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Simulative Study Of Dual Mode Resonant Inverter System For Improved Efficiency And Power Factor In Induction Heating Application

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Abstract

This paper present the basic dual mode based resonant inverter used for induction heating application. Induction heating is phenomenon that we are using in our day to day life in domestic cooking purpose as well as industrial purpose. For induction heating high frequency supply needed, resonant inverter is the soft switched dc-ac converter works at high frequency is the better option. in induction heating basically two mode are there one is preheating and other one is post heating. In first mode we higher power is required for start up and in post heating a constant power in low to medium range is required. In resonant inverter Class - D mode is used for higher power output range and Class-DE mode is used for low to medium power range & for wider power regulation we can combine both of them and we can call it as dual mode resonant inverter . here efficiency is important factor in case of resonant inverter and it should be cost effective. so we are using half bridge rectified input for the half bridge resonant inverter working in dual mode as Class - D and Class - DE by using appropriate switching and by Using half bridge topology number of switches & diode reduced so as conduction losses & there by system cost too. Here we are doing simulation of this circuit by using MATLB/ SIMULINK (13a). FFT analysis is done here and also as THD less we can see that power factor is unity and system efficiency improved.

Keywords: *Dual mode operation, FFT analysis, Induction heating , Resonant inverter, Power factor*

1. Introduction

Now a day's domestic induction heating has become a leading technology due to its various benefits such as increased efficiency, safety, cost effectiveness, reduced cooking times, higher reliability, higher power density, low electromagnetic noise easy controlling and operating capacity. Because all these factors in Asia and Europe Domestic induction are now becoming a standard option[1] . Induction Heating (IH) is a kind of electric heating based on Faraday's law of electromagnetic induction principle in addition to Joule's heating principle in which eddy current is used to heated up the device. The Induction cookers used in domestic application works on induction heating phenomenon. In an induction cooker, initially an AC supply of 50 Hz is applied. It is then rectified to DC and subsequently back to a high frequency AC source through an inverter. This high frequency current produces a high frequency alternating magnetic field through an induction coil. Therefore placing a cooking pan / appliance close to the induction coil will induce eddy current in the pan. As a result of which, heat energy will be produced on the surface of the pan. The internal resistance of the pan causes heat to be dissipated according to Joules effect. Thus, it is the pan itself and not the heater that heats up and cooks the food. Typically an induction heater operates at either medium frequency (MF) or audio frequency (RF) ranges. Three main components form the basis of a modern induction heater including the power unit (power inverter), the work head (transformer) and the coil (inductor).

1.1 Scope for research

In our day to day life cooking is an important phenomenon and by using conventional source for cooking as burning of fuel, we can see that harmful gases are produces which create the dangerous effect on atmosphere. Usage of renewable energy increases the pollution in environment creates many problems for the society. This motivate us to design efficient method for heating which is the alternate for conventional heating source.
By using power electronics technology we perform electrical heating or induction heating. Induction heating can be used not only in domestic appliances but also in industrial, telecommunication, military and medical applications .

2. DUAL-MODE RESONANT CONVERTER

To achieve improved efficiency domestic induction heating system, dual mode resonant converter can be implemented in which half bridge converter is used in two operating modes one in Class - D mode and Class - DE mode.

2.1 Block Diagram

The basic block diagram shown in figure-1, in which we are giving the ac input to the circuit by using uncontrolled half bridge rectifier and then this covert into dc supply, which is then filtered by using dc link capacitor. after by using half bridge series resonant inverter circuit we convert dc rectified voltage in high frequency ac output .the output current has switching frequency from 20kHz to 100kHz ,which is then fed to induction load.

