A NOVEL SOFT SWITCHING HIGH FREQUENCY AC TO DC SERIES RESONANT CONVERTER

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ABSTRACT

The use of soft-switching techniques, alleviates switching loss problems and allows a significant increase in the converter switching frequency. Small size and improved transient performance can be achieved through high switching frequency if resonant converter are adopted for these applications. Major advantages of this converter are leakage and magnetizing inductance of the high-frequency transformer that are used as a part of resonant circuit, and the output rectifier voltage is clamped to the output voltage. Converter operates in soft switching for the inverter switches with a narrow frequency control range and the tank current decreases with the load current. The switching process are softly commutated. Therefore the switching losses and noises are reduced. This makes this converter suitable for applications such as high performance electric drives, battery charges, with improved power factor. The current work is focused on simulation of Series Resonant Power Factor Correction AC – DC Converter using Matlab simulation.

Key words: High frequency, Soft switching, PFC Half Bridge Series resonant converter.

I. INTRODUCTION

The Conventional PWM technique processes power by controlling the duty cycle and interrupting the power flow. All the switching devices are hard-switched with abrupt changes of currents and voltages, which results in severe switching losses and noises. Meanwhile, the resonant technique process power in a sinusoidal form and the switching devices are softly commutated. Therefore, the switching losses and noises can be dramatically reduced. For this reason, resonant converters have drawn a lot of attentions in various applications [1].

Higher conversion efficiency and power density are urgent targets for power electronics industries. To satisfy these demands, many topologies and control methods are proposed. Among them, DC-DC series resonant converters (SRCs) with zero-voltage-switching (ZVS) features are getting more attention [2]. The series resonant asymmetric pulse-width-modulated converter (SR-APWM) is a half bridge load resonant topology that achieves ZVS while operating at constant frequency [3]. With the development of power conversion technology, power density and efficiency of converter has become the major challenge [4].

In the design of the pulse-width-modulated DC-DC converters, a high power packing density and a high power conversion efficiency are extremely desirable. In order to obtain a high power packing density, engineers prefer increasing the switching frequency to minimise the size of the magnetic components in the converter. However, significant switching loss can occur due to high voltage and high current overlaps during the switching period. The advantage of high switching frequency can easily be cancelled out by the low conversion efficiency.

Recent power converters tend to increase switching frequency to reduce the size and volume of the passive components, such as inductors, transformers, and capacitors. A high-frequency switching operation however brings a increased switching loss to the power semiconductor device, which is proportional to the switching frequency. The latest power semiconductor devices have a fast turn-on and turn-off capability to reduce the switching loss at a high-frequency operation. Wide bandgap semiconductors, such as silicon carbide (SiC), gallium nitride (GaN) and diamond (C), are expected to reduce the switching losses in power semiconductor devices as well as the on-state loss [5].

Resonant converter are extensively used in medium to high power application. For most of these applications, the most desirable features of the converter are high efficiency, high power density, high reliability and low EMI. But these needs to be a trade of off as its difficult to in corporate all the above features in a typical hard switching converter. Also these hard switching converters suffer from high switching losses and reduced reliability. To overcome these draw backs a soft switching resonant converter is proposed. ZVS technique can be realized in several ways based on positioning the resonant components in the converter circuit.

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 power transfer characteristic. The resonant DC-DC converter can considerably reduce the switching loss and obtain friendly EMI characteristic, which has facilitated its adoption in a diverse range of applications [6].

DC-DC converters are essential units for almost all of the electric/electronic equipment. To regulate the output power/voltage of DC-DC converters, various control methods have been proposed and implemented. The pulse width modulation (PWM) is commonly used, whereas the pulse density modulation (PDM) has been getting more attractive these days as the digital control has been getting popular [7]. In the present work half bridge series resonant PFC converter is designed and simulated results are presented for the high frequency soft switching converter.

II. CIRCUIT DESCRIPTION AND OPERATING PRINCIPLE

Fig.1 shows the half bridge series resonant converter. The circuit consists of a AC input source, full bridge diode rectifier, filter circuit, half bridge MOSFET inverter having a high frequency (HF) resonant circuit. A HF transformer provides voltage transformation and isolation between the source and the load. A load can be connected to the high frequency link circuit with secondary rectifier and smoothing capacitor.

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 half bridge inverter. Pulse generators are connected to the gate of the MOSFET. When M_1 conducts, M_2 should be in off state and vice versa, to avoid short circuit.

Output of the inverter is connected to LC tank circuit and primary of the transformer. The secondary of the transformer is then connected to diode bridge rectifier. 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. The voltage or current in the resonant components becomes maximum at the resonant frequency and by altering the frequency around the resonant point, the voltage on the resonant components can be adjusted to any desired value.

