



## Design of a Half –Bridge AC–AC Series Resonant Converter for Domestic Application

K. Prabu and A.Ruby Meena

Department of EEE Government College of Engineering Salem, India

### ARTICLE INFO

#### Article history:

Article Received: 12 January 2015

Revised: 1 May 2015

Accepted: 8 May 2015

#### Keywords:

inverter, induction heating, resonant converter, AC-AC converter.

### ABSTRACT

This paper explains the analysis and design of a new AC–AC resonant converter applied to domestic induction heating. The conventional circuit of an induction heating typically have a rectifier controller, and a frequency controlled current or voltage source inverter. It is a known fact that the input rectifier does not have a sinusoidal input current. The working is based on hard switching and only single output frequency. In this case, output voltage is very small so that the current flowing through the inductor is very high. And the inductor current affects the efficiency of the system. In order to overcome the limitations of the conventional circuit, a new AC-AC resonant converter is proposed. The proposed converter is based on the series resonant half-bridge topology, and it used two diodes only. The converter operates with zero-voltage switching conditions in both turn-on and turn-off transitions. As a consequence, the efficiency can be increased, and the number of a switching device is reduced and also multiple output frequency can be obtained. The proposed AC/AC converter topology and their design are investigated by using MATLAB/ Simulink.

© 2015 AENSI Publisher All rights reserved.

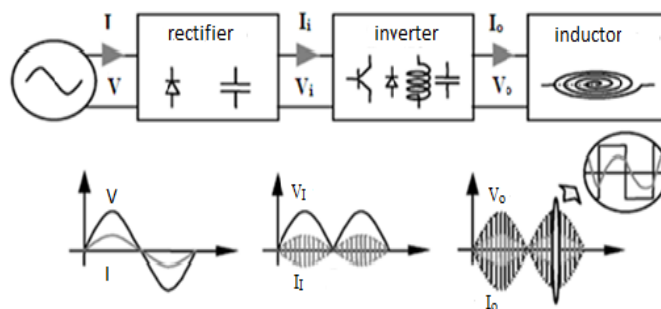
**To Cite This Article:** K. Prabu and A.Ruby Meena, Design of a Half –Bridge AC–AC Series Resonant Converter for Domestic Application. *Aust. J. Basic & Appl. Sci.*, 9(21): 160-165, 2015

### INTRODUCTION

Nowadays the Induction heating appliance market is increasing due to its lesser heating time and high efficiency. Domestic induction cook hobs are now becoming a standard option, especially in Asia.

The principle of operation is based on the generation of a variable magnetic field by means of a planar inductor below a metallic vessel (Fujita, 2010; Pham, 2011). The input voltage is rectified by the diodes and after that an inverter provides a medium-frequency current. That current is feed to the inductor. The operating frequency is between 20 kHz

to 100 kHz. The most of induction heating process used insulated gate bipolar transistor (IGBT) only, because of their high-frequency range and the high output power range. Nowadays, most designs use the half-bridge series resonant topology because of its simplicity in control and increasing efficiency (Ahmed, 2006). Results are provided. In the past, conventional AC–AC topologies have been proposed to simplify the converter and improve the efficiency. In induction heating application MOSFETs (Hector, 2012), IGBTs, or RB-IGBTs, have been proposed. By use of MOSFET or IGBT efficiency has been increased.

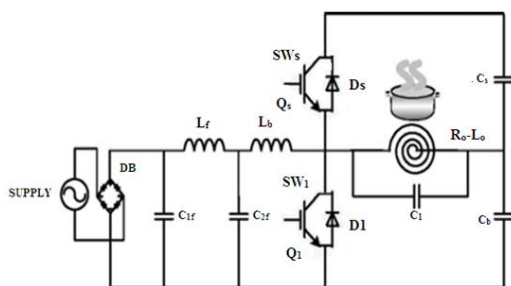


**Fig. 1:** Block diagram of induction heating

The aim of this paper is to propose a new topology to increase the efficiency while reducing the switching devices for induction heating applications. Proposed topology is based on the series resonant topology, and it used only two rectifier diodes. To allowing a significant current reduction in the switching devices, the effective output voltage is increased . Moreover, the proposed converter can operate with zero voltage switching conditions during switch-on for both switching devices, and also during switch-off transitions for one of them. As a consequence, the power quality is increased while the instrument count is reduced while keeping the same performance as more complex solutions.

