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Analysis, Design and Implementation of a Single Phase AC-AC Buck Boost Converter

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***Abstract:* --This paper presents a performance analysis and implementation of Single phase AC-AC Buck Boost Converter. This converter controls the voltage and current delivered to load. The performance of this converter emphasize on the output harmonic content and also on the effective utilization of the input voltage. This converter can be used in practical circuits like speed controlling of Induction motor, traction motor control etc. A single phase AC-AC Buck Boost converter is simulated and implemented to demonstrate the converter features using PSIM.**

I. INTRODUCTION

Recent advancements in Power Electronic technologies made the prices of semiconductor devices cheaper, compact in size and readily available. The Single phase AC-AC Converter has two different stages they are Single stage conversion i.e., direct conversion from AC-AC, and two stage conversion i.e., Rectifying and Inverting operations. This converter can be obtained by using cyclo converter also. This new AC-AC converter consists of less number of switches which results in reduction in cost, abundantly available in the market. [1]. In this paper analysing the performance of a single phase AC-AC circuit with enrich on the output harmonic content and utilization of input voltage. AC voltage controllers work to vary the RMS values of the output alternating voltage maintaining constant frequency by using different types of switches such as SCR, IGBT, MOSFET between the Source and the load. By using these switches the source and the load can be either connected or disconnected.

II. AC-AC CONVERSION

The basic block diagram of single phase AC-AC conversion is shown in Fig.1.

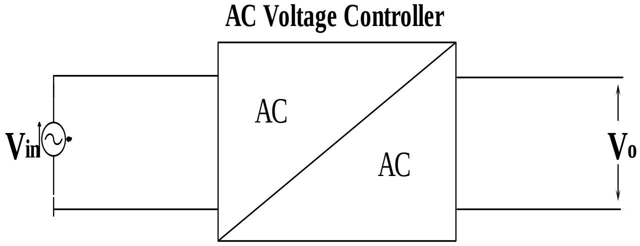

Fig.1. Block Diagram of AC-AC conversion.

The conversion of single phase AC-AC conversion is to convert an AC waveform into other AC waveform that allows controlling the voltage, frequency and phase of the load that is connected to the converter circuit. Without change in the frequency, change in the output voltage and the phase is known as AC voltage controllers (or) AC Regulators. For the conversion of the frequency, there are three different converters. They are cyclo converter, matrix converter, DC link converter. The usage of AC voltage controller or AC regulator is to vary the output voltage at a constant frequency. The controlling methods that are accepted are ON/OFF control, Phase angle control and Pulse Width Modulation AC Chopper control. These methods can be applicable for three phase circuits also.

III. DESIGN AND METHODOLOGY:

The AC-AC converter is designed to work either to reduce the voltage or to boot the voltage with respect to the input.

BUCK CONVERTER: In this paper AC-AC conversion is done by AC Voltage controllers where we use MOSFET as a switch for operation. The phase angle controlled Single Phase controllers are widely used in all type of power applications such as low, medium and high in order to control the voltage across the load. The main operation of Buck Converter is to decrease the output voltage when compared to the input voltage. The Buck Converter consisting of two unidirectional controlled switches, diodes, and load resistor. This is also known as Step-down Converter. The basic circuit diagram for Buck Converter is as shown in Fig.2.

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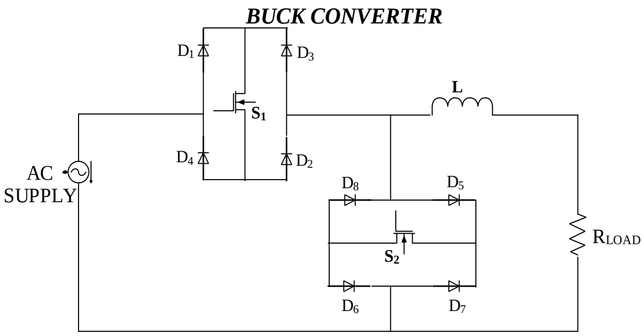

Fig.2. Block Diagram of AC-AC Buck Converter.

The condition of controlling the switches is when one switch is closed and other switch must be open. The converter is operated in four modes for buck operation. For positive half cycle two modes(mode 1 and mode 2) are applicable. In positive half cycle, when switch 1 (SW1) is closed, then current will flow directly through the load and the inductor (L) will be energized. The current direction is as shown in Fig.3.

