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Doubly Loaded Resonant Converter for the Application of DC to DC Energy Conversions

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Abstract: *The resonant power conversion having many advantages over conventionally adopted pulse width modulation that includes a high efficiency, low electromagnetic interference, small volume, low switching losses, and light weight of components due to a high switching frequency, and low reverse recovery losses in diodes owing to a low di/dt at switching instant. This paper presents the doubly loaded resonant power converter for dc to dc conversion. The proposed circuit consists of half bridge inverter, Double LCL filter and diode bridge rectifier. The output is filtered by a low pass filter. A MATLAB based simulation circuit is designed and verified for the different loads. The proposed novel loaded resonant circuit reaches up to 92% efficiency. The circuit result performs a satisfactory performance of the topology. The loaded resonant power conversion circuit is used in telecom power supplies, solar energy generation systems, UPS, battery charging system, switching circuits and power electronic circuits.*

Index terms: *Zero voltage switching, Zero current switching and resonant converter.*

I. Introduction

In recent years the use of semi conductor power switches are most widely used in power electronic technology. The semi conductor power switches plays vital role in energy conversions. Especially the dc to dc Converters are used in residential, commercial and industrial circuits. In the dc to dc converters the fixed dc is converted into variable dc by using the power semiconductor switches. Pulse width Modulation technique is the simplest way to control the power semiconductor switches. In the PWM technique the power is controlled by interrupting the voltage or current through means of switch action by applying different gating pulses.

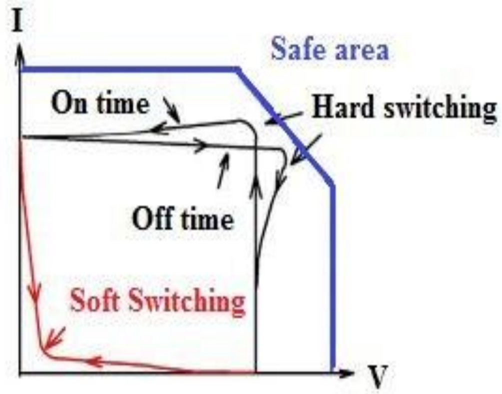

Figure1: Typical switching trajectories of power switches

In practice interrupting the current or voltage across the power semi conductor switch is referred as the hard switching. In the hard switching we can easily control the power semiconductor switches, for most of the conversions hard switched PWM has been largely adopted. To interrupt the current or voltage the switch must with stand high switching stress, a safe operating area, as shown by the dashed lines in Fig1. To reduce the switching stress snubber circuits are connected in series or parallel with the power semiconductor switches but the snubber circuits transfer the power loss from the switch to the snubber circuit, however the overall switching power loss is not reduced. The dc to dc converters are operated at the high switching frequency that implies smaller and lighter capacitors, inductors of the circuit. If the circuit is operated at high switching frequency the switching losses, electromagnetic interference also increases and efficiency, performance is decreases. To overcome this problem the dc to dc converters are operated at high switching frequency including soft switching methods. Soft switching is of two types I) zero current switching II) zero voltage switching. The current or voltage is zero during switching Period that reduces the switching losses, EMI and improves the efficiency of the power converters.

The soft switching method significantly reduces the switching losses and EMI such converters are called soft switching dc to dc converters. The soft switching converters first converts the dc to ac by using resonant inverter and then ac is converted back to dc by rectifying operation. The soft switching converters are of so many types among them loaded resonant converter is most popular of them owing to the easy control scheme, high reliability. Depending upon the energy extraction from a resonant tank, loaded resonant converters are classified into three types I) series II) parallel III) series-parallel resonant converters. The series resonant converter is constructed by an inductor, capacitor and bridge rectifier.

The series resonant converter makes possible to converts the ac input to dc output. The parallel loaded resonant converter contains inductive output filter and this converter controls the output voltage at no load by adjusting the switching frequency above the resonance frequency. It acts like a short circuit protector so that it is very useful in case of dc to dc converters. The output voltage at resonance frequency is a function of and it can rise to high values at no load. The series-parallel resonant converter performs the both series and parallel converter characteristics. The series-parallel resonant converter is equivalent to the parallel resonant converter except the additional resonant capacitor in series with the inductor. This converter can vary the input and load from full load to no load. This converter operation is easy to understand but analyzing the circuit parameters and calculating the equations is difficult. This converter must operate above and more for away from the resonant frequency therefore the dc to dc converter must operate in the high frequency mode resulting bulky size, high cost.