**Conventional topologies:**

The full-bridge diode rectifier plus a dc-link inverter topology contain two a power switch blocks Q1 (SW1/D1), QS (SWS/DS).And it's divided into a series capacitors CS and C<sub>b</sub> and lossless capacitor C1 in parallel to the coil R0-L0.The voltage boost block contains boost inductor Lb and power switch Q1, the switching block Q1 shares the operation of both single-phase boost chopper converter and ZVS-PWM high-frequency inverter. This full-bridge diode rectifier plus a dc-link inverter topology produces the THD greater than 5% as specified by IEEE standards IEEE 519-92 and European EN 61000-3-2 standards for allowable harmonic contents of mains.

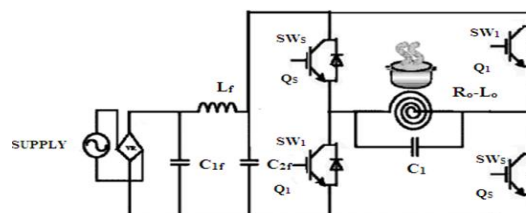


**Fig. 2:** Full-bridge diode rectifier plus a dc-link inverter.

Figure 3 represents the basic circuit configuration of ZVS-PWM Full bridge inverter topology. This topology includes two pairs of four active power switch blocks Q1 (SW1/D1), QS

(SWS/DS) for inverter operation. the IH working coil R0-L0 in parallel to snubbing capacitor C1 and a Vienna rectifier for sinusoidal current consumption. The inverter is fired by Sinusoidal PWM pulse.

The diode rectifiers and thyristor rectifiers draw current from input AC supply, causing significant current harmonics pollution. The international standards presented in IEEE Std. 519 and IEEE Monitoring Electric Power Quality Std 1159-1995 imposed harmonic restrictions to modern rectifiers, which stimulated a focused research effort on the topic of unity power factor rectifiers. By using a Vienna Rectifier with continuous sinusoidal input current and unidirectional power flow, We obtain the harmonics below 5% and overall efficiency higher than 97%. Moreover, any malfunction in the control circuit does not manifest itself in short circuit of output or PFC front end.

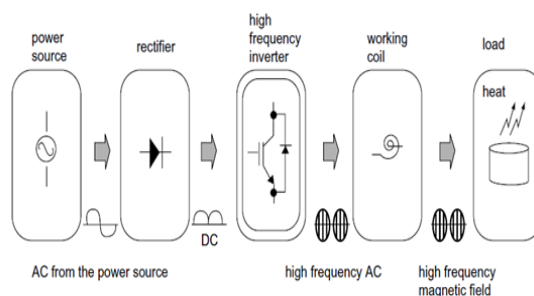


**Fig. 3:** ZVS-PWM Full bridge inverter.

**Operation theory of induction heating:**

The concept of induction heating, employed in the application of an IH rice cooker. This concept can be simplified as follows. First, convert the AC coming from the power source to DC using a rectifier. Then, connect this DC to a high- frequency switching circuit to administer high-frequency current to the heating coil.

According to Ampere’s Law, a high-frequency magnetic field is created around the heated coil. If a conductive object, e.g. the container of a rice cooker is put into the magnetic field, Then induced voltage and an eddy current are created on the skin depth of the container as a result of the skin effect and Faraday’s Law. The induced eddy current generates heat energy on the surfaces of the container. Other applications include melting, welding and brazing or metals. Induction cooking hobs and rice cookers.



**Fig. 4:** Operating theory of induction heating.

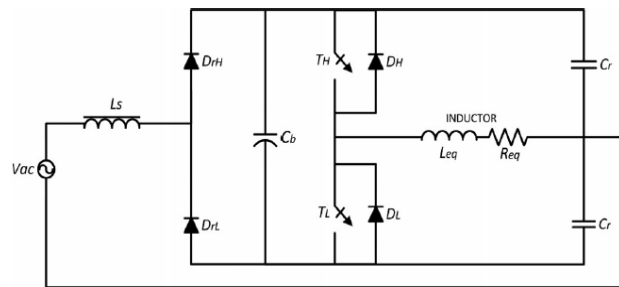


Fig. 5: Proposed AC-AC converter.

