International Journal of Research
Available at https://edupediapublications.org/journals

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue 13
October 2017

A Low Cost Zero Current Switching AC-AC Resonant Converter for 3-Phase Induction Heating

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ABSTRACT: This paper proposes the concept of three phase ac to ac resonant converter for Induction heating. As compared with basicconverters, ac to ac resonant converter has advantages of less components count, low cost, high reliability and betterefficiency. A closed loop control structure is proposed in this paper for controlling three phase resonant converter.The switch operates in the softcommutation mode and serves as a high frequencygenerator. The output power is controlled via switchingfrequency. A steady state analysis of the converteroperation is presented. The experimental results arecompared with the simulation results.

KEYWORDS:Ac-Ac Resonant Converter, Induction Heating, Zero Current Switching.

I. INTRODUCTION

Every Induction Heating (IH) put on the product is actually developedusing electromagnetic induction that had been first found by Michael Faraday in1831. Electromagnetic inductionrefers to the phenomena by which electric current isproduced in a closed circuit by the fluctuation of the present in an additional circuit placed subsequent to it. Because of it's noncontact, theheating procedure doesn't contaminate the substance actually being heated. Furthermore, it's quite effective because the heat isactually produced inside the workpiece. Besides theUnpleasant electrical accidents are precluded by the absence of any physical contact to heating devices. Inductionheating is working by using a supply of high-frequencyelectricity to operate a big alternating current by way of a work coil. The passage of current through the efforts coilcreates a really rigorous and quickly changing magnetic field in the area within the efforts coil. The workpiece tobe heated is actually positioned within this intensive alternating magnetic field [1], [2].As stated, there's a demand for an electric tool with increased frequency for IH. This's the main issue as thesemiconductor switching devices workingas a switch is hard and used inthedifferent kinds of PWM converters used in a power system.With this mode, a certain current is actually left turned on or perhaps off at a certain amount of voltage which results in actualswitching losses.

The bigger the frequency the much more the switching loss, that obstructs attempts to increase the frequency [2] [4].Higher energy conversion effectiveness at high-frequencyswitching may be received using soft switching techniqueswhich manipulate sometimes the voltage or even existing at the switching instants to be zero. Soft switchingtechniques are subcategorized into 2 primary methods: ZeroVoltage Switching (ZVS) and Zero Current Switching(ZCS) [4]-[6]. Resonant converters are actually used to achieveZCS or ZVS by employing the resonance produced by an LC resonant circuit [1],[3],[4], [seven]. In training, the effort coilis generally incorporated into resonant tank circuit which forms whether series or perhaps parallel resonance tank circuit. The reducedswitching losses of the resonant converter make it appropriate for implementing an effective IH system [2] [4].Converters for induction heating programs are actually found that up to 1.5 MW and turning frequencies up to 150kHz using IGBTs. For exclusive functions, it's appealing toimprove the frequency up to 500 kHz. This extremely highswitching frequency can easily be attained by using MOSFETs.

Direct ac–ac conversion is intended to reduce componentredundancy by using a single-stage converter.This leads not only to component and cost reduction but also toa potential improvement of efficiency and reliability. Severalapproaches have been proposed in the past. The first familyof direct ac–ac converters proposes the use of four quadrantswitches, formed by the combination of simple switches, typically insulated gate bipolar transistors (IGBTs), MOSFETs,and diodes [20]–[22]. These proposals lead to reliable andstraightforward implementations. However, the main drawbacks of these solutions are the increased number of switchesand control complexity that can compromise the convertercost and efficiency, which are two of the primary targets ofthis work. A second family of proposals has advantages ofcomponent redundancy to regroup or remove common elementswithout additional complexity.

