Source Current Ripple Reduction For Multiple Load Induction Cooking Applications

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***Abstract*— Multiple load Induction Cooking (IC) applications are present day need. It is required to have multiple induction heating coils with independent control for cooking applications. When such systems are powered from PV panels, there may be considerable ripple current drawn from the source. This paper proposes an inverter configuration and control technique which helps in reducing source current ripple considerably. This will help in providing the improved performance of the PV panels. Also this configuration provides independent control of each load. On-OFF control is used for power control in each load. High efficiency of the inverter is achieved. MATLab simulation results are presented.**

Keywords—*Induction cooking, PV panels, Inverter, ON-OFF control, multiple loads*

I INTRODUCTION

Induction cooking is more appropriate cooking method to move away from the traditional cooking systems such as using LPG etc.,. In case of traditional cooking systems it is easy to use the multiple vessels at the same time for cooking multiple items at a time which may not be possible with the induction cooking system. Using multiple loads for induction cooking is more costly than the traditional cooking system.

With the advent of the power electronic converters, now days, it is also possible to use induction cooking with the multiple loads[1]. The most commonly used power converter for these kinds of applications is the resonant inverter. This Resonant converter, in case of induction cooking systems, can be called as the high frequency inverter which acts as the source[2]. For IC applications half bridge[3] and full bridge inverter configurations are extensively used and relevant configurations. There are several output control techniques for IC applications such as Phase shift control, Asymmetric voltage cancellation (AVC) control, Asymmetric Duty Cycle (ADC) control, On-OFF control, pulse amplitude modulation etc.,. AVC and ADC control gives larger range for ZVS than phase shift control[4]. In Conventional IC applications, a single resonant inverter feeds the single load. In such case multiple inverters are required to feed the multiple load IC applications to get the independent control of the loads. This increases the component count and also increases the cost of the system[5].

Recently with the advent of PV panels and government of India initiation, the PV panels replace the conventional AC-rectifier structure. Because of this the conventional energy resource is replaced by the renewable energy source which is abundantly available. In the rural areas there is an abundant amount of solar power available, Hence this type induction cooking is basically useful for them where there is little amount of traditional gas cooking is available. This type of cooking can be done under safe and healthy conditions. The serious drawback of the PV panels is that they consist of ripple current component along with DC output current. The presence of ripple in the output current degrades the performance of the PV panel[6].

The aim of this paper is to propose a novel resonant inverter which will reduce the ripples in the DC source current and to improvise the domestic induction cooking with multiple load applications. The main characteristics of this inverter include reduced device count, independent control on multiple loads and high efficiency. This inverter includes ON-OFF control which will further improve the efficiency of the system and also expected to provide better reduction in the current ripple of DC source current.

II PROPOSED CONFIGURATION

The block diagram of the proposed model is as shown in Fig.1.

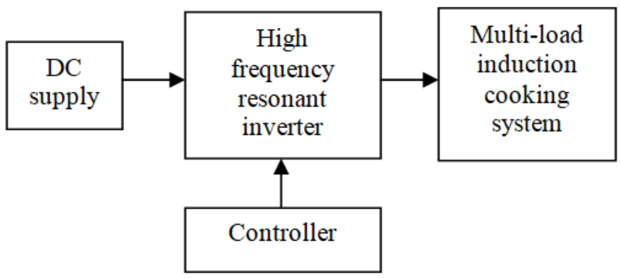

Fig.1. Block diagram of the proposed configuration

PV panels are used to supply the DC power which is taken as the source for the induction cooking. This DC power is fed to the high frequency resonant converter to generate the high frequency output voltage necessary for the induction coil. The principle of the half bridge inverter is used as the basic operating principle of this converter and made the inverter to be suitable for the multi load induction cooking/heating applications. Two PV panels are used in this configuration because of its half bridge arrangement. For powering the load series resonant converter principle is used.

