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High Power Factor Induction Heating System with Interleaved Variable Duty Cycle

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ABSTRACT

In the past two decades, induction heating has been broadly applied to the catering industry as domestic induction cooker. Currently, due to the numerous benefits brought, such as high heating efficiency, controllability, quiet, and cleanliness, the commercial induction cooker draws increasing attentions in restaurants to replace the traditional stove. The design of a new Ac–Ac resonant converter is applied to the purpose of domestic induction heating and this proposed topology is based on the half-bridge series resonant inverter, using two diodes to rectify the mains voltage. It can be activated with zero-voltage switching during both switches - on and off transitions. This topology and interleaved pulsing achieved a nearly unity power factor. Based on the result, the converter effectiveness and also efficiency are enhanced. The methodical and mock-up results have been demonstrated by means of a 3600-W induction heating prototype. A deep study has been carried out to attain the heating efficiency of induction cooker is more than 96%. The main voltage is rectified and then a medium-frequency current is provided for inverter to feed the inductor. Here the usual operating frequency is taken as more than 20 kHz to avoid the audible range and lower than 100 kHz to reduce switching losses.

Keywords - High frequency, half bridge, induction heating, power factor correction, zone control induction heating.

1. INTRODUCTION

With recent scientific advances of power semiconductor switching devices, the electromagnetic induction principle eddy current based direct heat energy processing products and applications using high frequency power conversion circuits like inverters, cyclo-inverters and cyclo-converters have attracted special interest for consumer food cooking and gradual changes in electrical appliances.

At present application, cost effective induction heating (IH) using high frequency inverters have been gradually developed for the utility frequency ac to high-frequency ac power conversion system for consumer power and energy applications.

The practical advantages of IH equipment’s using high frequency inverter are safety, cost effectiveness, energy saving, clean environment, high thermal conversion efficiency, rapid and direct focusing heating process, high power density, high dependability, environment non-acoustic and low electromagnetic noise.

The above unique merits are practically applied in accordance with great progress of power semiconductor switching devices, digital and analogue control devices, circuit components and high frequency soft switching inverters.

Under the present technological situations, high frequency soft switching inverter topologies are necessary for consumer IH appliances. These high frequency soft switching inverters should have the advantages of simple configuration, high efficiency, low cost and wide soft commutation operating ranges for high frequency operation.

In this paper, a novel prototype of a boost-active clamp bridge single stage high frequency zero voltage soft-switching PWM inverter is used, which converts the utility frequency ac power into high frequency ac power with voltage boosting.

2. INDUCTION HEATING FUNDAMENTALS

It is a non-contact type heating process and it uses high frequency electricity to heat materials that are electrically conductive. Because it is not a contact, the process of heating does not pollute the material being heated. It is also very efficient since the heat is actually produced inside the work piece. This can be contrasted with other heating methods where heat is produced in a flame or heating element, which is then applied to the work piece. For these reasons Induction Heating brought applied to some unique applications in an industry.

The various uses of induction heating are billet heating, surface heat treatment and melting. Currently less expensive power transistors capable of operating at higher frequencies made possible the use of this rule in home appliances such as induction cooktops.

3. INDUCTION HEATING SYSTEM

This proposed topology employs two bidirectional switches SH and SL composed of a transistor TH or TL, typically an IGBT, and an anti-parallel diode DH or DL, respectively. The mains voltage vac is rectified by two diodes Dr H and Dr L, but only one diode is activated at the same time. This operation will improve the efficiency with regard to classical topologies based on a full-bridge diode rectifier plus a dc-link inverter.