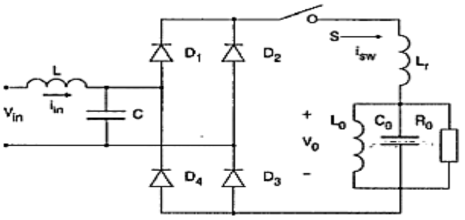
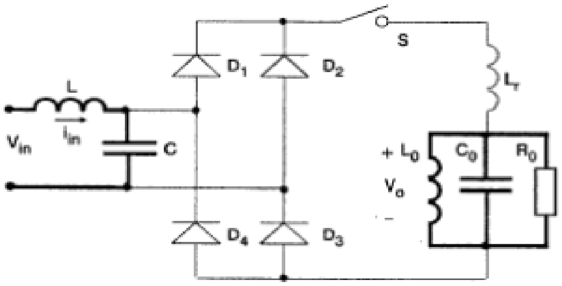


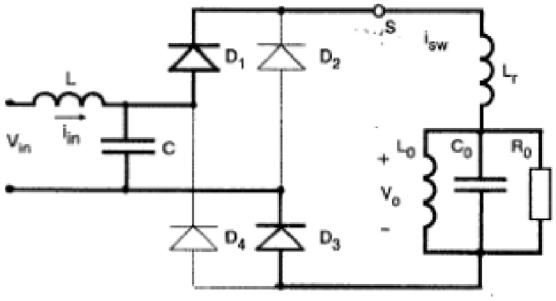
Fig.1. Single switch AC-AC converter

Nevertheless, it's a really expensive method because of the largesilicon area of MOSFETs and problems with the internal diode of the MOSFET. To reduce the costs for IHconverters, the modular IGBT grounded converter process, shown in Fig.1, is actually suggested. The modules can beconnected sometimes to boost the rated power or maybe the powerl frequency that is the problem of this paper. The outputfrequency is improved with the technique of shifted gateheartbeat while the switching frequency of every module continues to be regular [8].

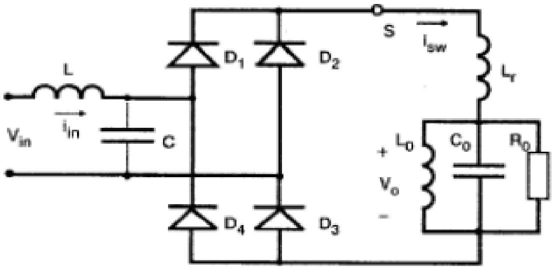
The operating principles of the circuitare illustrated by Fig.2 .



a Mode I (to-t1)



b. Mode II (t1-t2)



c. Mode III (t2-t3)

Fig. 2. Equivalent Circuits

The theoretical waveforms are shown in Fig.3.Wesuppose the switching frequency is much higher thanthe input line frequency and in the analysis wearbitrarily chose the time interval where $v_{in}>0$.

Interval 1: t0<t<t1: The equivalent circuit is shown in Fig.2a. Fourdiodes D1-D4 and the switch S are off. In this intervalthe capacitor C charges up practically linearly at a rateand a polarity corresponding to the instantaneous inputvoltage v_{in}.

Interval 2: t1<t<t2: The equivalent circuit is shown in Fig.2b. Twodiodes D1, D3 and the switch S are on. In this intervalthe capacitor C discharges via the circuit C-D1-S-Lrload-D3. This interval ends when the capacitor voltagereduces to zero.

Interval 3: t2<t<t3: The equivalent circuit is shown in Fig.2c. All thediodes and the switch S are on. In this interval thecurrent flows through switch S via two parallel bridgebranches. This interval ends when the switch currentdecreases to zero. At this moment the switch turns offand the process starts from the beginning.

