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Design of a Step-Up Interleaved Boost Converter with Fuzzy Controller

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ABSTRACT: Generally conventional boost converters have been used to obtain higher output voltage than the input voltage. When these boost converters are operated for high ratios it leads to high voltage and current stress on the switch. Hence an interleaving technique of boost converter has been presented. This method of approach can be used in high power applications to produce high voltage gain when compared to the conventional boost converter.
This project report deals with the simulation of Interleaved Boost Converter (ILBC). It is seen that, for higher power applications, more modules can be paralleled to increase the power rating and the dynamic performance. One of the challenges in designing a boost converter for high power application is how to handle the high current at the input side. In this project report an interleaved boost dc-dc converter is proposed for current sharing on high power application. Moreover, this converter also reduces the ripple of voltage. The simulated results are presented with R load.

KEYWORDS: Boost converter, Closed loop control, Open loop control, Interleaved, Ripple reductions.

I.INTRODUCTION

Power converters have required improvement as well as reduction of size and weight especially in mobile information/communication devices, traction converters, power control units for electric/hybrid vehicle, etc. Passive components and cooling devices usually occupy a much larger space than semiconductor devices in power electronics building block. It is well known that when many DGs are connected to utility grids, they can cause problems such as voltage rise and protection problem in the utility grid. To solve these problems, new concepts of electric power systems are proposed [1]. Resonant converters eliminate most of the switching losses encountered in Pulse Width Modulation converters. The active device is switched with either Zero Current Switching or Zero Voltage Switching at its terminals. When current through the switch is made zero, it is turned on /off, it is known as zero current switching and when voltage across the switch is made zero, it is turned on / off, it is known as zero voltage switching [2]. The main objective of this project report is to develop a modular high-efficiency high step-up boost converter with a forward energy-delivering circuit integrated voltage-doubler as an interface for high power applications. In the proposed topology, the inherent energy self-resetting capability of auxiliary transformer can be achieved without any resetting winding. Moreover, advantages of the proposed converter module such as low switcher voltage stress, lower duty ratio, and higher voltage transfer ratio features are obtained [3]. The DC-DC Converter has low switching power losses and high power efficiency. The use of single transformers gives a low-profile design for the step-up DC-DC converter for low-DC renewable energy sources like photovoltaic module and fuel cell [4]. The ILBC converter is gaining its popularity. An Interleaved boost converter usually combines more than two conventional topologies, and the current in the element of the interleaved boost converter is half of the conventional topology in the same power condition. Besides, the input current ripple and output voltage ripple of the interleaved boost converter are lower than those of the conventional topologies. Interleaved boost converters has higher efficiency than the conventional single boost converter [5]. In the interleaved boost converter topology, one important operating parameter is called the duty cycle D. For the boost converter, the ideal duty cycle is the ratio of voltage output and input difference with output voltage [6]. As already well known, the input current and output voltage ripple of interleaved boost dc-dc converter can be minimized by virtue of interleaving operation. Moreover, the converter input current can be shared among the phases, which is

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desirable for energy dissipation [7]. Therefore, the converter reliability and efficiency can be improved significantly. In this project report, comprehensive simulation analyses are presented to illustrate the performance of the interleaved boost dc-dc converter. The features of the interleaved boost dc-dc converter, the principle of operation and the design procedure are discussed in this project report. The simulation and experimental results are presented. The proposed converter is the parallel of the boost converters and their gate signals are generated by fuzzy controller and this makes the operation more accurate. Moreover, by establishing the fuzzy controller for the interleaved converter can further reduce the size and cost[8]. This work proposes simulation and model for closed loop control system.

II.INTERLEAVED BOOST CONVERTER

In case of boost converter ripple is present in the input current due to rise and fall of inductor current. This problem can be eliminated by using interleaved boost converter .This technique consists of a phase shifting of the control signals of cells in parallel operating at the same switching frequency. The main advantage are the current distribution .The current in the switches are just a function of the input current .So interleaved boost converters can reduce input current ripple and the switching losses.