**Proposed converter structure:**

The proposed topology includes two bidirectional switches SH and SL or TH and TL, and the switches are IGBT, and an anti-parallel Diode DH or DL, respectively. The applied voltage Vac is rectified by two diodes DRH and DRL, but only one switch is activated at a time. This operation increases efficiency concerning conventional topologies.

The proposed topology is a series-parallel resonant converter. The inductor contains a series resistance Req and inductance Leq, as shown in Figure. This topology uses resonant capacitors Cr and a bus capacitor Cb. Both resonant capacitors

have the same value because the symmetry between positive and negative mains voltage. An input inductor Ls is used to reduce the harmonic content to fulfill the electromagnetic compatibility regulations.

**Principle of operation:**

The topology presents symmetry between positive and negative AC voltage supply. Its symmetry simplifies analysis and makes possible to redraw the circuit as shown in Figure, Although this topology uses different resonant configurations, parallel and series, and different resonant tanks for each of them, it is possible to use a normalized nomenclature based on series resonance.

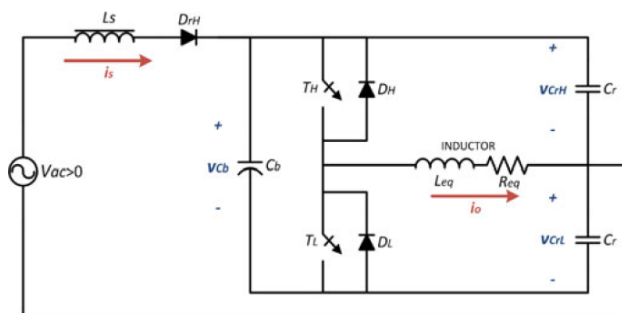


Fig. 5: Equivalent circuit during the positive mains voltage cycle.

State I operated with the high-side switching device S1 triggered on and the low-side switching device S2 triggered-off. The parallel resonant capacitor Ceq obtained from Cr and Cb, and the inductor contain the equivalent resistor(Req), and equivalent inductance (Leq). The current flowing through the switch S1 is the same as the current

flowing through the load. State I begin when S2 is triggered OFF. Transitions from this state can lead either to state II or state III. The voltage across S2 reaches zero, the transition condition to state II is fulfilled. On the other hand, if S1is switched OFF, the next state is state III.

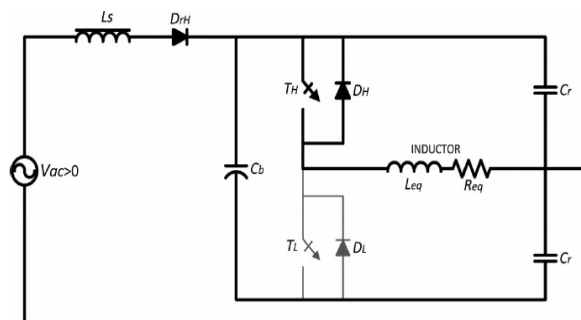
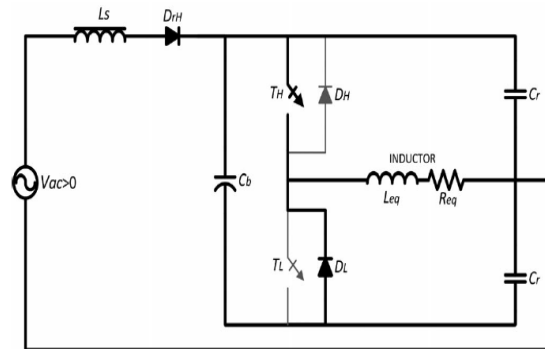


Fig. 6: State I Operation.



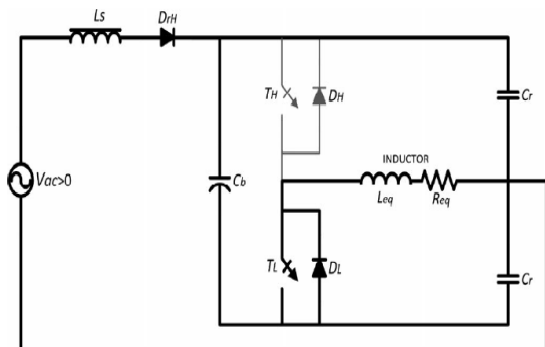
**Fig. 7:** State 2 Operation.