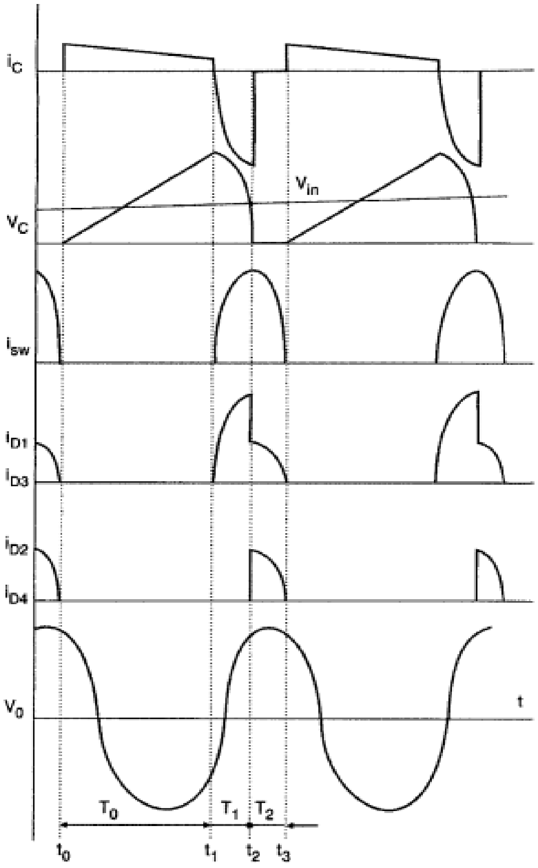


Fig.3. Ideal Switching Waveforms

II. PROPOSED CONVERTER FOR3-PHASE INDUCTION HEATING

Te proposed converter in this paper which directlyconverts single phase AC to three phase AC rather thanRectifying (AC to DC) and inversion (DC to AC) like inconventional voltage source PWM converters.Figure 4 shows the confgurable circuit for resonantswitching converter. The major components used forthis converter are small scale input flters, which is acombination of inductors and capacitors, and six bi-directional switches for inverting operation and also PWMcontroller consists of a gate drive ircuit for controllingthree phase inverter. In present scenario the applicationsof this AC to AC conversion are increased for providingan efcient and better solution with negligible energystorage elements.

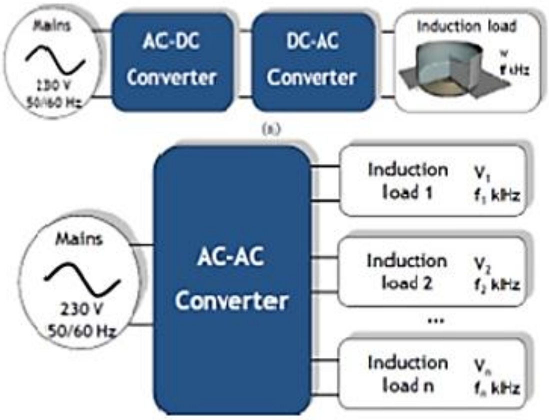


Figure3. Proposed AC-AC converter

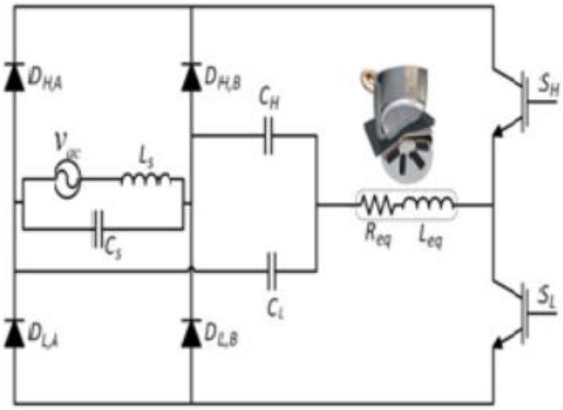


Figure 4. Direct AC–AC converter

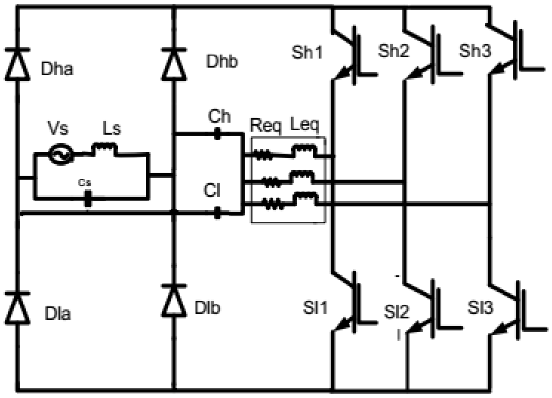


Figure 5. Tree phase ac to ac converter for induction heating.

Closed Loop Control Scheme:

The closed loop control diagram based pulse widthmodulation technique is proposed for this high frequencyinverter. Te output voltage and current reference components obtained from parks transformation techniqueis used for this control diagram. A conventional PI controller is utilized for controlling error signals. Since thecontrollers produce the reference voltage the control diagram for this resonant converter is shown in Figure 6.

$$V_d^* = \frac{(PI_d - QI_q)}{(I_d^2 + I_Q^2)}$$
$$V_q^* = \frac{(PI_d + QI_q)}{(I_d^2 + I_Q^2)}$$

Initially three phase output voltage and currents areconverts into two phase dqo using park's Transformation.From these currents calculating equations V_d* and V_q*.Tese are compared with V_d and V_q an error occurs. $T_e$obtained error is modifed using PI controller.