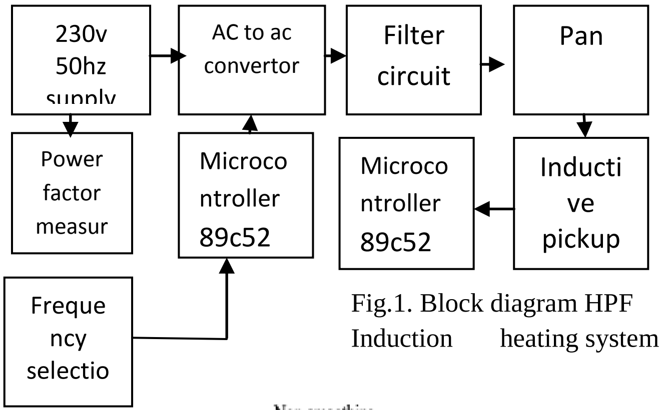

Fig.1. Block diagram HPF Induction heating system

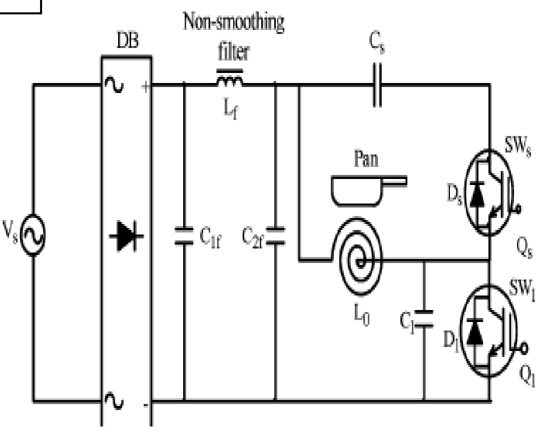

Fig.2. High power factor Induction Heating system.

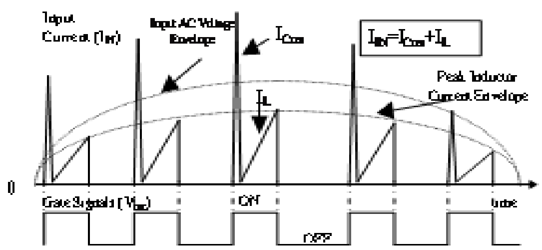

Fig.3.Input current, Current drawn by the power inverter, I_{IN}

The objective of the power stage is to try to transfer a user defined amount of power to the inductance (and hence the cookware) at resonant frequency of the LC circuit. This frequency is at about 25 kHz here.

$$I_{INav}(t) = \frac{I_{INpeak}(t)}{2}\frac{t_{ON}}{T_{SW}}$$

The rule of operation is based on the generation of a variable magnetic field by means of a planar inductor below a metallic vessel. The mains voltage is rectified and after that an inverter provides a medium-frequency current to feed the inductor. The usual operating frequency is higher than 20 kHz to avoid the audible range and lower than 100 kHz to decrease switching losses.

The frequently used device is the insulated gate bipolar transistor (IGBT) because of the operating frequency range and the output power range, up to 3 kW. At present, most designs use the half-bridge series resonant topology because of its control simplicity and high efficiency. In the past, several ac–ac topologies have been proposed to simplify the converter and improve the efficiency.

The methods of cooking mechanism method is unsustainable energy processing. Magnetic induction heating is a common technique producing high-frequency eddy currents losses on metallic objects.

4. SOURCES OF POOR PF

In its easy way, poor power factor caused by reactive linear circuit elements results as the current either leads or lags the voltage, depending on whether the load looks capacitive or inductive.

In most off-line power supplies, the AC-DC front end includes a bridge rectifier. It is these harmonics that cause the problems with the power distribution system.

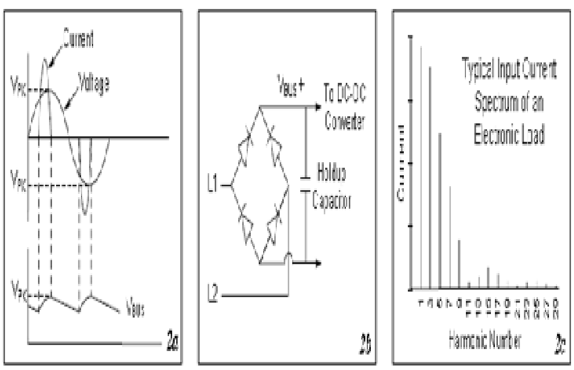

Fig. 4 Poor PF occurring in electronic loads

These methods of poor power factor are easily corrected by adding a reactive component of opposite sign in parallel with load to cancel the reactive term. On the other hand, less than acceptable power factor typically associated with electronic power conversion equipment is caused by nonlinear circuit elements.

5. THE ACTIVE APPROACH TO PFC

It is common and most effective way to correct the poor power factor of electronic power supplies is to take an active approach. Whereas in passive approach we have to connect the capacitor banks in parallel to the lagging load like inductors. Passive approach does not give a unity power factor.