The induction cooking load draws the sinusoidal current. The PV panels supplies the rectified sinusoidal which will be having the high low frequency ripples in the source current. An inverter configuration has been proposed which will reduce the ripples in the source current. The inverter is designed for multiple loads with switching frequency of 100 kHz. The ADC control is

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usedfor independent control of the multiple loads. The devices in the proposed inverter are switched with ZCS resulting in high power converting efficiency. In this configuration the resonant frequency is equal to the switching frequency.

The proposed inverter is as shown in Fig.2.

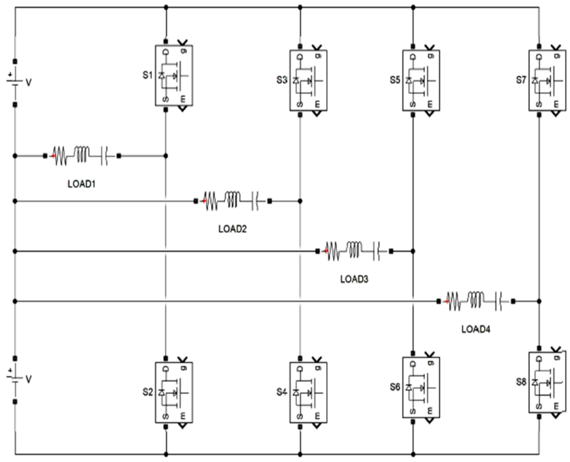

Fig.2. Proposed inverter Configuration

The multiple loads are connected between the centre point of the PV panels and the legs. For example load-1 isconnected between centre point of PV panels and Leg-1 and similarly the other loads of the system are also connected. The idea of the Series resonance is used for calculating each load. All loads are composed of passive elements such as resistor, inductor and capacitor elements which are all under resonance.

The resonant elements of the load can be calculated as follows:

The resonant frequency is given by:

$$\omega_r = \frac{1}{\sqrt{LC}} \qquad (1)$$

The normalised switching frequency is:

$$\omega_n = \frac{\omega_s}{\omega_r} \qquad (2)$$

Where ω_r is the resonant angular frequency

ω_s is the switching angular frequency

The characteristic impedance of the circuit is given by:

$$z_0 = \sqrt{\frac{L_r}{C_r}} \qquad (3)$$

The Quality factor of the induction heating is:

$$Q = \frac{z_0}{R} \qquad (4)$$

The impedance is given by:

$$Z = R(1 + jQ(\omega_n - \frac{1}{\omega_n}) \qquad (5)$$

The Proposed inverter principle can be explained as below:

1. During Positive half cycle, switch S1 is turned ON and S2 is turned OFF which corresponds to load-1 and hence $V_0 = +V_{DC}$.
2. During negative half cycle, switch S1 is turned OFF and S2 is turned ON which corresponds to load-1 and hence $V_0 = -V_{DC}$.

This process continues for all the remaining loads. 90^0 phase shift has been maintained between the voltages of one to the other load. Hence the independent control of the multiple loads in the induction cooking/heating applications has been achieved. For testing purpose the PV panels are replaced with DC sources.

The parameters of the proposed configuration are as given in Table.1.

Table.1: Parameters of the proposed configuration

Item	Value
DC voltage(V_{DC})	50V
Equivalent Resistance of each load	13Ω
Equivalent Inductance of each load	0.02mH
Equivalent Inductance of each load	0.122µF
Resonant frequency	100kHz
Switching frequency	100kHz
Quality factor	1

III Simulation Results

The MATLab simulation has been done for proposed inverter, shown in Fig.2.