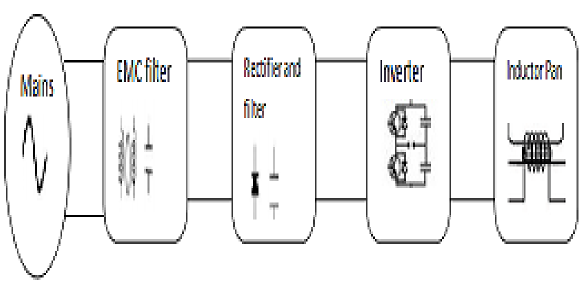

Figure 1. Basic Block diagram of IH system

2.2. Basic Circuit Operation

The proposed dual-mode resonant converter can be used in order to improve the efficiency in the whole operating range. In proposed dual-mode resonant converter, electromechanical switches SPST 1 and 2 allow varying the snubber and resonant capacitance in order to select class D and Class DE mode[2]. SPST 1&2 is opened for class D mode of operation and closed for class DE mode of operation. The circuit diagram of dual mode resonant converter with half bridge rectifier is shown in Fig2. Half bridge[4] rectifier consists of the boost inductor L at input side and diodes Drh, Drl. For both positive and negative half cycle of the supply voltage, the converter has symmetric operation. for positive half cycle Drh is forward biased and for negative half cycle Drl is forward biased. In the positive half cycle, Sh is controlled with duty ratio D and so the conduction times of the switches Sh and Sl are DTs and (1– D) Ts. In the negative half cycle Sl is controlled with duty ratio D and so the conduction times of the switches Sh and Sl are (1–D) Ts and DTs. There are six operation modes for the converter.

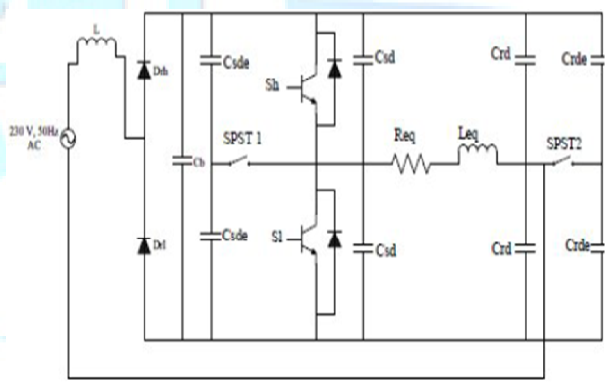

Figure 2. proposed circuit for dual mode operation

2.3 Operating Modes

2.3.1 Class-D Operating Mode

In the proposed converter, class D mode half bridge converter is used in the higher output power ranges. The maximum output power occurs at resonant frequency. To decrease the turn off switching losses, the snubber capacitance is used. This capacitance must be charged or discharged during dead time between transistors activation with the output current. To achieve ZVS in a wide range of operating conditions, a small value of capacitance must be used to ensure charge/discharge . In this mode initially switch SH is on, SL is off, both diode D1 and D2 is off. The load current is positive. The input power is delivered to the IH load through upper switch SH. when the switch SH is turned off, the current transfers to the switch-associated snubber capacitor Csnb. initially the snubber capacitor has a Zero voltage and it starts to charge snubber capacitor which is gradually charging. In this case, a reduced voltage will appear across the switch SH at turn off instead of zero voltage through IH load. When the reverse conducting diode D2 becomes forward biased, the load current is positive. During the conduction of diode D2, the switch SL can be turned on at any time, achieving ZVS turn on commutation. When current starts to reverse its direction, its starts to flow through switch SL, therefore switch SL turned on. Then the load current is negative. The switch SL is switched off at reduced voltage because of the snubber capacitor voltage transition then the Conduction is transferred from the switch SL to associated snubber capacitor Csnb. When this capacitor is charged to the supply voltage, then diode D1 is forward biased and negative current flows through this diode. Finally when the load current reaches zero, switch SH can be turned on at ZVS and the new switching cycle is started.

2.3.2 Class -DE Operating Mode

This mode is designed to supply the low medium output power for the same load. In this mode, the output power strongly depends on the duty cycle. The load resistance can be designed by assuming the maximum output power. Both resonant and snubber capacitor values are higher than the class D operation mode[5]. To change the modes from class D to class DE mode electromechanical switches are used to increase the capacitance values. Operation of this mode is similar to class D mode, whereas here there is no diode conduction, since the time duration for charging / discharging of the snubber capacitance is more.

