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Direct AC-AC Resonant Boost Converter for Induction Heating Application

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ABSTRACT: Induction heating is being the fast technology in industrial as well as domestic field due to their advantages such as efficiency, fast heating, and improved control .This paper proposes a direct AC - AC boost converter. For this application. The main feature of this paper is minimum components and high output frequency. By using Soft switching PWM pulses, a high frequency AC is supplied to the induction heating appliance. The advantages of direct AC - AC converter over conventional design are reduced component size, higher flux distribution around the objects to be heated, reduced size of the converter having same power rating. The scheme of control used in the inverter is pulse width modulation with asymmetrical duty cycle .A 3KW power rated prototype is using MATLAB/SIMULINK

KEYWORDS: Induction heating (IH), Pulse width modulation (PWM),THD(total harmonics distortion)

I. INTRODUCTION

Among various emerging applications of power electronics induction heating plays a great role in industry and home appliances. It is a well-known technique to produce very high temperature for applications like steel melting, brazing, and surface hardening. In each application, an appropriate frequency must be used depending on the work piece geometry and skin-depth requirements. In general, the induction-heating technique requires high-frequency current supply that is capable of inducing high-frequency eddy current in the work piece that results in the heating effect. Recently, cost effective induction heating (IH) appliances using high frequency inverter have been rapidly developed for utility frequency AC to high-frequency AC power conversion system for consumer power and energy applications. These unique advantages are practically brought in accordance with great progress of power semiconductor switching devices, digital and analogue control devices, circuit components and high frequency soft switching inverter. Classical IH solutions are based on two separated stages: a rectifier plus a resonant inverter. First, a four-diode full bridge rectifier is commonly used to rectify the mains ac voltage. A small value dc-link capacitor is used to ensure an input power factor close to 1.Thus; a high-ripple dc-link voltage is used to supply an inverter stage. The resonant inverter used to supply the inductor-pot system 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 one-switch topology is the most used. The half-bridge inverter is used for medium output power. Finally, for high output power levels, the full-bridge inverter is used.

II. CONVENTIONAL INDUCTION HEATING TECHNOLOGY

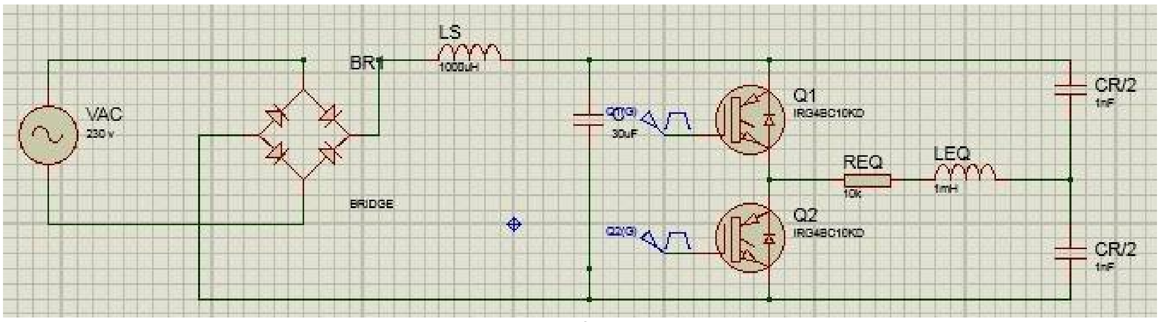

Fig 1. Circuit diagram of conventional converter

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Here in the conventional method, there is a indirect method of conversion. It has two stage of conversion process. Firstly, it converts AC to DC then it again converts this DC to AC. o it is an indirect method of conversion. The component count is higher due to EMC filter requirement. as compared to Direct AC to AC converter. Due to the activation of more than one diode, at a time leads to conduction loss. The major problem deal with here is the input current cause harmonics. So the output frequency should be less as compared to Direct AC to AC converter. So we go for direct conversion method using Half Bridge Resonant converter.