Comparing the above three resonant converter methods reveals that the parallel loaded resonant converter is the optimum for the dc to dc conversion because of its merits like low switching losses, low noise, low stresses. Moreover for the dc to dc conversion the parallel loaded resonant converter is preferable because of its simple construction and typical I/O characteristics. This work presents a novel loaded-resonant converter and it is superior to the conventional parallel resonant converter in terms of light weight, size, simple topology, and easy control. To attain the maximum efficiency we are using zero voltage/current switching is used and it is a square wave power conversion during the switch on/off time. The voltage or current is zero at switch on time and it varies the switching frequency to reduce or eliminating high switching stress. The rest of this paper is organized as follows: Section II describes the proposed loaded resonant converter and operation of the proposed converter. Section III describes the simulation results. Next, Section IV describes conclusion and future scope of the system.

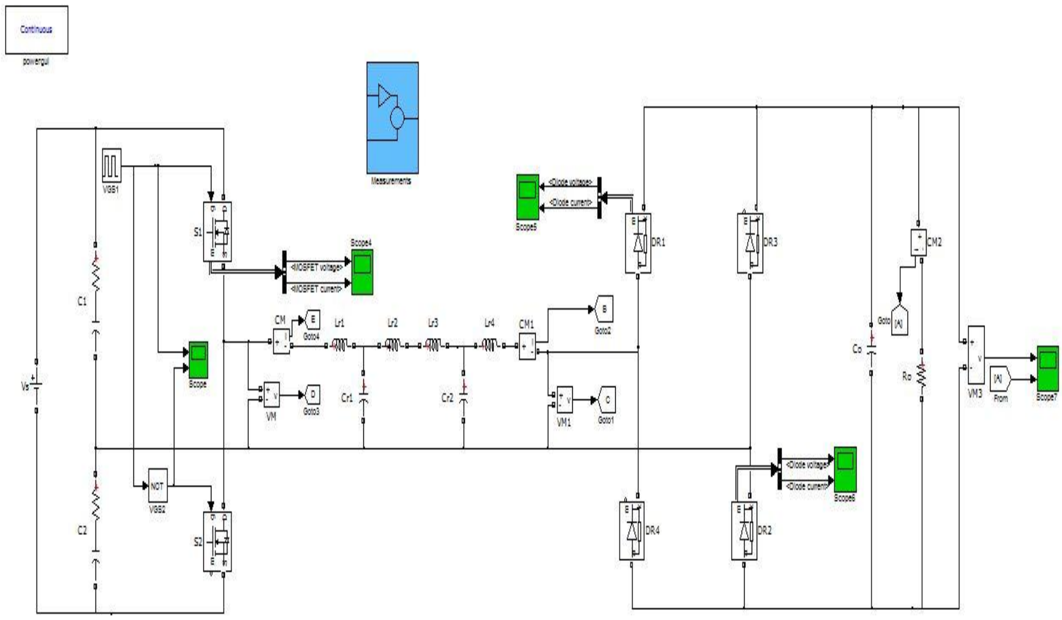

Figure2: Proposed loaded resonant converter for a dc-to-dc energy conversion system.

II. Description Of Circuit And Operating Principles

A. Description of circuit

Increasing oil prices and energy shortages have created the demand for a high energy conversion efficiency and performance. The growing power electronic product market has increased the demand for high power density and high energy conversion efficiency of dc to dc energy power converters. In recent years the soft switching scheme is the most effective and attractive for dc to dc energy conversion. It can reduce the EMI and switching losses of the switch mode converter. The figure2 shows the proposed loaded resonant converter for dc to dc conversion.

The two capacitors *C*1 and *C*2 on the input side are big and used to split the input voltage. The resistance 'R' (negligible size) is connected in series with the input voltage Vs because the capacitors don't allow the dc to flow across through it. The elements Lr1, Lr2, C r1, L r3, L r4, Cr2 forms the doubly loaded resonant tank. The resonant tank is connected to a bridge rectifier and the output of the bridge rectifier is connected the load Ro via filter Co. The proposed converter consists of two bidirectional switches operated at 50% duty ratio. The bidirectional switch consists of active switch and an anti parallel diode. The bidirectional switch turn on and off by providing the gate triggering pulse to the switches. The output of the bidirectional switches are used to split the input dc voltage to square pulsating ac voltage.