Table 1. Simulation parameter for class D mode

1.	**Switching frequency**	**20-40 KHz**
2.	**Input inductor**	**1mH**
3.	**Dc link capacitor**	**100mf**
4.	**Snubber capacitor**	**15nf**
5.	**Resonant capacitor**	**1.04 µf**
6.	**Req**	**3.57Ω**
7.	**Leq**	**30*e-6**

Table 2. Simulation parameter for class DE mode

1.	**Switching frequency**	**20KHz**
2.	**Input inductor**	**1mH**
3.	**Dc link capacitor**	**100mf**
4.	**Snubber capacitor**	**464nf**
5.	**Resonant capacitor**	**7.35µf**
6.	**Req**	**3.57 Ω**
7.	**Leq**	**30*e-6**

3. SIMULATION RESULTS

The dual mode resonant inverter based induction heating system is simulated using MATLAB/SIMULINK (2013 a) and their results are presented here. The SIMULINK model of class D mode and class DE mode is shown in Fig 3 & 4 and its corresponding waveforms is also shown by various figure. fig 5 shows the power factor measurement block that we used as subsystem in the simulation circuit. Single phase 230 V, 50Hz AC supply is applied as input to the diode half bridge rectifier ,shown in fig 6. The dc link voltage across the smoothing capacitor is measured using scope as shown in figure 7 . pulse generator is used for switching two IGBTs. The firing pulses for both modes are shown in figure 8 & 9 .Series RL branch is the

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representation of equivalent inductance and resistance of inductor pot system. The output voltage across the series RL branch is measured with the help of voltage measurement block and the output current is measured with the help of current measurement block and scope is used for observing the output voltage waveform and output current waveform. figure 10 & 11 shows scope output for voltage and current for class D &DE mode respectively . FFT analysis is done and shown in figure 12 & 13
The circuit components are listed in the table I and table II for class D and class DE operation modes.

