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High Frequency Isolated Series Parallel Resonant Converter

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Abstract

Objective: Due to small size and high power density, the DC / DC converter is gaining more attention in renewable energy systems. In this paper, Bi-Directional Series-Parallel Resonant Converter (SPRC) are simulated at high frequency and the results are presented. **Method/Analysis:** The converter is analyzed using MATLAB Simulink for the different values of input voltage with switching frequency remains same. **Results/Findings:** The efficiency of the SPRC has linear behavior with the input voltage. **Conclusion/Application:** Zero Voltage Switching (ZVS) High frequency bidirectional resonant converter suitable for low voltage DC applications.

Keywords: High Frequency Isolated Converter, Series Parallel Resonant Converter, ZVS Bi-Directional Converter

1. Introduction

Resonant converters are steadily increased due to the advantages of smaller-size and lighter in weight with faster transient response. It is possible to operate such converters at high frequency to reduce the size of their reactive components. With the development of power conversion technology, power density and efficiency of the converter has become the major challenge[1] . In recent years, the series-parallel resonant converter becomes more and more popular in isolated DC-DC / AC-DC applications due to its high power density, high efficiency and long hold-up time capability[2].

The increasing efforts on pushing to high power density and high efficiency DC/DC converter have lead us to develop converters capable of operating at higher switching frequency with high efficiency. For this reason, resonant converters have drawn lot of attentions due to high efficiency, high switching frequency and high power density.

Resonant switching techniques have been used in high frequency DC-DC converters for more than fifty years[3]. Theoretically, resonant converters are more suitable for high frequency operations, as they have no switching loss. This is due to turn on and off under zero current and/or zero voltage. Bi - Directional dual-bridge DC/DC converter with high frequency isolation is gaining more attention in renewable energy system due to small size and high-power density[4].

The design procedure for high frequency operation of the modified series resonant PWM converter with improved efficiency and reduced size, had given a generalized analysis for the auxiliary network series resonant asymmetrical pulse width - modulated converter[5]. Phase-shifted full-bridge series-resonant DC-DC converters are applicable for wide load variations[6].

In low and medium power applications, the conventional PWM power converters are widely used. Because of the known limitations exhibited by PWM converters, such as drop in efficiency and deterioration of EMI problem at high-switching frequency and high-input voltage, the efficiency and power density cannot easily be further improved. For this reason, a resonant converter could be a good alternative because of its soft-switching

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power transfer characteristic[7]. Zero Voltage Switching (ZVS), Continuous Conduction Mode (CCM), and Boost Converter reduces switching loss and voltage stress of the main switch[8]. The resonant DC-DC converter considerably reduced the switching loss and obtain friendly EMI characteristic, which had facilitated its adoption in a diverse range of applications. Bi-Directional Series Parallel Resonant Converter for Power Factor Correction[9]. Comparative Study on Solar Powered Interleaved Boost Converter[10]. A New Single-Stage Solar based Controlled Full-bridge DC-DC Converter[11]. In the present work efficiency of the series parallel resonant converter for variable input voltage are presented.

2. Series Parallel Inverter

A full bridge series parallel resonant inverter is used for the investigation is presented in Figure 1. The circuit consists of full bridge MOSFET inverter. The resonant inductor Lr and capacitor Cs and Cr. The resonant capacitor Cs is in series with resonant inductor Lr and the load, Cr is in parallel with the load and they form a Series Parallel LC circuit. From this configuration, the resonant tank and the load circuit act as a voltage divider. By changing the frequency of the input voltage, the impedance of the tank will change. This impedance will drive the input voltage with the load. The resonant frequency fr of the LCC resonant converter is given by,

$$f_r = \frac{1}{2\pi\sqrt{L_r\left(C_s + C_p\right)}} \qquad (1)$$

3. Circuit Description and Operating Principle

Figure 2 shows the simulation circuit for full bridge series parallel resonant converter. The circuit has AC source at the input side, followed by full bridge diode rectifier. Filter circuit filter are the DC ripples, High Frequency (HF) full bridge MOSFET inverter and resonant circuit. Isolation between the source and the load is provided by HF transformer. A load can be connected to the high frequency link circuit with secondary full bridge rectifier and smoothing filter circuits.