State II is characterized by the conduction of switch S1 and S2, although only S1 is triggered ON. This state starts when the voltage across S2 reaches zero. This state finishes when SH is triggered OFF, and the next state is state III. The main benefits results in the lower switch-off current achieved when S1 is triggered OFF because both devices supply the load current. In addition, S1 achieves ZVS conditions during both switch-on and switch-off transitions, reducing the switching loss consequently.

State III is start conduction when the switch S2 on and S1 in off. One resonant capacitor sets the

equivalent resonant circuit in parallel with the series connection of the  $C_s$  capacitor and the parallel connection of the inductor and the other one resonant capacitance. Note that when  $C_s$  is zero ( $\alpha = 0$ ), the equivalent resonant circuit is a series RLC circuit composed of the inductor–Pot system and one resonant capacitor.

This state started when S1 is triggered OFF and S2 is triggered ON to achieving ZVS switch-on conditions. This state finishes when S2 is OFF, and the next state is state-I.



**Fig. 8:** State 3 Operation.

#### Simulation result:

Principle of operation presented in the previous section and operating modes can be described as shown in Figure, achieve ZVS switch-on conditions. The operation contains three states described earlier: I, II, and III. It makes possible to achieve ZVS conditions for the high- side switch in state II. The low-side switch does not have ZVS turn-off. However, turn-off current is always lower than in the high-side switch. Nowadays, the induction heating appliances power is limited by mains maximum current and voltage. Simulation parameters are  $C_r = 470$  nF, and the inductor is modeled by  $L_{eq} = 65$   $\mu$ H and  $6.5$   $\Omega$  for the series equivalent resistor at switching frequency.

To obtain a high power factor and a proper power control the dc- link capacitor has been selected to below range, as it is shown in this section,

And it can be neglected in this analysis. The control strategies considered to control the output power is the square wave (SW) control, based on changing the switching frequency (SF) of the switching devices (Chien-ming, 2008).

#### A. SW control:

In Square Wave control method to control the switching frequency to obtained the required output power. To switch-on ZVS, the switching frequency is higher than the resonant frequency, and when the switching frequency is increased the output power is decreased. As is shown in Figure, the frequency range starts at 22kHz, which is the resonant frequency determined by  $L_{eq}$  and  $C_r$ , which ensures power ZVS switching-on conditions and can be increased to decrease the output.

However, if the switching frequency reaches

30kHz, switching-off losses increase because ZVS switching-off conditions are not achieved. As a result, the suitable switching frequency range and,

therefore, the output power range is reduced. To overcome this limitation, the asymmetric duty cycle (ADC) control strategy is proposed.

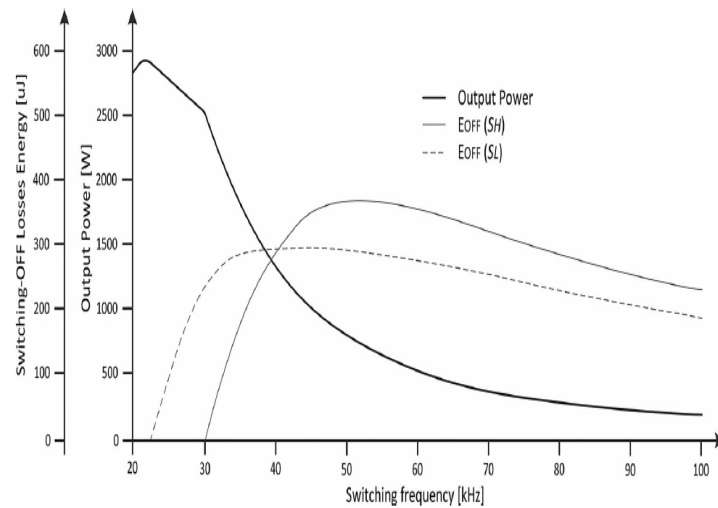


Fig. 9: SW control.

**B. Asymmetrical duty cycle control:**

In ADC control the output power is controlled by changing the switching device duty cycle. This control strategy delivers different output powers by changing the percent of conducting angle ( $\theta$ ) in which the high-side switch SH is activated  $D(SH)$ .