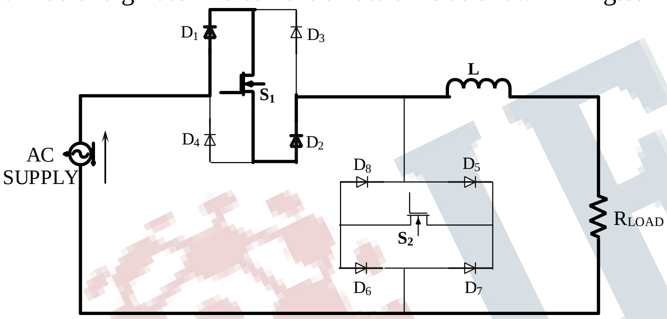

Fig.3. Mode 1 operation.

In next state, SW1 is open and SW2 is closed, the load will be detached from the source and the inductor will supply the current at same direction, and this current will flow through SW2 and the load like a loop. The current direction is as shown in Fig.4.

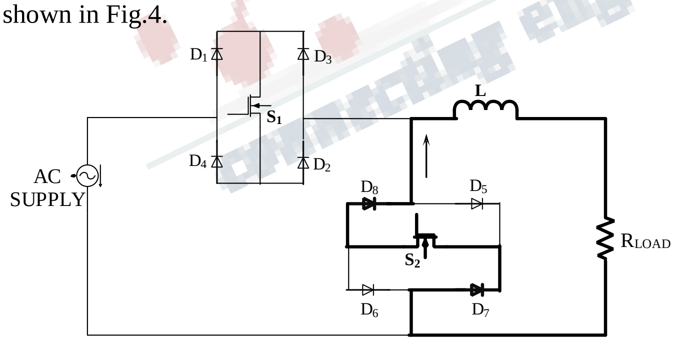

Fig.4. Mode 2 operation.

For negative half cycle, two modes (mode 3 and mode 4) are applicable. When SW1 is closed and SW2 is open, then the current flow through the load and returns to the source. In this cycle also, the Inductor is energized. The current direction is as shown in Fig.5.

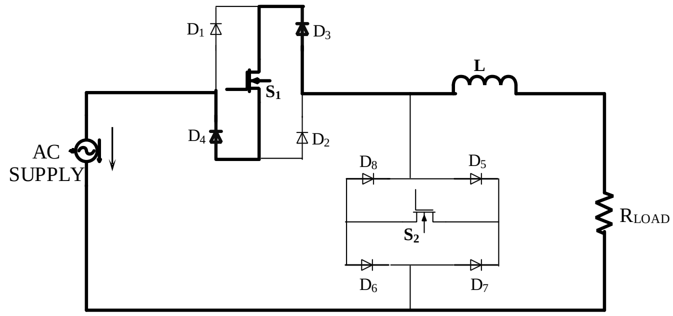

Fig.5.Mode 3 operation.

When SW1 is open and SW2 is closed then the inductor again supply current which will flow through SW2 and the load like a loop and again the source will be detached. The current direction is as shown in Fig.6.

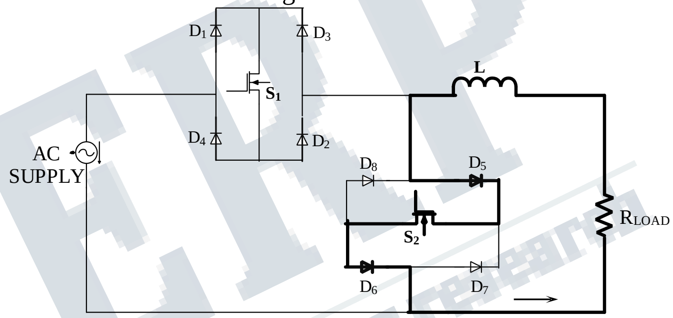

Fig.6. Mode 4 operation.

BOOST CONVERTER: In this converter, the output voltage across the load is greater than the applied voltage. This is also known as Step-up Converter. In this converter source is always present for all modes of operation. It is also same as that of Buck Converter but arrangement of the circuit is little modified. The circuit diagram is as shown in Fig.7.