The input AC source is rectified by full bridge diode rectifier. The DC voltage is filtered by using capacitor. The DC voltage is inverted by high frequency MOSFET full bridge inverter. Pulse generators are connected to the gate of the MOSFET. When M1 M2 conducts, M3 M4 should be in off state and vice versa, to avoid short circuit. Output of the inverter is connected to primary of the transformer through resonant inductor Lr and capacitor Cs in series. The secondary of the transformer is then connected to

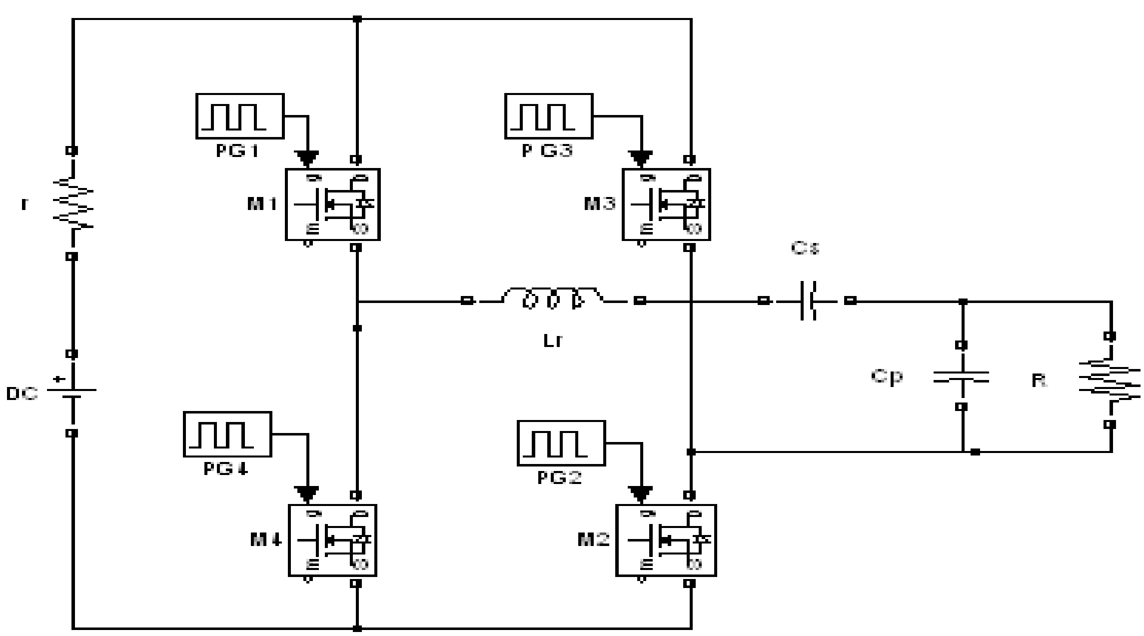

Figure 1. Full bridge basic series parallel inverter.