III.ILBC OPERATING PRINCIPLE

The proposed interleaved converter topology with high voltage transfer ratio is proposed as shown in Fig.1. The proposed converter consists of two-phase circuits with interleaved operation. The first phase is a boost integrating the forward-type circuit structure, which includes inductor L1 and switch S1 for the boost and an isolated forward energy-delivering circuit with turn ratio N. The second phase of the proposed converter is a boost circuit which contains inductor L2, switch S2, blocking capacitor C2, and diode D2 followed by the common output capacitor Co. From Figure.1, one can see that the proposed converter is basically based on the conventional voltage-doubler for the second phase circuit. However, for the first phase, in order to reduce the voltage stress of switch S1 and diode D1, an additional blocking capacitor C1, is added to function as that of C2 for the second phase. The operation principle can be described by considering the key waveforms of the proposed converter as shown in Figure.2. For simplicity, assume that all the components in Figure.1 including the high-frequency transformer of the forward energy delivering circuit are assumed ideal and under steady-state condition.

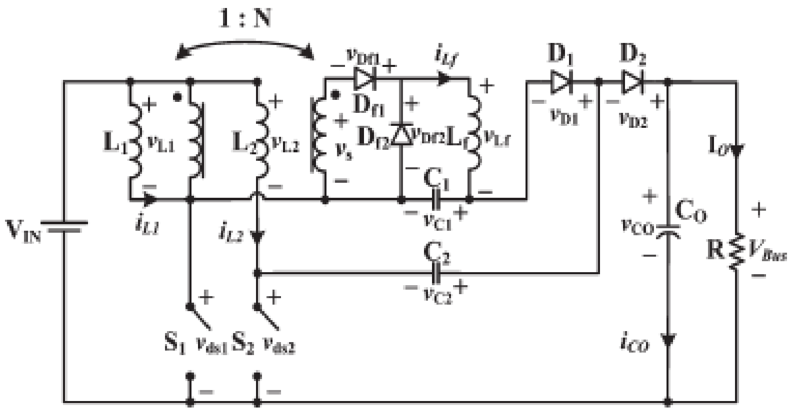

Figure 1: Proposed Interleaved high step-up boost converter.

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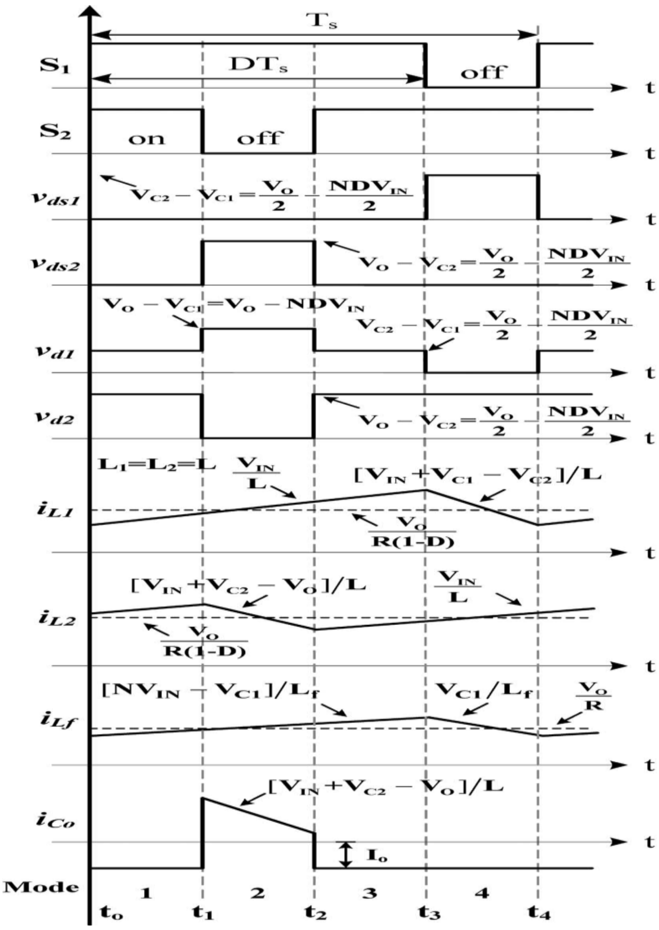

Figure.2: Key waveforms of the proposed converter.

