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# Dual-Mode-Resonant Class D/DE Converter for Improved Efficiency Domestic Induction Heating System

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***Abstract*—Now-a-days the induction heating market is continuously growing due to its benefits including precise output power control, cleanness, reduced heating times, faster heating process and high efficiency. This paper proposes to achieve higher efficiency in a wide output power range with the use of the half-bridge inverter in two operating modes i.e., class D/DE mode. The entire efficiency of the cooking process is improved with a cost-effective procedure by reconfiguring power converter topology i.e., changing the resonant capacitor through electromechanical relays.**

***Keywords*— Induction heating (IH), resonant power Conversion, inverter.**

## I. INTRODUCTION

The main advantage of domestic induction heating technology are the precise output power control, cleanness, faster heating process, reduce heating times and high efficiency so, the more adaptable cooking surfaces obtained. Induction heaters directly heated up the vessel by means of a varying magnetic field in the range of 20-100 Kilo Hertz. This magnetic field is originated from an inductor-coil system equipped by a resonant power converter.

A cooking action can regularly be divided into two segments. The first one is known as pre-heating, high output power levels for short time are achieved in this segment. The second one consists of keeping the temperature for a lengthy time with low-middle output power levels. As a consequence, the efficiency of low-medium power levels has a compelling impact on the efficiency of the whole cooking movement.

The proposed series half-bridge ZVS resonant inverter (class D operation mode) is used for the induction heating application. In this ZVS resonant converter, the maximum output power occurs at the higher resonant frequency compared to switching frequency, yielding high efficiency. However for the higher switching frequency, low-medium output power levels are achieved at the lower efficiency. Thus losses are increased due to increased switching frequency for low output power range [2] [3]. To beaten this control a dual mode operation of resonant converter is ref [6], which further improves efficiency in low output power range due to the rebated switching losses. MATLAB/SIMULINK is used for simulation understanding.



## II. CIRCUIT TOPOLOGY

Fig 1 shows block diagram for the conventional converter. Here the power conversion occurs in three segments. In the first segment single phase AC supply is fed to the rectifier bridge, to convert AC to DC. The DC link capacitor, a smoothing capacitor is used to filter the converted DC voltage. Then the obtained DC voltage is given to the high frequency inverter bridge. Output voltage from the inverter bridge is applied to the load.

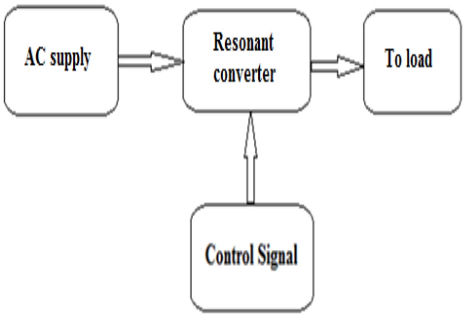


Fig.1. Block diagram of conventional converter

### *A. Circuit Diagram Of Conventional Converter*

The series resonant half-bridge applied to the induction heating operates at switching frequency more than the resonant frequency. Zero Voltage Switching technique is used in converter for the soft switching. Therefore lossless snubber circuit Cs is added to rebate the switching losses. In class D mode operation, the resonant capacitor Cr is larger than the snubber capacitor Cs. In class DE mode operation ZVS and ZVDS are achieved at turn OFF. In this case, the switching frequency higher than resonant frequency. Thus the switching losses are raised which results in low efficiency. To reduce this, a dual mode resonant converter implemented to improve the efficiency in the whole operating range.

The dual mode resonant converter shown in fig 2.To vary the snubber capacitance Cs and the resonant capacitance Cr, SPST1 and SPST2 electromechanical switches are used in order to switch the operation modes (class D/DE mode).

