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Design of ZVS with Highly Efficient Boosting Technique for Induction Heating Application

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ABSTRACT: Induction heating is becoming popular due to its features of safety, cleanliness, quick warming and high efficiency. This paper presents a full bridge boosting technique in industrial purpose for induction heating (IH) application using a full bridge direct ac-ac resonant converter. The benefits of this method by using direct ac-ac converter under full bridge configuration are reduced number of components, reduced losses, low cost and direct conversion solution. Moreover, this converter topology achieves soft switching during both transitions, further improving the efficiency and losses are reduced. The simulations were obtained by MATLAB/SIMULINK.

KEYWORDS: Induction Heating, AC-AC converter, Efficiency, Direct Conversion.

I.INTRODUCTION

The use of induction heating improves the speed of the heating process. Its precision, efficiency and repeatability are the highlighting features. A full bridge direct AC-AC resonant boost converter for induction heating is presented here. The converter supplies more power than half bridge converter. Moreover, the voltage stress across the switch is reduced and so is the current level.

Direct ac-ac converter have been widely used in many applications due to its features like reduced number of components, low cost, reduced switching losses and direct conversion. The required topology of direct ac-ac converter was finalized by weighting its advantages with that of the other topologies. The power converter operates under ZVS condition during both turn on and turn off transitions. Fig.1 shows the block diagram of direct ac-ac converter.

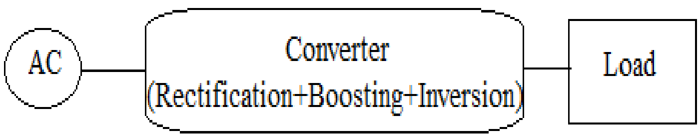

Fig.1. Block diagram of direct ac-ac converter

II. FULL BRIDGE TOPOLOGY

A full bridge topology is more desirable than other topologies due to its special features are improvement of power and voltage withstanding capacity. The converter supplies more power than half bridge topology. It reduces voltage stress and current stress on the switches. ZVS soft-switching conditions are guaranteed reducing both conducted and radiated EMC issues, and increasing efficiency. Thus the new converter circuit offers high efficiency. The equivalent operation of the proposed direct ac-ac resonant converter can be modelled by superposition of a boost dc-dc converter and a Full Bridge Series Resonant Inverter (FB-SRI).

III. OPERATION OF THE PROPOSED TOPOLOGY

The circuit diagram of direct ac-ac converter as shown in Fig.2. The ac supply Vs is rectified by the half wave rectifier branch consists of two diodes $D_{R,H}$ and $D_{R,L}$. The operation of the proposed direct AC-AC converter can be analysed through the four modes. D_H conducts during the positive cycle (modes 1 and 2), whereas D_L is activated during negative cycle (modes 3 and 4). As a result, only one rectifier diode is activated simultaneously.

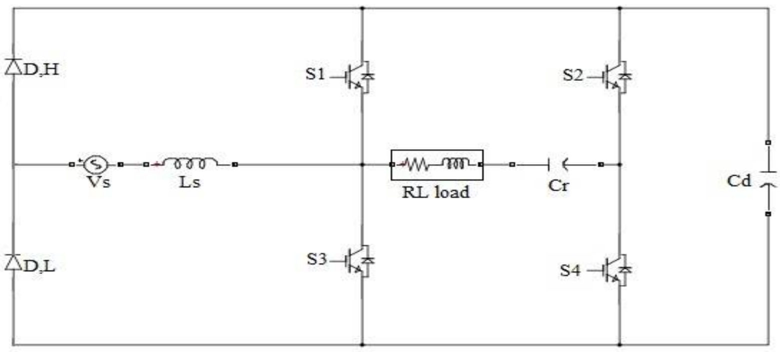

Fig.2. Circuit diagram of ac-ac converter

The Induction Heating load (IH) is modeled as a series equivalent RL circuit, composed of Req andLeq. In order to complete the series RLC resonant tank, a resonant capacitor Cr is used. Cr can be split into two capacitors connected to the positive and negative side in order to reduce EMC filter requirements. Due to the symmetry between positive and negative mains voltage, both resonant capacitors have the same value, i.e., Cr /2.

