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An Efficient Resonant Inverter for Induction Heating Using an Auxiliary Switched Capacitor Cell

Aswani.Y.S[1], Mrs.Surumi Hassainar[2]

PG Student [PEPS], Dept. of EEE, FISAT Engineering College, Angamaly, Kerala, India[1]

Assistant Professor [PEPS], Dept. of EEE, FISAT Engineering College, Angamaly, Kerala, India[1]

ABSTRACT: A novel soft-switching high-frequency (HF) resonant (HF-R) inverter for induction heating (IH) applications is presented in this paper. It is a unique topology of voltage-fed high-frequency series load resonant inverter with a lossless snubber capacitor and an auxiliary switched cell for induction heating appliances. The decrease in number of switches compared with the existing topologies is the main highlight of this paper. It demonstrates how high power density can be achieved and how the total harmonic distortion is getting reduced. The essential performances on soft-switching operations are demonstrated in an experiment using 25-kHz HF-R inverter prototype, and then, the topological validity is evaluated from a practical point of view.

KEYWORDS: soft Switching, High Frequency Resonant Inverter

I.INTRODUCTION

Among the various emerging applications of power electronics, induction heating (IH) plays a great role in industry and home applications. IH systems have many positive properties, including cleanliness, carbondioxide less than the fossil burners, safety, high thermal efficiency. The IH is a kind of highly efficient heat conversion system. For the same quantity of heat energy, IH cookers have 84percent efficiency of energy transfer where non induction electrical cookers achieve only 74.2percentage.IH systems simply consist of an inverter and an IH coil and a heating object.AC current flows through the surface of a conductor and home IH systems produce heat based on eddy current and skin effect resistance of the coil and metal pots. High-frequency current moves around the surface of the conductor due to the skin effect, so it is necessary to use litz wire planar-type induction coil for utilizing whole area of the conductor. IH load functions like a transformer in which metallic pot is considered as a single turn. The induction coil and the metallic pot function as the primary and the secondary of a transformer, respectively. The greatest advantages of high- frequency IH appliances are to save energy while serving the same temperature and to take less heat loss. In IH applications, higher switching frequency carries two benefits: reducing the components size, and higher flux density around the surface of the heating objects. Consequently, high frequency reduces the size of the converter at the same power rating. Motivated by these properties, researchers intend to extend its application to various consumer appliances. In particular, domestic IH cooker requires miniaturized, cost effective and efficient power conversion unit.

As a new solution for the technical problem, an innovative soft-switching HF-R inverter is proposed in this paper. In the HF-R inverter proposed herein, ZVS operations can be attained over the wide range of output power variations. Therefore, the soft-switching operations can be maintained even in the low output power conditions, and consequently, the reductions of switching power losses and EMI noises can be reduced effectively for the wide-range output power setting.

In order to promote both high-frequency ac power and homogeneously current following around the surface of the cooking object, a capacitor-clamped switched capacitor circuit topology of load resonant soft-switching inverter is demonstrated in this paper as a modification to the proposed one. The capacitor-clamped inverters are more attractive regarding device losses and cost than the switch and diode-clamped inverters. The new inverter circuit offers a high power density with zero voltage switching (ZVS) operation that is in demand for higher switching frequency, miniaturized inverter and light weight. A design example of the inverter circuit considering the THD value of the output current and its operation principle and implementation are discussed.

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II.SYSTEM MODEL AND OPERATION

The new inverter circuit offers a high power density with zero voltage switching (ZVS) operation that is in demand for higher switching frequency, miniaturized inverter and light weight. A design example of the proposed inverter circuit considering the THD value of the output current and its operation principle and implementation are discussed. Some of the disadvantages of the proposed are overcome in this topology.