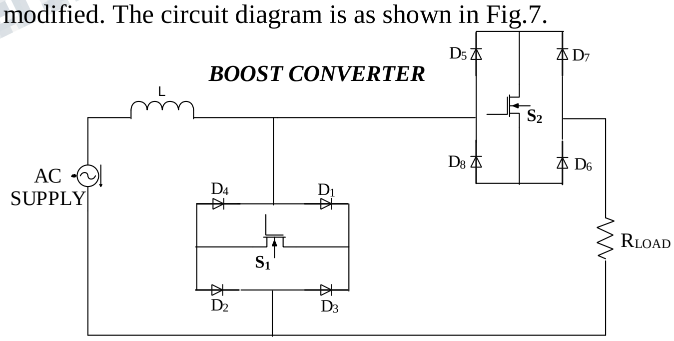

Fig.7. Block Diagram of AC-AC Boost Converter.

The condition of controlling the switches is as same as that of buck operation. In positive half cycle, when switch 1 (SW1) is closed, the input current will flow through the inductor L1 and SW1. L1 get energized and the current return to the source. The current direction is shown in Fig.8.

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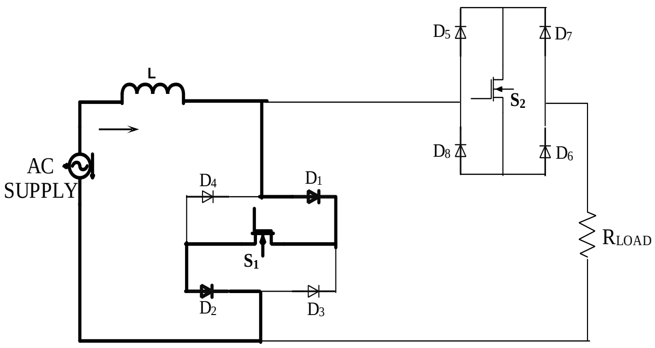

Fig.8. Mode 1 operation.

When SW1 is open and SW2 is closed, the input current will flow through the load. At the same moment L1 also supply current at the same direction. The current direction is shown in Fig.9.

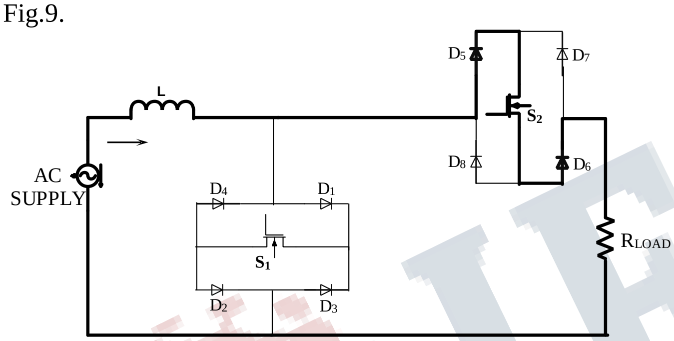

Fig.9. Mode 2 operation.

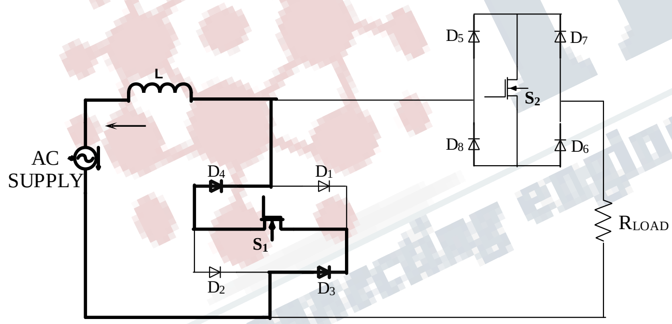

Fig.10. Mode 3 operation.

In negative half cycle, when SW1 is closed, input current passes through SW1 and L1 and L1 get energized. The current direction is shown in Fig.10.

When SW1 is open and SW2 is closed the combination of input current and inductor current passes through the load. The current direction is shown in Fig.11.