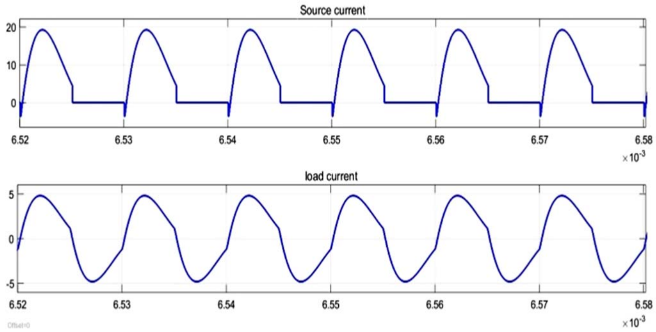

Fig.3.Waveforms of Source current and Load current

The inverter initially operated without any phase difference of 90^0. All loads are powered by the same voltage i.e. all input voltages to the resonant loads are in phase. The source current and the load-1 current is as shown in Fig.3

The source current from one PV panel is showing 20A(peak) as there is no phase displacement between the switches. Since all the load is operating at the same time the ripple in the source current is more. The load voltage and load current waveforms are as shown in Fig.4.

The load current and load voltage are in phase with eachother as shown in Fig.4. The load current is 5A (peak) andthe load voltage is 50V. Load voltages are indicated in redcolour and the currents with blue colour. And the loadcurrent is scaled to match with the load voltage. The loadvoltage and load current are in phase with each other.

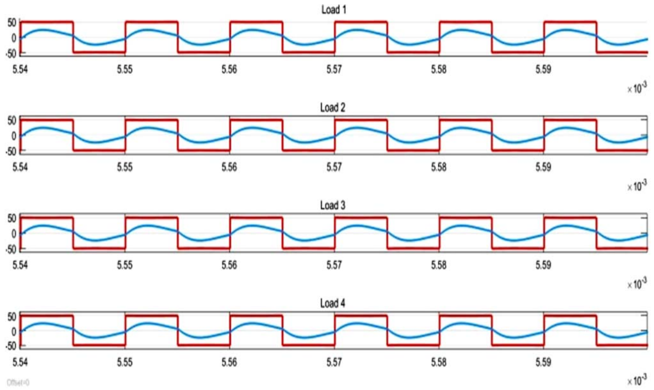

Fig.4. Load current and Load voltage waveforms.

Now a phase shift of 90^0 has been introduced between the switches in the consecutive legs. For example if Leg-1 operates at 0^0 then the Leg-2 operates at 90^0. Similarly this phase shift is introduced between all the other legs.

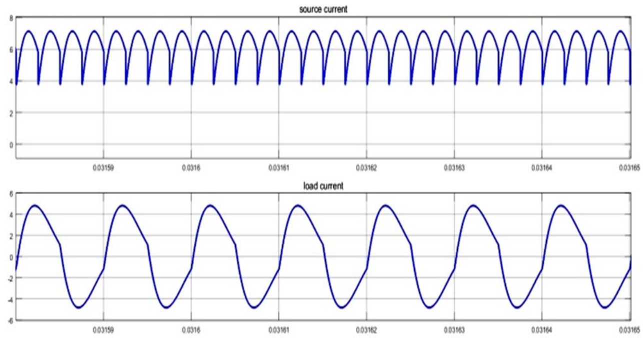

Fig.5. Source current and Load-1 current waveforms

With the change in the phase shift of the switchesbetween the legs it can observed that the ripple in thesource current has been decreased to 3A. The variationof the ripple is from 3.9A to 7.1 A. The load current andload voltage waveforms are as shown in Fig.6

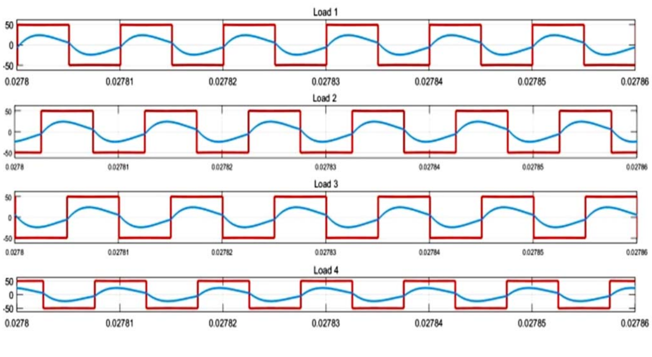

Fig.6. Load current and Load voltage waveforms with phase shift

The load current is maintained at 5A and is in phase with the load voltage waveforms. Here also it is observed that the load current and the load voltage both are in phase.

