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Full Bridge AC-AC Converter with High Gain Applied to Domestic Induction Heating Appliances

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Abstract: ***Domestic induction heating appliances have become popular due to their advantages such as fast heating, cleanliness, efficiency, and safety. This paper introduces a new topology of full bridge ac to ac converter for induction heating appliances. The main features of this converter are reduced component count, reduced switching losses, reduced conduction losses and high efficiency. Its operating principles and modes of operation are explained in this paper. The Simulations of the full bridge ac to ac converter were obtained by MATLAB/SIMULINK software.***

Keywords: Induction heating (IH), Full Bridge ac to ac converter, Resonant conveter, Zero voltage switching, Zero current switching

1. Introduction

Domestic induction cookers are the most popular application of induction heating phenomena. It became increasingly popular and will make drastic changeover in the field of induction heating because of their attracting features such as safety, quick warming, cleanliness, and high efficiency. Compared to traditional contact heating methods here we are using direct heating methods that carried in a vessel. In such devices the desired heating is done in metallic vessels and it is created by varying the magnetic field. The main fact is that the required magnetic field is generated by a coil fed by a power electronic inverter. Basically, a domestic induction heating arrangement consists of a planar multi turn coil situated below a metallic vessel and then it is supplied by a medium frequency power inverter, normally operated between 20 and 100 kHz.

Induction appliances get energy from the main ac voltage, which is rectified by a diode bridge rectifier circuit. A bus filter is used for getting input power factor close to one. Then an inverter arrangement supplies the ac (between 20 and 100 kHz) to the induction heating coil. A block diagram of the power stages of a domestic induction apparatus is shown in fig 1.Resonant inverter topologies are commonly used for induction hobs and it can be classified as a function of the number of active devices, which is directly related to the final cost. For low cost appliances and low output power levels, the single switch topologies namely zero voltage switching (ZVS) and zero current switching (ZCS) is the most used. The half bridge inverter is used for medium output power. For high output power levels the full bridge inverter is used. This paper introduces a new full bridge ac to ac converter for domestic induction heating applications. The converter supplies more power than half bridge topology. It reduces voltage stress and current stress on the switches and also it reduces both switching and conduction losses.

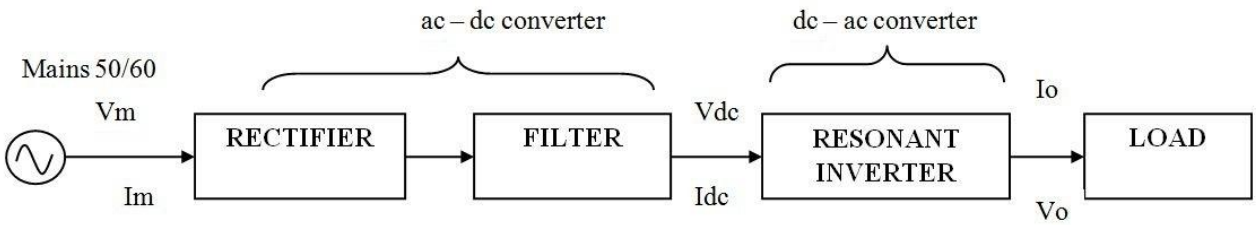


Figure 1: Block diagram representation of the power stages of a domestic induction hobs

2. Full Bridge AC - AC Resonanat Converter

The new full bridge ac-ac converter is shown in fig.2.The converter mainly consists of four switches S_1,S_2, S_3 and S_4 , dc link capacitor C_b, input inductor L_s ,diodes D_H and D_L ,resonant capacitor C and induction load .The converter are supplied by the input voltage V_s. The input AC supply is rectified by the diode bridge rectifier consists of two diodes D_H and D_L .The boost conversion of the main AC voltage and supplying high frequency current to the inductor load are done by the switches. The voltage boost is performed by means of input inductor L_s and dc link capacitor C_b . The series equivalent RL circuit composed of R and L is modeled as the IH load. Additionally, the series RLC resonant tank is completed with a resonant capacitor C.