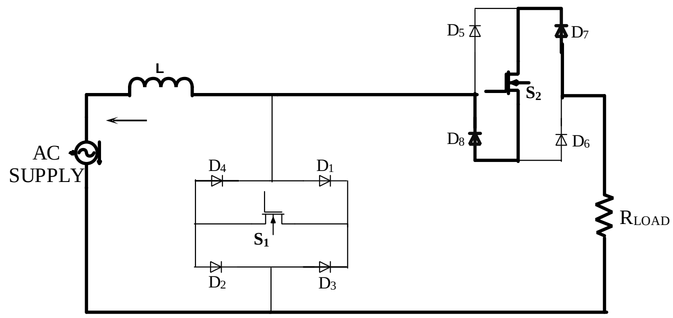

Fig.11. Mode 4 operation.

The output voltage of a Single phase AC Voltage Controller in Buck and Boost mode are given in equation 1

$$\left.\begin{aligned} &\mathbf{V_O = V_{in} * D}, \text{ for Buck Converter} \\ &\mathbf{V_O = V_{in} / (1-D)}, \text{ for Boost Converter} \end{aligned}\right\} \quad - (1)$$

Where, V_o= Output Voltage across the load

V_{in}= Input Voltage applied

D= Duty Cycle (T_{ON}/T).

IV. SIMULATION AND RESULTS

The AC-AC converter is simulated in PSIM with the parameters of input voltage of 12V, switching frequency f_s=10 KHz, Inductor L=10mH, and load resistor R_L=10Ω.

BUCK CONVERTER:

The circuit shown in Fig.12. is simulated and simulation results of Buck converter of input voltage, input current, output voltage and output current for applied voltage of 12V at 10 KHz with duty cycle of 0.5 for both switches and for SW2 a phase delay of 180^0 with the help of PSIM software is shown in Fig.12.

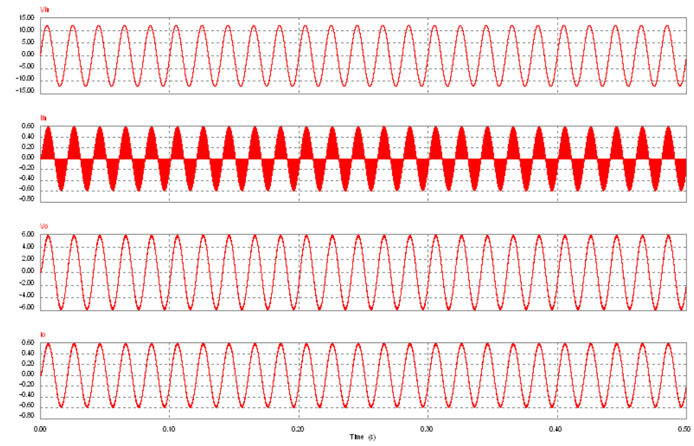

Fig.12. Simulation results of Buck Converter.

In Fig 12. the first trace is an input voltage of 12V, second trace is an input current of 0.6A, third trace is an output voltage of 6V, fourth trace is an output current of 0.6A.

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BOOST CONVERTER:
The circuit shown in Fig 13. is simulated and simulation results of Boost converter of input voltage, input current, output voltage and output current for applied voltage of 12V at 10 KHz with duty cycle of 0.5 for both switches and for SW2 a phase delay of 180^0 with the help of PSIM software is shown in Fig.13.

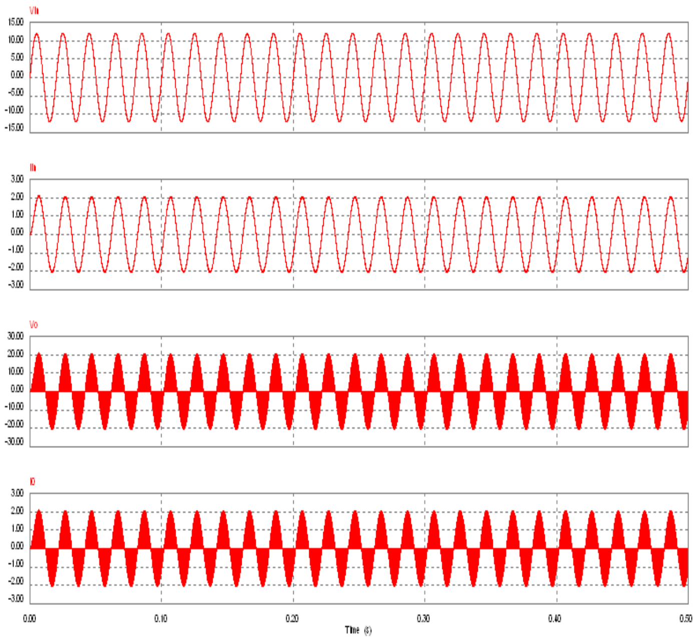

Fig.13. Simulation results of Boost Converter.