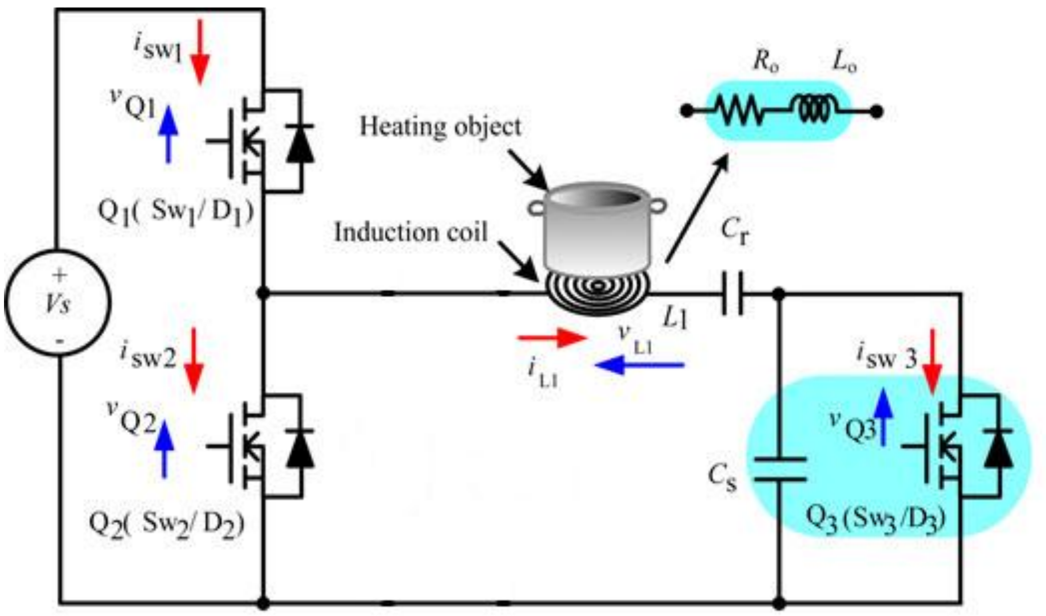

Fig.1 Circuit Topology

Fig.1 shows the basic configuration of the proposed high frequency inverter circuit. The inverter circuit mainly comprises input dc voltage V_s, switches Q_1 (SW_1 / D_1), Q_2 (SW_2/ D_2), IH load (L_0 and R_0), resonant capacitors, and auxiliary switched capacitor cell composed of Q_3 (SW_3/ D_3) and C_s . The switches are Q_1 and Q_2 and the auxiliary switch Q_3 are the reverse conducting type MOSFET. C_r is engaged in series with IH load and creates resonance with L_0 . Switched capacitor C_s is connected in parallel with Q_3 and also creates the resonance and zero voltage soft-switching condition of SW_3. C_1 acts as an edge resonant snubber of $Q_1$and Q_2 and creates the zero voltage soft-switching condition of SW_1, SW_2. L_0 and R_0 are the lumped effective inductance and resistance of the IH coil and load, respectively. The operation of the auxiliary switch cell depends on the main switches.

The gate signals, g_1, g_2, and g_3 sequentially regulate the switches Q_1, Q_2, and Q_3 respectively. All active switches are bidirectional-type MOSFETs. D_1, D_2, and D_3 are the anti parallel body diodes of each switch, and every critical time in a cycle has been pointed out. Operation of this new resonant inverter circuit depends on the auxiliary switched capacitor cell function. For description of the circuit operation, we assume that some energy is stored into C_r. There are three modes of operation.

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III. SIMULATION MODEL

Simulation is done in PSIM. The switches Q_1, Q_2, and Q_3 are fired by the gate pulses g_1, g_2 , and g_3 respectively. Rectangular pulses are given to the switches. Each mode consists of a 90^0 duration of a cycle. So Q_1 conducts for $(0\text{-}180)^0$. Q_2 for $(180\text{-}360)^0$, $Q_3$for $(0\text{-}180)^0$ .So same pulses are given to Q_1 and Q_3 and complementary pulses are given to S2.All the switches conducts for a total of 180^0 and the corresponding duty ratio is 0.5.The pulses are as shown in Fig.2.