III. DIRECT AC - AC CONVERTER USING HALF BRIDGE

The proposed converter is shown in fig.2.The converter consist of two switches S1 and S2 , resonant capacitor $C_{r,}$ dc link capacitor Cb, input inductor $L_{s\,,}$diodes D_H and D_L and induction load which are supplied by the input voltage V_s.The input AC supply is rectified by the half bridge rectifier composed of two diodes D_H and $D_{L.}$ The half bridge inverter circuit consist of two switches with an anti parallel diodes .The boost dc - dc conversion of the main AC voltage , and supplying high frequency current to the inductor load are performed by the two switches S1 and S2. 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_{eq} and L_{eq} is modeled as the IH load .In addition to this, the series RLC resonant tank is completed with a resonant capacitor Cr which is split into two capacitors having the same value $C_r/2$.These capacitors are connected to the positive and negative bus so as to reduce EMC filter requirement.

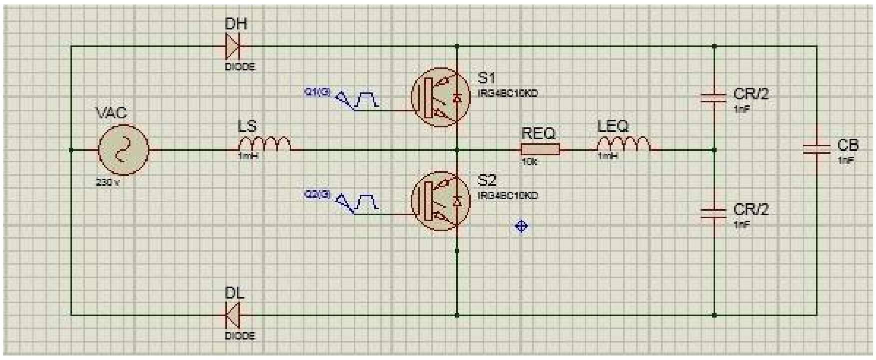

Fig.2. Circuit diagram of Direct AC - AC converter using Half Bridge Inverter

IV. CONVERTER ANALYSIS

The direct AC - AC converter operation can be analyzed through the four modes of operation through the equivalent circuit I to IV. During the positive half cycle of the main voltage D_H conducts that is in indicated by the two stages I and II. Where as D_L conducts during the negative half cycle that is indicated by the stage III and IV. This shows that only one rectifier is activated at a time , that will reduce conduction loss as it is compared to the conventional converter. The Zero voltage switching is guaranteed in it by providing time delay between the switching of each switch.
The supply voltage is applied across the inductor during the modes I and III and the dc link capacitor is charged by the inductor current during mode II and IV. The rectification for positive supply voltage is done by switch S1 and for the negative cycle ,its done by switch S2. The required high frequency AC current i_o to supply the IH load is performed by the inverter branch composed of S1 and S2, and the resonant capacitors. The voltage across the dc link capacitor is $C_{b.}$
There are many advantages of direct converter over conventional converter that the output frequency of direct AC - AC converter is higher. Because of the input current is free from harmonics.

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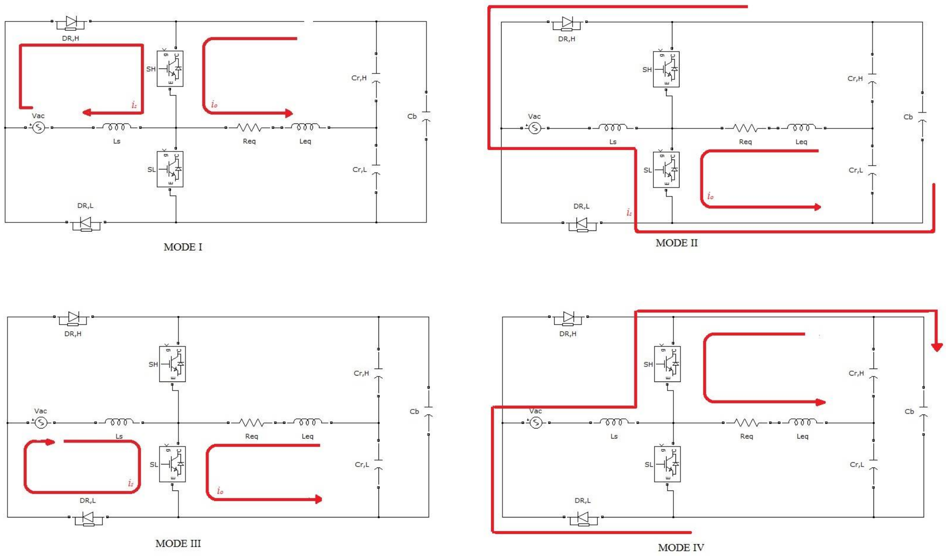