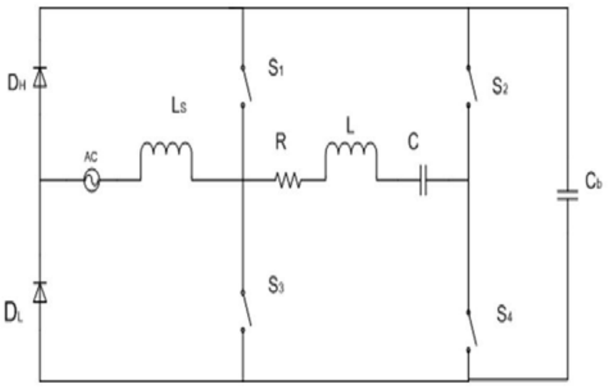
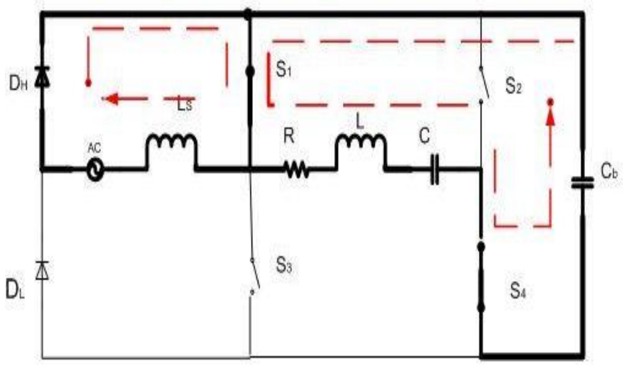
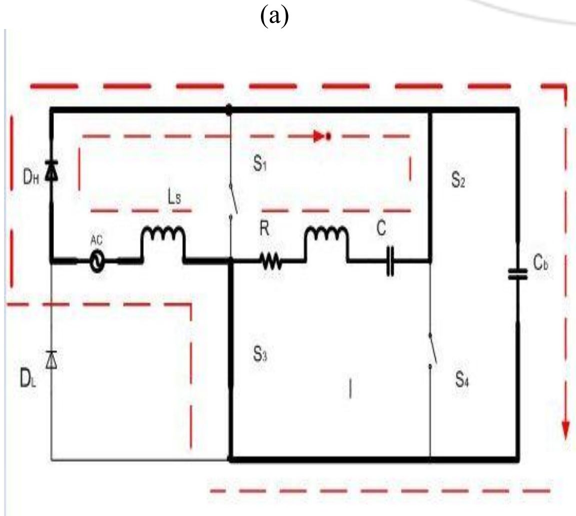


Figure 2: Circuit diagram of direct ac-ac full bridge resonant converter

Mode 1 and mode 2 for positive half cycle and mode 3 and mode 4 for negative half cycle. In mode 1 S_1 and S_4 are turned on, D_H conducts. Supply voltage is applied to the input inductor L_s and already charged capacitor C_b discharges through the induction heating load. S2 and S3 are turned on during mode 2 D_H conducts and ac supply voltage and charge stored in the input inductor charges the dc link capacitor C_b. In mode 3 S2 and S3 are remains in ON condition. D_L conducts and Supply voltage is applied to the input inductor L_s and already charged capacitor C_b discharges through the induction heating load. In mode 4 S_1 and S_4 are turned on. D_L conducts and supply voltage and charge stored in the input inductor charges the dc link capacitor C_b. Modes 1, 2,3 and 4 are shown in figure 3.



(a)



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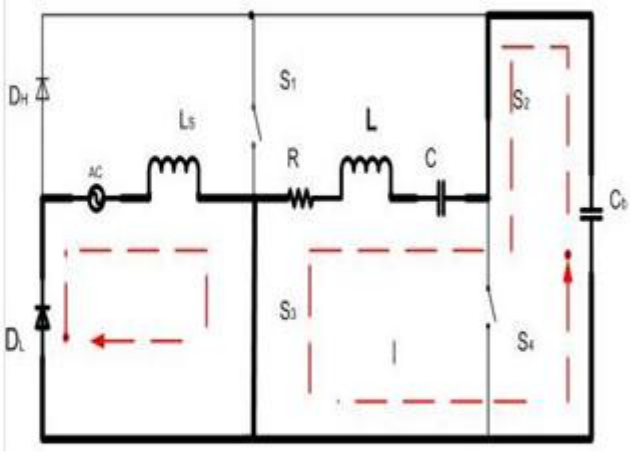