III. SIMULATION AND RESULTS

The AC to AC converter fed induction heater issimulated using the matlabsimulink and the results arepresented here. The circuit model of the AC-ACconverter is shown in Fig.6a.. Scopes are connected tomeasure output voltage, driving pulses and capacitorvoltage.

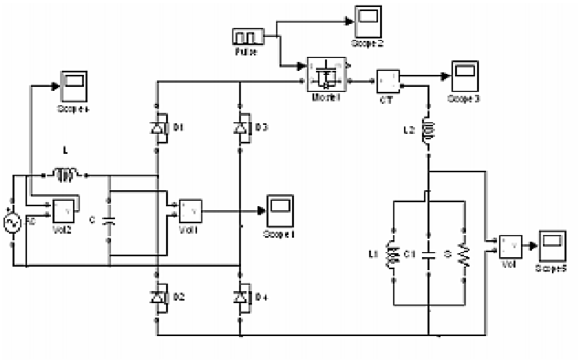


Fig.6a. simulation Circuit

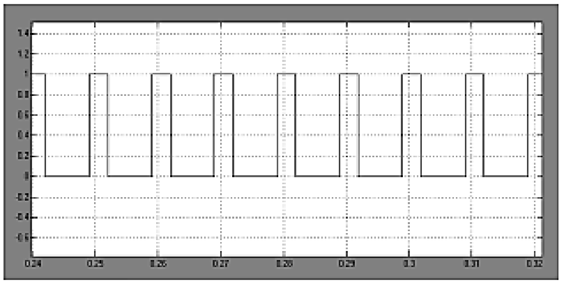


Fig.6b. Driving pulses

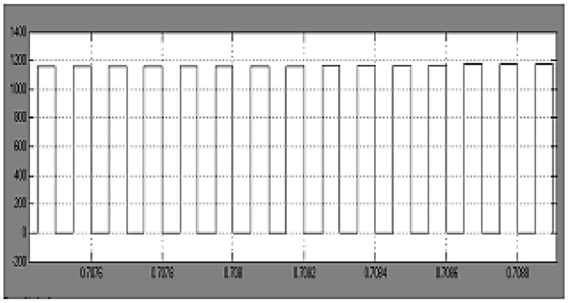


Fig.6c. Voltage across Switch 'S' (Vds)

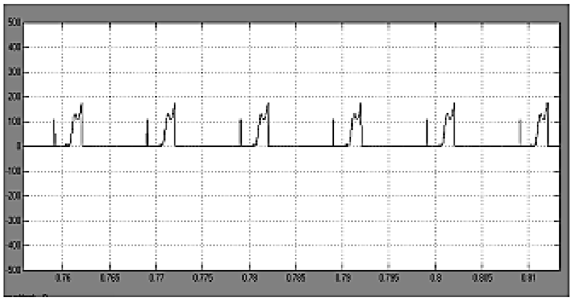


Fig.6d. Current through Switch 'S'

Switching pulses are shown in Fig 6b.Voltage andcurrent waveforms of the switch are shown in Fig.6c &Fig 6d respectively. Output of converter is shown infig. 6.e.