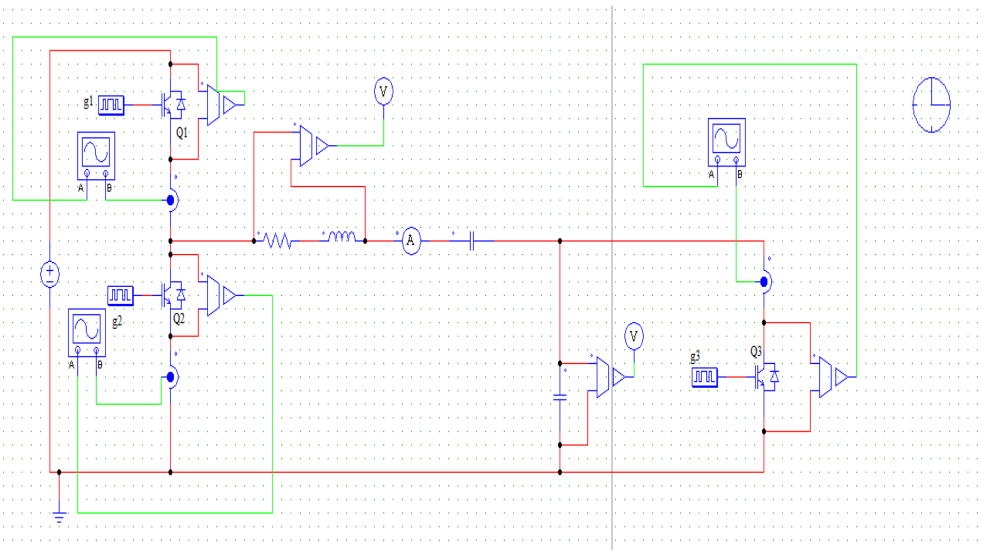

Fig.2 simulation Model

IV. RESULT AND DISCUSSION

Output voltage and current waveforms after simulation are as in fig.4 for the input as in Fig.3. Switching periods of the switches doesn't have current or voltage. So the power loss during switching interval is tremendously reduced. This modified topology as it contains only three switches not only plays an important role in reducing switching losses but reduces the total size and complexity. The total harmonic distortion is less in this topology as compared with the proposed topology. Power density obtained is also more in this topology.

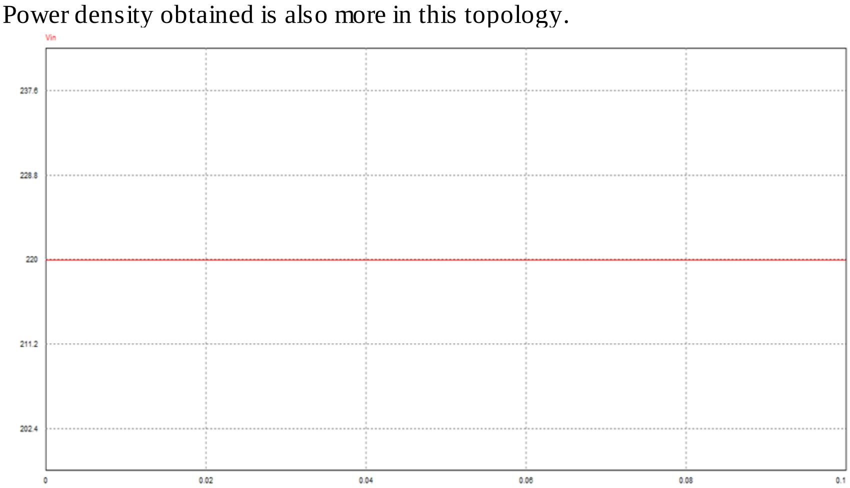

Fig.3.Input voltage applied

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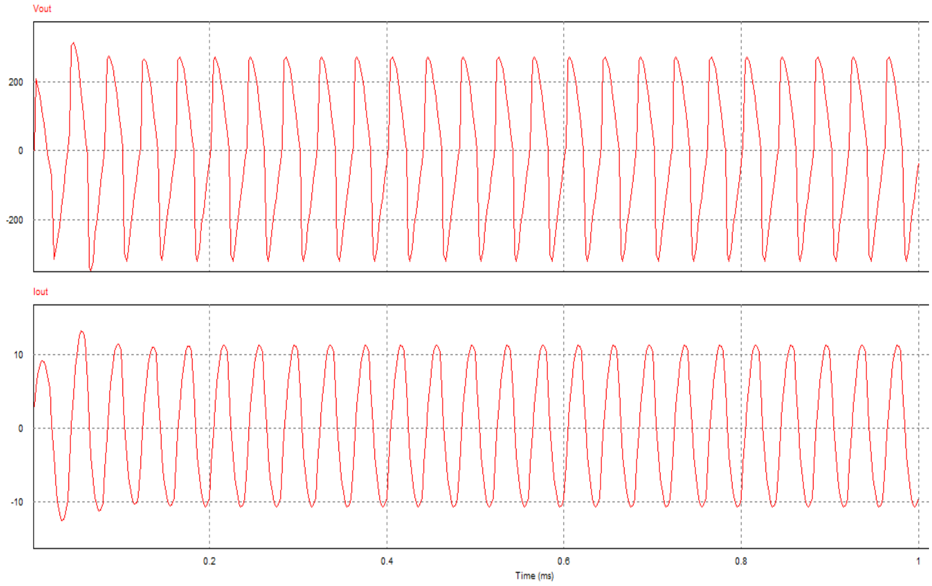

Fig.4.output Voltage and Output Current.

A laboratory prototype of the inverter circuit has been implemented (as shown in fig.5.) and evaluated using the parameters values without any parasitic elements. The gate pulse signals for the active switches are generated using arduino. The pulses are fed to the switches with the use of an optocoupler circuit. Components are selected in such a way that it is feasible to do the experiment in the laboratory. Inductor is designed and wounded as per the data sheet values. Switching frequency f_s =25 kHz is selected. Mosfet switches used in here is IRFZ44. Output waveforms were viewed using a DSO. The obtained waveforms are as in fig.6.