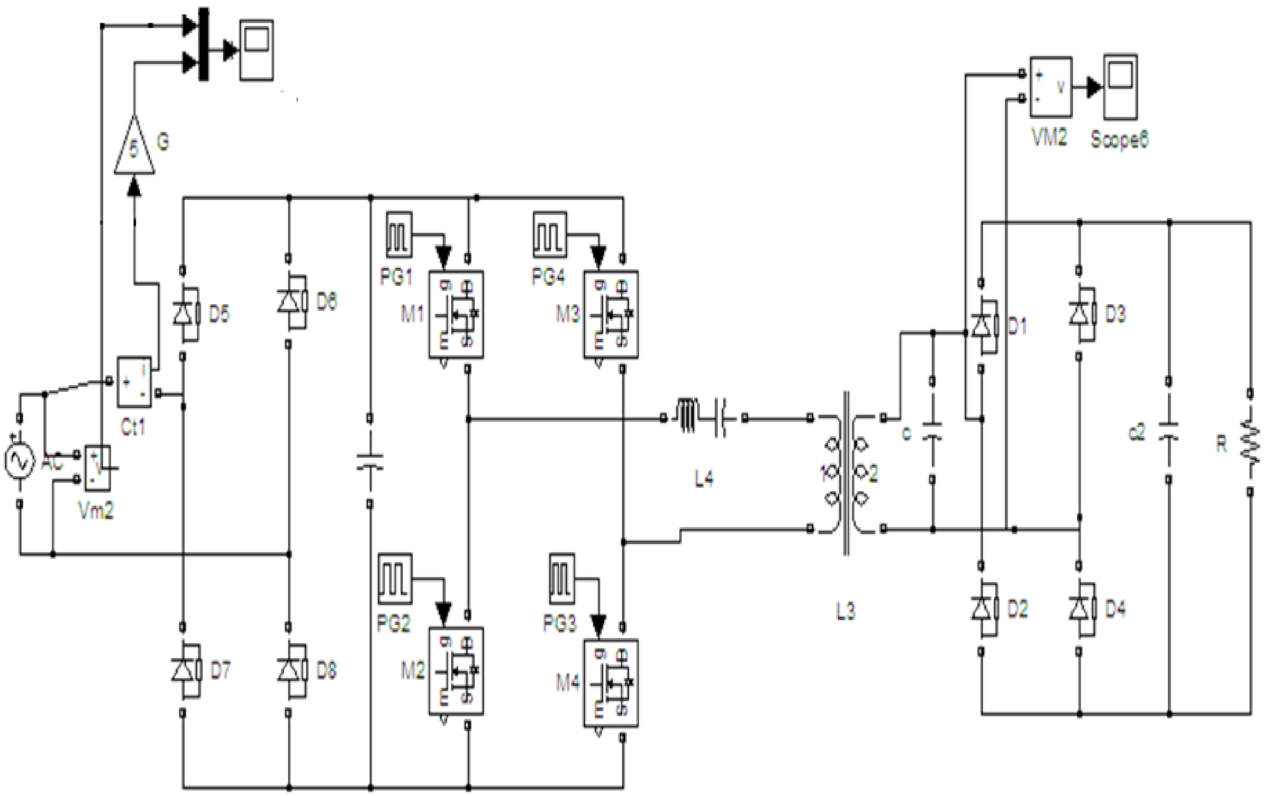

Figure 2. Simulation circuit for series parallel resonant converter.

MOSFET full bridge rectifier. The resonant capacitor Cp is connected in parallel with secondary instead of primary. The LC tank circuit is called as resonant circuit.

The resonant link circuit is driven with either square waves of voltage or current in the inverter. At resonant frequency, the voltage or current becomes minimum in the resonant components. This can be adjusted to any desired value by altering the frequency around the resonant point. By rectifying the voltage across the secondary of the transformer, a dc voltage is obtained which is filtered to achieve smooth DC. Scopes are connected to display the input current and voltage, gate pulses, output voltage, current, etc.

4. Simulation Results

The simulation of full bridge series parallel resonant converter is done using Matlab and results are presented here. Figure 3. shows the gate pulse and drain source voltage waveforms for MOSFET's M1 and M4. From the wave form it is clear that when the pulse to the MOSFET is high, the output is low. That is the switch is in conduction state. When the device conducts the voltage across the device is very less.

The output of series resonant inverter, primary side voltage and current waveforms are shown in Figure 4. The sinusoidal current waveforms are obtained at the output of LC circuit. The series parallel resonant inverter reduces harmonics of the transformer. DC output voltage and current waveforms are shown in Figure 5 and Figure 6. respectively. DC output voltage across the load is found to be 12V. The performance measures are Settling time t_s : 0.57 second, Delay time t_d : 0.025 second, Rise time t_r : 0.054 second and Peak time t_p : 0.18 second respectively. It has been observed that, constant output voltage and current waveforms are obtained for the series parallel resonant converter.

Output power waveform is shown in Figure 7. The output voltage, power and hence the efficiency is calculated for the different values of input voltage. The values are tabulated and they are given in Table 1. From these results, it has been observed that, output voltage, percentage of efficiency are varies linearly with the input voltage.