Fig.3. Modes of operation

V. DESIGN OF HALF BRIDGE RESONANT CONVERTER

The input voltage is boosted by the input inductor L_s and dc link capacitor C_b. The switch S1 and S3 perform the boost dc to dc conversion. The dc–dc boost circuit waveform are shown in Fig.7,where the steady state average input current is $I_{s.}$ In order to avoid the current ripples and high frequency current through the rectifier diode, a continuous current mode is assumed. In steady state average voltage across inductor is zero.

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

The ratio of voltage conversion is same as the boost converter.

$$\frac{V_b}{V_s} = \frac{1}{1-D} \quad (2)$$

The input current of the temporal waveform can be calculated using the input current ripple $\Delta I_{s,}$

$$\Delta I_S = I_{S,D} - I_{S,0} = \frac{V_S}{L_S} DT_{SW} \quad (3)$$

Where the minimum and maximum input current values during a switching period is Is,0 and I s,D respectively. Consequently, the input current of the temporal waveform i_s results

$$I_s(t) = \begin{cases} \left\{\left(I_s - \frac{I_S}{2}\right) + \frac{\Delta I_s}{DT_{SW}} t, (0 \le t < DT_{SW}) \right. \\ \left(I_S + \frac{\Delta I_S}{2}\right) - \frac{\Delta I_S}{DT_{SW}}(t - DT_{SW}), (DT_{SW} \le t < T_{SW}) \end{cases} \quad (4)$$

The condition of CCM is satisfied as ,

$$CCM \Rightarrow I_{S,0} > 0 \Rightarrow I_S > \frac{\Delta I_S}{2} \quad (5)$$

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The input power Pin for an unity power factor is assumed

$$I_S > \frac{\Delta I_S}{2} \Leftrightarrow \frac{P_{in}}{V_s} > \frac{V_S}{2L_S} DT_{SW} \quad (6)$$

that will lead to,

$$P_{in} > \frac{V_S^{\,2}}{2L_S} DT_{SW} \quad (7)$$

So there is a trade off between the input power, the input inductor value, and modulation parameters for a given supply voltage level to ensure CCM. The full bridge series resonant inverter consists of four switches S1, S2, S3 and S4. It is supplied by the output voltage of the boost stage Vb . By using the Fourier harmonic analysis, the output power Po results

$$P_o = \sum_{h=0}^{\infty} R_{eq} \frac{V_{0,h,rms}^2}{Z_{o,h}^2} = \sum_{h=0}^{\infty} R_{eq} \frac{\frac{1}{2} V_{o,h}^2}{Z_{o,h}^2}$$

$$= \sum_{h=0}^{\infty} \frac{R_{eq}}{2} \frac{V_{o,h}^2}{R_{eq}^2 + \left(2\pi f_{SW} h L_{eq} - \frac{1}{2\pi f_{SW} h C_r}\right)^2} \quad (8)$$

where h is the harmonic number, Zo is the impedance of the series RLC resonant tank, and Vo is the output voltage of the inverter. Its sinusoidal peak voltage results

$$\hat{V}_{0,h} = \frac{V_b}{h\pi} \sqrt{a_h^2 + b_h^2} \quad (9)$$

Where coefficients of fourier series are,

$$a_h = \sin(2\pi h D), b_h = 1 - \cos(2\pi h D)$$

The output power results,

$$P_0 = \sum_{h=0}^{\infty} \frac{(1-\cos(2\pi h D))}{(h\pi(1-D))^2} \frac{R_{eq} V_S^2}{R_{eq}^2 + \left(2\pi f_{SW} h L_{eq} - \frac{1}{2\pi f_{SW} h C_r}\right)^2} \quad (10)$$