This method also achieves ZCS results in good performance. The results are as shown in Fig.7.

Fig.7. shows the validation of ZCS in the proposed resonant converter.

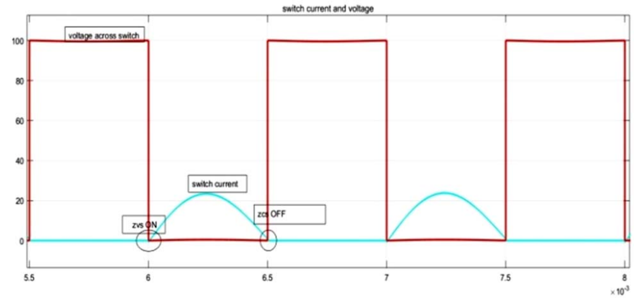

Fig.7. Verification of ZCS

i. ***ON-OFF controller***:

The basic operation of generating the pulses through ON-OFF controller is as shown in Fig.8.

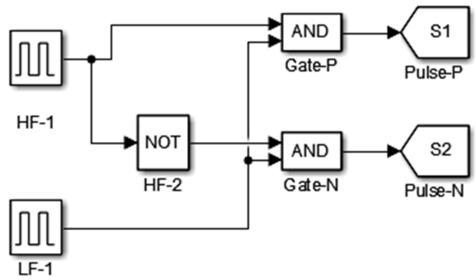

Fig.8. ON-OFF controller

In this controller, one High Frequency (HF) signal of 100kHz is taken which is equal to the resonant frequency. The second HF signal is obtained by using the NOT gate for the first HF signal. Consider Low Frequency (LF) signal of 1kHz frequency. The HF-1 and LF are AND to get the pulses during the positive half cycle and HF-2 and LF areand to generate the pulses during the negative half-cycle. The signals generated are shown in Fig.9.

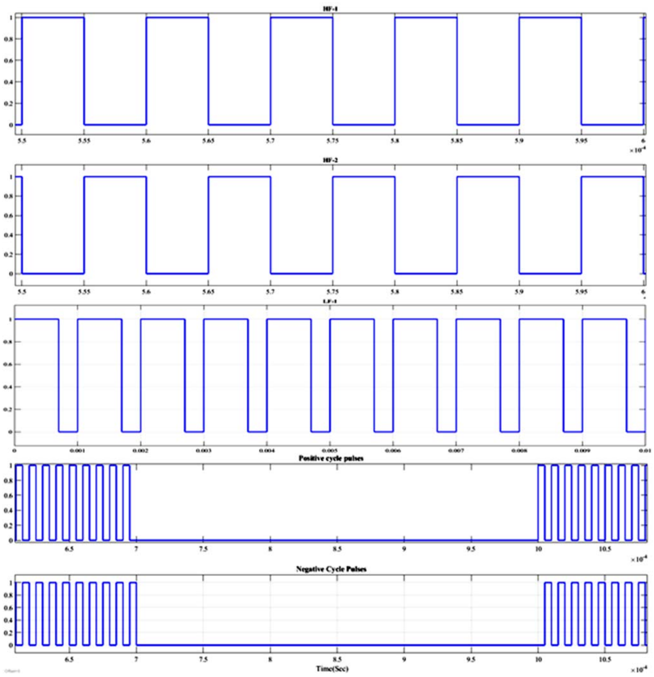

Fig.9. The pulses generation through the ON-OFF controller

The generated pulses are given to the switching devices placed arranged in such a way to fire during the positive and negative half cycles.

The resultant waveforms are as shown in Fig.10. It shows that the ripples are reduced in the source current when all the loads are acting at a time. The waveforms are also showing the results of the source current when one load, two loads, three loads and all loads are switched OFF. As the loads are switching OFF, gradually the ripples in the source current are also increasing and it can be observed clearly in thewaveforms shown in Fig.10. Here also it can be observed that the variation of the ripple is from 3.9A to 7.1A.