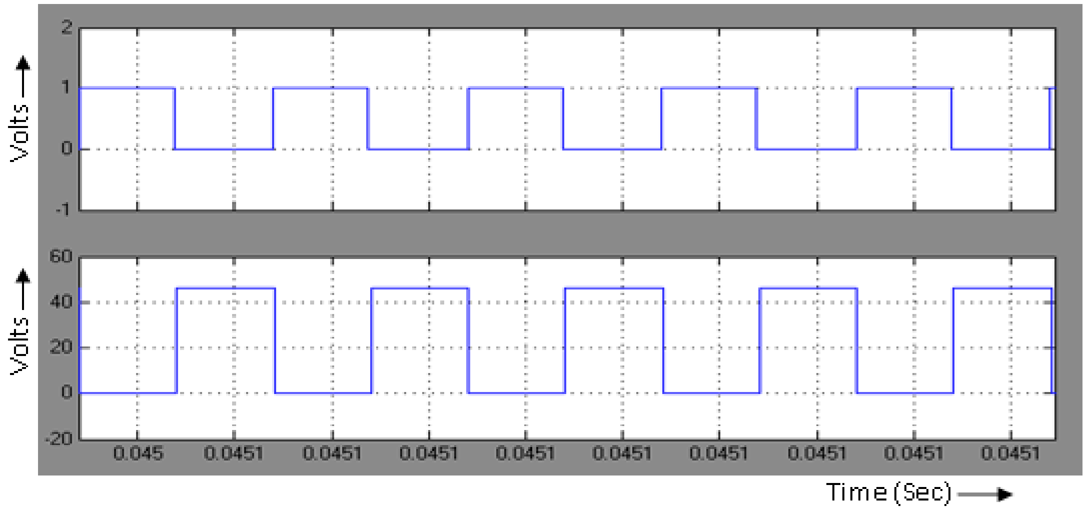

Figure 3. Gate pulse and drain source voltage across switch 1,4.

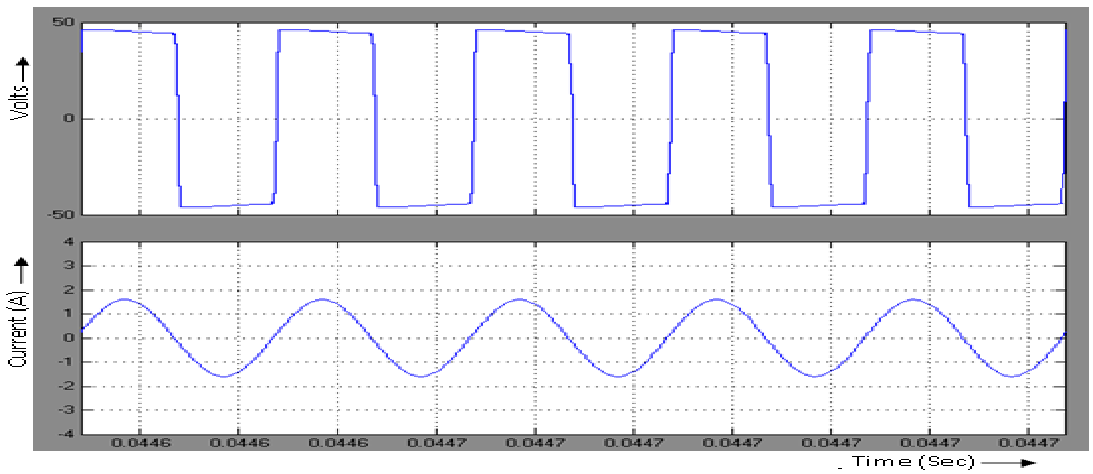

Figure 4. Transformer primary voltage and current.

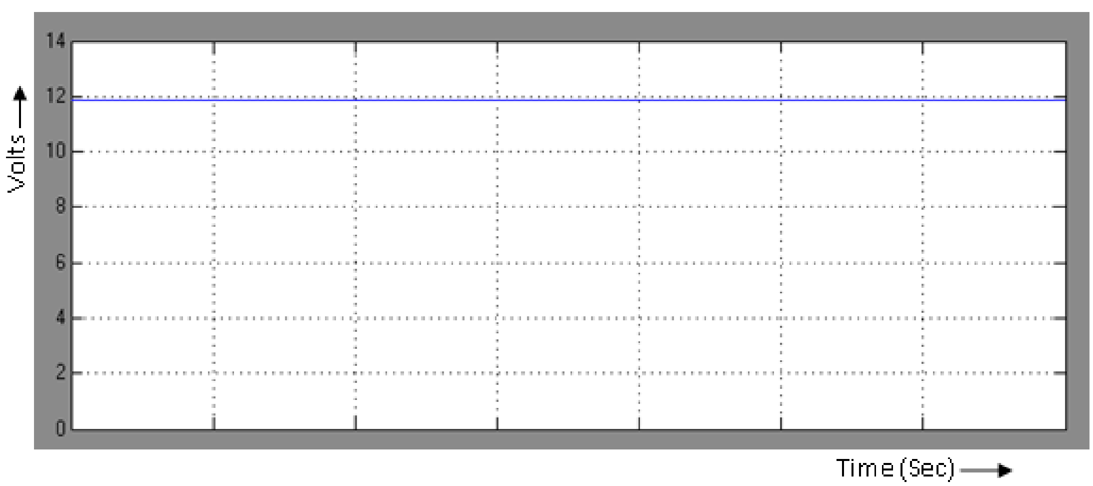

Figure 5. Output voltage.