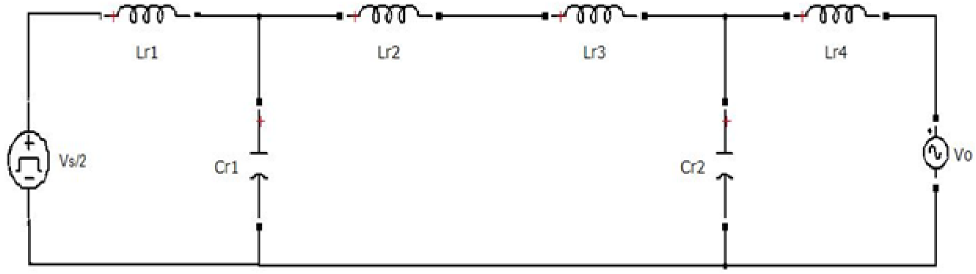

Figure3: Equivalent circuit of the proposed doubly loaded resonant converter

The resonant tank converts the square pulsating ac voltage to the sinusoidal ac voltage and it is given to the bridge rectifier. The bridge rectifier converts ac to the pulsating dc and large capacitance is placed to get the pure dc voltage.

B. Operation of the circuit

The proposed converter operates in continuous mode so the semi conductor shows the ideal characteristics. In these proposed circuit semiconductors switching frequency (81KHZ) is slightly more than that of resonant frequency (80KHZ) because to attain soft switching (ZVS & ZCS). In diode bridge rectifier for positive half cycle the diodes Dr1&Dr2 operated through the load and for negative half cycle the diodes Dr3&Dr4 operated through the load.

Figure 2 shows the doubly loaded resonant converter for the application of dc to dc energy conversions. Here the output voltage (i.e., dc) may be constant because the switching frequency is greater than the resonant frequency of the doubly loaded LCL filter. For analysis the figure 2 is simplified as figure 3. When ILr2 is positive the output voltage across the rectifier is Positive and if ILr4 is negative the output voltage across the rectifier is negative. The input part of the doubly loaded resonant converter of the application of dc to dc energy conversions consists of dc voltage source and bidirectional switches and these switches are controlled by the square wave pulsating signal. The proposed converter mathematical modeling is ease [1]-[2].

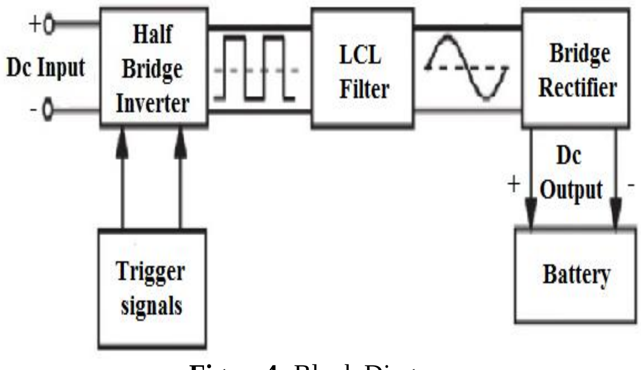

Figure4: Block Diagram

The above figure 4 represents the block diagram of the propose doubly loaded resonant converter for the application of dc to dc energy conversions and it consists of trigger signal, half bridge inverter, LCL filter, bridge rectifier and battery. The energy from the natural resources (like photovoltaic, fuel cells and solar energy) which produces the DC output for that type of systems these proposed converter is very useful it converts pulsating DC to continuous DC without any intervals and the output of the converter is fed to battery for storing the energy and it is connected to grids by rectifying the stored dc into ac. The operation of block diagram is discussed above.

III. Simulation Results

A MATLAB based simulation circuit for the doubly loaded resonant converter for the application of dc to dc converter is developed and simulated using MATLAB 2014a version. The proposed circuit parameters & simulation results are listed below.

