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A New Arrangement of Resonance Tank Circuit for DC-To-DC Energy Converting Applications

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***Abstract*-- Till now, various types of circuits has been designed for DC-DC energy conversion applications. Mainly, those circuits depends on conventional method for power flow control i.e., Pulse Width Modulation (PWM) technique. Instead of this technique, the circuits with Resonant power conversion exhibit many advantages such as low electromagnetic interference, low switching losses, small size and less weighted components because of using high switching frequency. Now, this proposed circuit presents a new arrangement of loaded resonant converter for dc-dc energy conversion circuit applications. This circuit consists of a Capacitor-Inductor-Capacitor (C-L-C) Resonant inverter and a half bridge diode rectifier. This work replaces the existence arrangement of resonant circuit (L-C-L) arrangement. The network elements with small ratings than in L-C-L circuits can be employed and better performance is achieved. Moreover, this proposed arrangement used for power electronics applications like uninterrupted power supplies, battery chargers and more.**

Keywords— Loaded resonant converter, resonance frequency, resonant converter, soft switching converter, switching frequency.

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I.INTRODUCTION

Developing of Power Electronic devices and their emerging circuits led to rapid advancements in recent years. Power electronic switches play a crucial role in energy conversion applications. Generally, Pulse width modulation (PWM) technique is adopted for controlling the power flow in power semiconductor switches. Because of its easiest procedure, it has been employed from olden days. The switching devices in converters with a PWM control can be used to obtain the desired output voltage or current. The switches are subjected to a high voltage stress and the switching power loss of the device increases linearly with corresponding increase in switching frequency. The turn-on and turn-off loss of switching devices could be a significant portion of the total power loss. This situation can be reduced by connecting a simple dissipating snubber circuit in series and parallel with switches. But this will not completely avoid the power loss due to switching stress.

Now-a-days, new inventions must required to be small sized and light weighted, as well as should have a high energy conversion efficient devices. This can be accomplishing by operating the circuit at higher switching frequency. Moreover, it results smaller filter components. But increasing switching frequency causes for EMI and switching losses. As a result overall circuit performance will reduces. Using smaller switching frequency will increases the efficiency and performance of the converter, but size of the overall converter will increase, due to capacitor and inductors and filters. Operating under smaller frequencies requires high rated capacitor and inductors; as a result, size of those components will increase according to capacity. Both situations degrade the performance of the circuit. The remedy for this problem is to use soft switching approaches under a high switching frequency. The disadvantage of PWM control can be eliminated or minimized if the switches are turned ON and OFF when the voltage across a device or its current becomes zero. The voltage and current are forced to pass through zero crossing by creating an LC resonant circuit, thereby called a “Resonant Pulse Converter”.

Various types of resonant converters are existed, among them ZVS and ZCS and most popular due to its advantages. ZVS can eliminate the switching losses at turn-off and reduce the switching losses during turn-on and eliminates the capacitive turn-on loss. It is suitable for high frequency operation. For both the ZVS and ZCS, output voltage control can be achieved by varying the frequency. These circuits can resist the excess stress, which is drawback in PWM control. Moreover these circuits are frequency dependent. The circuits which are operating under this control are called soft-switching converters. A soft switching dc-dc converter is series combination of a resonant inverter and a rectifier. Loaded–resonant converter is the most advantageous among all soft switching converters. Depending on the extraction of energy from the resonant tank, the loaded resonant converters are classified as three types. Parallel loaded resonant converter is used in this topology because of its advantages including low switching loss and low stress. This proposed circuit is replacement of existing L-C-L resonant converter. Newly developed C-L-C arrangement with the elements, which are rated below the existed circuit shows a satisfactory performance, the conversion efficiency and power developed in the proposed topology is more than the previous circuit.

