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A Three Phase AC-AC ZCS Resonant Converter for Induction Heating

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ABSTRACT

Generally, domestic induction-heating technology requires a high output power levels with less number of components in a compact size. To satisfy these requirements, the basic circuit configurations are considered based on the combination of a rectifier and a inverter. The main disadvantage of this method has low-efficient and economic problems. This paper proposes a new concept unlike previous method, i.e the direct conversion of ac–ac converter for reducing the component count, reduce cost, improve reliability, and also efficiency. Generally, the proposed converter is a voltage-source based series-resonant converter used for controlling output power, and minimizing the control complexity. This paper also proposes a concept of AC-AC converter based three phase Induction Heating applications.

KEYWORDS: *AC-AC Converter, Zero Current Switching, Resonant Converter, Induction heating*

I. INTRODUCTION

Generally, the term Induction heating is the process of heating an object by electromagnetic induction. The component used for induction heater are an electromagnet, a high-frequency alternating current is passed through it. Due to magnetic hysteresis losses present in the materials and have sufficient permeability also causes for generating heat.

For domestic and other classifications of induction heating at low and medium power appliances (such as military canteens, machine building and other industries) uses generally static frequency converters. The basic converter, which is used for controlling Induction Heating (AC-AC) is two stage conversion process i.e. first one is rectifier for converting AC-DC and second converter is a high frequency inverter which is used for converting DC-AC at constant/variable frequency.

The inverter used in above process is a two leg, four switch circuit. And the control design constructed for this inverter is an open loop, so it is difficult to control the output. And this type of two stage conversion converter is more economical at low efficiency

Direct ac–ac conversion is intended to reduce component redundancy by using a single-stage converter as shown in figure 1. This leads not only to component and cost reduction but also to a potential improvement of efficiency and reliability. Several approaches have been proposed in the past. The first family of direct ac–ac converters proposes the use of four quadrant switches, formed by the combination of simple switches. These proposals lead to reliable and straightforward implementations. However, the main drawbacks of these solutions are the increased number of switches and control complexity that can compromise the converter cost and efficiency, which are two of the primary targets of this work. A second family of proposals has advantages of component redundancy to regroup or remove common elements without additional complexity.

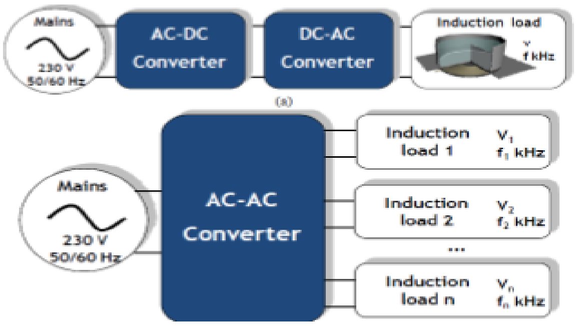

Fig: 1 Proposed AC-AC Converter

Resonant power converters are constructed with combination of L-C resonant elements, who's its output is changes periodically. So, the variations in magnitude are occurred in these waveforms. So, for eliminating these variations a small scale converter is not suitable.

Classifications of resonant converters are as follows:

- Ac-Ac resonant converters
- Rectifying-Inversion Process.

The main advantage of this type of resonant converters are, low switching losses and the concept like turn-on and turn-off switching transitions for semiconductor devise can occur also due to zero voltage and zero current switching techniques in resonant tank voltage and current waveforms.

II. AC-AC CONVERTER

Generally, the direct AC-AC converter employs a high frequency switching devices for reducing switching losses thereby improving system efficiency. For regulating the output these type of AC-AC resonant converters require a variable frequency control.

The Schematic diagram for proposed power converter (as shown in fig 1) is designed to include the rectifier within the inverter stage, eliminating therefore the component redundancy and switch count when compared with classical direct ac–ac solutions as in fig 2. In addition to this, the proposed converter optimizes the switching conditions.

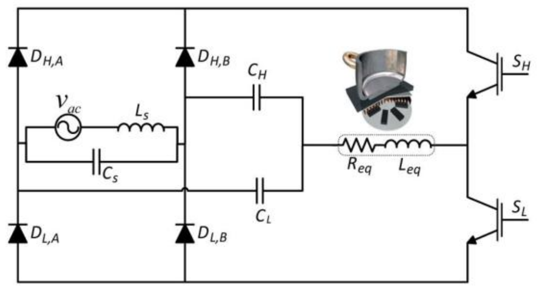

Fig 2: Proposed direct ac–ac converter

The power converter operation modes depend on the mains voltage sign. Six different configuration states. States I to III correspond to positive mains voltage, whereas states IV to VI correspond to negative mains voltage.