VI. SIMULATION OF CONVENTIOANAL CONVERTER AND DIRECT AC - AC CONVERTER

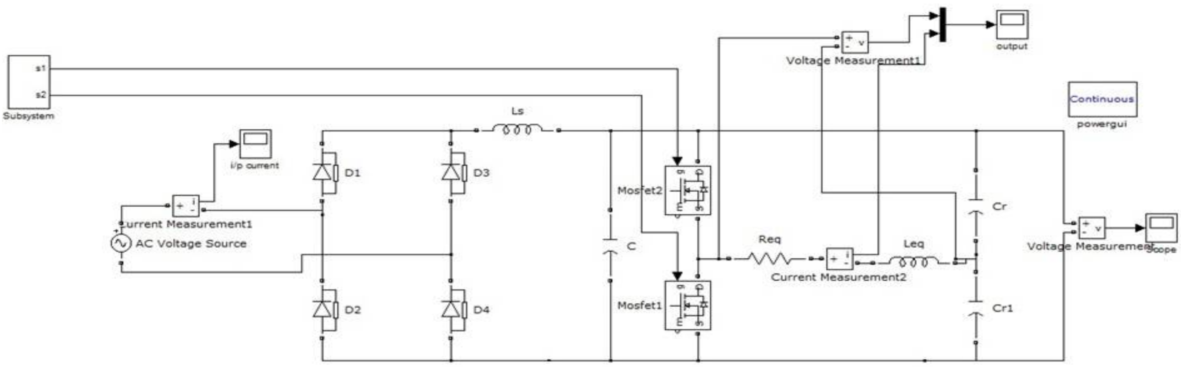

Fig.4. Simulation of conventional converter

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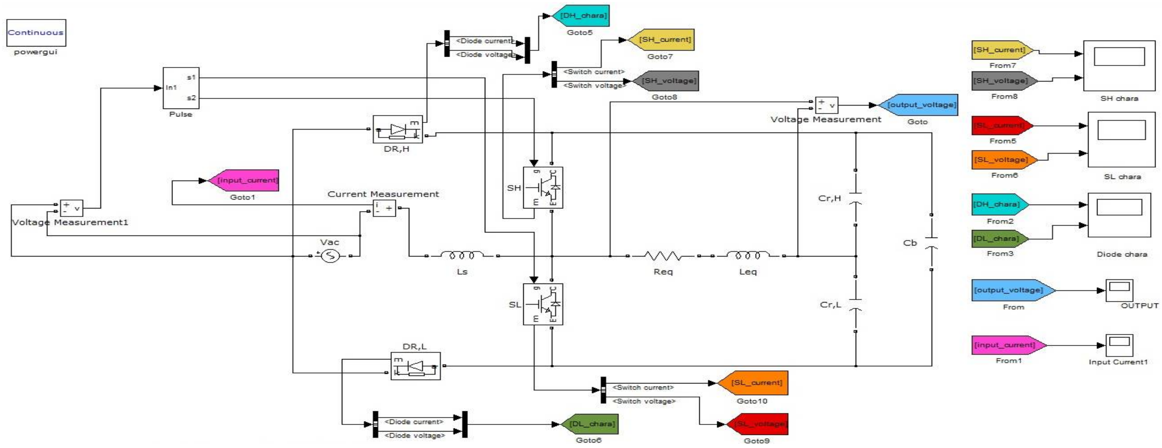

Fig.5.Simulation of Direct AC - AC converter using MATLAB

The design parameters for the Direct AC - AC converter using half bridge converter are shown in table 1

Table 1: Design values for Half bridge converter

VII. COMPARISON OF CONVENTIONAL CONVERTER AND DIRECT AC - AC CONVERTER USING MATLAB RESULTS

In conventional converter, the input current cause harmonics due to the non-linear diode in the input.But it is seen from the simulated result that direct AC - AC converter didn't have the effect of input harmonics.