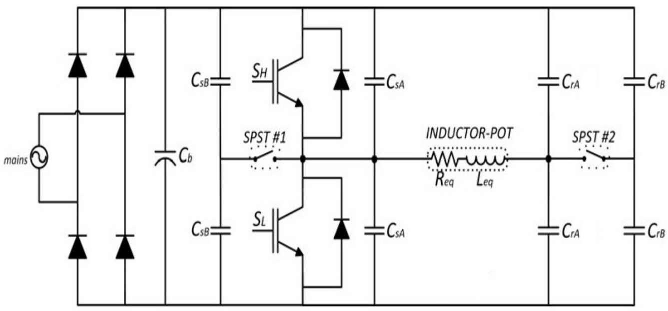


Fig.2.Dual mode resonant converter

A 230volts 50Hz power line connected to the diode bridge rectifier to generate DC power supply to the inverter. Output power segment consists of single phase voltage source inverter with two IGBTs [2] [3].

Zero Voltage switching means the switches are turn ON and turn OFF at zero voltage. Hence the transient performance is improved, eliminating the peaking of voltage across the switch; meanwhile ZVS reduces the power losses across the switch by reducing the overlapping of the voltage and current.



## III. OPERATION MODES IN DUAL-MODE RESONANT CONVERTER

During the first section I, the load current is positive and it is supplied by the switch $S_1$.

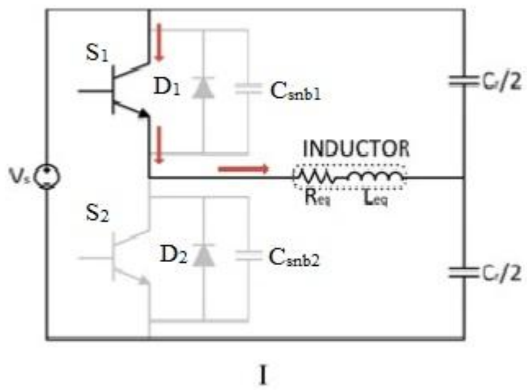


Fig.3. section I $S_1$ ON, $S_2$ OFF

In section II, switch $S_1$ is OFF, the switch OFF current is used to charge or discharge the snubber capacitor $C_{snb1}$, i.e., snubber capacitor $C_{snb1}$ is charged to the supply voltage, whereas the snubber $C_{snb2}$ capacitor is discharged.

In section III, the load current is also positive, and thus, it is supplied by the diode $D_2$.

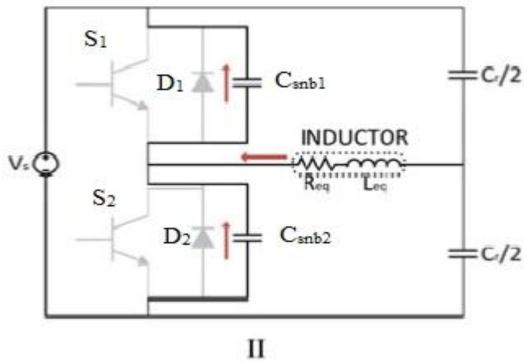


Fig.4. section II $S_1$ OFF, $S_2$ OFF

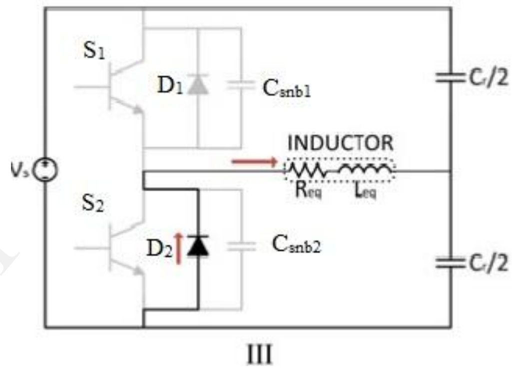


Fig.5. Section III $S_1$ OFF, $S_2$ OFF $D_2$ is ON

In section IV, the load current becomes negative; it is supplied by the switch $S_2$.

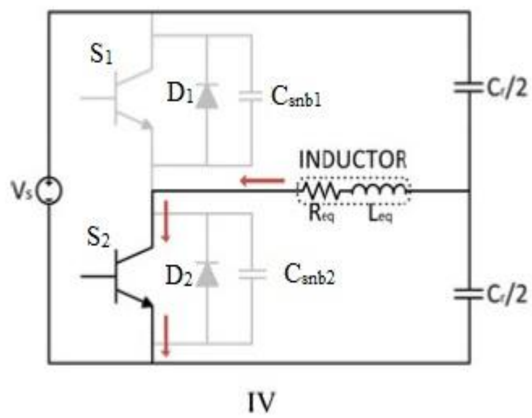


Fig.6. Section IV $S_1$ OFF, $S_2$ ON

In section V, as soon as the $S_2$ is OFF, the load current charges the snubber capacitors $C_{snb2}$ to the supply voltage, whereas the snubber capacitor $C_{snb1}$ is discharged.

