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AC-AC RESONANT BOOST CONVERTER FOR INDUCTION HEATING WITH CLOSED LOOP CONTROL

[1]Ajin Sebastian, [2]Prof. Kiran Boby, [3]Prof. Ninu Joy

[1]PG Scholar, [2,3]Professors, Department of Electrical and Electronics Engineering, Mar Athanasius College of Engineering, Kothamangalam, Kerala, 686666

Abstract: **Induction heating is a promising technology which requires power electronics component. It is a heating method for electrically conductive materials using the heat generated by the eddy currents, by means of a varying magnetic field. The power converter feature a half-bridge resonant converter operating with a switching frequency between 50kHz and 120kHz to improve efficiency, accurate smooth power control while assuring the safety of power devices. Power requirement of an induction heating system can be varied during the heating process. A closed loop control is required to have a smooth control over the power. This work presents the analysis of an AC-AC resonant converter with closed loop which is based on the half-bridge series resonant inverter for induction heating. Only two diodes are used in this topology to rectify the mains voltage. The converter can be operated with zero-voltage switching during both switch-on and switch-of transitions. In conventional AC-AC resonant boost converter output power varies according to input voltage. In the designed system a closed loop is implemented in order to keep output power at desired value irrespective of supply voltage. The circuit is simulated using PSIM**

Keywords: **Induction Heating (IH), inverter, Half Bridge Series Resonant Inverter (HB-SRI), Zero Voltage Switching (ZVS).**

I. INTRODUCTION

Induction heating application becomes more popular due to some advantages such as fast heating, cleanliness, safety, high efficiency, low cost [1]. The development of these appliances features and performance is highly linked to the advances in power electronic converters. In order to achieve high efficiency induction cooktops uses resonant converter in which the induction vessel system is a part of the resonant tank. Classical IH contain two section, a rectifier and a resonant inverter [1]. Direct ac-ac converters have been widely used, due to the component count reduction and, reducing the intermediate dc-link storage requirements. For matrix converters, direct ac-ac converter introduction reduce or eliminate the required dc-link capacitor [2]. Besides, in the case of wireless power transfer application, direct ac-ac converters have demonstrated to enable the use of advanced modulations that reduce switching losses. Today, direct ac-ac conversion has been also applied to IH applications. These converters are based on the HB-SRI, featuring a four-quadrant equivalent switching device, composed of two antiseries IGBTs [3]. The converter proposed is based on the half bridge boost rectifier, which make a high reduction in the current levels not only in the power converter, but also in the inductor acting as IH load. As a consequence, the converter efficiency is significantly improved. As a difference with previous works, the low-frequency ac current do not flow through the IH load, which reduces the peak current and conduction losses. In addition, ZVS soft-switching conditions are guaranteed in the wide output power region, decreases both conducted and radiated EMC issues, and improves the efficiency [4]. Moreover, the proposed solution is in full agreement with recent developments in high-voltage and high-frequency switching devices, such as the embedded-diode field-stop 1200-V IGBTs or new wide bandgap devices. Based on that, an IH prototype has been built to prove the feasibility of this

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proposal, featuring 1200-V SiC JFETs in order to maximize the efficiency. In the proposed system a closed loop is introduced in order to keep output power at the desired value irrespective of supply voltage.