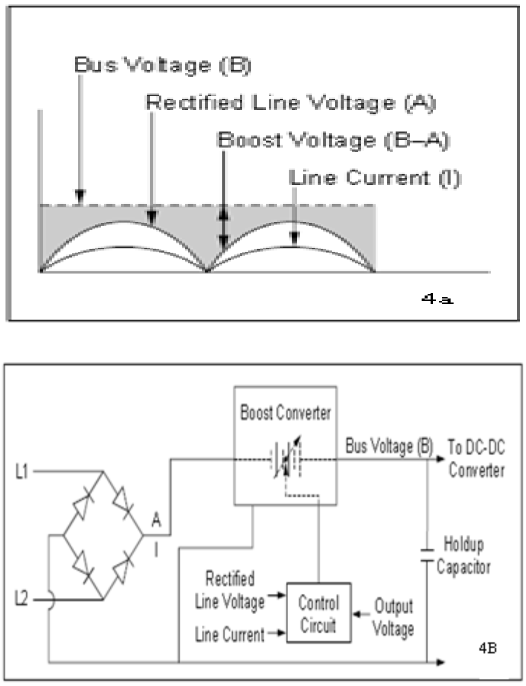

Fig.5.a & b. PFC associated with electronic power supplies requires an active approach

5. WORKING OF INDUCTION HEATING

A source of high frequency electricity is used to drive a large alternating current through a coil. This coil is known as the work coil. The passage of current through this coil generates a very intense and rapidly changing magnetic field in the space within the work coil. The work piece to be heated is placed within this intense alternating magnetic field. Depending on the nature of the work piece material, a number of things happen.

The alternating magnetic field induces a current flow in the conductive work piece. The arrangement of the work coil and the work piece can be thought of as an electrical transformer. The work coil is like the primary where electrical energy is fed in, and the work piece is like a single turn secondary that is short-circuited. This causes tremendous currents to flow through the work piece. These are known as eddy currents.

The advantage of this technology, against its counterparts is its high efficiency and flameless thus safer operation. Furthermore, fast cooking and quick reaction time of such equipment is an added advantage.

Fig. 6 Induction heating equipment

6. THE ADVANTAGES OF INDUCTION HEATING

Heating speed linked to the possibility of obtaining very high power density, Exact location of the heating effect thanks to the inductor design and an operating frequency perfectly adapted to the part to be heated, The possibility to heat at very high temperatures with an efficiency practically independent of the temperature, A process perfectly adapted to industrial medium-sized and mass production requirements Easy automation of equipment, Absence of thermal inertia (rapid start-up), Repeatability of operations carried out, Often extremely high heating efficiency, Absence of pollution from the source of heating (cold source), Good working conditions.