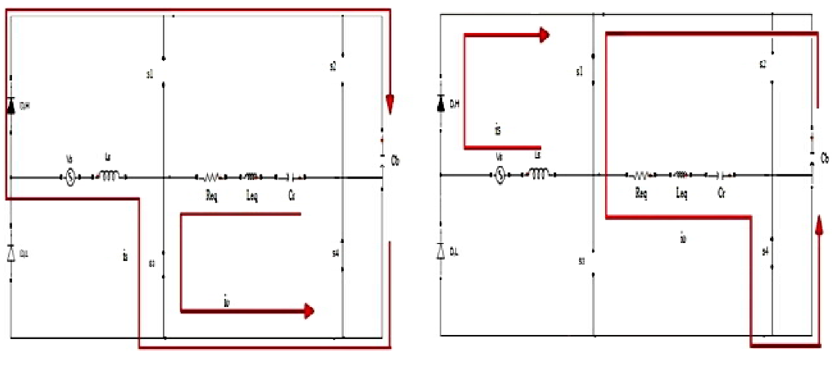

Fig.3 Modes 1 and 2

During modes 1 and 3, the supply voltage is applied to the input inductor Ls, whereas in modes 2 and 4, the dc-link capacitor Cb is charged by the inductor current. Thus, the converter is operated as a classical boost converter, performing S1 for the rectification of positive supply voltage levels, and S2 in the case of negative ones. On the other hand, an equivalent full bridge series resonant converter composed of S1, S2, S3 and S4 and the IH load modelled as series resistance and inductance, and the resonant capacitors Cr is used to generate the required high frequency ac current to supply the IH load.

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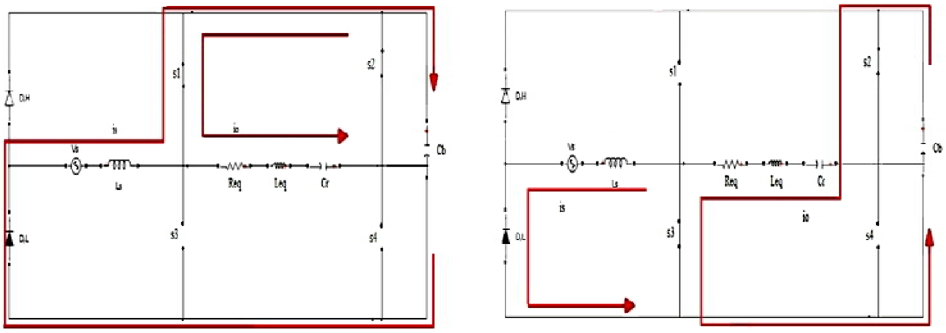

Fig.4. Modes 3 and 4

This equivalent full bridge series resonant circuit is supplied by the dc link capacitor voltage Vb. The equivalent operation of direct ac-ac converter of this topology is the superposition of a boost dc-dc converter and a full bridge series resonant inverter.

IV. BOOST ANALYSIS

In this circuit, it is assumed in continuous current mode (CCM) to minimize the current ripple and to avoid high-frequency currents through the rectifier diodes. In steady state, the average voltage in the inductor is zero and, thus

$$V_s D T_{sw} + (V_s - V_b)(1 - D) T_{sw} = 0 \quad (1)$$

Consequently, the voltage conversion ratio is same as in boost converter

$$V_s / V_b = 1/(1 - D) \quad (2)$$

The waveforms of the input current can be calculated by using the input current ripple ΔI_s

$$\Delta I_s = I_{s,d} - I_{s,o} = (V_s/L_s)\, D\, T_{sw} \quad (3)$$

Where $I_{s,0}$ and $I_{s,d}$ are the minimum and maximum input current values during a switching period, respectively.
The continuous current mode (CCM) condition to be satisfied is

$$CCM \Rightarrow I_{s,o} > 0 \Rightarrow I_s > \Delta I_s / 2 \quad (4)$$

Assume that power factor close to one, it can be related to the input power Pin resulting

$$P_{in}/V_s > (V_s / 2L_s)\, D T_{sw} \quad (5)$$

TABLE I

Parameters	Ratings
AC Input Voltage	230V
Switching Frequency	455kHz
Input Inductor	100µH
Equivalent Load Resistance	98.9Ω