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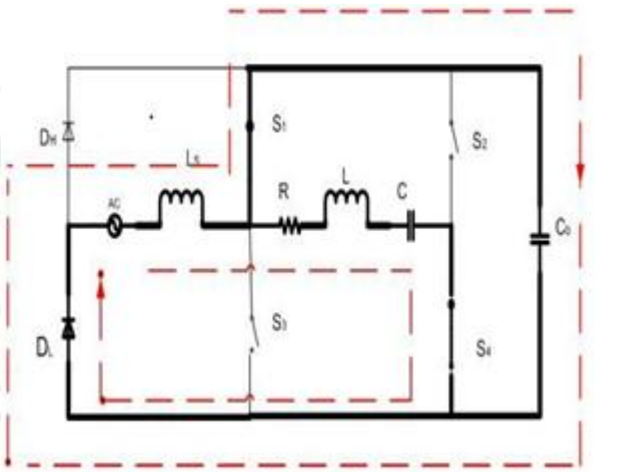


(d)

Figure 3: Modes of Operation

3.Simulation of Full Bridge AC-AC Resonant Converter

Design parameters and simulation circuit for the full bridge ac-ac resonant boost converter are shown in the table 1 and fig 4 respectively.

Table 1: Design Values for Direct ac-ac full bridge resonant boost converter

Parameters	Values
Input Voltage	325.2V(peak)
Switching Frequency,f_s	150KHz
Equivalent Load Resistance,R	90Ω
Equivalent Load Inductance,L	100µH
Input Inductor,L_s	150µH
DC Link Capacitor,C_b	470pF
Resonant Capacitor	1300pF

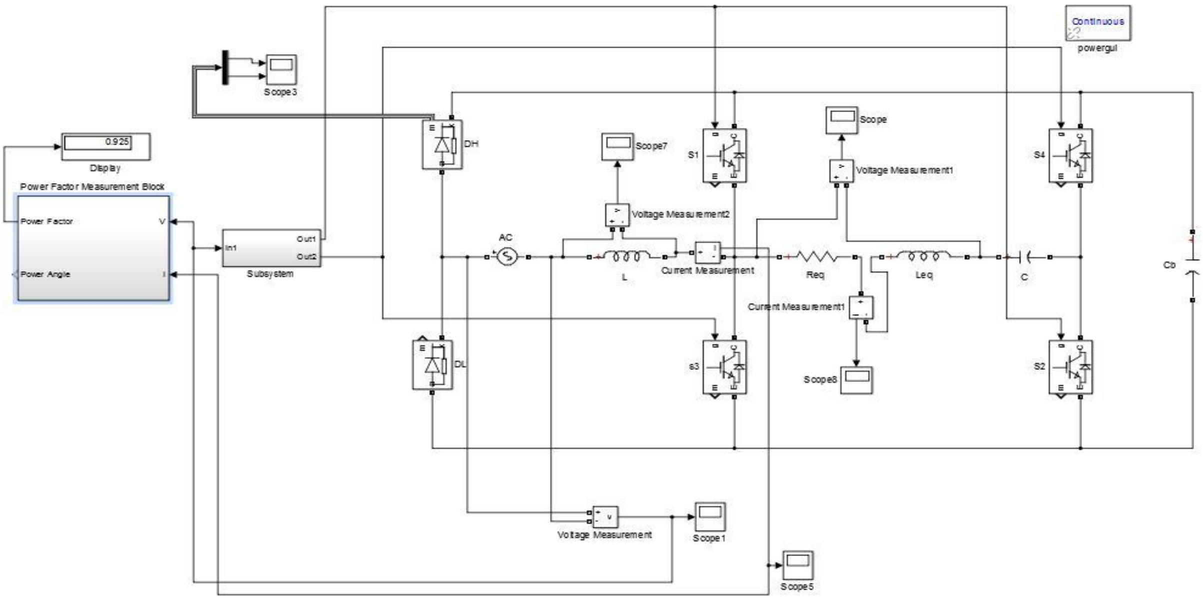


Figure 4: Simulation of Full Bridge AC-AC Resonant Converter using MATLAB

4. Simulation Results

Simulation results are shown below. Single phase 230V, 50 Hz AC supply is applied to the input of the full bridge ac to ac converter.