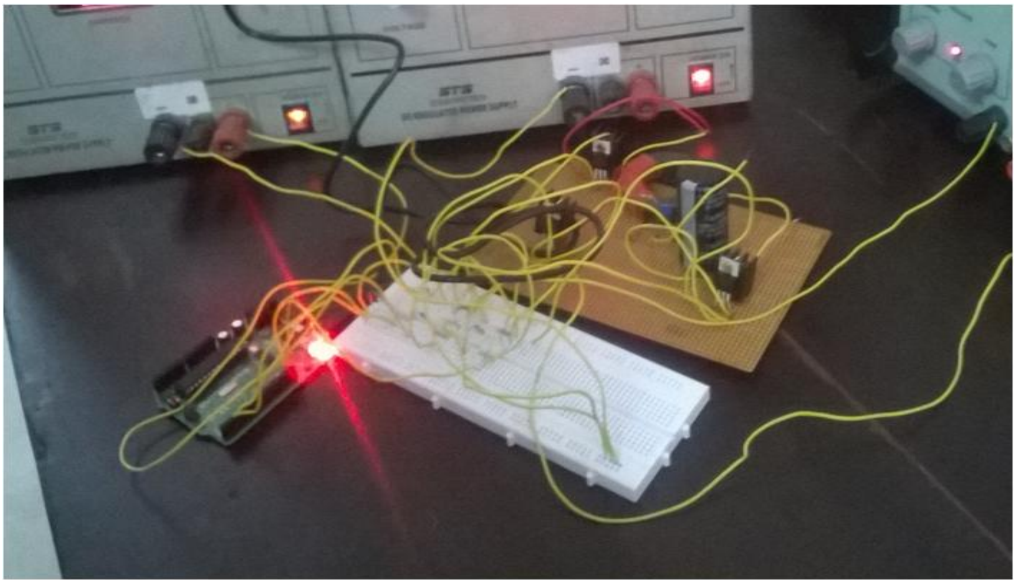

Fig.5. Hardware implementation.

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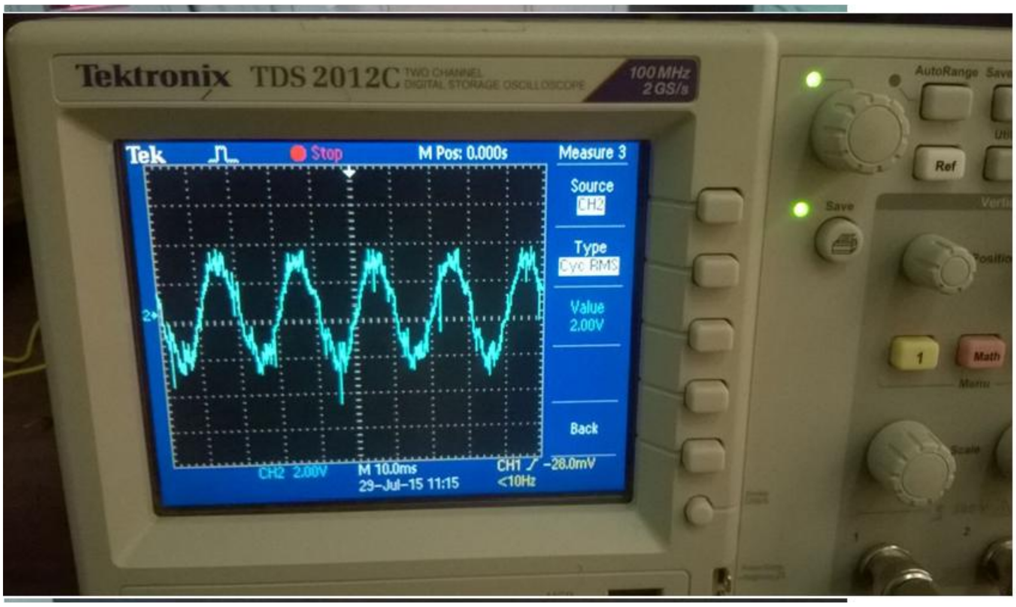

Fig.6. Hardware Output waveforms.

VI.CONCLUSION

In this paper, a novel switched capacitor ZVS-PWM high-frequency resonant inverter circuit is practically introduced as a modification to the existing topology for IH appliances. The greatest advantage of this topology is a high power density capability, which is obtained practically. The topology described is beneficial compared with the previous one. We are able to obtain a perfect soft switching compared with the other topology. It also reduces the losses of the circuit and THD.

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