II. AC-AC RESONANT BOOST CONVERTER FOR INDUCTION HEATING WITH CLOSED LOOP CONTROL

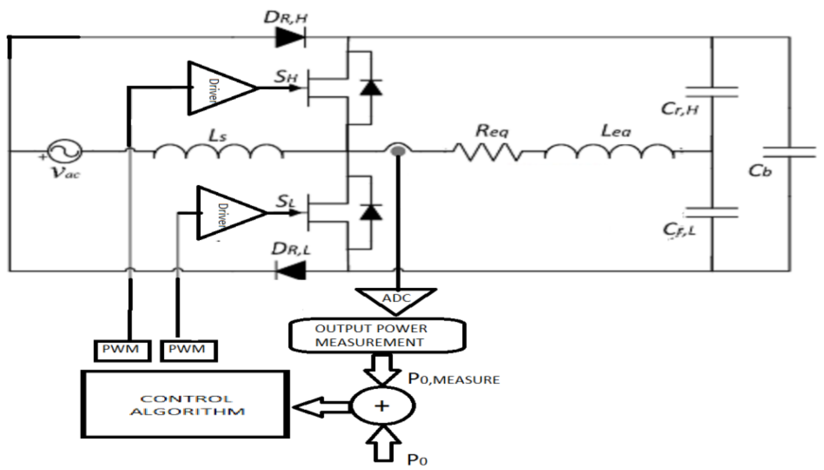

Fig.1 Proposed circuit for Induction Heating

Fig.1 shows proposed circuit for closed loop induction heating. Output power $P_{measured}$ is measured using an ADC. Desired power P_0 is entered to controller. The error is calculated and send to control algorithm. Depending upon error gate signals were generated, to get desired power output. The proper power delivering to the load the modulation factors such as maximum value of the output current, RMS value of output current, peak value of output voltage, are measured for each half period of the main cycle.

A. Open loop configuration

The open loop configuration AC-AC resonant boost converter is shown below.

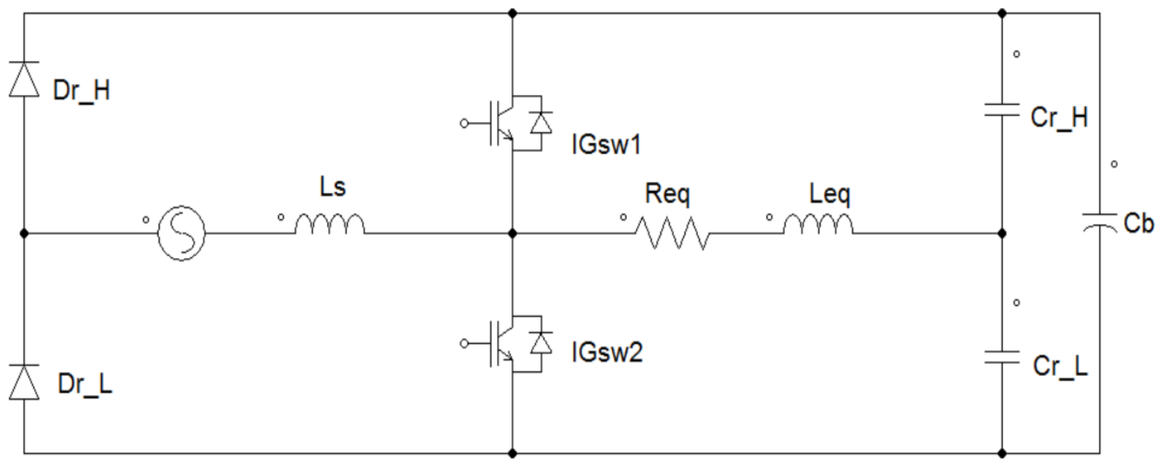

Fig.2 Open loop circuit for induction heating

The Ac power supply,Vs , is rectified by the half-wave rectifier branch which is composed of Dr_H and Dr_L. An inverter branch composed of IGsw1, IGsw2, are used to perform a boost dc-dc conversion of the main Ac voltage and, additionally, to supply the high frequency current to the inductor. The voltage is boosted by means of the input inductor Ls and the dc-link capacitor Cb . The Induction Heating load is modelled as a series equivalent RL circuit composed of Req and Leq. The series RLC resonant tank is completed with a resonant capacitor Cr. It is split into two capacitors

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Connected to the positive and negative bus in order to reduce EMC filter requirements. Both capacitors, CrH , CrL, have the same value, i.e., Cr /2.