In present scenario the application of these ac to ac conversion are increased for providing an efficient and better solution with negligible energy storage elements. Also, the Matrix type converters have been applied to resonant loads under 3-phase induction heating appliances. This proposed resonant converter have some positive points such as high power factor, less harmonic distortion, due to this it have high power density, and it is economical because of less number of switching devices. This paper proposes the circuit configuration for resonant ac-ac converter with ten switching devices for converting single phase ac to three phase conversion.

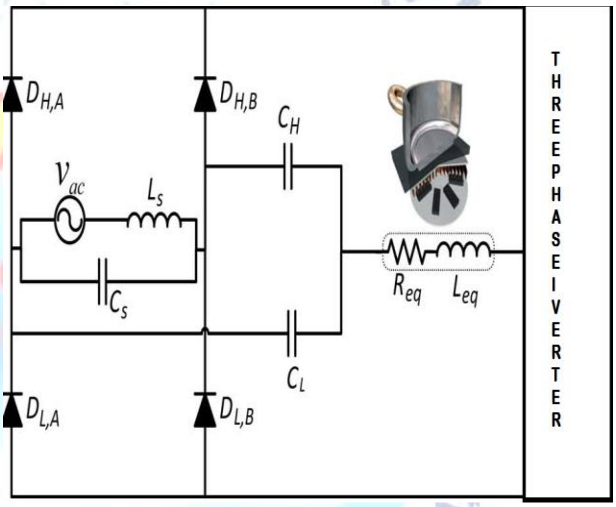

Fig 3: Three Phase Resonant Inverter for Induction Heating

The switching converter proposed in this paper directly converts single phase AC to three phase AC rather than Rectifying (AC to DC) and inversion (DC to AC) like in conventional voltage source PWM converters. Then figure 3 shows the configurable circuit for resonant switching converter. The proposed converter have the following major components such as, small scale input filters, which is a combination of inductors and capacitors, and 6 bi-directional switches for inverting operation. And PWM based voltage source converter consists of a power Drive circuit which is a combination of input rectifier which is used for converting AC-DC, at intermediate part a smoothing capacitive circuit, and IGBTs for inverting operation at output side.

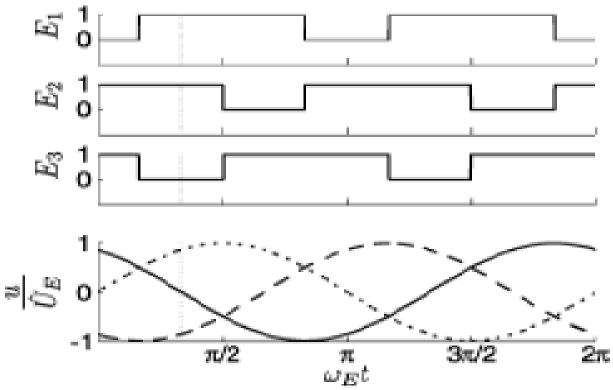

Fig 4: Switching Pattern

III. Closed Loop Control Circuit

The control signals for controlling the high frequency inverter is obtained by the method of pulse width modulation. The reference signal for this modulation technique is obtained by using output voltage and currents comparison. And also this paper discuss about parks transformation which is used for transforming three phase coordinates to two phase coordinates i.e. direct and indirect quantities. Two proportional integral controllers are used to regulate the current errors. Since the controllers produce the reference voltage commands. The control diagram for this resonant converter is shown in figure 4.

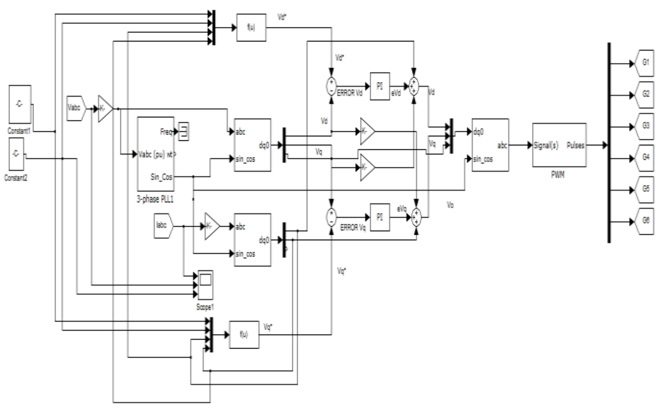

Fig 5: Control Diagram for Three Phase Inverter

IV. Experimental Discussion

The proposed three phase type resonant AC-AC configuration have been successfully simulated and verified the output waveforms through Matlab/Simulink. The controlling circuit for this inversion stage is implemented in closed loop form and also shown in this Simulink. The Experimental diagram and results are shown below.