IV.MODES OF OPERATION

Mode 1 [t0 < t ≤ t1]: From Fig. 2, one can see that for mode 1, switches *S*1, *S*2 are turned on. Diode *D*f1 is forward biased, while diodes *D*1,*D*2,*D*f2 are reverse biased. During this operation mode, both *i*L1 and *i*L2 are increasing to store energy in *L*1 and *L*2, respectively. Meanwhile, the input power is delivered to the secondary side through the isolation transformer and inductor *L*f to charge capacitor *C*1. Also, the output power is supplied from capacitor *C*o. The voltage across inductances *L*1 and *L*2 can be represented as follows:

$$L1\frac{diL1}{dt} = L2\frac{diL2}{dt} = VIN$$

Mode 2 [t1 < t ≤ t2]: For this operation mode, switch *S*1 remains conducting, and *S*2 is turned off. Also, diodes *D*1 and*D*f2 remain reverse biased; *D*2 and *D*f1 are forward biased. The energy stored in inductor *L*2 is now released through *C*2 and *D*2 to the output. However, the first phase circuit including the forward-type converter remains the same. The voltage across inductances *L*1 and *L*2 can be represented as the following:

$$L1\frac{diL1}{dt} = VIN$$

$$L2\frac{diL2}{dt} = VIN + vc2 - Vbus$$

Modes 3 [t2 < t ≤ t3]: For this operation mode, both *S*1 and *S*2 are turned on. The corresponding operating principle turns out to be the same as Mode 1. So it can be represented as follows:

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$$L1\frac{diL1}{dt} = L2\frac{diL2}{dt} = VIN$$

Mode 4 [t3 < t ≤ t4]: During this operation mode, *S*1 is turned off, and *S*2 is turned on. Diode *D*2 and *D*f1 are reverse biased, and diode *D*1 is forward biased. Since diode *D*f1 is reverse biased, diode *D*f2 must turn on to conduct the inductor current *i*Lf.. The energy stored in *L*1 is now released through *C*1 and *D*1 to charge capacitor *C*2 for compensating the lost charges in previous modes. The energy stored in transformer is now treated to perform the self-resetting operation without additional resetting winding. Also, the output power is supplied from capacitor *C*o. The voltage across inductances *L*1 and *L*2 can be represented as follows:

$$L1\frac{diL1}{dt} = VIN + vc1 - vc2$$

$$L2\frac{diL1}{dt} = VIN$$

V.FUZZY LOGIC CONTROLLER (FLC) DESIGN

The block diagram of fuzzy logic controller (FLC) is shown in fig.3. It consists of three main blocks: fuzzification, inference engine and defuzzification. Thetwo FLC input variables are the error E and change in error E*. Depending on membership functions and therules FLC operates

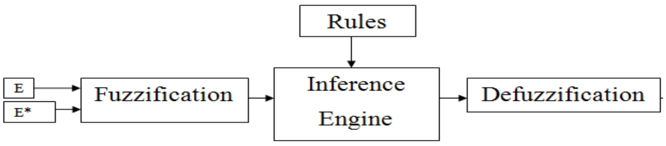

Figure 3: Block Diagram of FLC.

Fuzzification

The membership function values are assigned to the linguistic variables using seventeen fuzzy subsets. Table-I shows the rules of FLC. E and E* are input variables,where E is the error between the reference and actual voltage of the system, E* is the change in error in thesampling interval.