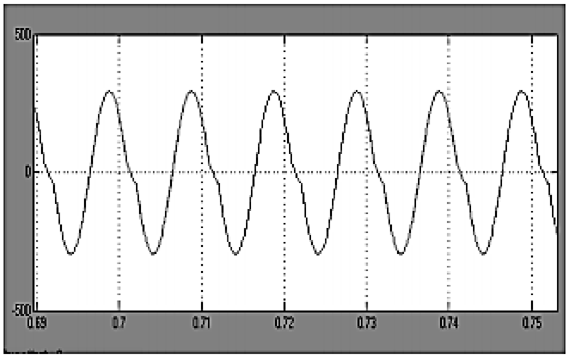


Fig. 6e. Output voltage

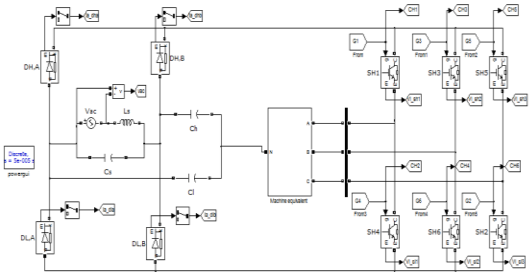


Fig.7.closed loop control scheme

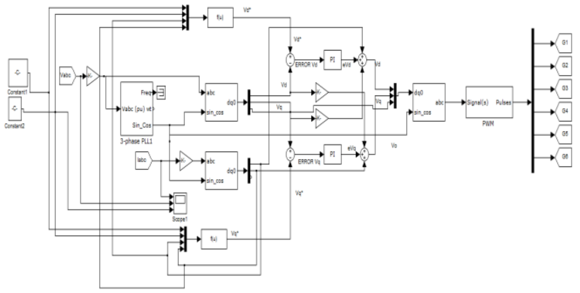


Fig.8. simulation of 3phase ac Converter for IH

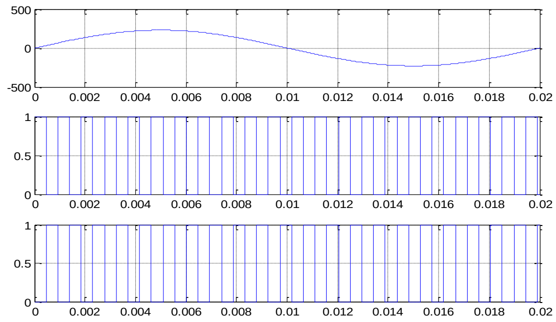


Fig 9. pulse generation for switches

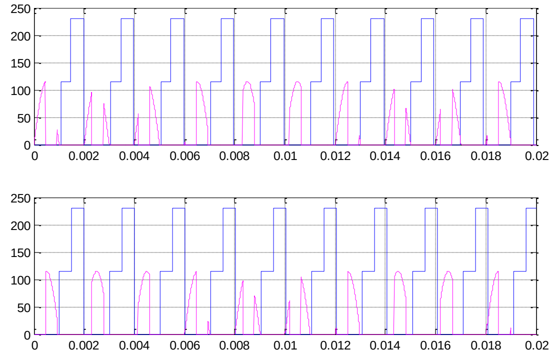


Fig 10. output voltage & current of the switches.

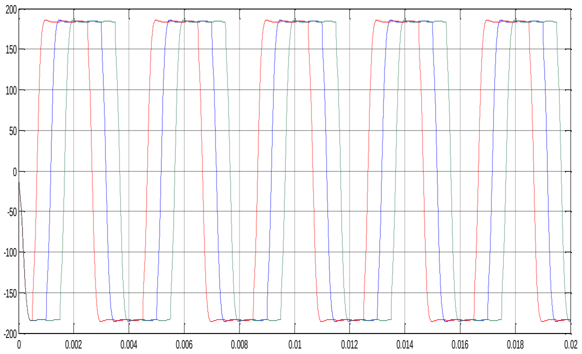


Fig 11.Three phase output voltage across the load.

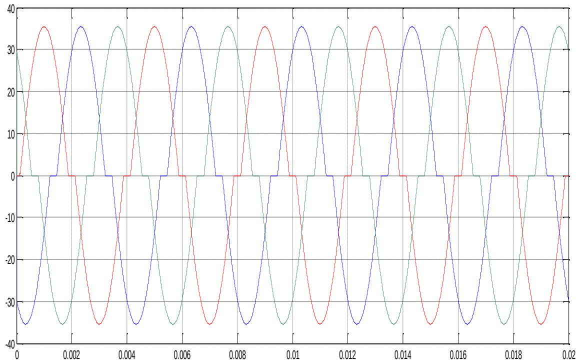


Fig 12. three phase output current through load

IV. CONCLUSION

With this paper, a direct ac ac converter has been recommended for a domestic IH program. The primary advantages of the proposedconverter are the decreased number of pieces and improved effectiveness. Additionally, linear output power management is actually achieved,lowering the control complexity. This switch works in a softcommutation mode. The converter offers a wide range power control. This converter has advantageslike decreased hardware, decreased stresses, and high energy density. Experimental results and the simulation demonstrate the real converter ability to manage the heat.

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