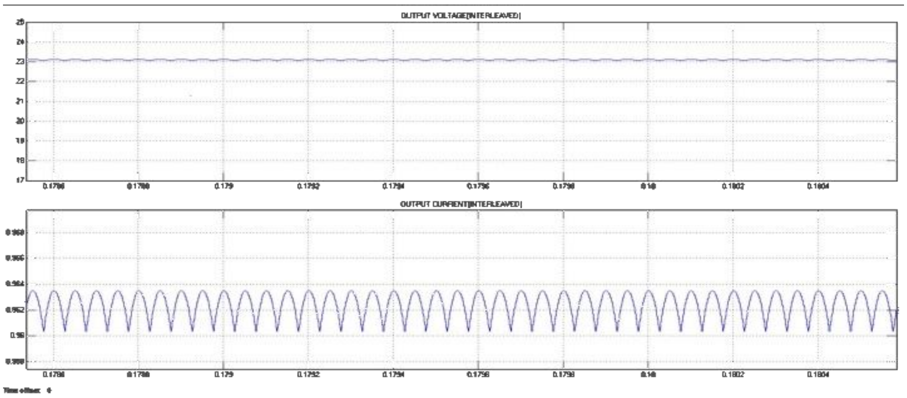

Fig.10: Output Waveforms of Interleaved Boost Converter

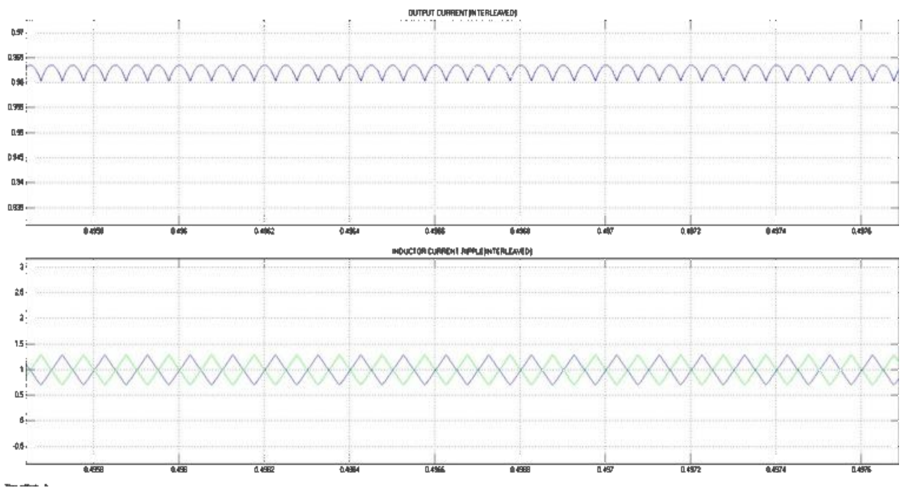

Fig.11: Output Current and Inductor Current Waveforms of Interleaved Boost Converter

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The following Table.1 displays the Input and Output Parameters of Interleaved Boost Converter in CCM Mode derived from simulation results in MATLAB/Simulink

S.NO	PARAMETERS	VALUES
1.	Input Voltage	12V
2.	Input Current	2 A
3.	Duty Ratio	0.5
4.	Switching Frequency	10 kHZ
5.	Inductance	1 mH
6.	Capacitance	47 uF
7.	Output Voltage	23.5 V
8.	Ouput Power	24W
9.	Output Current	0.96 A
10.	Output Current Ripple Factor	0.003

Table.1: Interleaved Boost Converter Parameters

PARAMETERS	CONVENTIONAL BOOST CONVERTER	INTERLEAVED BOOST CONVERTER
Input Voltage	12V	12V
Input Current	2.25A	2A
Output Voltage	23.5 V	23.5 V
Ouput Current	0.97A	0.96A
Duty Ratio	0.5	0.5
Switching Frequency	10 kHZ	10 kHZ
Inductor Current Ripple	0.75	0.5
Output Current Ripple Factor	0.045	0.003

Table.2: Comparison of Conventional Boost Converter and Interleaved Boost Converter

The above Table.2 describes the comparison between Conventional Boost Converter and Interleaved Boost Converter when simulation is done for both the converters. From both the tables it can be inferred that Interleaving of Boost Converters will reduce the ripple content in output current. The Reduction of Ripple Current in Interleaved Boost Converters is due to the usage of Coupled Inductors in place of Normal Inductor. The Ripple Factor is reduced to 0.003 in Interleaved Boost Converters.

VI.CONCLUSION AND FUTURE WORK

In this paper, the effect of a coupled inductor on both the inductor and the output current ripple is studied in great detail. From the analysis, it was shown that the coupling coefficient should be high enough to effectively reduce the inductor current ripple. It was also shown that enough leakage inductance is required to minimize the output current ripple of the converter. Through Simulation Results, It is inferred that Interleaved Boost Converter has higher

Efficiency than Conventional Boost Converters. Future work is to design a system of Three Phase Interleaved Boost Converters for Complete Ripple Cancellation.

VII. ACKNOWLEDGEMENT

Our sincere gratitude and thanks to Dr.N.Senthilnathan, Professor and Head of the Department, Department of EEE for guiding and mentoring us through the different stages of the project. We also thank the management of Kongu Engineering College for supporting the project and appreciating our efforts.

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