In Fig.13. the first trace is an input voltage of 12V, second trace is an input current of 2A, third trace is an output voltage of 20V, fourth trace is an output current of 2A.

V. EXPERIMENTAL RESULTS:

To validate the results a proto type model of AC-AC converter is built up with the parameters shown in Table 1.

Table 1. Circuit Parameters

Transformer	230V/(12-0-12)V
Inductor	10mH
MOSFET	IRF540N
Diode	IN4001
Load Resistance	10Ω
Pulse Generator	MSP430G2553 BOARD
Switching frequency	10KHz
Duty cycle	0.5

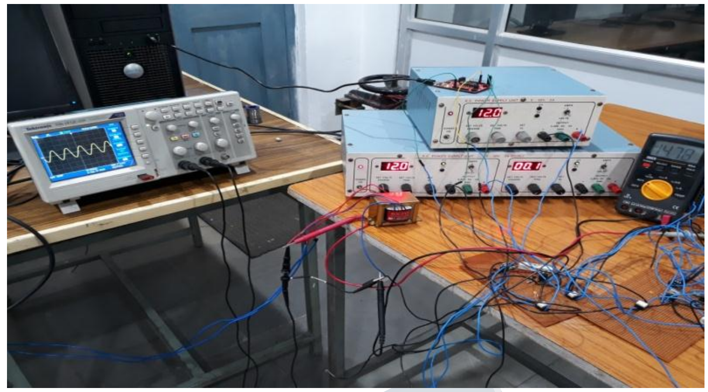

Fig.14. Picture of Buck converter.

The prototype model of AC-AC converter in Buck mode of operation is as shown in Fig.14. The pulse pattern of the switches is shown in Fig.15. The input voltage is as shown in Fig 16. And the output voltage is shown in Fig.17.

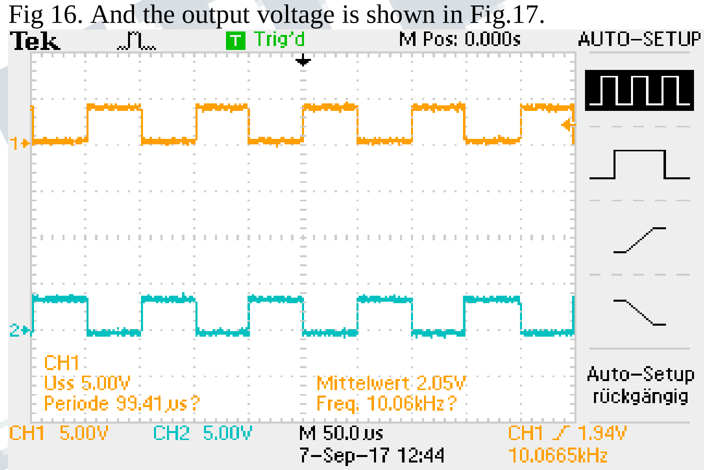

Fig.15. Pulse pattern of the switches with duty cycle of 0.5.

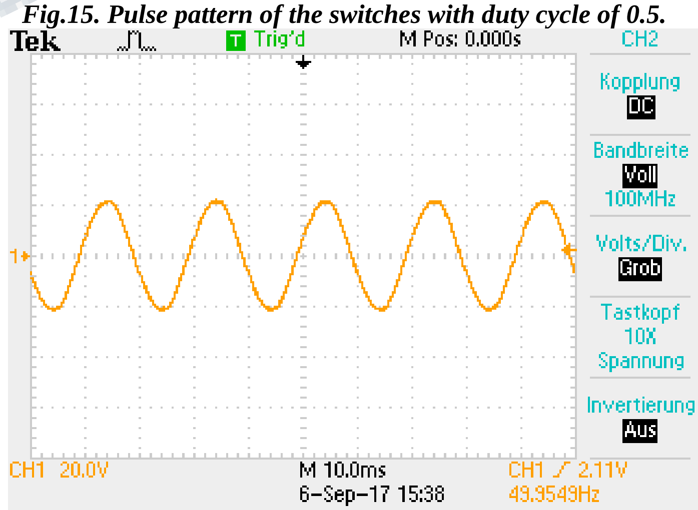

Fig.16. The input voltage of Buck converter.