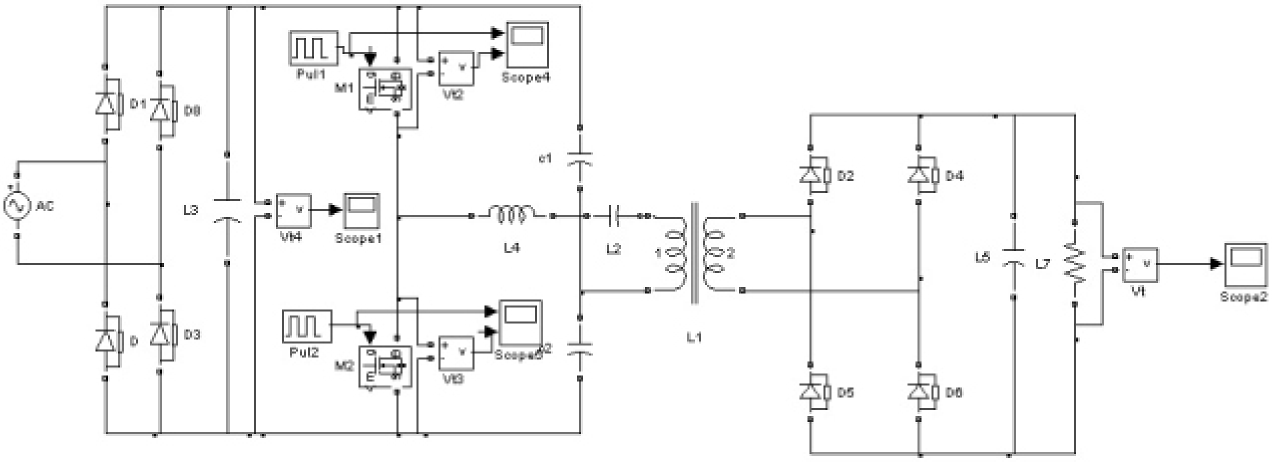

Fig. 1. Half Bridge Series Resonant Converter

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.

III. SIMULATION RESULTS

The simulation of half bridge series resonant converter is done using Matlab and results are presented. Fig.2 shows the switching pulse for MOSFET M_1 and M_2. When the pulse to M_1 is high, the pulse to M_2 is low. i.e. When MOSFET M_1 is on MOSFET M_2 must be in off state.