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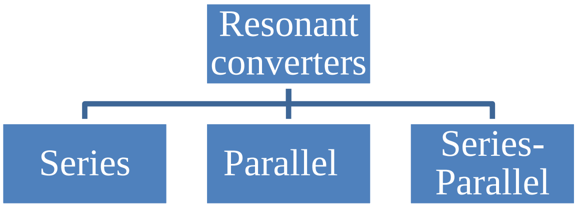

Fig. 1.Types of Resonant Converter based on extraction of energy from the resonant tank

II. CIRCUIT DESCRIPTION AND PRINCIPLE OF OPERATION

A. Circuit Description

The proposed circuit shown in fig.2.consists of two split capacitors C_1 and C_2, which are large and splits the voltage of the input DC source. The elements C_1, L_R, C_2 combines form a resonant tank. This circuit output is fed to load through a diode rectifier in the form of dc. Load resistance *R* is connected across the rectifier bridge through a low pass filter capacitor C_o. Each bi-directional power switch at input side is connected with an anti parallel diode. The switches are operated as active power switches over a switching period *T* with voltage input V_S. The two switches S_1 and S_2 are driven by non overlapping rectangular wave trigger signals V_{GS1} and V_{GS2}. Both the switches are operated with an amplitude of $\pm Vs/2$. The output filter capacitance C_o serves two purposes, as it will minimize the loading effect of the output circuit and to make sure that the output voltage is constant. The output voltage across the bridge rectifier depends on the resonant tank output. The dc bus voltage can be adjusted by varying the switching frequency. The frequency of the above waveform is same as that of switching frequency. Hence, the proposed circuit can be modeled as simplified equivalent circuit as shown in fig.3.and the simplified equivalent circuit for existence loaded resonant circuit is shown in fig.4.

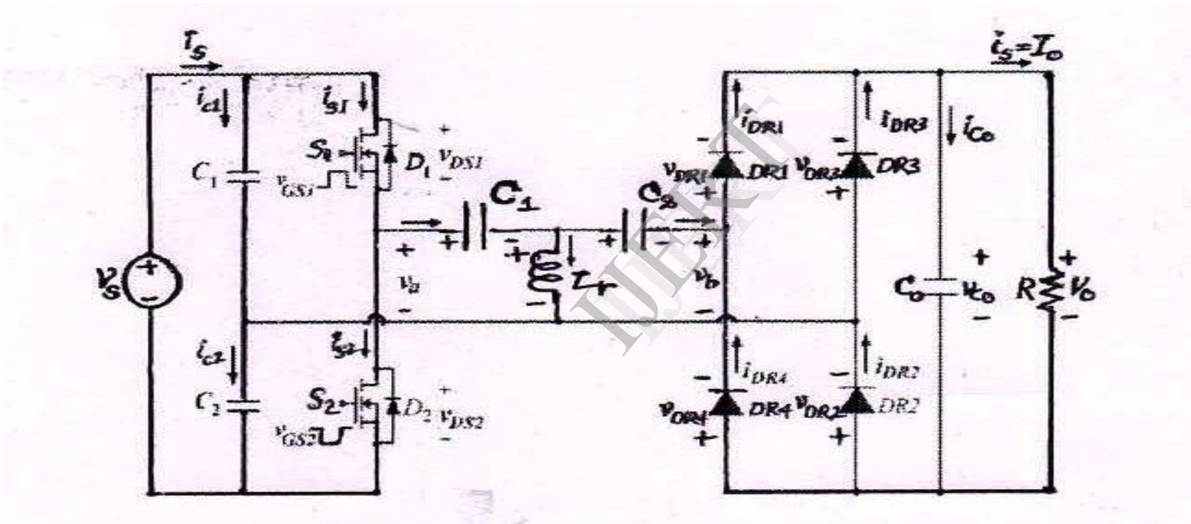

Fig. 2: Proposed efficient loaded resonant converter for a dc-dc energy conversion system

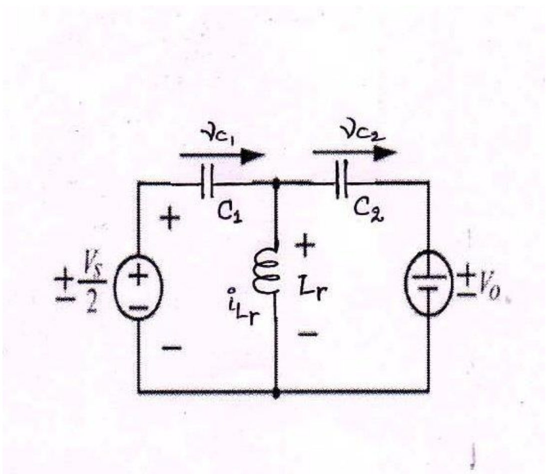

Fig .3: Simplified equivalent circuit for proposed new arrangement

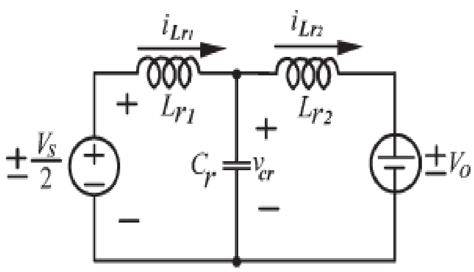

Fig -4: Simplified equivalent circuit for existence loaded resonant circuit.