B. Modes of operation

The operation of the proposed converter can be analysed through the four modes. Its main waveforms are shown in Fig 4

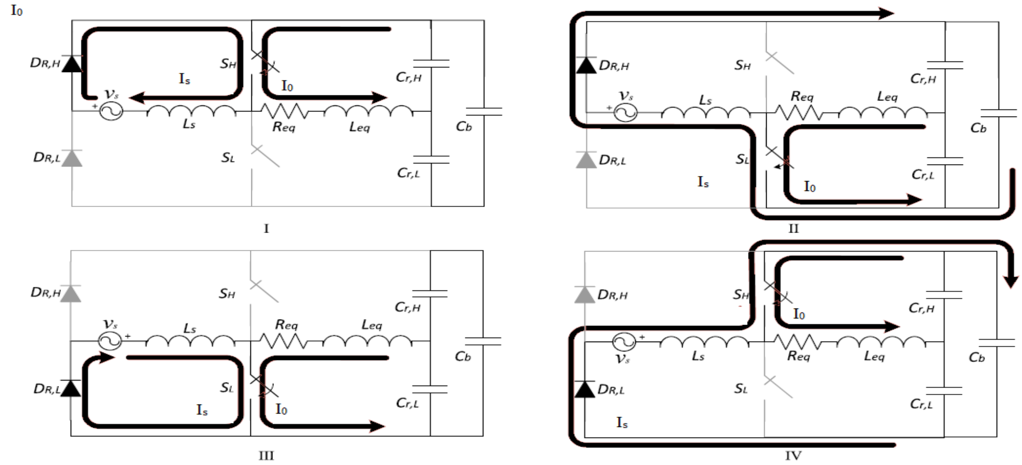

Fig.3 operating modes

Mode 1: In mode 1 the supply voltage V_s applied to the input inductor Ls through path V_s, D_{RH},S_H Ls.The load current I_0 flows through switch S_H,Req,Leq.

Mode II: In mode 2 the capacitor C_b is charged by the inductor current I_s through the path Vs, D_{RH}, C_b, Ls and the load current flows through Req, Leq, S_L.

Mode III: During negative main voltage, the inductor charged through the path Vs, Ls, S_L, $D_{R;L}$. Since $D_{R;L}$ is activated during negative main voltage period it reduces Conduction loss.

Mode IV: The capacitor C_b charged by the inductor current I_s through path Vs, Ls, S_H, C_b, $D_{R;L}$ and load current flows through S_H, Req, Leq.