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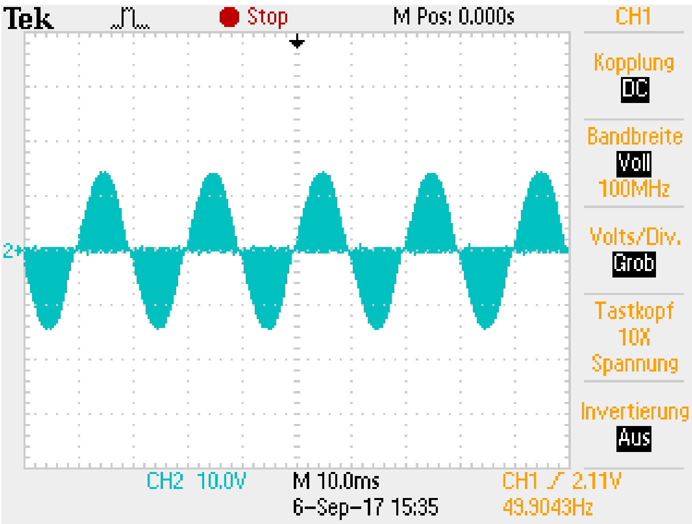

Fig.17. The output voltage of Buck mode of operation.

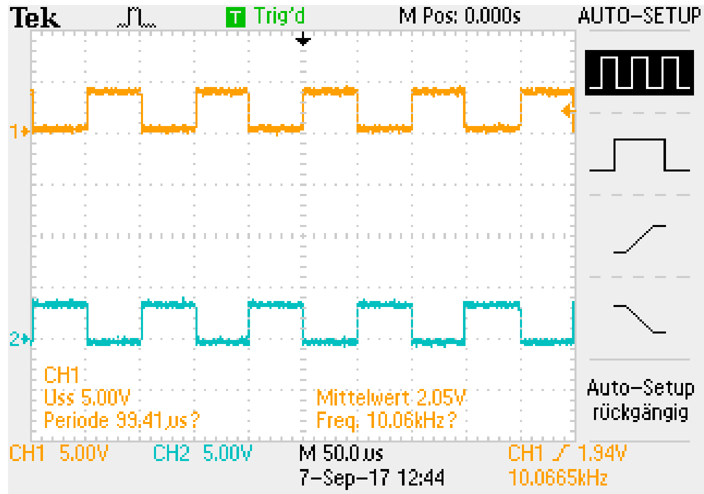

Fig.19. Pulse pattern of the switches with duty cycle of 0.5.

The AC-AC converter in Boost mode of operation is as shown in Fig.18. The pulse pattern of the switches is shown in Fig.19. The input voltage is as shown in Fig.20. The output voltage is shown in Fig.21. And the current flowing through the inductor is shown in Fig.22.

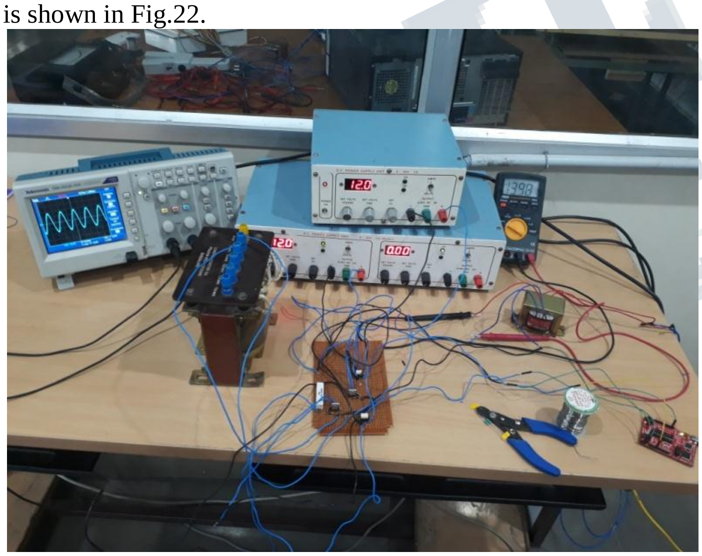

Fig.18. Picture of Boost converter.