Parameters	Values
Input voltage	325.2V
Switching frequency,f_s	150KHz
Equivalent load resistance, R_{eq}	98.9Ω
Equivalent load inductance,L_{eq}	155µH
Input inductor , L_s	900µH
DC link capacitor C_b	470pF
Resonant capacitor	8.56nF

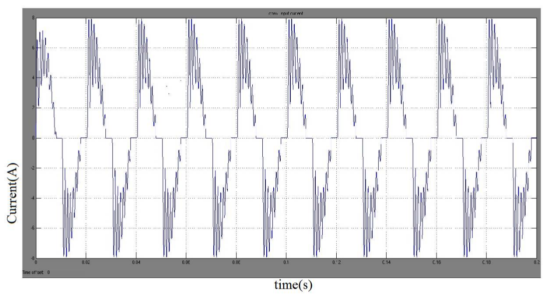

Fig.6. Harmonic Input current of conventional Converter

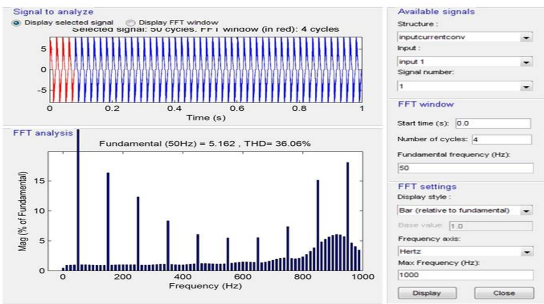

Fig.7. THD of conventional Coverter

The THD (Total Harmonics Distortion) comparison of both conventional and direct AC - AC converter are shown in Fig 8 and 9. The THD of conventional converter is 36.86 and that of Direct converter is 22.87. It depicts that there is an

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improvement in THD using direct converter.The THD comparison of both conventional and direct AC-AC converter is shown in table 2.

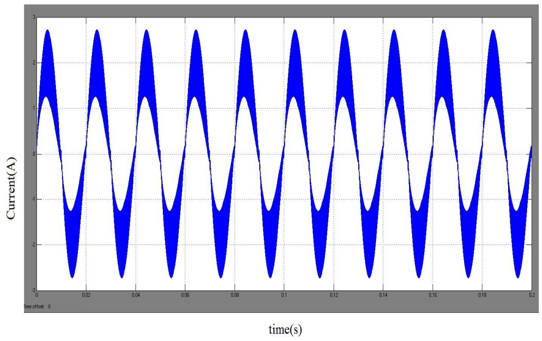

Fig.8.Input current of Direct converter

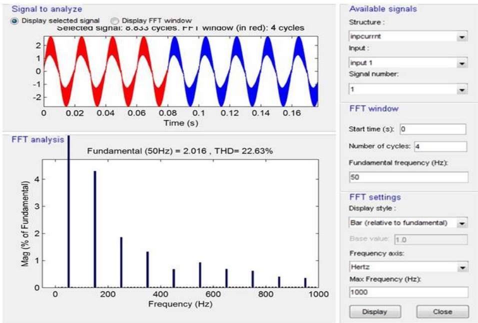

Fig.9. THD of Direct AC-AC Converter

Input inductor (Ls)	Direct AC-AC	Conventional converter
900µF	25.25	36.17
1000µF	22.7	36.05
1100µF	20.47	36.15
1500µF	14.94	36.44

Table:2 THD comparison

The Fig 10 and 11 shows that the output frequency of the direct AC- AC converter should be higher than the conventional converter. So high frequency voltage across the inductive load. So the IH load becomes easily heated up.