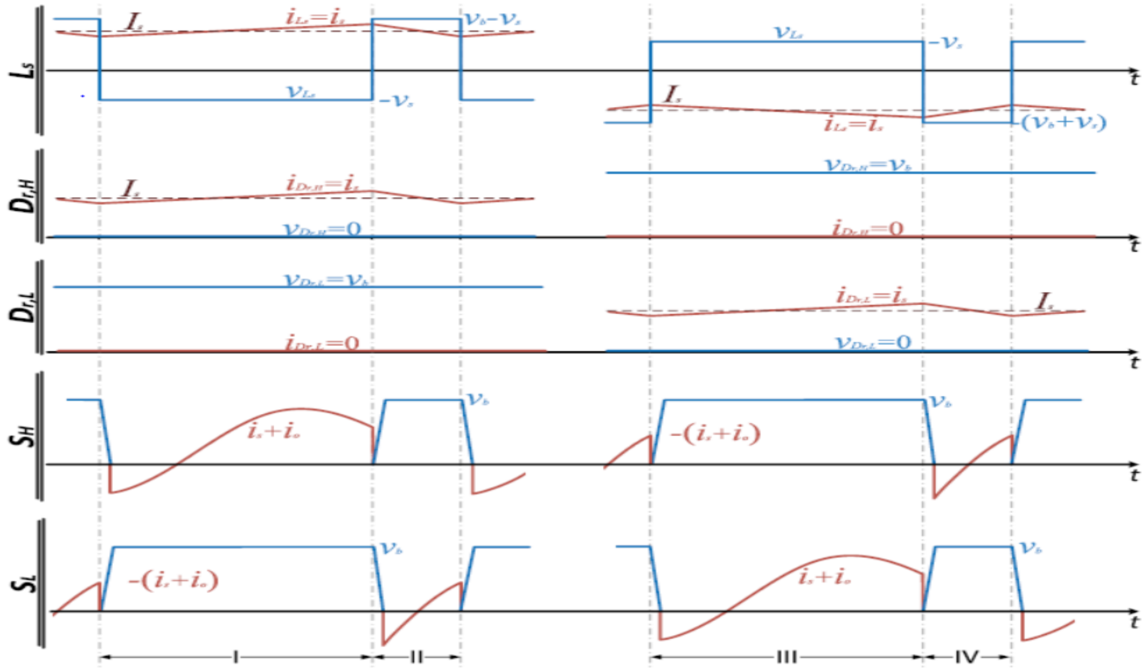

Fig.4 Main waveforms

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III. DESIGN OF PARAMETER

According to the supply voltage specifications and the device peak voltage, the maximum duty cycle.

$$\frac{V_b}{V_s} = \frac{1}{1-D}$$

Resulting in D=0.7.where supply voltage V_s is 23V and peak device voltage V_b is 120V. The equivalent IH load resistance results

$$R_{eq} < \frac{(1-\cos(2\pi D)V_s^2)}{(\pi(1-D)^2P}$$

The load resistance result 100Ω taking load inductance 140μH and resonant capacitor as 15nF.Assuming input inductor as 121.9μH.

IV. SIMULATION RESULTS

The simulation diagram of closed loop AC-AC resonant boost converter circuit is shown below.

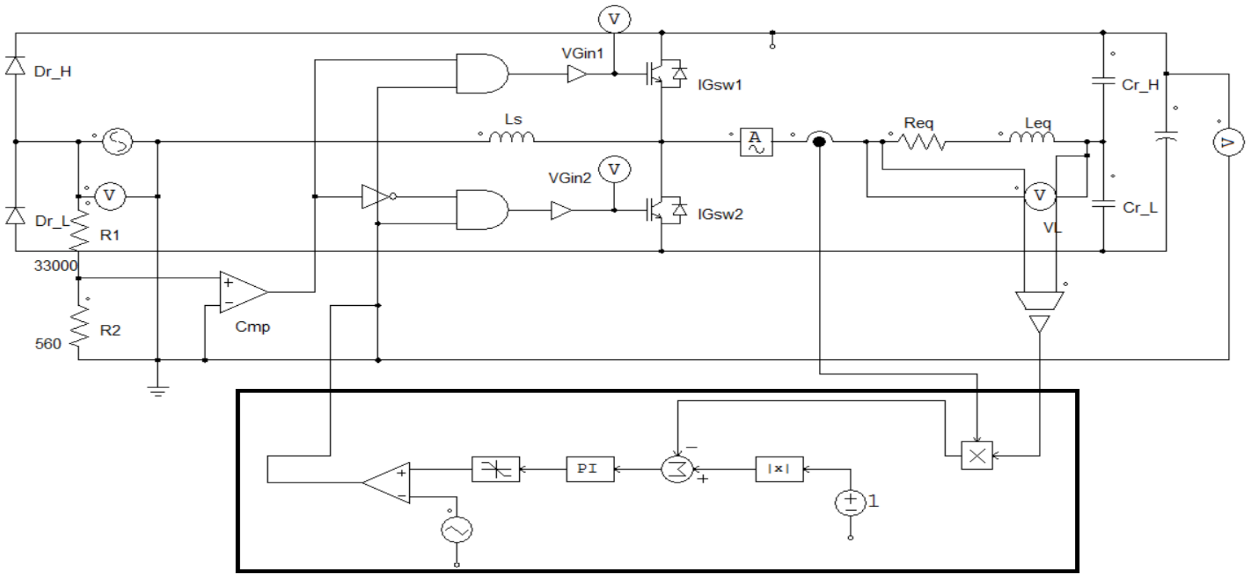

Fig: 5 closed loop AC-AC resonant boost converter

The output power is measured and it is compared with reference value. The error signal is generated after the comparison. In this circuit, PI control method is applied to control the duty ratio of switches. The error signal is given to the PI controller and generates the gate pulses for switches. The simulation result of proposed converter for different duty ratio is given below