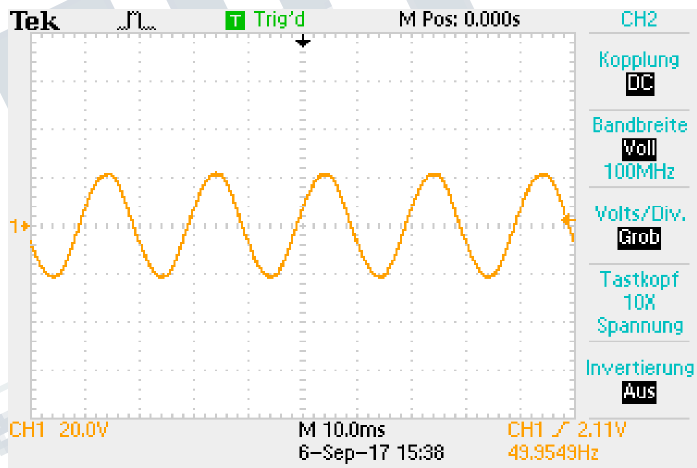

Fig.20. The input voltage of Boost converter.

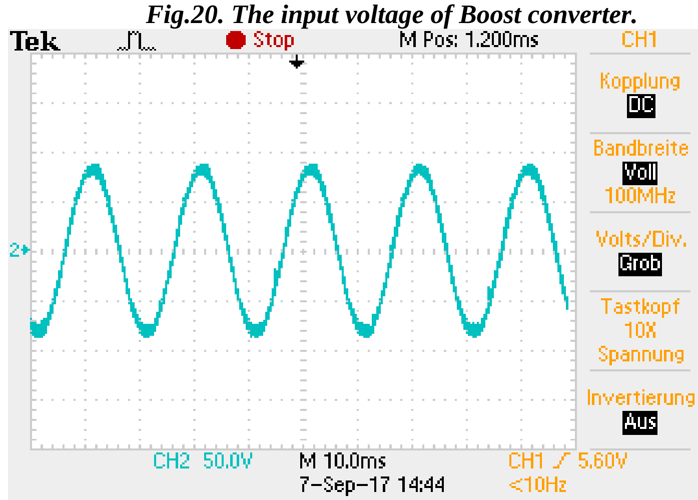

Fig.21. The output voltage of Boost mode of operation.

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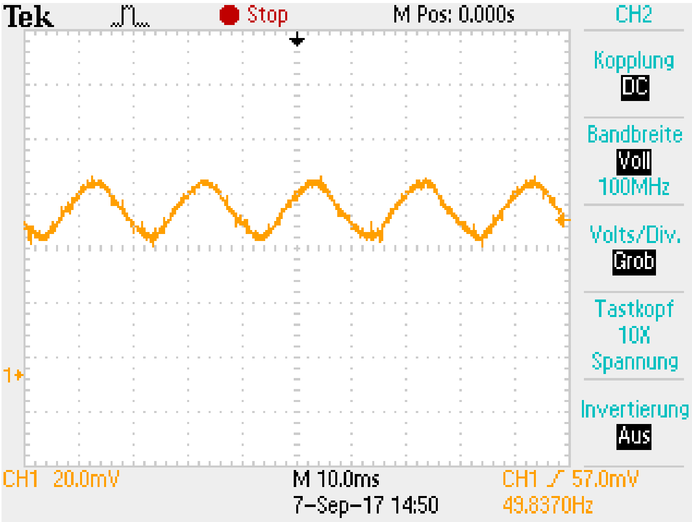

Fig.22. The current flowing through the inductor.

VI. CONCLUSIONS

The AC-AC converter is analyzed and simulated in buck and boost mode of operation. The simulated results shows that the output is varied based on the duty ratio to attain a low level or high level of output voltage for a given input voltage with constant frequency. The AC-AC converter is implemented to validate the results obtained during simulation. The hardware results shows the buck and boost operation of AC-AC converter.

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