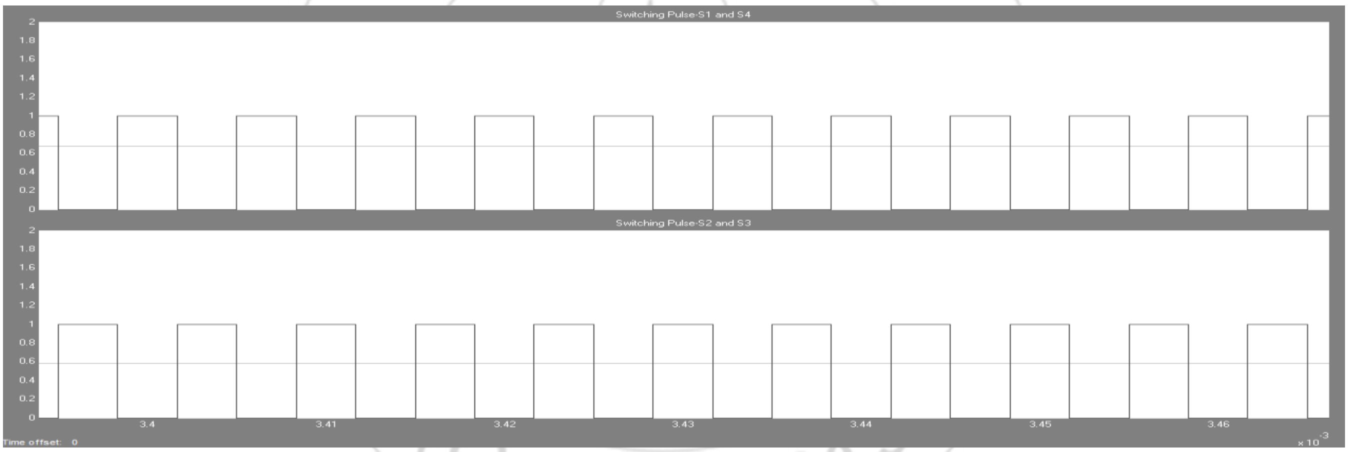
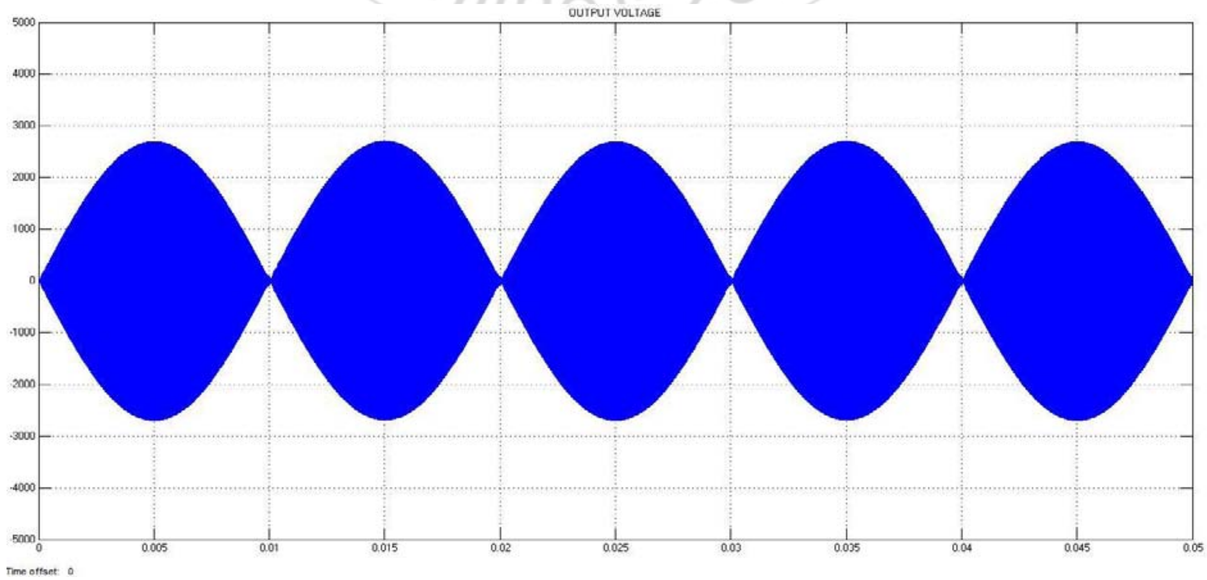