Table I: Design parameters of full bridge topology

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V. RESULT AND DISCUSSION

The Simulation of the proposed circuit has been done using MATLAB R2014a/Simulink. The open loop simulation of full bridge topology is carried out in boost mode of operation with simulation parameters given in the table I [5].The output current and voltage waveform of direct ac-ac converter based on full bridge series resonant inverter as shown in fig.6 and fig.7.

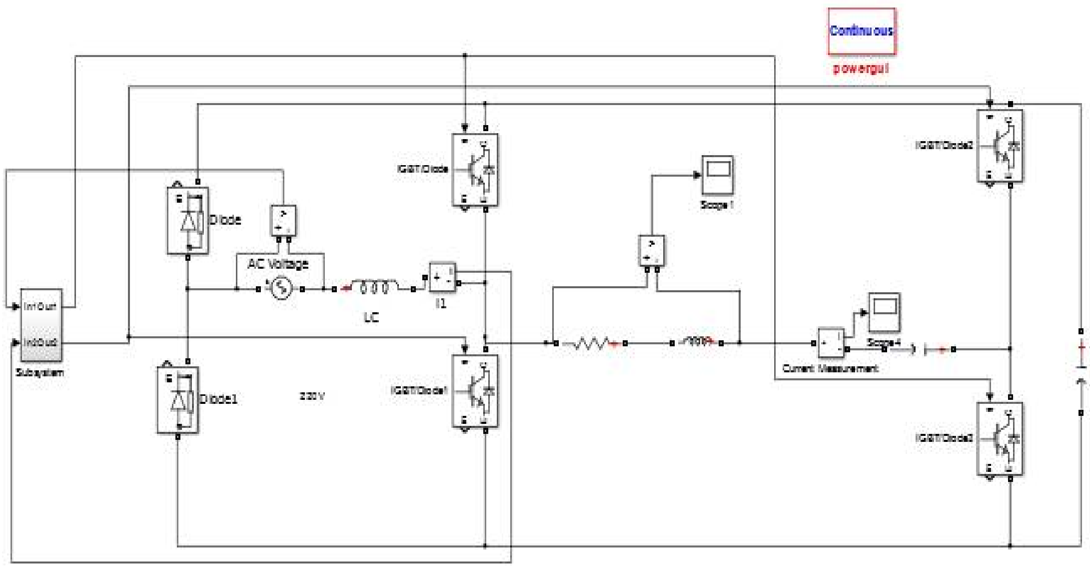

Fig.5. Simulation diagram of ac-ac converter

The lower switching frequency was set to 455 kHz and the maximum frequency can be 500 kHz. Single phase 230V, 50 Hz AC supply is applied to the input of diode rectifier. Series RL branch is the representation of equivalent inductance and resistance of load.