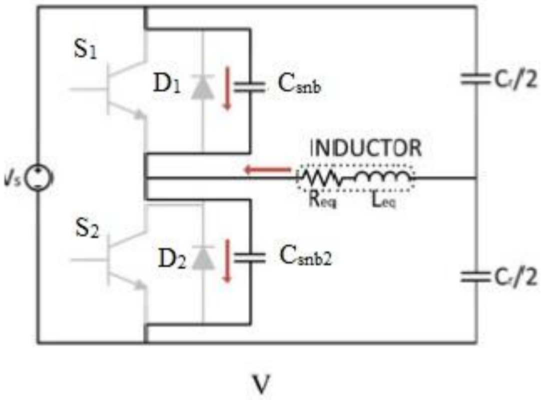


Fig.7. Section V $S_1$ OFF, $S_2$ OFF

In section VI, when both snubber capacitors $C_{snb1}$ and $C_{snb2}$ are charged or discharged, the negative load current flows through the diode $D_1$. Finally, when the load current becomes zero, the load current is given by switch $S_1$

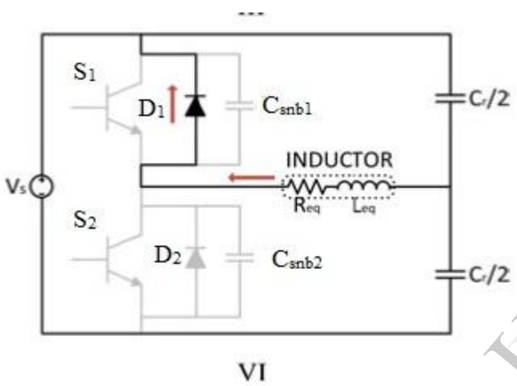


Fig.8. Section VI $S_1$ OFF, $S_2$ OFF

### A. *Class D Mode Operation*

In this mode the maximum output power occurs at the resonant frequency. Class D operation mode uses the sections I to VI, where the snubber capacitor $C_{snb}$ is used to reduce the switching losses. $C_{snb}$ must be charged or discharged during the dead time between switches activation with the output current. To achieve ZVS in a wide range of operating modes, a small value of capacitance must be selected to charge or discharge [7].

### B. *Class DE Mode Operation*

This mode is designed to supply low-medium output power for the equivalent inductor. Class DE modem operation uses the section II and V, i.e. , snubber capacitance $C_{snb}$ charge or discharge, are continued bypassing the use of section III and VI, diode conduction.

## IV. SIMULATOIN RESULTS

MATLAB/SIMULINK is used for the simulation studies. Fig 9 shows the simulation circuit of dual-mode-resonant class D/DE converter.

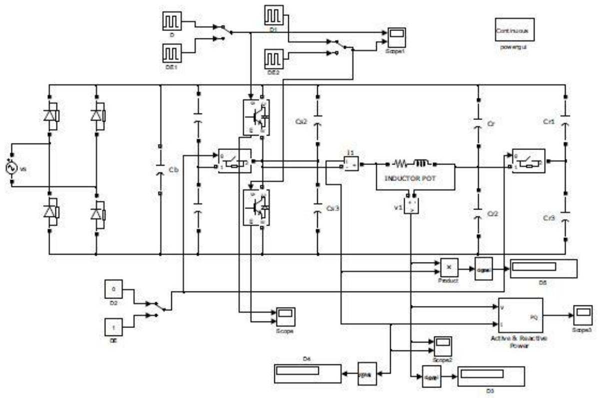

Fig.9.Simulation circuit of dual-mode-resonant class D/DE converter

For class D mode at switching frequency 13 KHz with applied voltage, the output voltage is 102.4 volts (rms) and current 25.3 amps (rms) as shown in fig 10. The gate pulse with 50% duty cycle shown in fig 11.The Zero voltage switching condition (ZVS) is shown in fig 12. The maximum output power of 3.2 kilo watts shown in fig 13.