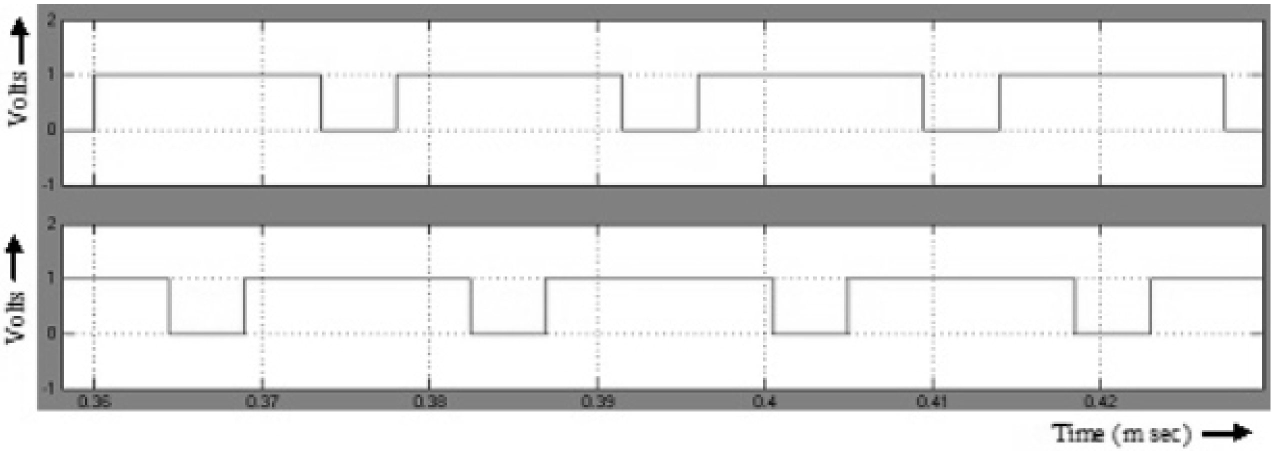

Fig. 2. Switching Pulse for MOSFET M_1 and M_2

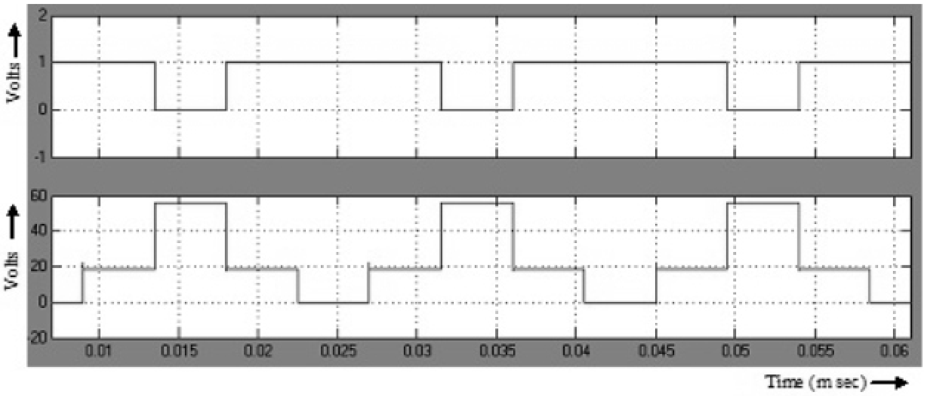

Fig. 3. V_{gs} and V_{ds} for MOSFET M_1

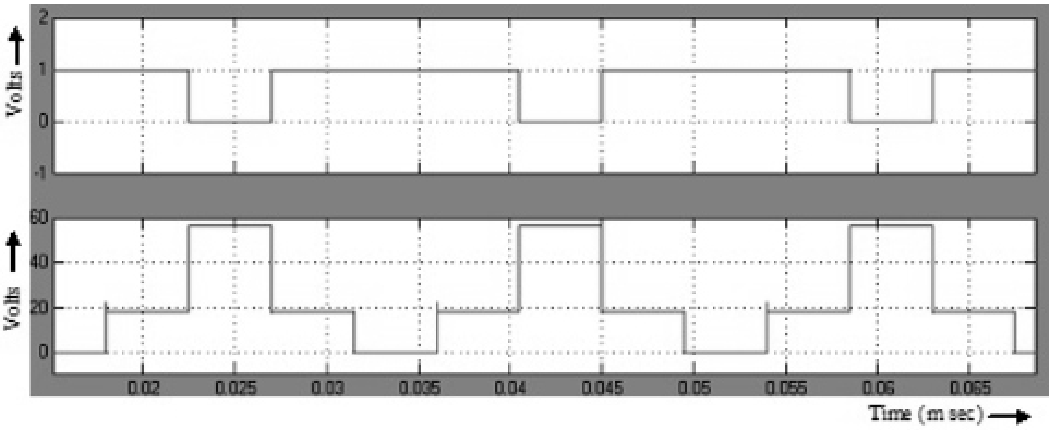

Fig. 4. V_{gs} and V_{ds} for MOSFET M_2

Input voltage V_{gs} and output voltage V_{ds} for the MOSFET M_1 and M_2 are shown in fig. 3 and fig. 4. From the wave forms it is clear that when V_{gs} is high and V_{ds} is in low. When input V_{gs} rises the V_{ds} falls down and vise versa. i.e. the switch is on during zero voltage and it is known as zero voltage switching. The MOSFET M_1 conducts, resonant current flows in clock wise direction through the primary of the transformer. The MOSFET M_2 conducts, the resonant current flows in anti-clock wise direction.

Input voltage and current waveform is shown in fig.5. Input current waveform lags the input voltage waveform with large angle. Since the phase angle difference between the voltage and current is high, the power factor is poor.

IV. HALF BRIDGE SERIES RESONANT PFC CONVERTER

Fig 6 shows the modified half bridge series resonant Power Factor Correction (PFC) converter. The circuit consists AC input source with inductance, full bridge diode rectifier, filter circuit, half bridge MOSFET inverter having a high frequency (HF) resonant tank circuit, HF transformer, rectifier, filter and load. The circuit operation is similar to that of the circuit in fig.1

The inductor connected in series with the source improves the power factor in the circuit.