Figure 5: Switching Pulses



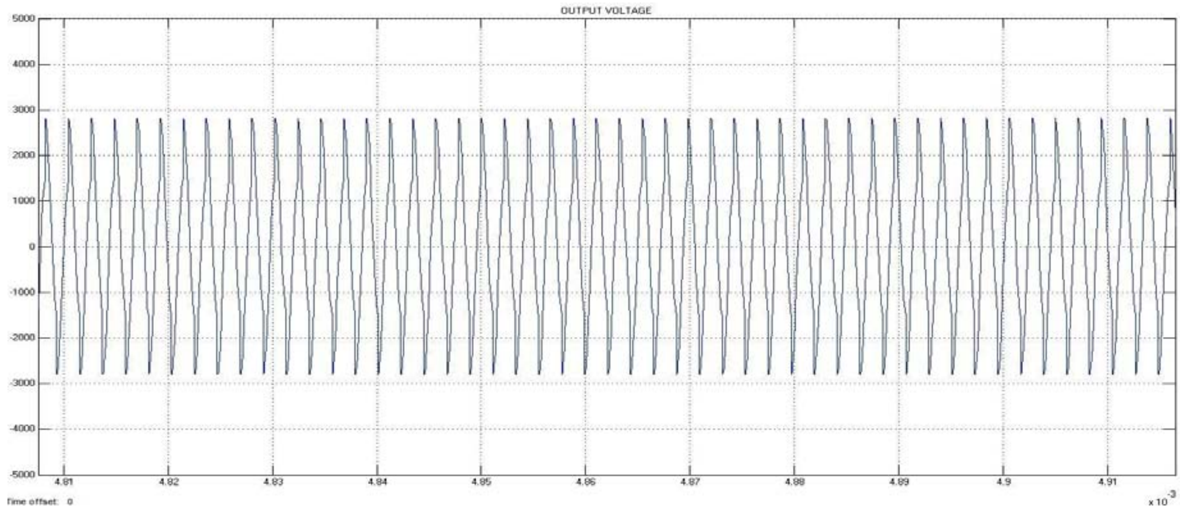


Figure 6: Simulated Waveform of Output Voltage.