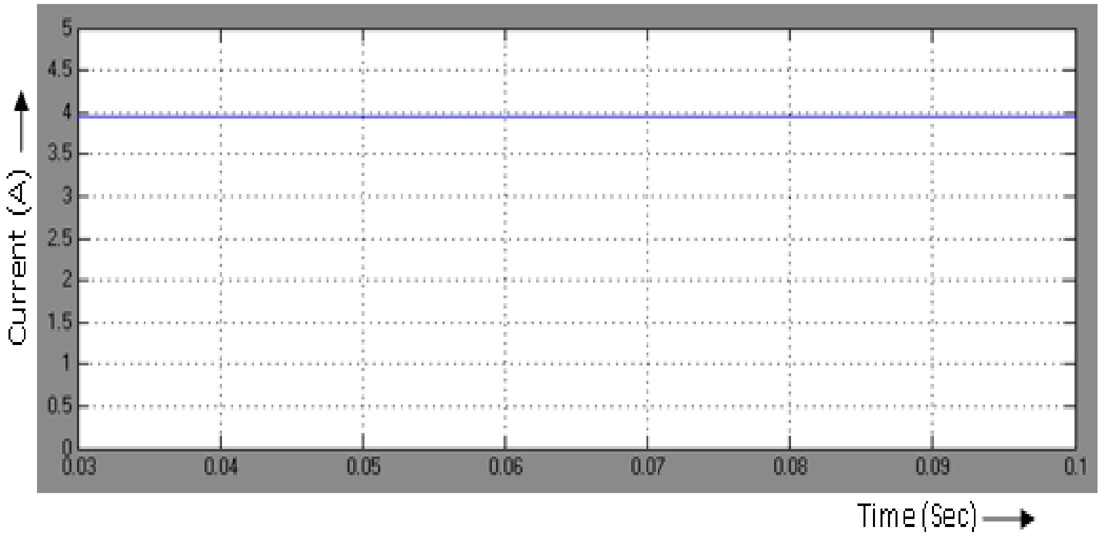

Figure 6. Output current.

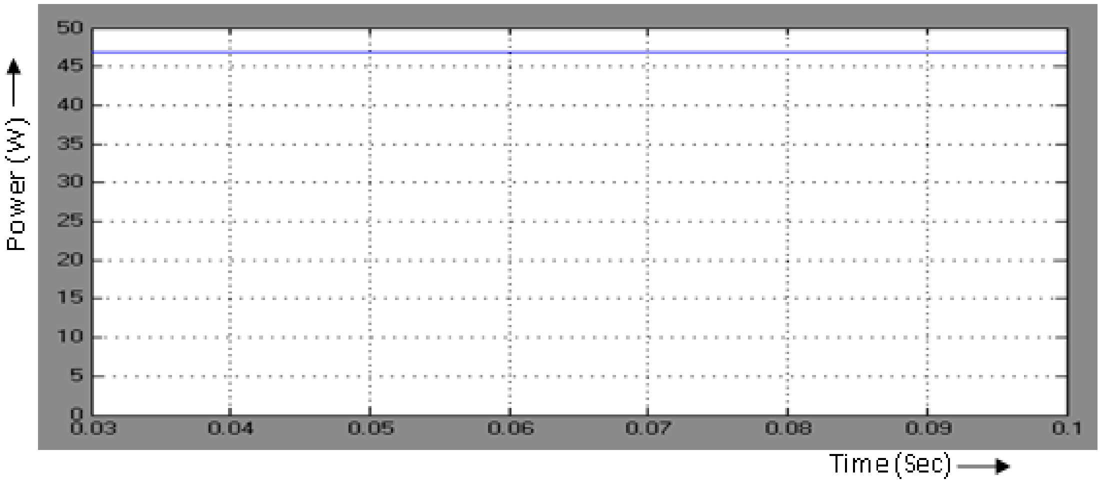

Figure 7. Output power.

Table 1. Simulated results for series parallel resonant converter

Input Voltage (V)	Output voltage (V)	Input power (W)	Output power (W)	Efficiency (%)
40	9	39	30	76.92
44	11	47	38	80.85
48	12	57	47	82.456
52	13	67	57	85.07

5. Conclusion

Series parallel full bridge resonant converter with high frequency is simulated using Matlab simulink and the results are presented. Smooth and ripple less output voltage waveform is obtained from the converter. Efficiency of the converter is calculated for the various values of input voltage. It is found that the efficiency has linear behavior with the input voltage. The series parallel converter has advantages like high power density, reduced EMI, reduced switching losses and stresses. This converter is suitable for low voltage DC applications.

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