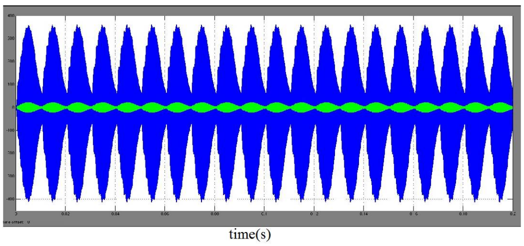

Fig.10.Conventional output current & voltage
output current output voltage

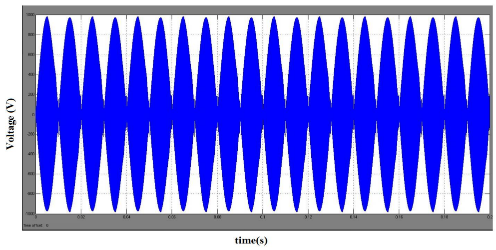

Fig.11. Output voltage of Direct AC-AC Converter

VIII. RESULT ANALYSIS

The voltage and current across switch S1 and S2 is shown below. The switch S1 conducts 70 percent during positive half cycle and 30 percent during negative half cycle. The switch S2 is in the reverse manner

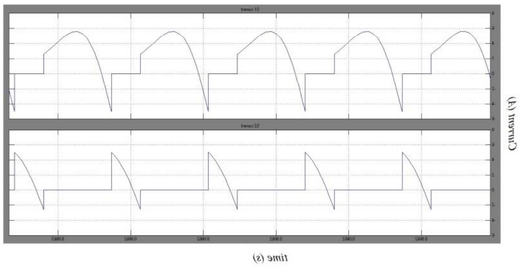

Fig.12.current across S1 & S2

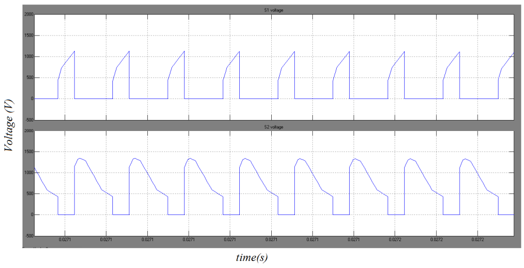

Fig.13 .Voltage across S1 & S2

The diode characteristics of D1 and D2 are shown below. The current and voltage across D1 and D2 are shown in fig.14 and fig.15.

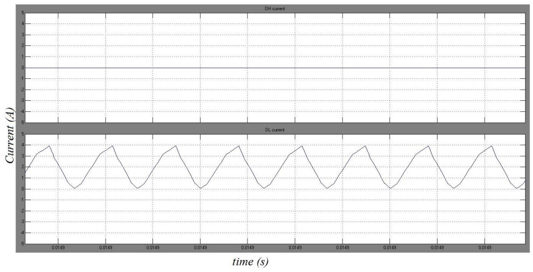

Fig.14.Current across D1 & D2

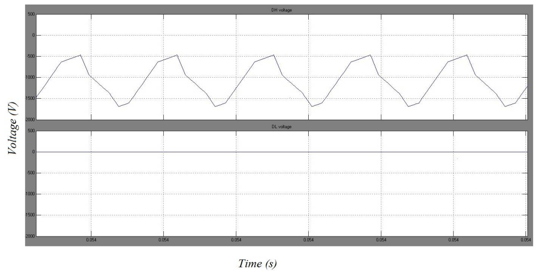

Fig.15.Voltage across D1 &D2

IX. CONCLUSION

A voltage- fed direct AC - AC converter is proposed here. We use half bridge inverter for this purpose. In this paper describes the comparison of a conventional converter with the direct AC - AC converter. From the above results shown that the efficiency of the direct AC - AC converter is higher than the classical converter.. ZVS (zero voltage switching) is offered here. Since input current harmonics is reduced, THD is improved The major advantage of Direct AC - AC converter is that a higher frequency output will pass through the IH load. So the pan gets easily heated up.

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