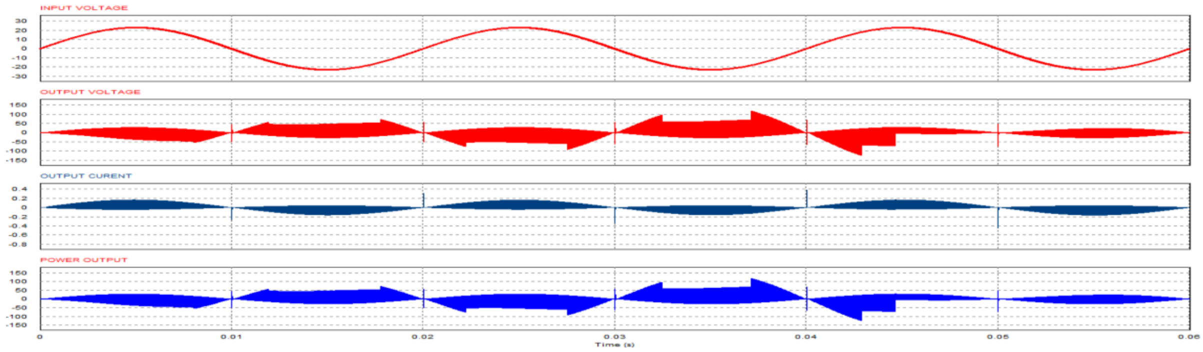

Fig: 6 Waveform of Closed loop AC-AC resonant boost converter with D=0.25

The output power across load obtained as 0.28W.The output voltage is obtained as 10.33V and the THD of output current is obtained as 21.13%.

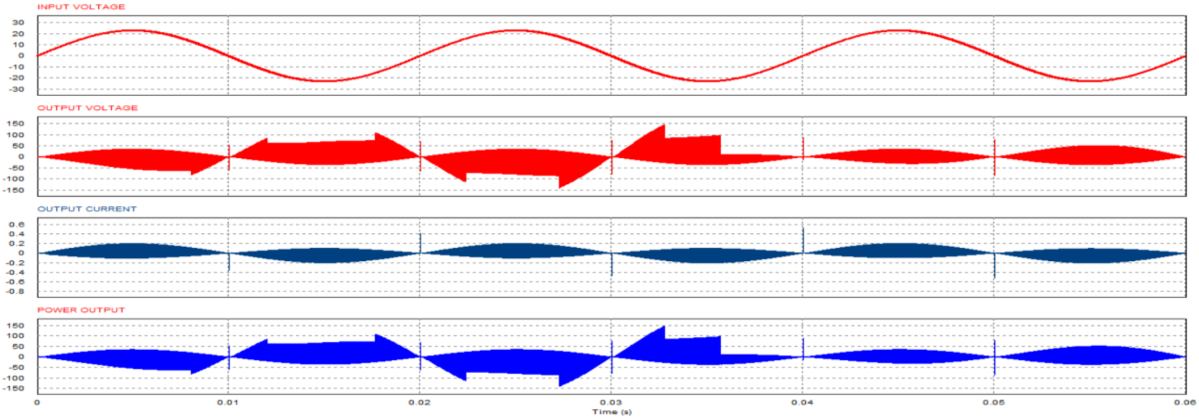

Fig.7 Waveform of Closed loop AC-AC resonant boost converter with D=0.4

The output power across load is obtained as 0.8W. THD of output voltage is obtained as 11.03V and the THD of output current is obtained as 31.138%.The variation of Gain with Duty ratio is shown below.