7. MAT LAB SIMULINK MODEL

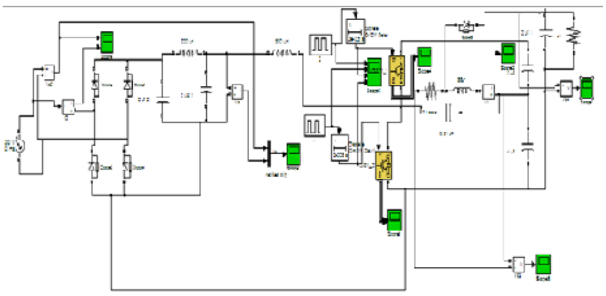

Fig.7 Main Simulink model

8. SIMULATION RESULTS

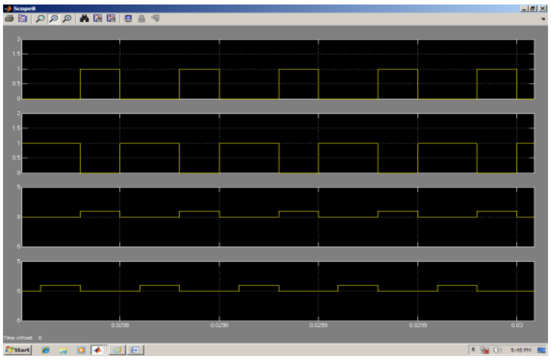

Fig.8 Simulation results of interleaved pulses

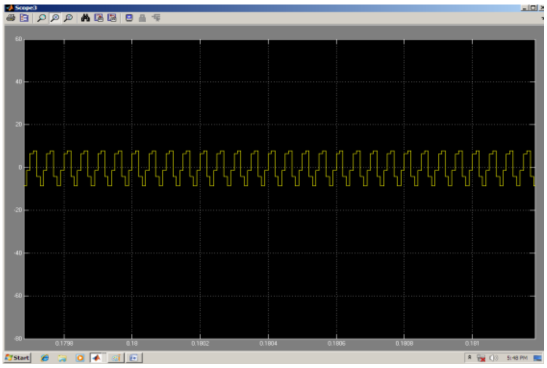

Fig.9 Simulation of pan current

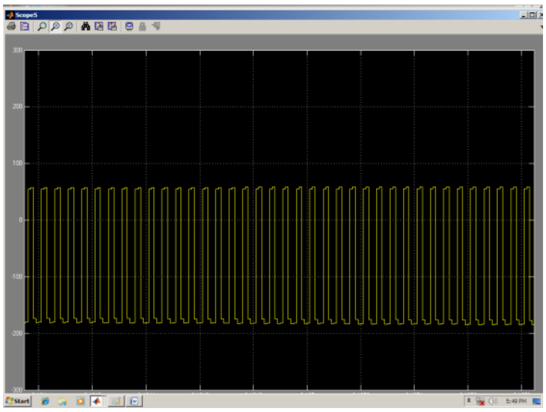

Fig. 10 Simulation output voltage

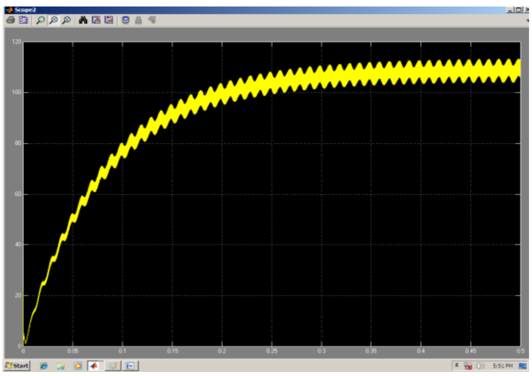

Fig. 11 Simulation of output efficiency

From the above result analysis, it is noted that all the interleaved pulses are constant for all the values of frequencies. It is also noted that the efficiency, pan current and output voltage were increased while increasing the value of frequency.

9. OUTPUT GRAPHS

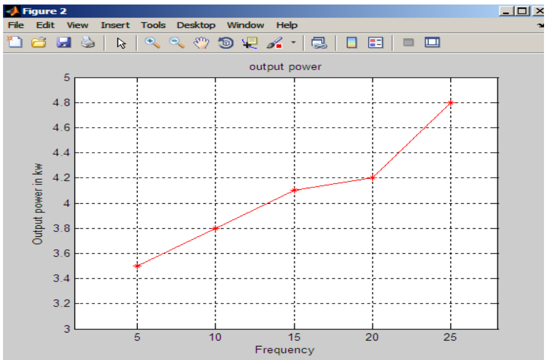

Fig.12 Output power vs Frequency graph

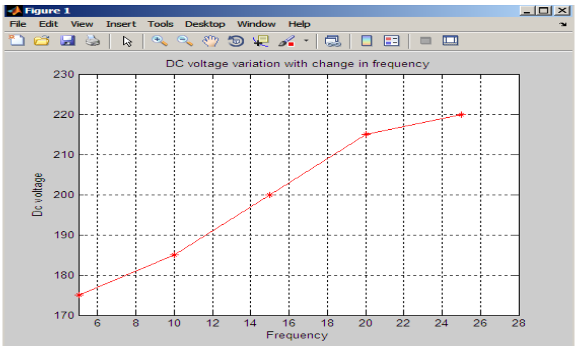

Fig.13 DC voltage vs Frequency graph

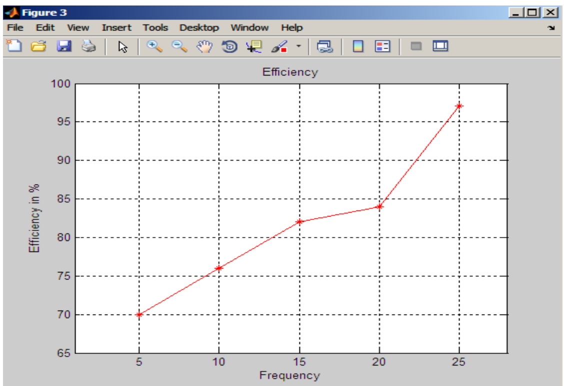

Fig.14 Efficiency vs Frequency graph

5. CONCLUSION

This method is to simulate using matlab 7.10 and hardware block diagram has been designed. This paper describes a low cost solution is realized to the problem of controlling the operation of a resonant inverter designed for an induction cooker. It is very clear that operating at high frequencies in the order of 25 khz gives a better Dc voltage to the inverter circuit. More over the efficiency of the system is fine when it is operated at 25 khz. The output power is about 4.8kw. The symmetricity in the output voltage and current is produced high switching frequencies. The controller allows both the control of the output power level of the cooker and assures a nearly unity power factor sinusoidal current to be drawn from the mains side. The method is applied to the induction cooker system and the design steps and test results are presented. The other related wave forms are plotted using MATLAB.

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