Inference Engine

Mamdani method is used with Max-Min operation fuzzy combination. Fuzzy inference is based on fuzzy rules. Rules are framed in inference engine block. The output membership function of each rule is given by MIN (Minimum) operator and MAX (Maximum) operator.

Defuzzification

The output of fuzzy controller is a fuzzy subset. As the actual system requires a non fuzzy value of Control, defuzzication is required. Defuzzifier is used to convert the linguistic fuzzy sets back into actual value. Table 1 shows the representation of the typical Rule Surface of fuzzylogic controller.

E \ E*	N	Z	P
N8	N7	N8	N6
N7	N6	N7	N8
N6	N5	N6	N7
N5	N4	N5	N6
N4	N3	N4	N5
N3	N2	N3	N4
N2	N8	N2	N3
N1	N8	Z	P2
Z	P1	Z	N1
P1	P2	P1	Z
P2	P3	P2	P1
P3	P4	P3	P1
P4	P3	P4	P3
P5	P6	P5	P5
P6	P7	P6	P5
P7	P8	P7	P6
P8	P8	P8	P7

Table-1 Rule Table For Flc

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VI.MATLAB SIMULATION

This is the Simulink diagram of interleaved boost converter with R-Load is shown in Fig 4. The voltage and current measurement blocks are connected to measure the output voltage and output current. The scopes are connected to measure the driving pulse and voltage across the switch. DC input voltage 24v DC is shown in the Figure 5. The gating pulse across the switch is shown in Fig.6. The output current is 5Amps and output voltage is 200V DC is shown in the Fig.7. and Fig.8.

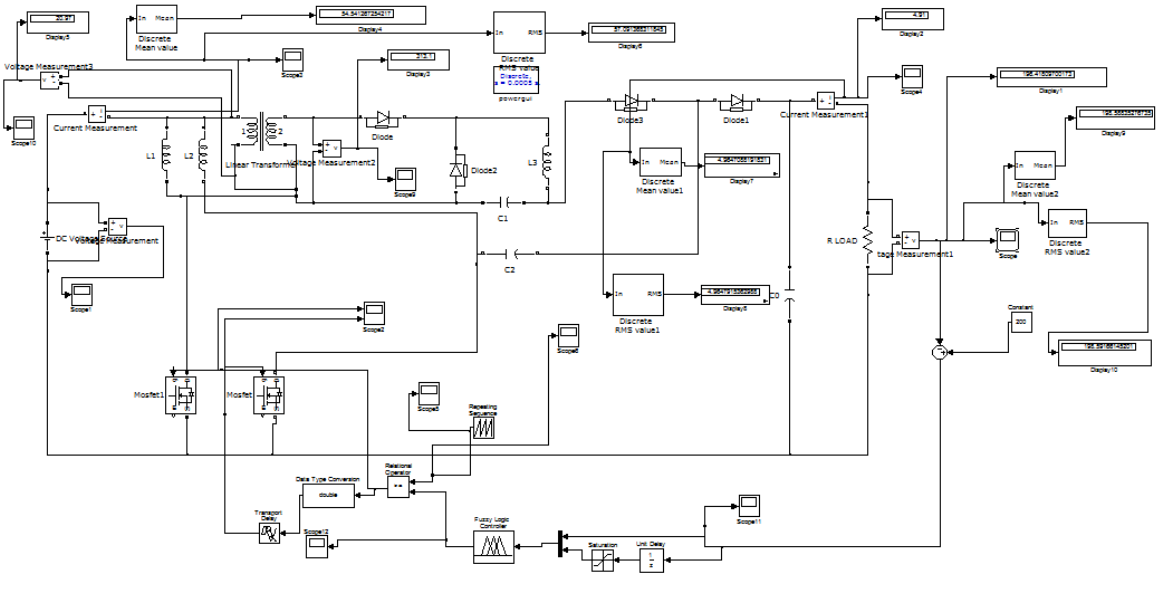

Figure 4: Simulation Circuit Diagram of ILBC with R-load Using Fuzzy controller

Here the filter capacitor is used to reduce the ripples of the output voltage. The simulation result is given below:

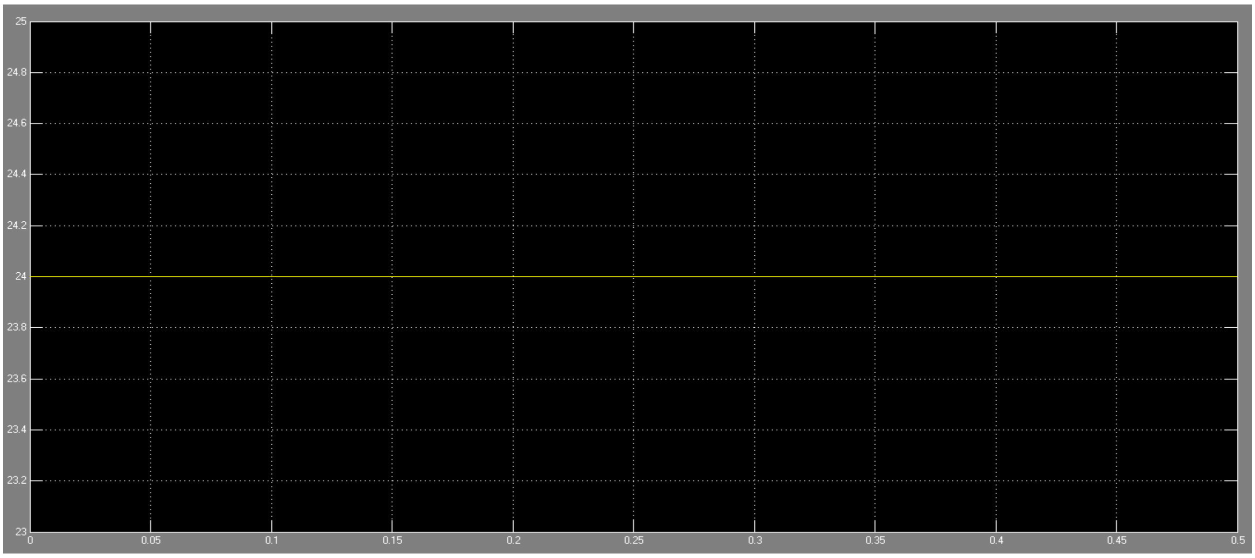

Figure 5: Input Voltage Waveform

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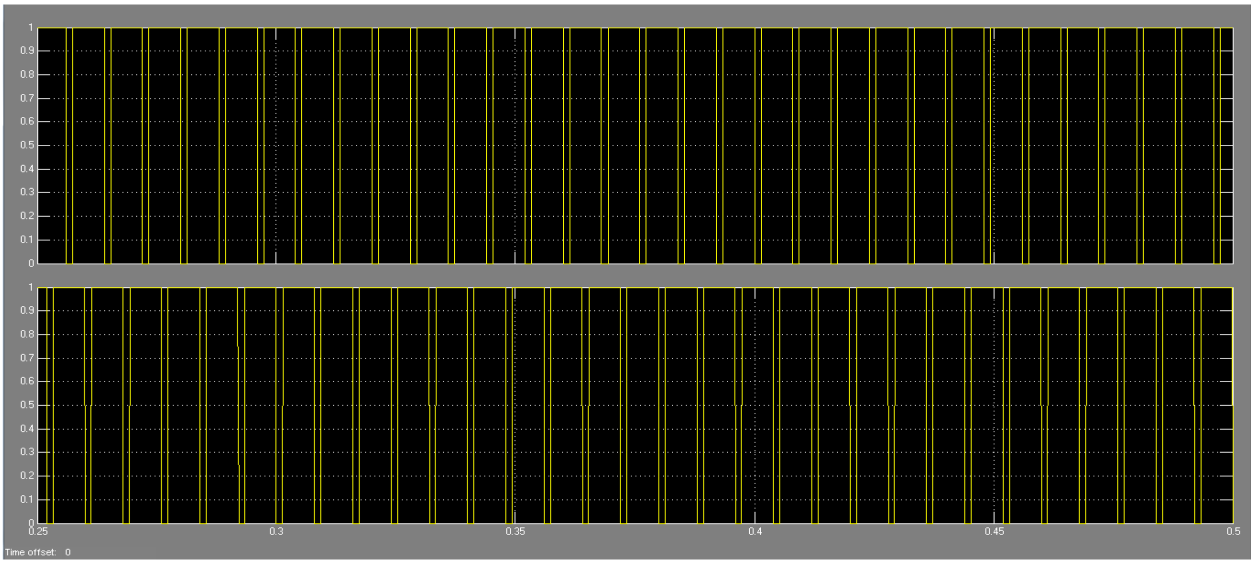

