A Review on Solar Based Induction Cooker using Different Topologies

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Abstract— Nowadays Induction heating applications are quickly gaining popularity. Induction Heating technology not only offers the advantage of having a better efficiency conversion compared to the other standard technologies, but also offers safety, cleanliness, and compact size, high reliability, low running cost and non-acoustic noise. Induction cooking system utilizes electricity for the generation of heat, in this study solar energy is used as a source of power for the induction heating. Combining solar energy with induction heating technique is the efficient solution for the induction heating and cooking application. This paper reviews a solar based DC induction heating and cooking using different topologies like voltage source inverters of full bridge series resonant inverter, half bridge series resonant inverter, and quasi resonant topology and the resonant converter topology. This study has established a baseline for further research in the area of solar based induction heating and cooking.

Keywords— solar energy, topologies, converter, induction heating, efficient.

I. INTRODUCTION

The continuous exhaustion of conventional energy sources and their environmental impacts have created an interest in choosing renewable energy sources such as solar-photovoltaic, solar-thermal, and wind energy, producer gas and biomass sources to power induction heating system [1]. The need for the optimum utilization of water and energy resources has become a vital issue during the last decade, and it will become more essential in the future. The availability of renewable energy sources such as solar photovoltaic, solar thermal, wind, biomass and various hybrid forms of energy sources provides good solutions for energy related problems in India [2].

To meet the energy demands and reduce the environmental impact, the idea of integrating renewable energy sources such as solar photovoltaic, solar thermal, wind, and biomass and hybrid forms of energy with induction heating has been proposed by many researchers around the world. Solar energy is a good and clean source of energy, which can help the world in experiencing the dirty and short of non-renewable resources, such as coal, etc. In case of rural area, cooking is heavily dependent on inefficient biomass based cooking. The main problems include the time that is needed to collect the firewood and other biomass by the people, indoor air pollution induced health hazards and various other environmental concerns [3].

Cooking using electricity is one of the most clean and efficient method of cooking as compared to biomass and other method of cooking [4]. At present only few people in the urban area use solar PV technology for cooking purposes. In their system, solar charged battery in used in conjunction with inverter to run induction cooker. The solar powered induction cooking is technically feasible but the use of inverter has reduced efficiency. Therefore, there is a need to explore the possibility of induction cooking using solar powered DC battery. The DC system not only increases efficiency but also eliminates large and costly inverter that is required for cooking purpose using existing AC induction cooker [5].

Induction heating is widely used nowadays in domestic appliances because of it cleanness, high efficiency, safety, low cost advanced power semiconductors and high performance [6]. Induction heating is commonly used in industries for melting, hardening and brazing [7]. High efficiency comes with the idea that all the magnetic field created between the coil and the pan is at least 80% transferred to the coil [8]. The cooker presents the quick warming energy saving with high speed cooking with many temperature ranges [9].

Domestic and commercial cookers work in the same principle and the performance is identical. Induction heating is the process of heating electrically ferromagnetic (conductive) materials by a process called electromagnetic induction. One of the many applications of induction heating is cooking. Induction cooking is derived from the principle of magnetic induction by inducing eddy currents in the coil that get excited in the ferromagnetic material to cause heating [8].

A number of converter topologies exist for efficiently producing the time varying magnetic field needed for induction heating. In this paper, working principles of induction heater / cooker has been discussed. Moreover reviews a solar electricity based DC induction cooker using different topologies like resonant converter and the voltage source inverters of full bridge series resonant inverter, half bridge series resonant inverter, and quasi resonant topology.