The variation of conducting angle is restricted to the achievement of soft-switching conditions for SH, ZVS for switching-off, and by the achievement of ZVS in the switching- on commutation for both

devices (anti-parallel diode conduction at the beginning). To obtain the switch-on ZVS conditions, the duty cycle must be higher than 30%. To obtain a proper safety margin and to control the total amount of losses per switching device,so, the upper boundary is kept to 60%. Figure shows the power output variation achieved and the switching losses. One of the key design aspects when designing the proposed converter to operate with the ADC control is the voltage that the switching devices must withstand.

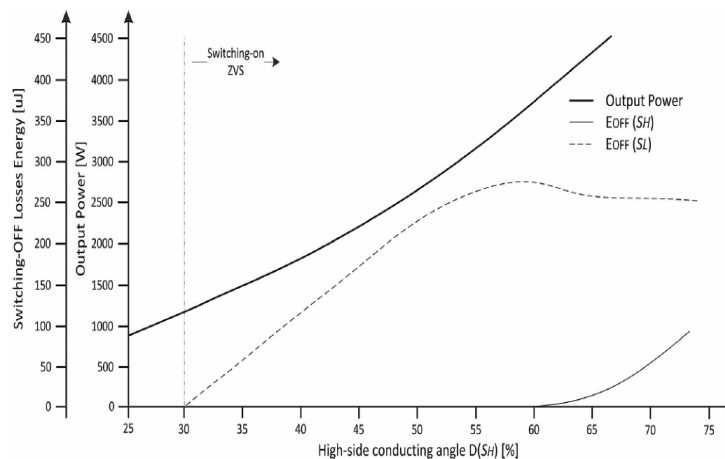
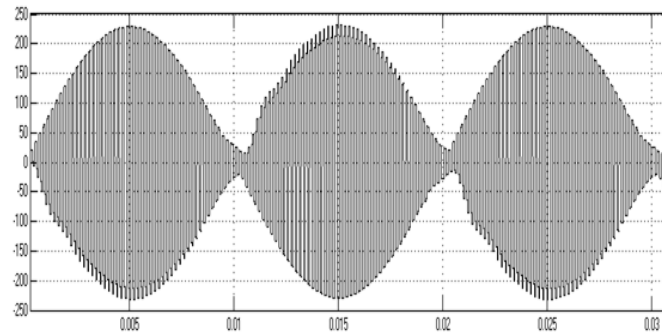


Fig. 10: ADC control.

Here figure shows the output voltage waveform of an AC-a converter circuitry. Input voltage of 230v is applied. Output of the simulation is taken across

the load. High-frequency level is obtained when it is compared with the input frequency.



**Fig. 11:** Output voltage with high-frequency.

### **Conclusion:**

This paper presents a half bridge AC-AC converter topology applied for induction heating application. The design and analysis have been performed to obtain the operation mode that describes the proposed converter. The zero-voltage switching operation can be obtained for both turn-on and turn-off commutations. And the output voltage is doubled compared to the conventional topology, and also reducing the current flow through the switching devices. As a consequence, the power converter power qualities improved in the whole operating range. A 3-kW prototype has been designed and simulated to validate the analytical and results. The simulation measurements show a power quality improvement compared to the conventional topology and validate the feasibility of the proposed converter.

### **REFERENCES**

- Ahmed, N.A. and M. Nakaoka, 2006. "boost-half-bridge edge resonant soft switching PWM high-frequency inverter for consumer induction heating appliances," *IEEE Proc. Electr. Power appl*, 153(6): 932–938.
- Ahmed, N.A., M. Nakaoka, 2006. " half-bridge edge resonant soft switching pm high-frequency inverter for consumer induction heating appliances," *IEEE Proc. Electr. Power appl*, 153(6): 932–938.
- Chien-ming, W., 2008. "A novel single-stage high-power-factor electronic ballast with asymmetrical half-bridge topology," *IEEE Trans. Ind. Electron*, 55(2): 969–972.
- Fujita, H., K. Ozaki, 2010. " heating system using multiple inverter units applicable under mutual magnetic coupling conditions," *IEEE Trans. Power electron*, 26(7): 2009–2017.
- Hector, Auto media, 2012. "high-efficiency AC-AC power electronic converter for heating appliances," *IEEE Proc. Electr. Power appl.*, 27(8).
- Pham, H., N. Uchida, 2011. "phase angle control of high-frequency resonant currents in multiple inverter systems for zone control induction heating," *IEEE Trans. Power electron*, 26(11): 3357–3366.