Table I: Circuit Parameters

Input voltage	24V
Resonant inductor L_{r1}, L_{r3}	8µH
Resonant capacitor C_{r1}, C_{r2}	0.5µF
Resonant inductor L_{r2}, L_{r4}	3.5µH
Input resistor R_s	0.0001Ω
Switching frequency f_s	81KHz
Resonant frequency f_o	80KHz
Filter capacitor C_o	100 µF
Output resistor R	6Ω
Output voltage V_o	12V

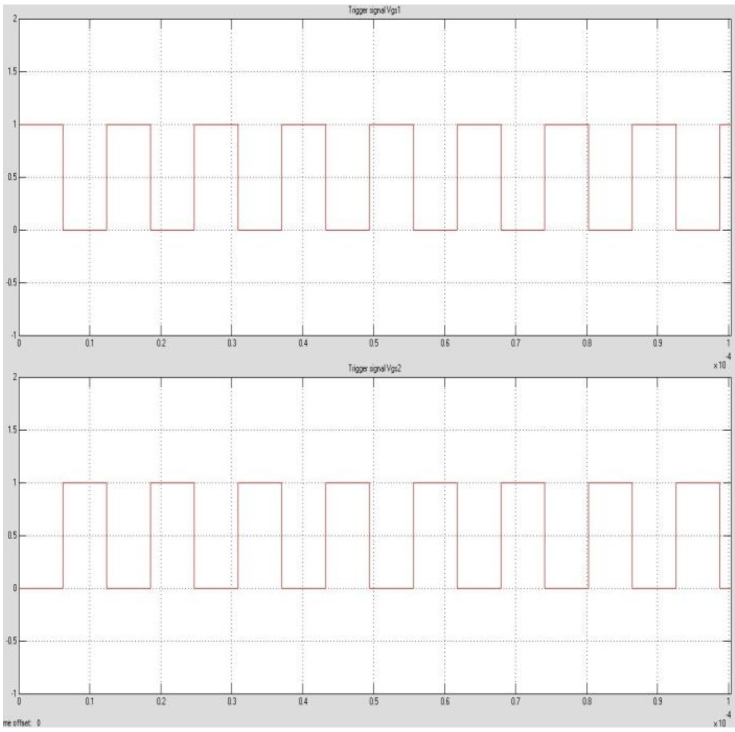

Figure5: Trigger signals for S1 & S2

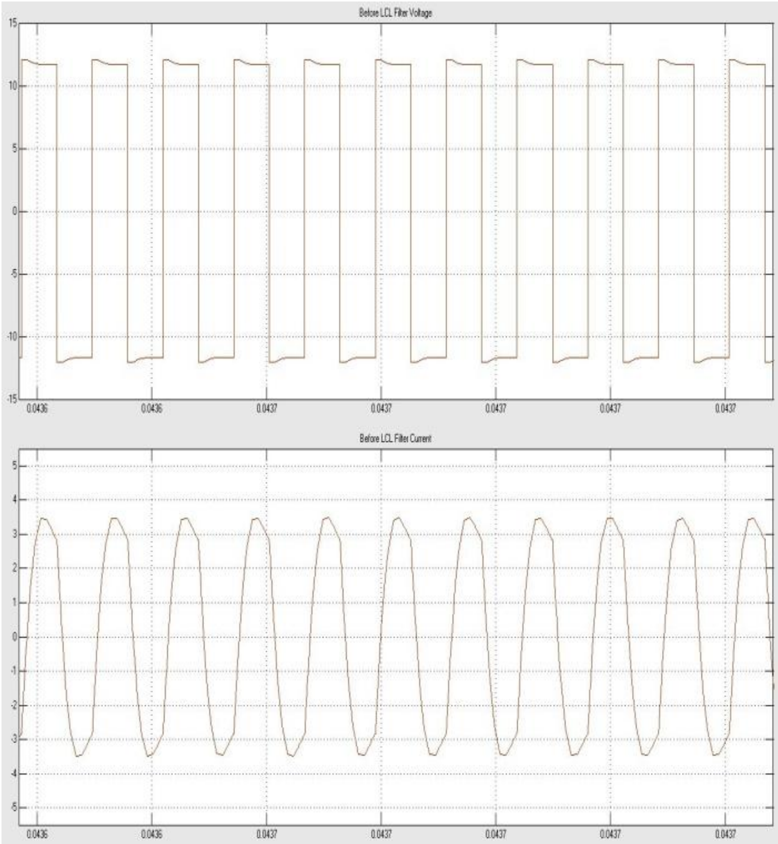

Figure6: Input voltage & current for the Double LCL filter

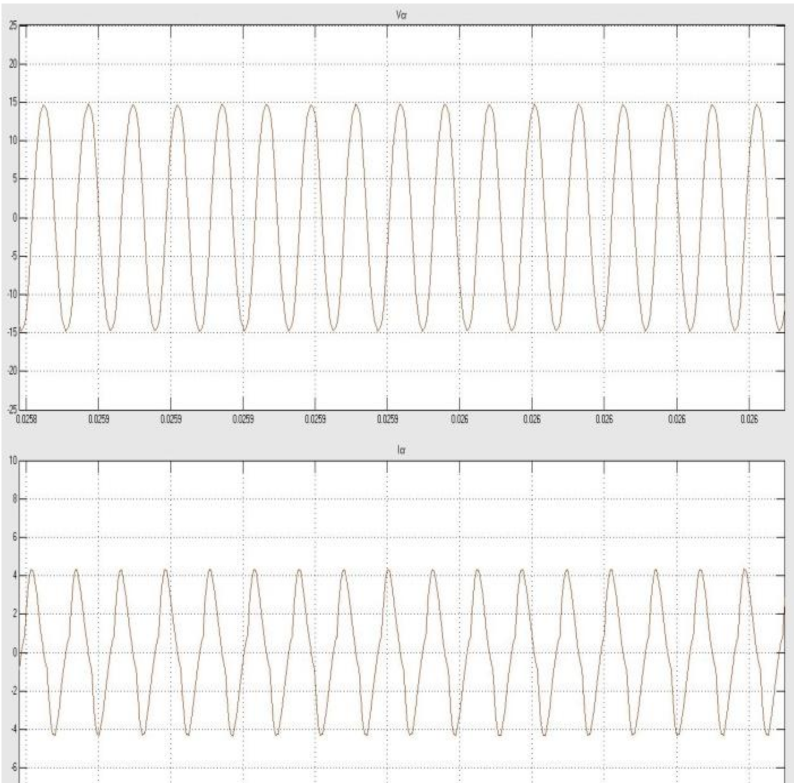

Figure7: Voltage and current of the resonant capacitor Cr