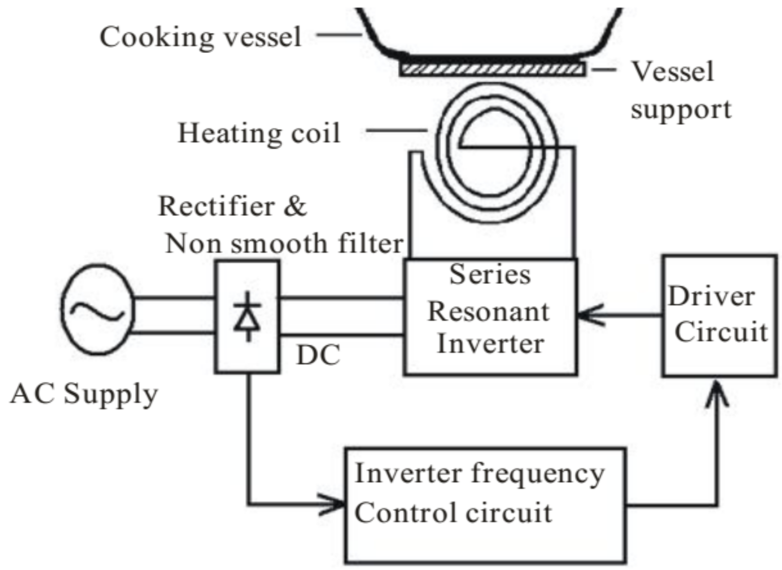

Fig.1. Basic circuit of a domestic purpose induction cooker

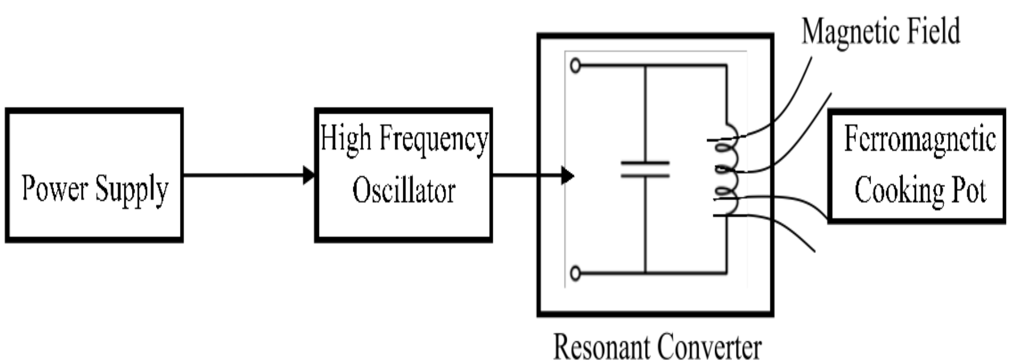

Fig.2. Basic circuit of a solar powered induction cooker

II. WORKING PRINCIPLE OF INDUCTION COOKER

A. Conventional Induction Cooker

The basic circuit of a domestic purpose induction cooker is shown in Fig.1. In an induction cooker, initially an AC supply of 50 Hz is applied. It is then rectified to DC and subsequently back to a high frequency AC source through an inverter. This high frequency current produces a high frequency alternating magnetic field through an induction coil. Therefore, placing a cooking pan / utensil close to the induction coil will induce eddy current in the pan. As a result of which, heat energy will be produced on the surface of the pan. The internal resistance of the pan causes heat to be dissipated according to Joules effect. Thus, it is the pan itself and not the heater that heats up and cooks the food.

Basic Requirement of an Induction Cooker

(i). Switching in the radio-frequency range
(ii). Power factor close to unity
(iii). Wide power range
(iv). Reliability

B. Solar power induction cooker

The basic circuit of a solar powered induction cooker is shown in Fig. 2. In an induction cooker, initially the supply from the solar panel is controlled using a controller. It can be directly used in an induction cooker or can be stored in a battery in the form of DC for a later purpose. Then it was converted to a high frequency AC source through an inverter. This high frequency current produces a high frequency alternating magnetic field through an induction coil. Therefore, placing a cooking pan close to the induction coil will induce eddy current in the pan. As a result of which, heat energy will be produced on the surface of the pan. The internal resistance of the pan causes heat to be dissipated. Thus, it is the pan itself and not the heater that heats up and cooks the food.