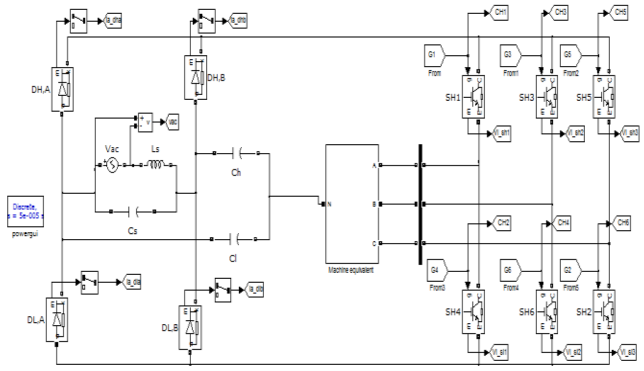

Fig 6: Simulation Diagram for Three Phase Resonant Converter.

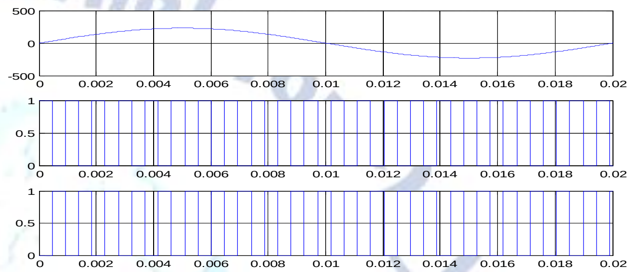

Fig 7. Pulse generation for switches

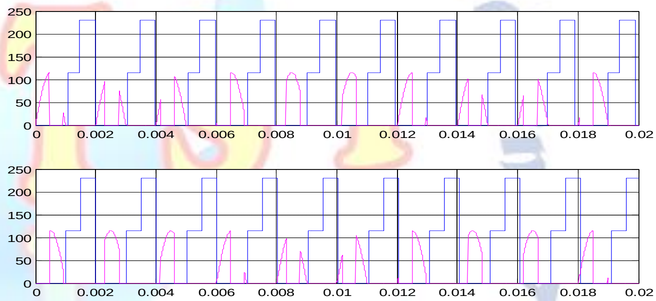

Fig 8: output voltage & current of the switches.

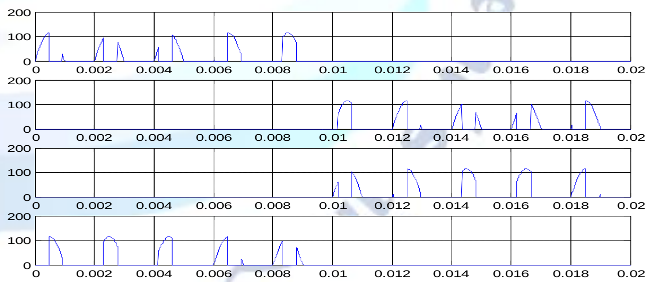

Fig 9: currents flowing through the four diodes

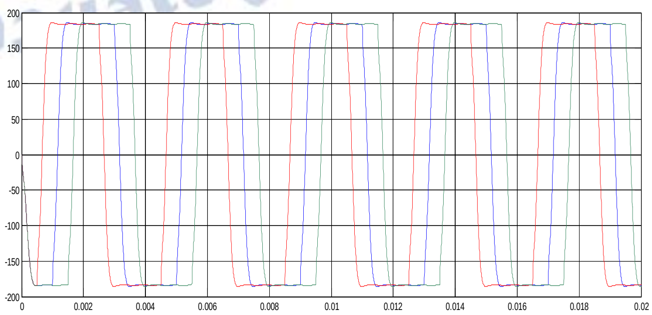

Fig 10. Three phase output voltage across the load.

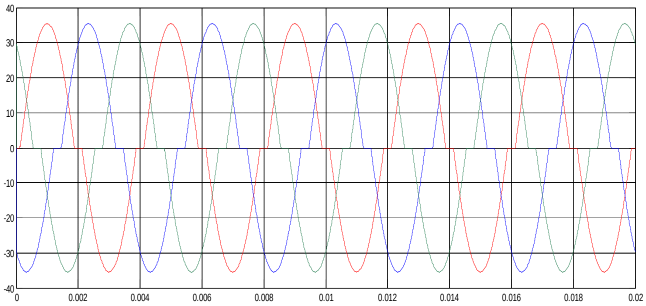

Fig 11: three phase output current through load

V. Conclusion

Direct ac-ac conversion has proved that it is an efficient technique and also can be extended version to basic inverters which is present used in most household appliances. The proposed converter have combine features of higher power density with a reduced number of conversion stages and energy-storage elements. In this paper, a three phase application for induction heating based matrix converter has been proposed. The control strategy used in this paper for maintaining a direct commutations between the base main states and the normal main states. The results are shown for three phase and from this experimental setup we proves that these converters have low switching losses and have high efficiency as compared to conventional two stage conversion converters.

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