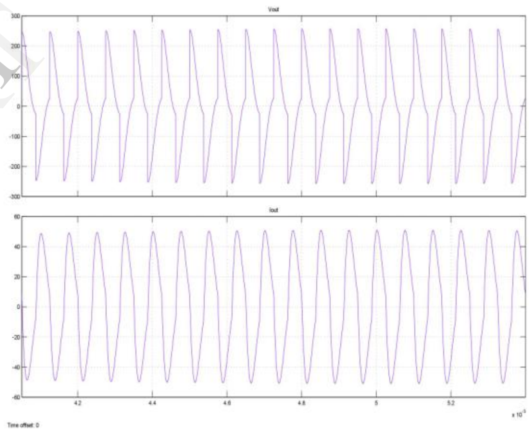

Fig.10. Output voltage and current for class D resonant converter

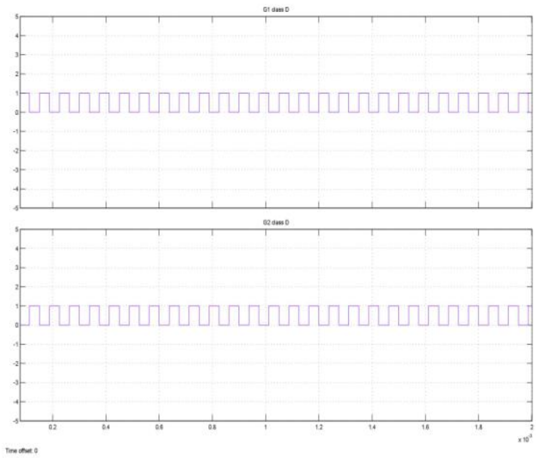

Fig.11.Gate pulses of the switch $S_1$ and $S_2$ with Duty cycle 50% of class D mode resonant converter.

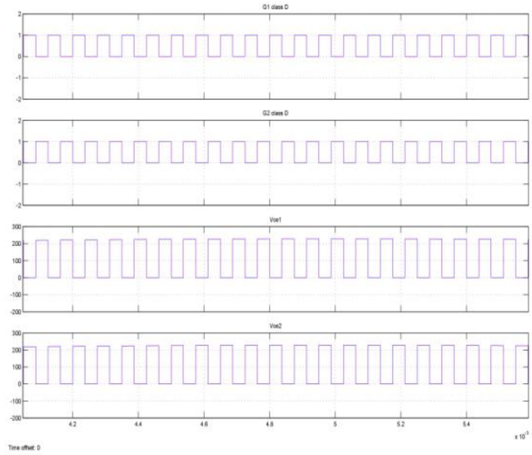

Fig.12. Zero voltage switching condition (ZVS) in class D mode

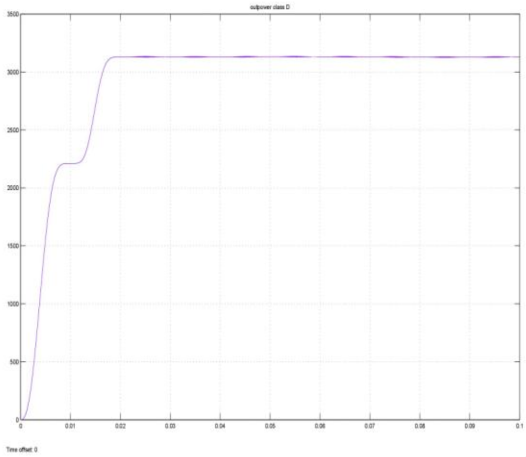

Fig.13.Maximum output power at switching frequency 13 KHz

In class DE mode at switching frequency 20 KHz with applied voltage, the output voltage is 105.3 volts (rms) and current is 15 amps (rms) shown in fig 14.