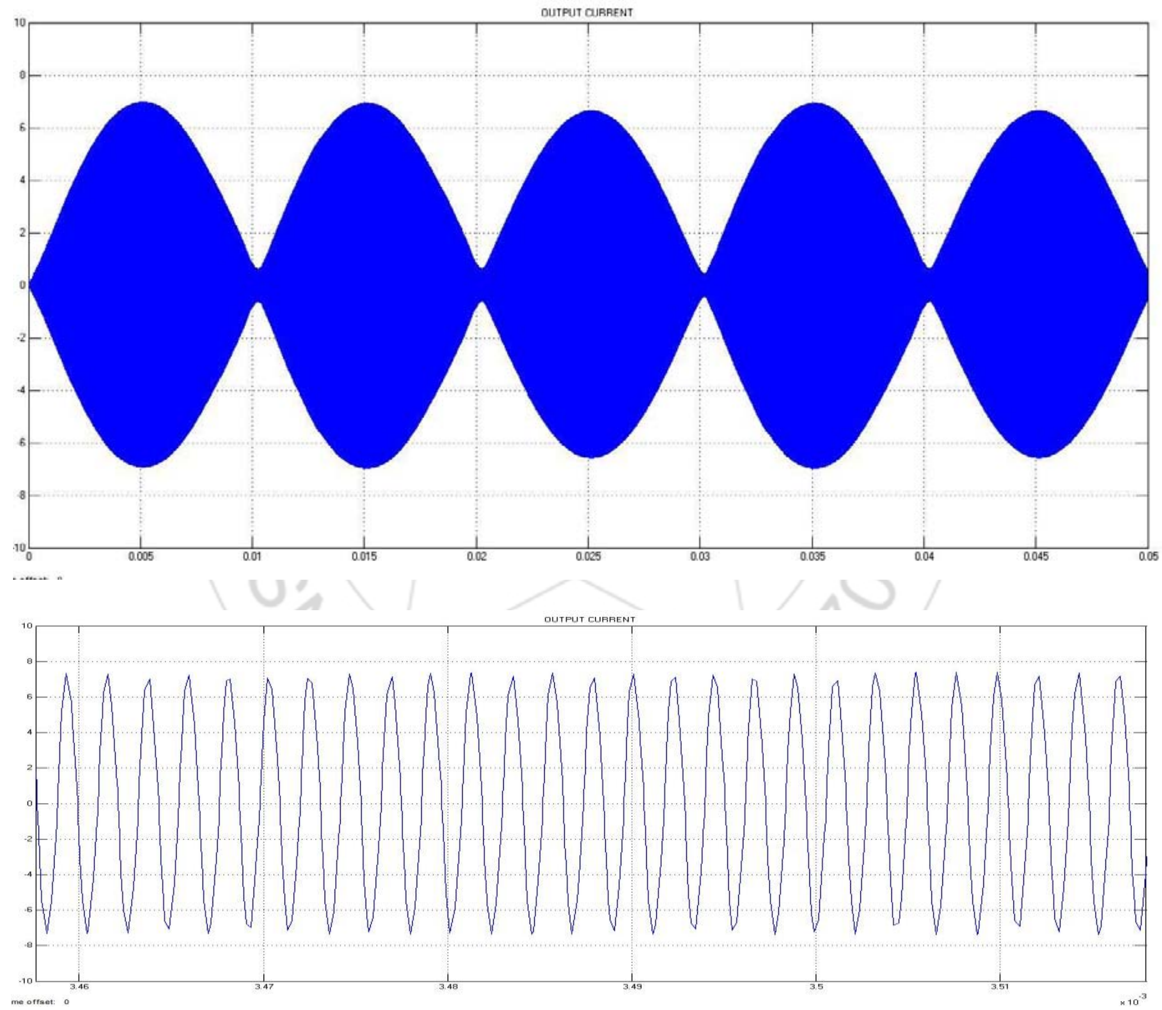


Figure 7: Simulated waveforms of Output Current

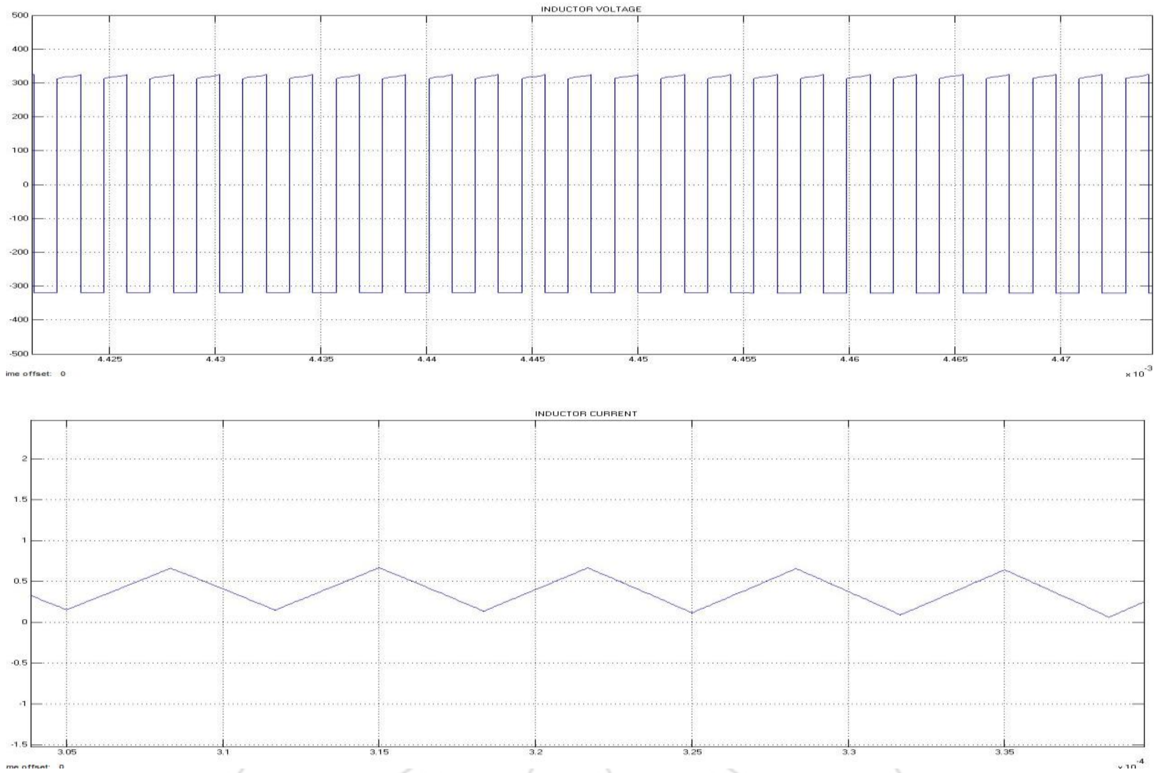


Figure 8: Simulated Waveform of Inductor voltage and Inductor Current

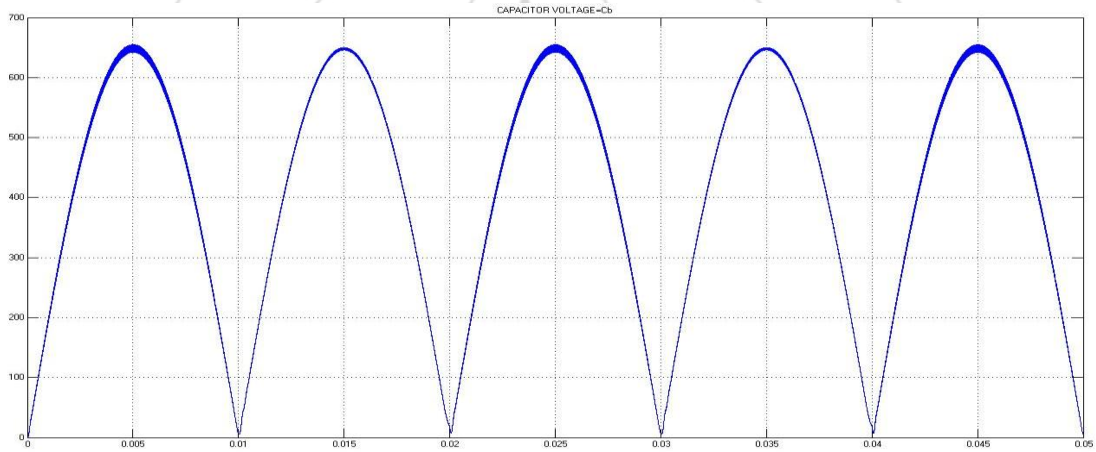


Figure 9: Simulated Waveform of Capacitor Voltage

5. Hardware Implementation of Full Bridge AC-AC Resonant Converter

The functional block diagram of the system shown in fig.10.Hardware setup consists of control circuit, driver circuit and power circuit