C. Advantages of induction cooker:

- Only radiation that comes from an induction cooker is heat radiation,
- The coil stays cool, and is therefore safer,
- Higher efficiency, i.e. lower electricity bills,
- Constant output power,
- Absence of shock hazard in the cooking pan,
- Flexible temperature control,
- Cheaper than readily available microwave-oven,
- Common kitchen-purpose steel utensils are sufficient for cooking.

D. Disadvantages of induction cooker:

- Costlier than common electric hot plate,
- Only heating vessels with high resistivity and relative permeability can be used.

III. TOPOLOGIES OF INDUCTION COOKING

A number of converter topologies exist for efficiently producing the time varying magnetic field needed for induction heating. Two topologies are of particular interest in the field of induction cooking: series resonant converters and series quasi-resonant converters.

The series resonant converter consists of a series resonant tank. This tank is fed by a voltage fed bridge, switching at the resonant frequency of the tank. By driving the tank at its resonant frequency, large resonant currents are induced, which in turn are responsible for heating the cookware. Additionally, the power devices are inherently soft switched with this control mechanism. The driving bridge can either be a half bridge with two power devices (as shown in Figure 1-2) or full bridge with four devices.

The series quasi-resonant converter also uses a resonant tank, but just a single power device. The device is turned on and the tank is allowed to resonate for one half cycle. At the zero crossing, the device is switched off. This alternate method also guarantees soft switching, but the controller must now pulse the power device to achieve heating.

A. Series Resonant Converter

The series resonant converter is nothing but a voltage fed bridge converter. According to number of switching devices, Voltage source Inverter topologies used in Induction Heating are half-bridge, full bridge voltage source inverters. Basic voltage source inverter categorized into half bridge & full Bridge voltage source Inverter.

(I). Full Bridge Voltage Source Inverter

The full bridge topology is shown in fig.3. which consists of four switches with load. The induction heating load consists of a metallic pan and the induction heating working coil is represented by the equivalent effective resistance R0 and equivalent effective inductance L0. The resonant and Power factor correction tuned capacitor C0 is connected in series with the induction heating load. The full-bridge topology can offer the higher output power (up to 5 kW) and control flexibility, and its efficiency can be significantly optimized through the proper control strategy. However, its higher cost makes it unfeasible for the mean induction heating appliance [10]

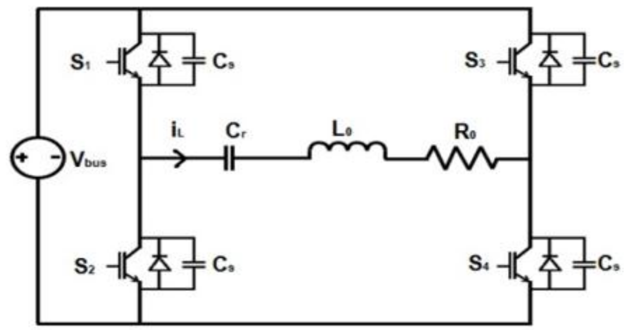

Fig.3 Full Bridge Voltage Source Inverter

(II). Half Bridge Series Resonant Voltage Source Inverter

The half-bridge series resonant inverter (Fig. 4) is the most used topology. The half bridge circuit is designed to convert the direct current from PV to alternating current. The advantage of using half bridge is that the high frequency harmonics can be utilized to produce heat in the coil. The half bridge circuit is designed using two IGBTs to convert DC into AC. An 115VDC source is fed to the two IGBTs which is converted to an alternating current by sending opposite PWM signals to the switches. The amount of voltage created on the coil depends on the switching frequency and the pot material used. The power ranges from 200W to 1200W. L1 and R1 represent the cooker coil and the pot respectively. Voltage and frequency is controlled by pulse width modulation by changing duty ratio. The inverter makes it easier in the flexible range of frequencies. The frequency ranges from 10 KHz to 65 KHz for all different power levels [11]. The resonant tank consists of the induction coil, the pan, and the resonance capacitor (C0). Induction-coil and-pan coupling is modeled as a series connection of an