Figure 6: Switching Pulse

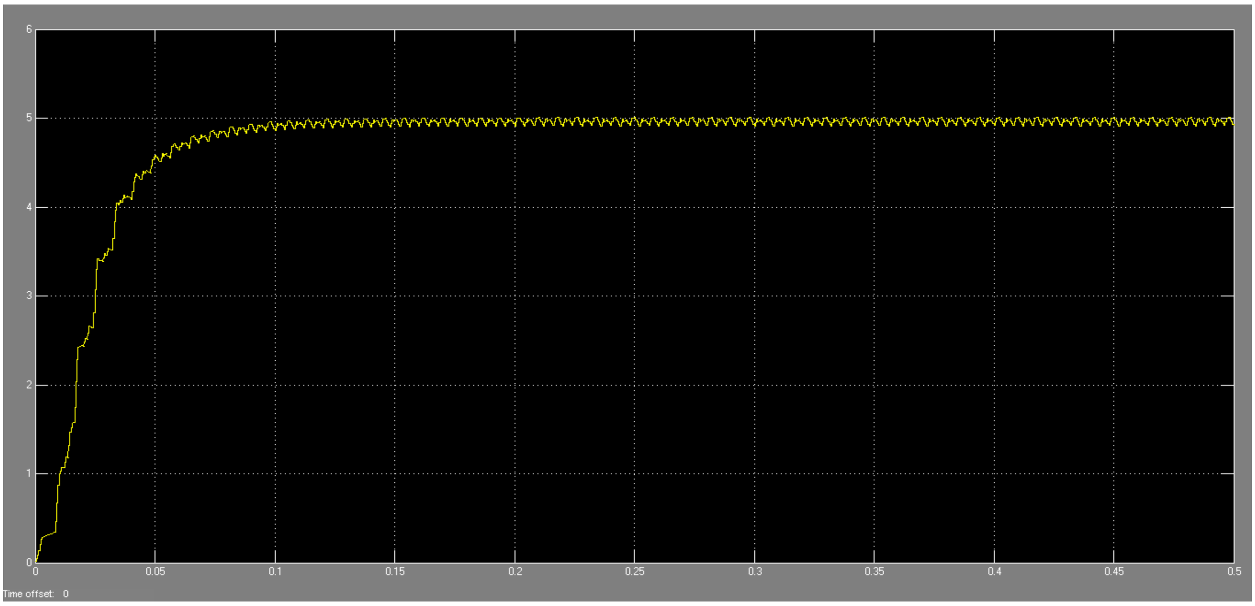

Figure 7: Output Current Waveform

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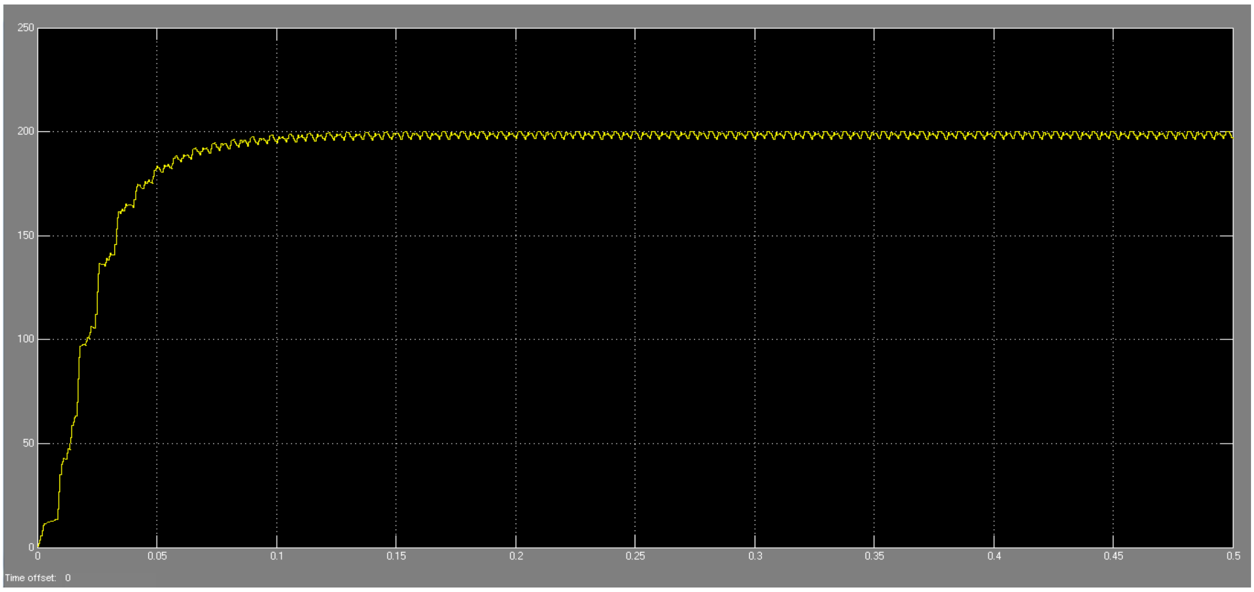

Figure 8: Output Voltage Waveform

VII.RESULTS

After simulation of conventional boost converter and interleaved boost converter we get this results is given below in table 2.

Boost Type	Vin	Iin	Pin	Vout	Iout	Pout	Efficiency
Interleaved(FUZZY)	24	54.5	1308	200	5	1000	**76.5%**

Table 2. Simulation Parameters Value

For different types of load calculating ripple factor with FUZYY controller we get
.
Load R =38ohm,
Iin(rf)= 1.046491721, Io(rf)= 1.000012724, Vo(rf)= 1.000012724

Load R =40ohm,
Iin(rf)= 1.046741888, Io(rf)=1.000011599 , Vo(rf)=1.000011599

Load R =42ohm,
Iin(rf)= 1.047503097, Io(rf)= 1.000010523, Vo(rf)= 1.00001052

VIII.CONCLUSION

Astep-up inter leaved boost converter is simulated with R load using PI and Fuzzy controller. The simulation results are in line with predictions. The scope of this work is designing, modeling and simulation of ILBC. The model is developed using the blocks of Simulink. After this we can conclude that interleaved boost converter provides high step up voltage 200V and high power. and it is also minimize the ripples of output voltage and current.

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IX.FUTURE SCOPE

A step-up interleaved boost converter has been simulated in this paper with PI and fuzzy logic control can be simulated with different types of feedback control like genetic algorithm ,artificial neural network and others can be used for power quality improvement or to get better efficiency advanced tuning and to check the constant output voltage with least ripple and to support different appliances with different voltage ratings.

Further this simulation model can be hardware implemented for practical output.

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