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B. Operating principle of the proposed circuit

The proposed loaded resonant converter is made to operate with the switching frequency f_s above resonance frequency f_o. Fig.5. displays the idealized steady state voltage and current waveforms. The proposed circuit is assumed to be operating in continuous conduction mode, in which switching devices as ideal characteristics. During the positive half cycle of the current through the resonant circuit, the power is supplied to the load resistor *R* through D_{R1} and D_{R2}. Similarly, during negative half cycle of current through the resonant circuit, the power is fed to load resistor R through diodes D_{R3} and D_{R4}. Some of the assumptions are considered for this loaded resonant converter. They are

1) Switching elements of the circuit are ideal, such that the decay in forward voltage in the on-state resistance of the conducting switch is negligible

2) Equivalent series resistance of the capacitance and stray capacitances is negligible

3) Filter capacitance C_o at the output side is usually very large and can be treated as ideal dc voltage in the switching period.

4) Characteristics of passive components are assumed to be frequency independent, linear and time invariant.

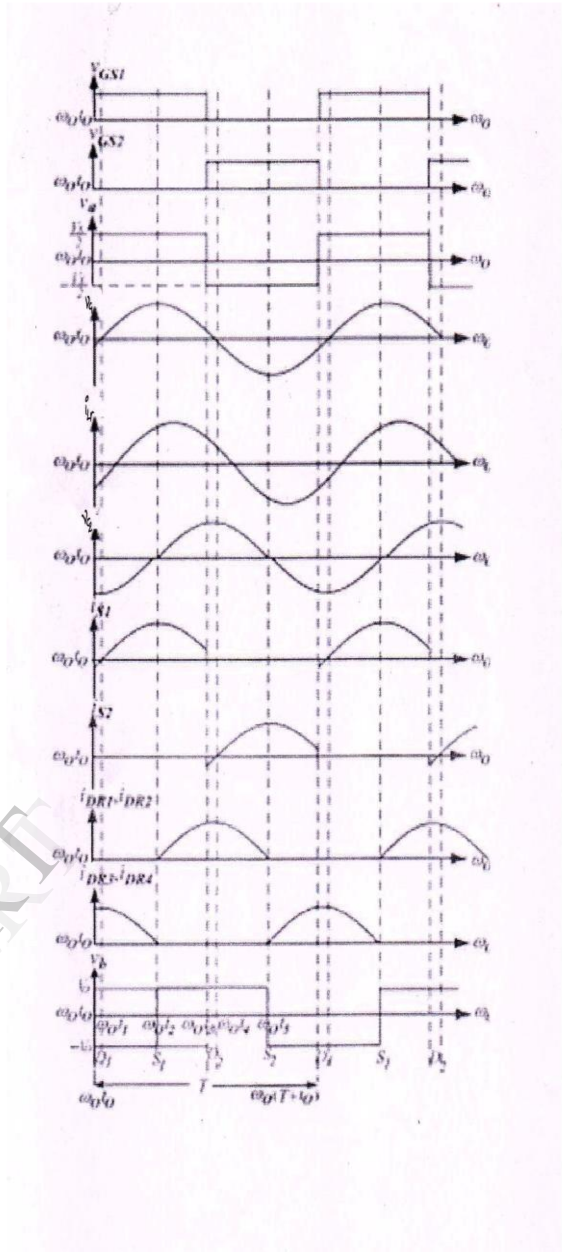

Fig.5: Idealized voltage and current waveforms

Operation of the proposed circuit can be explained in four modes.

C. Mode-1

A square wave voltage across the input terminal is generated by continues periodic switching between *+V/2* and *–V/2* across the input. Since the output voltage V_o, is pretended as constant, the input voltage applied to the bridge rectifier is V_0, when resonant tank output is positive and is $-V_o$ when resonant tank output is negative.