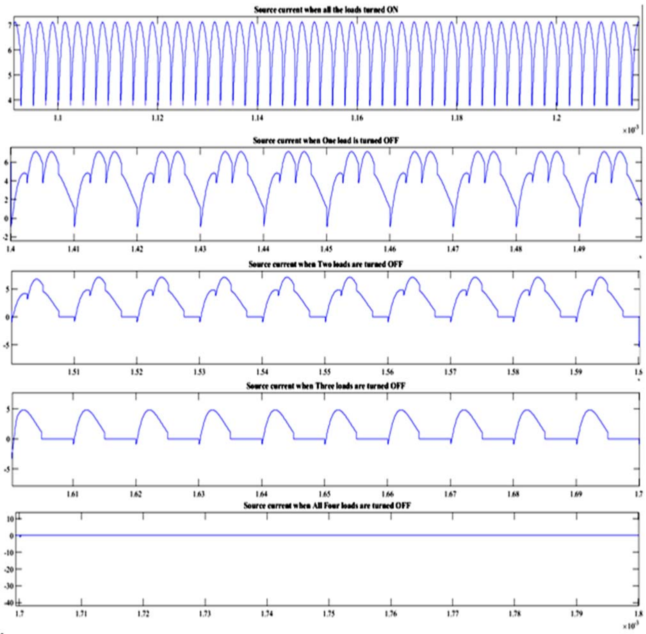

Fig.10. Source current variation with on-off controller

This shows that ON-OFF controller and the method in which phase shift of the switches in the successive legs are done, showing the same reduction of the current ripples in the source current. In ON-OFF controller also the independent operation of the loads is possible. The load variation is more appropriate in this method compared with the phase shiftingmethod.

The variation of the source current with the On-OFF controller is as shown in Fig.11.

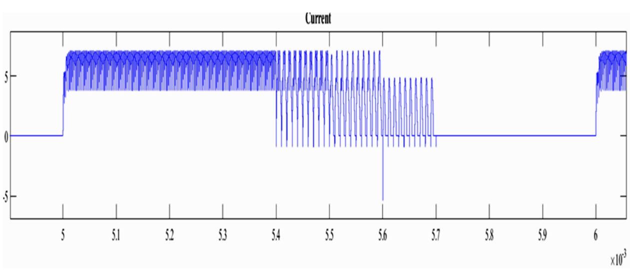

Fig.11. Variation in the source voltage and the source current with on-off controller

The variation of the load current and the load voltagewaveforms are as shown in Fig.12, which shows that the load voltage and load current are in phase with each other.

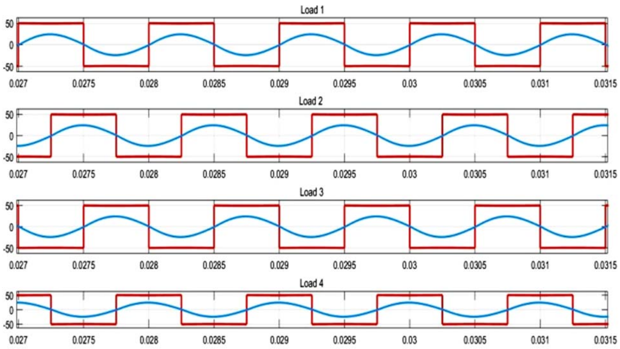

Fig.12. Load current and Load voltage waveforms with on-off controller

IV CONCLUSIONS

An inverter configuration for induction cooking application with multiple loads is proposed. It is powered from PV panels. ON-OFF control is used for independent control of individual loads. Voltage of each load is phase shifted by 90^0 w.r.t the next load. Reduction in the ripple current drawn from the PV panels is achieved. The reduction in ripple current is maximum when all the loads are operated with maximum output power. There is a change in the ripple current magnitude based on the variation of the individual loads. Overall, this gives improvement in the ripple current reduction compared to the operation when all the loads powered in phase. This helps in improving the performance of the PV panels.

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