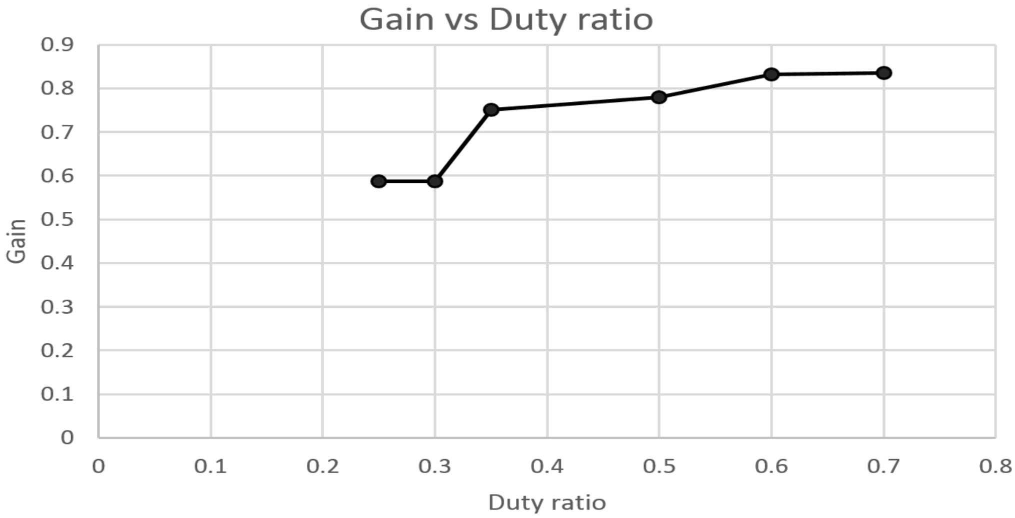

Fig.8 Gain VS Duty ratio

As duty ratio increases the gain of proposed converter in increases. The gain corresponding to each duty ratio is shown in graph. The variation of output power with duty ratio is shown below.

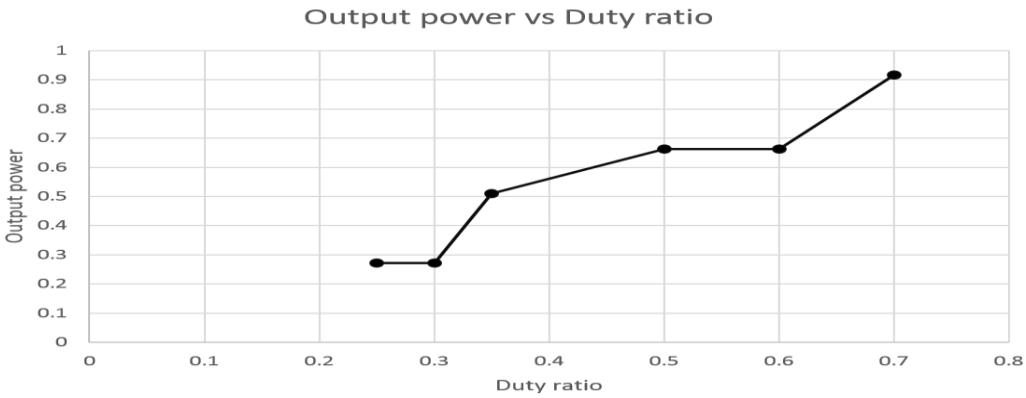

Fig.9 Output power VS Duty ratio

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As duty ratio increases the output power of proposed converter increases. The output power corresponding to each duty ratio is shown in the graph.

V. CONCLUSIONS

AC-AC boost resonant converter with closed loop applied for domestic IH application was designed. The main features of the designed converter include a reduced component count, high efficiency due to the reduced current levels and proper controlling of the output power. The simulation results show that for the proposed converter where high-frequency and high voltage levels are involved, the SiC technology is more appropriate, maximizing efficiency in the entire operation range. The proposed direct AC-AC boost resonant converter not only reduces the count of component, but also shows higher efficiency, making it more appropriate for the domestic IH application.

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