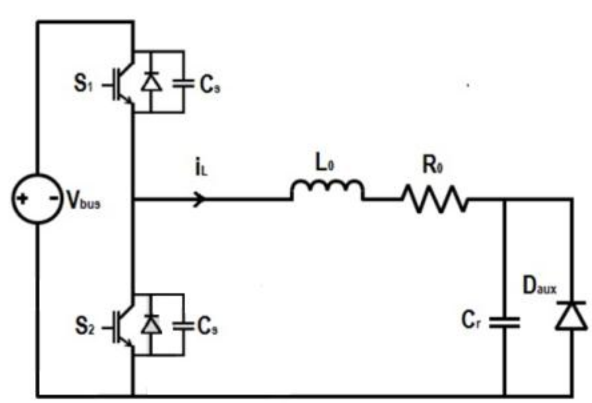

Fig.4. Half Bridge Series Resonant ZVS Inverter

inductor and a resistor, based on the analogy of a transformer and it is defined by the values of L0 and R0. These values change mainly with pan material, temperature, excitation frequency ω, and inductor–pan coupling. This implies a wide operation range, where a ZVS condition must be fulfilled to ensure high efficiency. It is used to design converters with up to 3.5-kW output power. VFDC(voltage frequency drive control) control for half bridge topology improve efficiency in whole power range & achieving power loss reduction higher than 25 % for typical domestic induction heating [12], [13].

B. Quasi resonant topology

Quasi resonant converters are widely used in induction cooker for implementing power converters. The quasi resonant topology for induction heating is shown in fig.5. The quasi resonant circuit is designed using one IGBT to convert DC into AC. Such converters are quite attractive for domestic induction heating because it requires only one switch, usually an IGBT, and only one resonant capacitor. The frequency ranges from 25 KHz to 30 KHz for all the different power levels. Voltage and frequency is controlled by pulse width modulation by changing duty ratio. The resonant tank consists of the induction coil, the pan and the resonance capacitor.

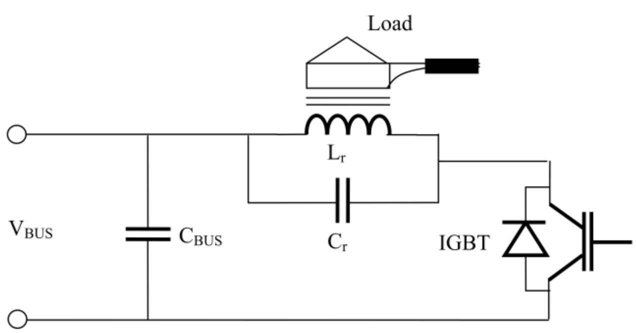

Fig.5 Quasi Resonant Topology for Induction Heating

The resonant converter is the heart of the entire induction cooker. The geometry and inductance of the resonant coil and the value of resonant capacitor has prominent effect on the performance of the entire system operation

IV. DISCUSION

In this paper the topologies which is used in the induction heating and induction cooking application was discussed. The construction of the topologies and the working is presented. The full-bridge topology is commonly used for output powers higher than 5 kW, and it is the standard choice for industrial systems. However, its higher cost makes it unfeasible for the mean induction heating appliance.

The half bridge series resonant topology is efficient technique for the control of the temperature and for the solar charge control of the battery. Comparing conventional solar heating system with solar induction system using half bridge series resonant converter has various advantages such as performance in terms of time. It is used for the output powers in the range of 3.5 kW. The solar powered induction cooking System using half bridge series resonance topology has the efficiency of 80 % efficiency. Conventional solar heating system has only 50% efficiency.

Comparing both the full bridge and half bridge series resonant converter the solar powered induction cooking using quasi resonant converter has the maximum efficiency of 91.46%. The average efficiency of the existing AC based induction cooker from the simulation has been found to be 87%. It is in close agreement with the experimentally measured efficiency (85.56%). Solar powered induction cooking using quasi resonant topology runs on the input power in the range 46.4 W to 1500 W drawing current in the range 1.93A to 62.5 A and the output power is in the range 40.8 W to 1310 W.

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