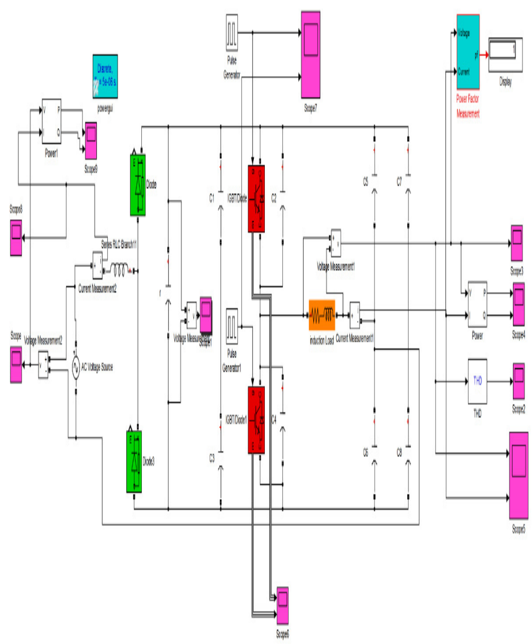

Figure 3 Simulation diagram of class D mode

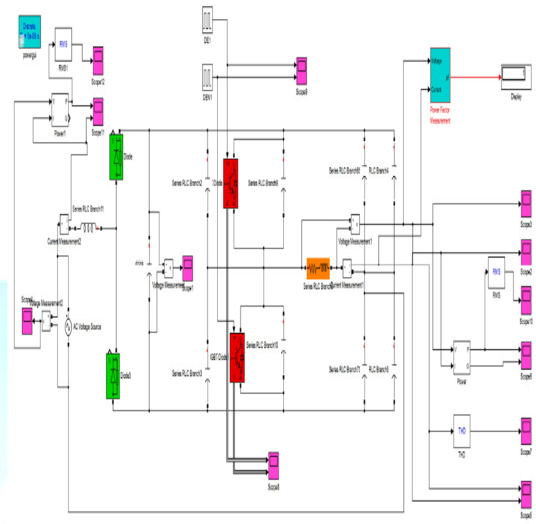

Figure 4 Simulation diagram for class DE mode

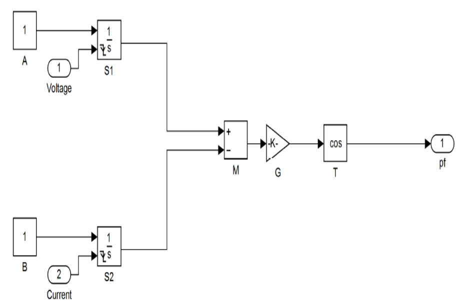

Figure 5. **Power factor measurement block**

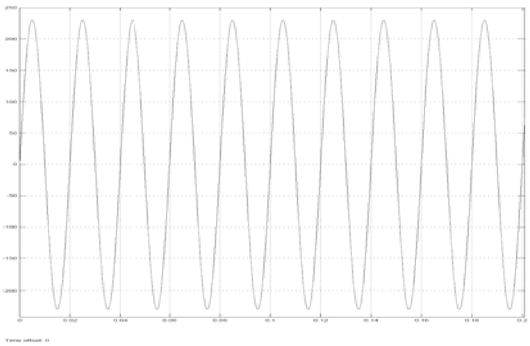

Figure 6. Ac input waveform

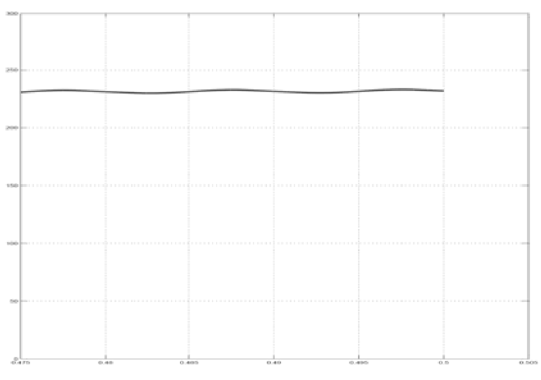

Figure 7. DC capacitor rectified voltage

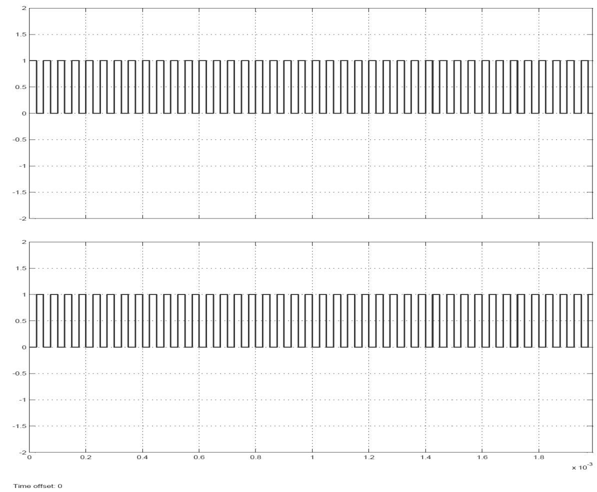

Figure 8. Gate pulses for class D with 50% duty ratio

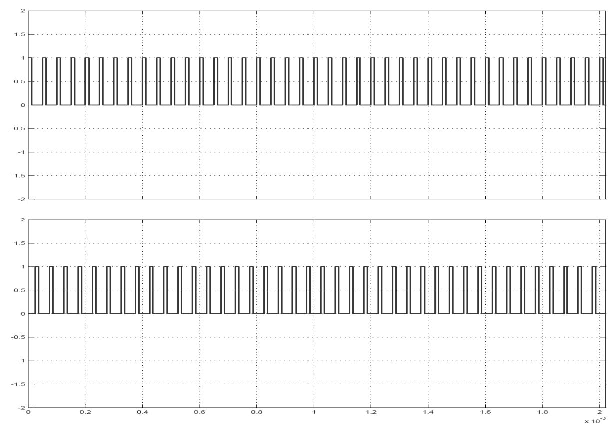

Figure 9. Pulses for class DE mode with 24% duty ratio

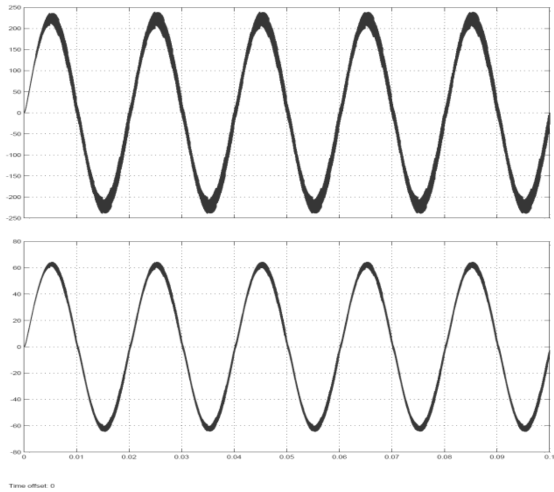

Figure 10 output vtg & current waveform for classD mode

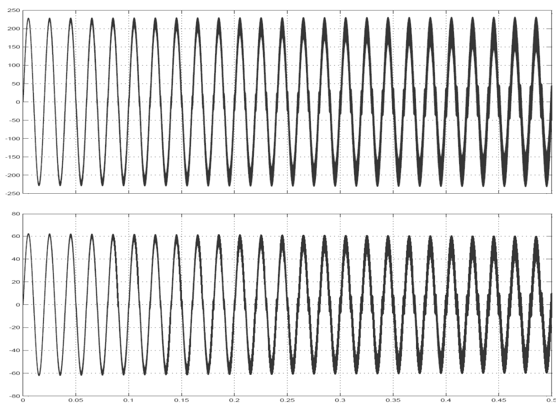

Figure 11. Output vtg and current waveform for classDE

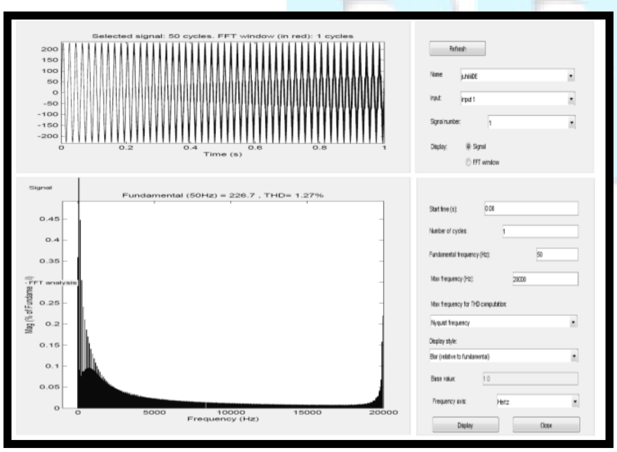

Figure 12. FFT analysis for class D mode

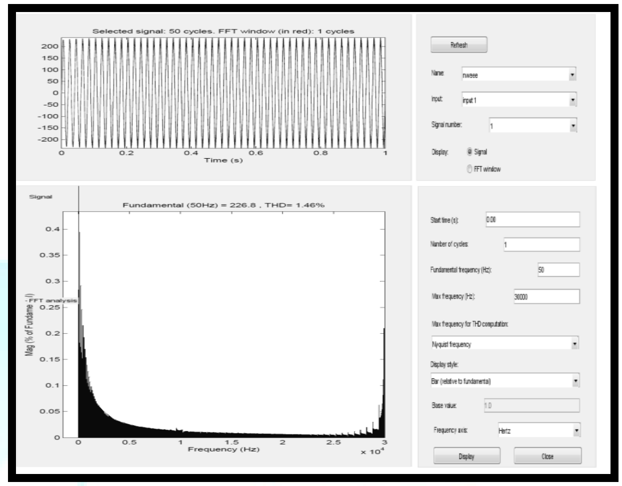

Figure13. FFT analysis for class DE Mode

4. CONCLUSION

This paper tried to tackle with the efficiency of the half bridge series resonant inverter for domestic induction heating system . The dual mode resonant converter with half bridge rectifier has been simulated using MATLAB/SIMULINK. From the simulation results. The Total Harmonic Distortion of dual mode resonant converter with half bridge rectifier is very less and thus improved power factor is obtained for this type of inverter. Half bridge rectifier with two diodes is used for the rectification purpose of the system. Rectifier based on half bridge reduces component count and conduction losses also. Because of the inductor present at the input will do power factor correction and fast output voltage regulation. Thus dual mode resonant converter without full bridge rectifier shows better performance for wide range of power regulation. We regulate the power up to 7kw. After FFT analysis we conclude that THD component reduced to 1.27% for Class - D and THD component 1.46% for Class - DE mode and unity power factor. Thus, the presented dual-mode resonant inverter is a cost-effective implementation for domestic induction heating.

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