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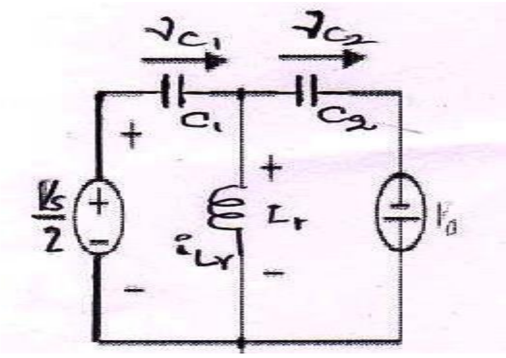

Fig .6: Equivalent circuit of MODE 1

Fig.6. displays the equivalent model of proposed circuit operating in mode 1. Conducting switch S_2 is excited before the period $\omega_o t_0$ and conducts current. Switch S_1 will be turned on at $\omega_o t_0$. The current from resonant circuit is negative and it will flows through freewheeling diode D_1 to switch on S_1. Hence, the switches are turned on naturally at zero voltage and zero current. Therefore, the current through the switch which is in conduct mode will be negative before turn on and positive before turn off.

D. Mode-2

In this mode, current through resonant tank is transforming from negative to zero at $\omega_o t_1$. The switch S_1 is commutated to turn off, forcing the current to flow through freewheeling path D_2. Fig.7. represents the equivalent model of proposed circuit in mode 2. The positive dc input applied across the tank causes the resonant current that flows through the semiconductor power switch to go to zero.

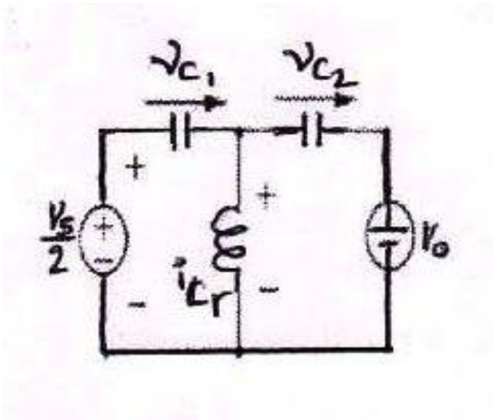

Fig- 7: Equivalent circuit of MODE 2

E. Mode-3

Now a turn off trigger signal is given to the gate of S_1 which is conduction mode. The inductor current then spontaneously turns off S_1 from active mode to flow through freewheeling path D_2. This mode starts when diode D_2 starts conduction. The equivalent arrangement for this mode is shown in fig.8.

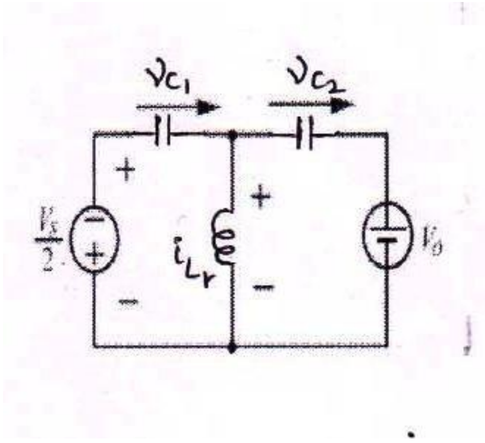

Fig -8: Equivalent circuit of MODE 3

F. Mode-4

When voltage across the resonant tank is positive, rectifier diodes D_{R1} and D_{R2} comes to conduction mode and input is carried out to the load through these diodes. Similarly, when the direction of the flow changed in resonant tank these diodes D_{R1} and D_{R2} are turned off because of reverse voltage and one switching cycle is completed. When trigger signal V_{gs1} applied, excitation starts and process will repeat from MODE 1.

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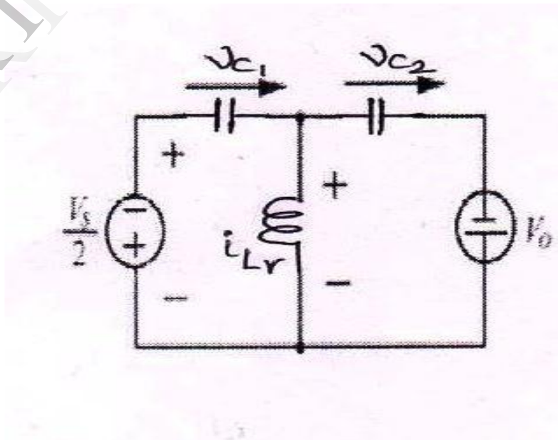

Fig- 9: Equivalent circuit of MODE 4

III. OPERATING CHARACTERISTICS

Since, the output of the resonant tank is directly given to the load, we can assume the voltage or current applied to the load, and the voltage or current generated from the resonant tank is equal. Hence, the overall proposed circuit can be modified as shown in fig.10.