and it is shown in fig 11. The switching pulses are generated by using a microcontroller ATMEGA16A.The pulses are generated with a delay of 1µs for avoiding the ON condition of switches at the same time. The power circuit consists of input power supply, switches, diodes, capacitors and induction heating load.

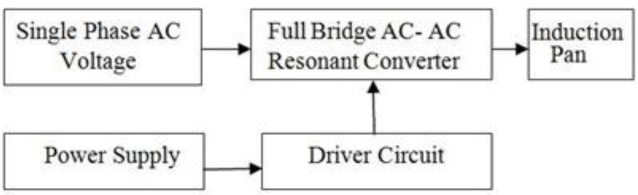


Figure 10: System Overview

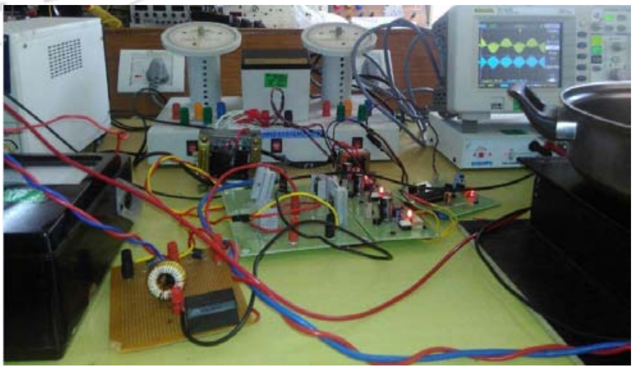


Figure 11: Experimental Set-up of Full Bridge AC-AC Resonant Converter.