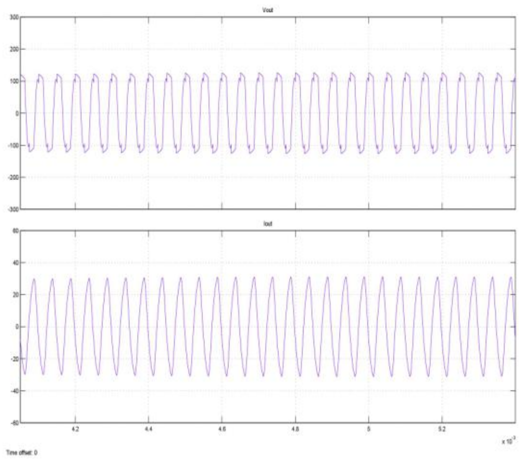

Fig.14. Output voltage and current for class DE resonant converter

The gate pulse with 24% duty cycle shown in fig 15. The Zero voltage switching condition (ZVS) is shown in fig 16. The low output power of 1.28 kilo watts shown in fig 17.

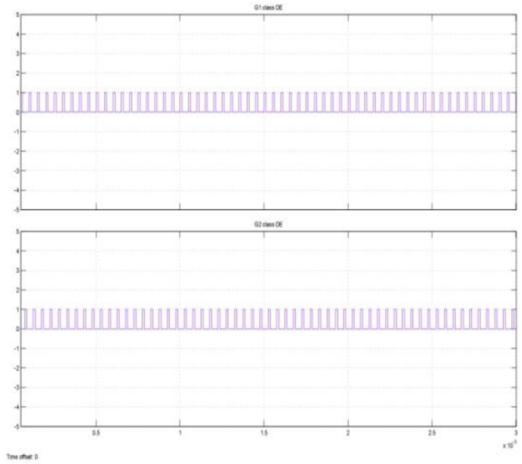

Fig.15.Gate pulses of the switch $S_1$ and $S_2$ with Duty cycle 24% of class DE mode resonant converter.

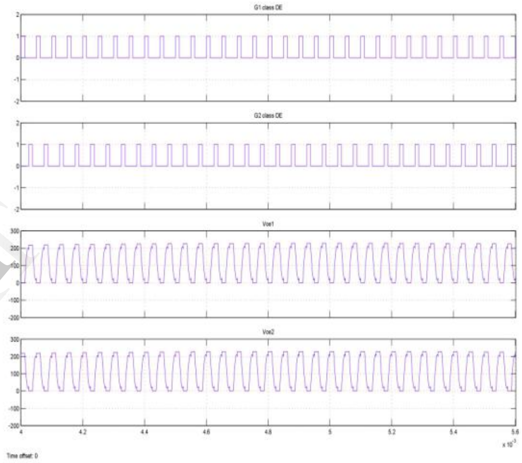

Fig.16. Zero voltage switching condition (ZVS) in class DE mode

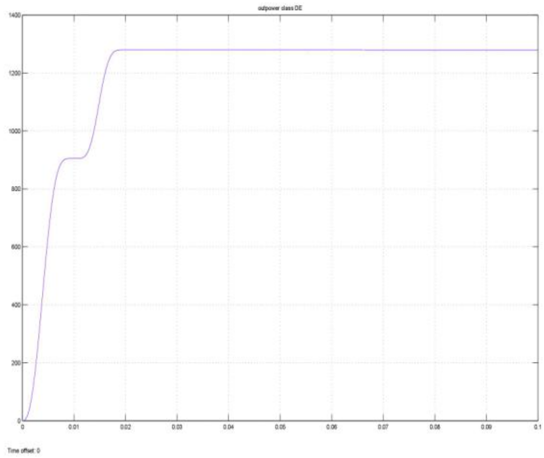

Fig.17. Low-medium output power at switching frequency 20 KHz

## V. CONCLUSION

In this paper, a novel reconfigurable series resonant inverter topology is proposed in order to better the efficiency in the entire operating area. It is based on an improved dual-mode resonant converter where the class-D and class-DE modes of operation are combined to gain the efficiency.

The dual mode resonant half bridge converter has been simulated using MATLAB/SIMULINK.

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