Figure8: output wave forms of the double LCL filter

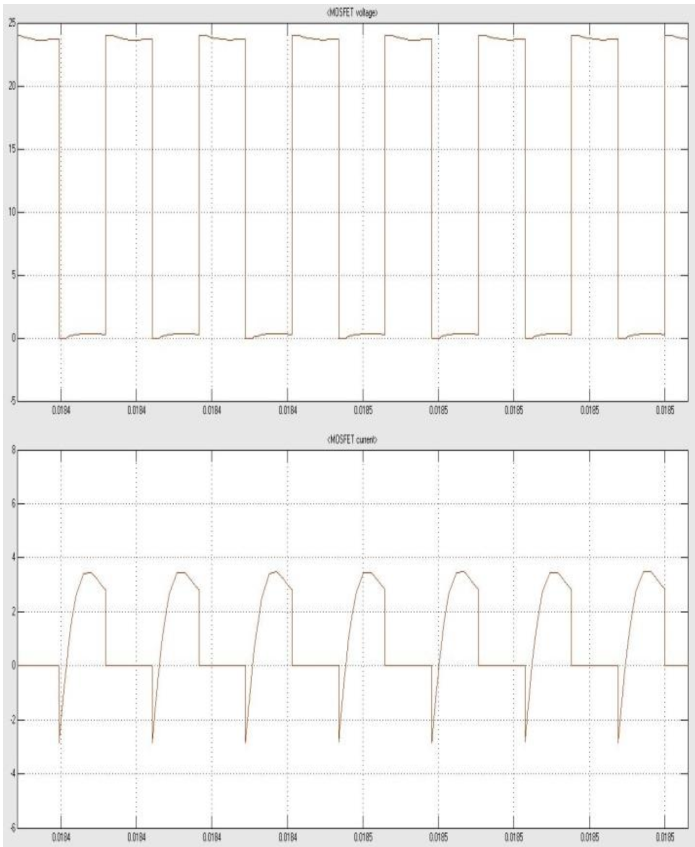

Figure9: Voltage & current waveforms of the switch S1

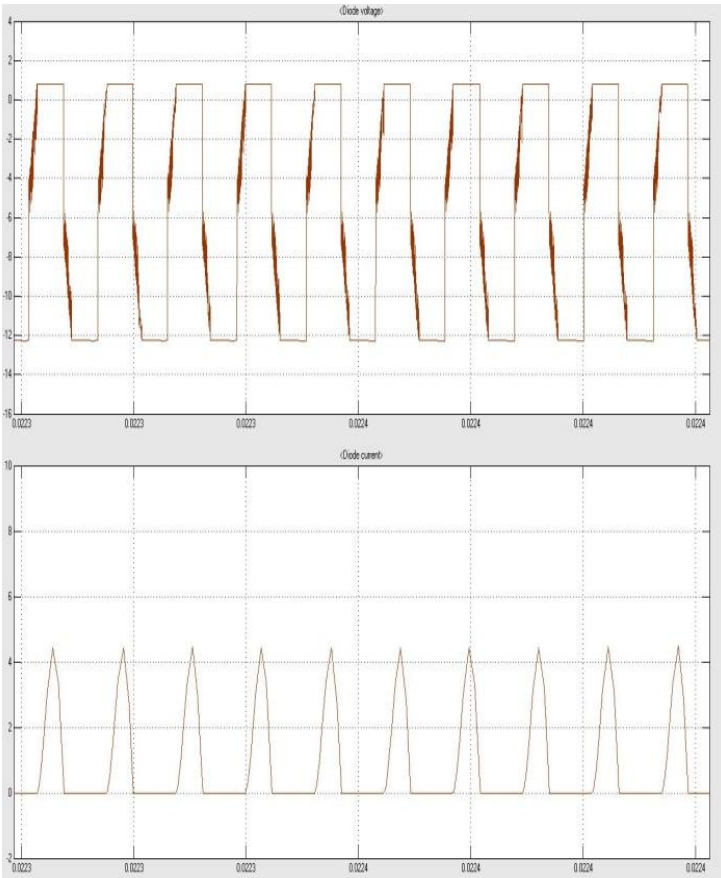

Figure10: Voltage & current waveforms of the diode Dr1

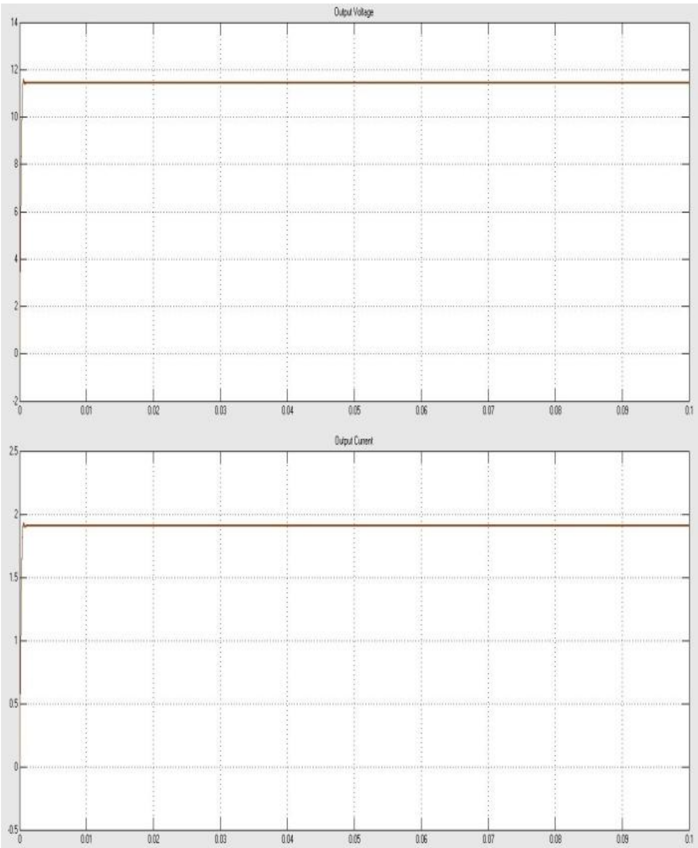

Figure11: Output voltage & current waveforms

IV. Conclusion

The proposed circuit is easy to understand and low cost compared to other techniques which requires many components. The proposed system efficiency is high because it is operated with soft switching technique. By adjusting the switching frequency of converter the resonant tank characteristic impedance is determined and which is used to determine the output voltage and current. In order to get the required output the resonant converter output is applied to the load. Effectiveness of the proposed system is demonstrated with experimental results. The efficiency of the proposed system is 92% which is more than that of other topologies. In contrast with the conventional system the overall efficiency is improved by proposed doubly loaded converter.

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