The switching pulses, input waveform and output waveform are obtained by hardware setup is shown in fig 12, 13 and 14 respectively. In fig 14, the output waveform is obtained for the input of 70V .

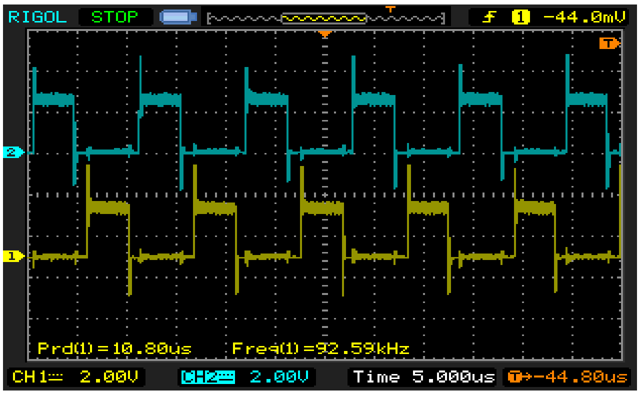


Figure 12: Switching pulses obtained by hardware setup.

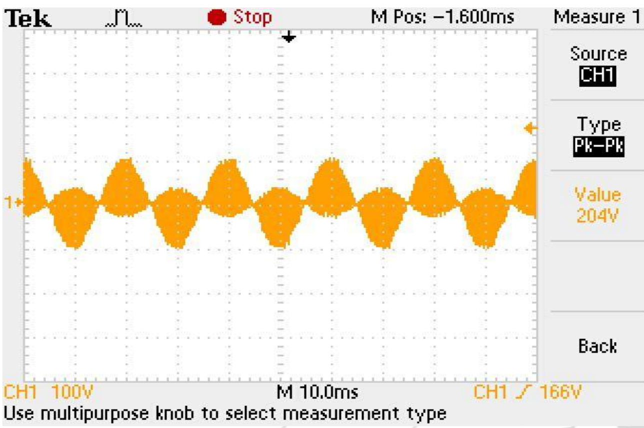


Figure 13: Input waveform obtained by hardware setup.

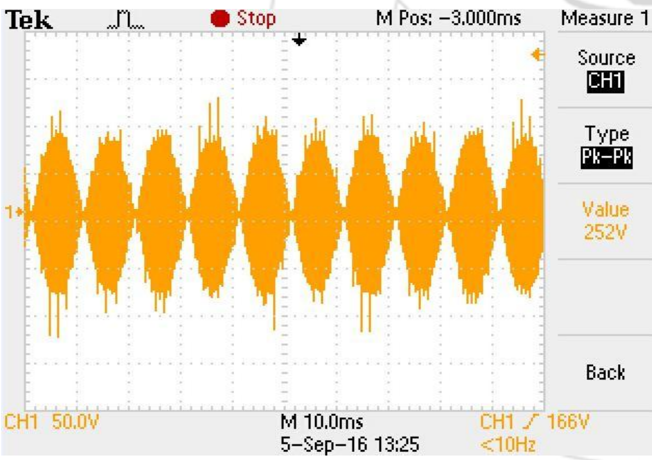


Figure 14: output waveform obtained by hardware setup.

6. Conclusion

In this paper, a full bridge ac-ac converter for industrial induction heating applications has been explained. The benefits of this full bridge AC-AC resonant converter are the high output voltage, reduced conduction losses and less number of components, which results in lesser cost and less system complexity. The simulation of this converter, is obtained by using MATLAB/SIMULINK software the hardware setup of the system was developed. Among the many applications of induction heating, industrial, domestic and medical are the most important in terms of installed power and economic importance.

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