The circuit represents input voltage $V_s/2$, C-L-C arrangement of Resonance tank circuit and load connected R_e .The input voltage applied changes according to switching cycle.

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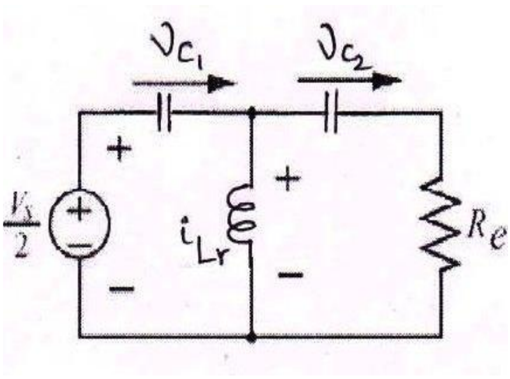

Fig- 10: Equivalent circuit for the proposed circuit with load

The circuit parameters that are used in the circuit are tabulated as below.

TABLE 1: CIRCUIT PARAMETERS

Input voltage V_s	24V
Resonant capacitor C_1	1μF
Resonant inductor L_r	4μH
Resonant capacitor C_2	1μF
Resonant frequency f_r	80KHz
Switching frequency f_s	81KHz
Output voltage V_o	21
Filter capacitance C_o	100μF
Output resistor R	6Ω

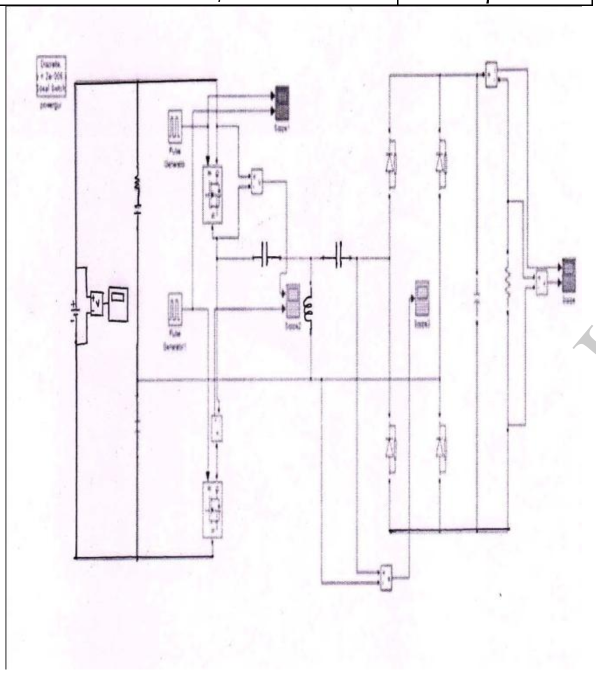

Fig .11: MATLAB simulation circuit for the proposed converter

IV. EXPERIMENTAL RESULTS

A simulation circuit is designed in MATLAB with above specified values and obtained output power developed more than the existence circuit. Moreover, size of overall circuit also reduced by using small rated devices. Switching losses incurred in the circuit can be eliminated or reduced using high switching frequency. Hence, this circuit is most preferable to the existence circuit in terms of size and weight. Fig.11 shows the simulation circuit for the proposed converter, and fig.12, 13, 14, 15 shows the MATLAB responses of the circuit.