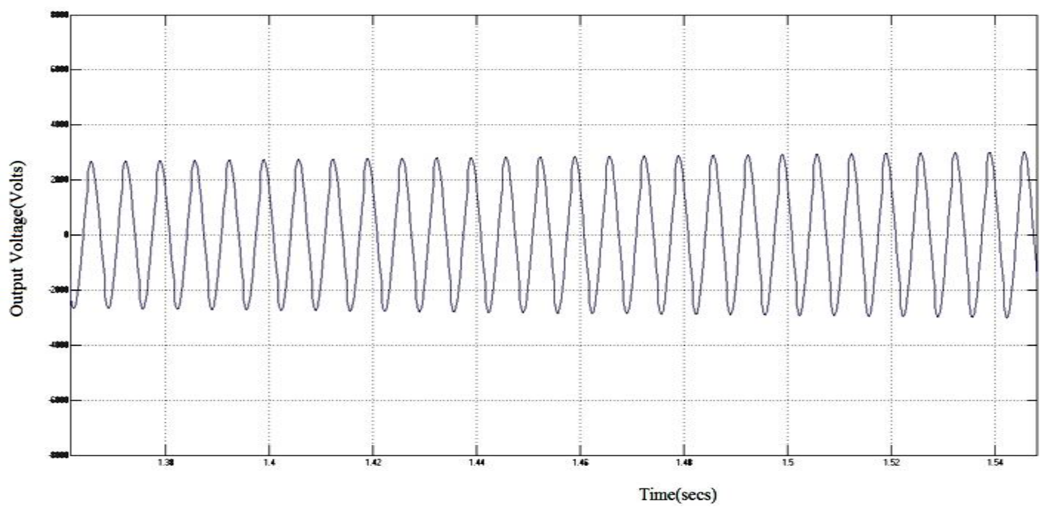

Fig.6. Output voltage waveform

The output voltage across the series RL branch is measured using voltage measurement block and the output current is measured using the current measurement block and scope is used for observing the output voltage and current waveform. Output voltage and current across the load is shown in figure 6 and 7 respectively and obtained high frequency AC wave. The waveform of output voltage and current is of high frequency. ZVS soft switching is

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guaranteed by providing a time delay between the switching of switches. Soft switching reduces the losses due to high voltage and high current present in switch during transitions.

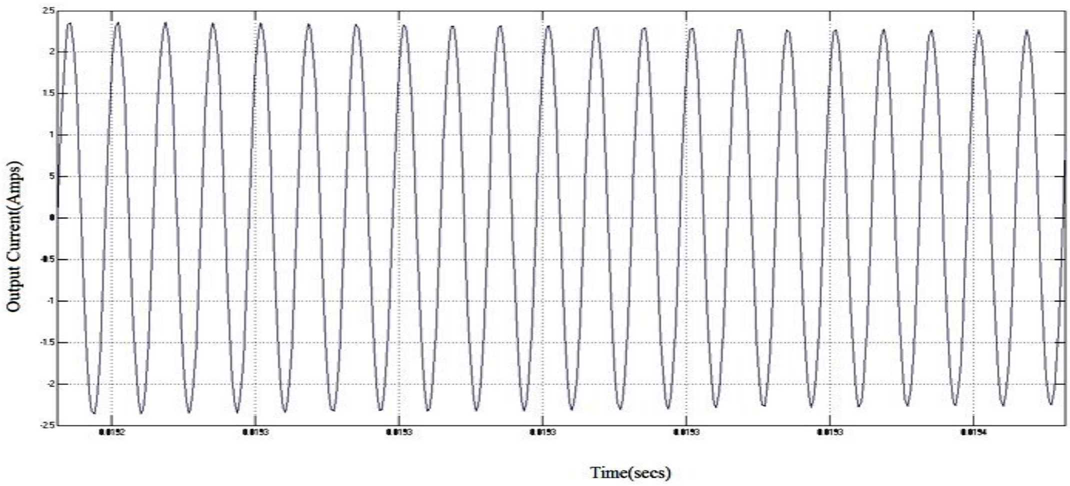

Fig .7 Output current waveform

VI.CONCLUSION

In this paper, a direct AC-AC boosting technique for industrial induction heating applications has been explained. The benefits of this direct AC-AC resonant boost converter are the low current levels, high output voltage, reduced switching losses and less number of components, which results in lesser cost and less system complexity. The power converter operates under zero voltage switching condition during both turn on and turn off transitions. As a conclusion, a direct ac–ac converter under full bridge configuration is proposed as a cost-effective and less complex design for the industrial IH application. The simulation of this converter is done by using MATLAB/SIMULINK.

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