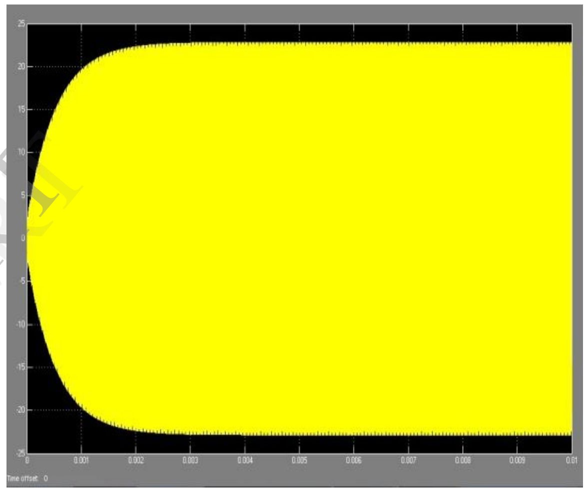

Fig -13: Voltage measured across the resonant tank

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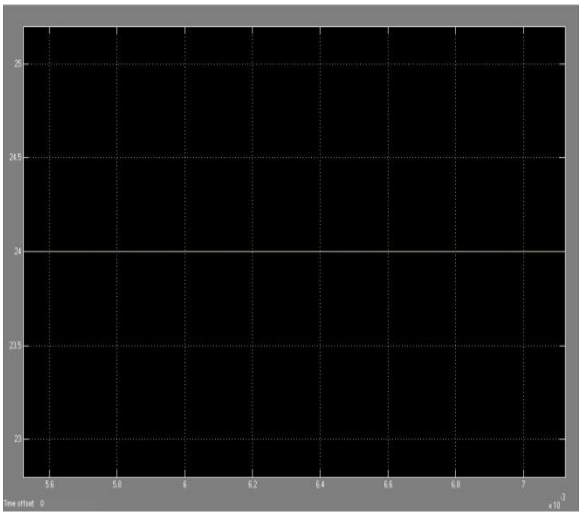

Fig .12: Input voltage applied to the system

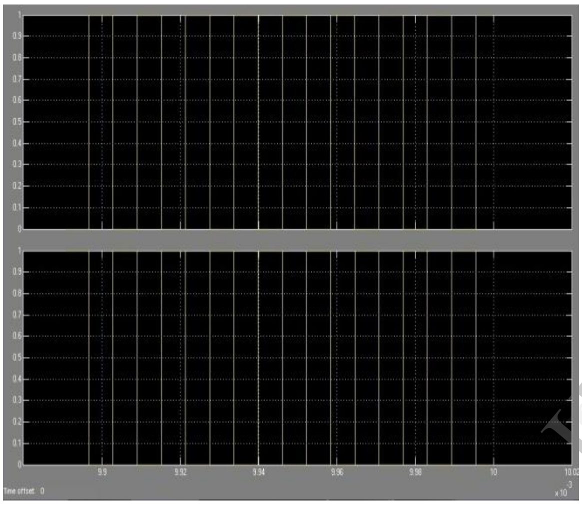

Fig .14: Trigger pulses applied to the active power switches S_1 and S_2

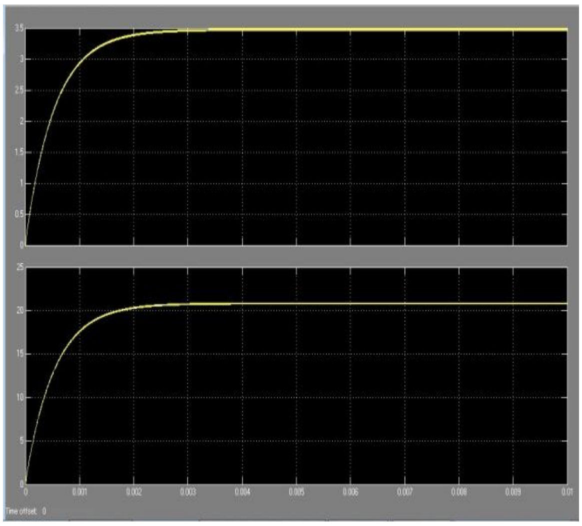

Fig -15: Output current and voltage measured across the load

V. CONCLUSION

The proposed converter is set to operate under same resonant and switching frequency as in existence arrangement but, with small rated network elements as compared to previous circuit. This paper presents the C-L-C arrangement which replaces the existence system L-C-L circuit. The output developed in the proposed circuit is comparatively high and more energy conversion efficient. ZVS and ZCS approaches are used, the high switching stress and device destruction also eliminated. Since, the proposed circuit is worked under switching frequency which is more than resonant frequency the switching and EMI losses are decreased. The output of the system can be controlled by regulating switching frequency of the active conducting switches. The size and weight of the overall converter also decreased, since elements are small rated than existence system. An excellent improvement is achieved with fewer components than the conventional converter with high energy conversion.

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