Power Factor $\cos\Phi = \frac{R}{Z}$ ... (1)

The impedance $z = \sqrt{R^2 + \left(X_L - X_C\right)^2}$ ... (2)

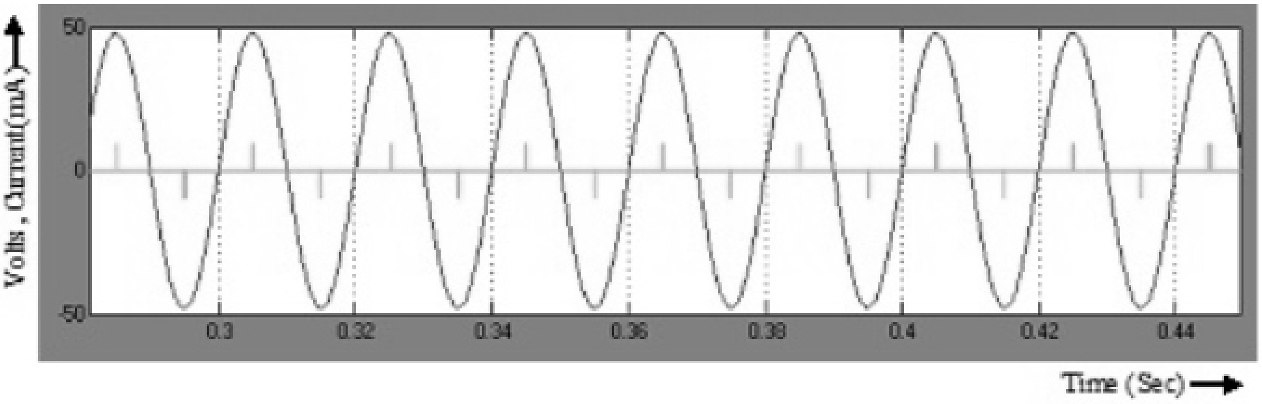

Fig. 5 Input Voltage and Input Current waveform

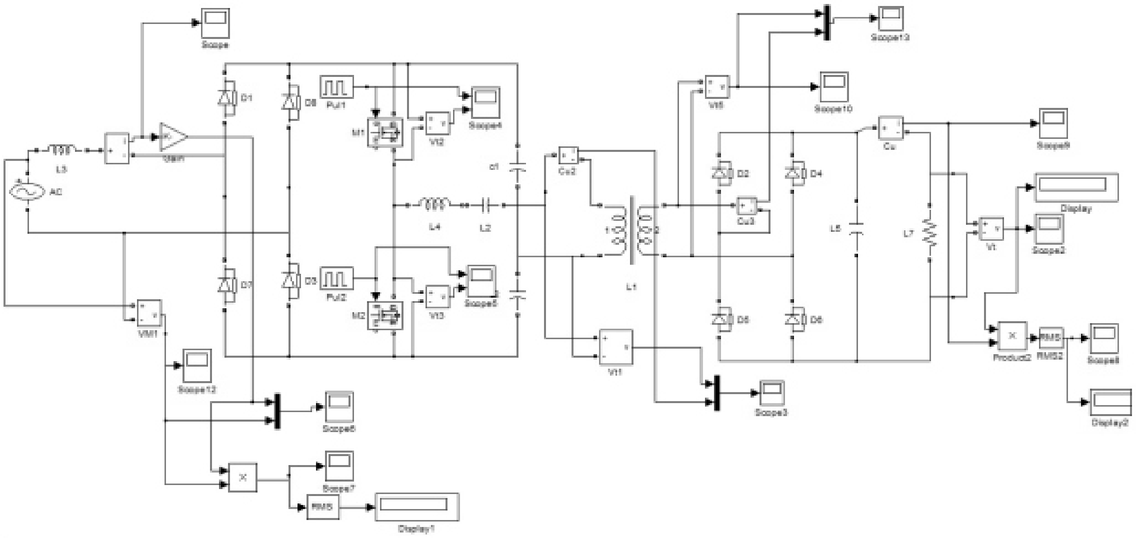

Fig. 6. Half Bridge Series Resonant PFC Converter

In the circuit when connecting the inductance, the impedance value decreases and the power factor increases.

Also, when the value of $X_L = X_C$, the impedance and the circuit is at resonance and the power factor is unity.

V. SIMULATION RESULTS FOR THE MODIFIED CIRCUIT

The simulation of half bridge series resonant PFC converter is done using Matlab and results are presented for the circuit. The input voltage and the switching pulses for the MOSFETs M_1 and M_2 are same as that of the fig.1.

The output voltage and output current waveforms are shown in fig.7 and fig.8 respectively. The output voltage is 12V and the output current is approximately 1.2 mA.

The input power and output power waveforms are shown in fig.9 and fig.10 respectively. The power for the different values of input voltage and hence the efficiency is calculated. The values are tabulated and it is given in table.1.

Table 1. Input Voltage and Efficiency

Input voltage(Vin)	Efficiency
56	64%
46	65%
36	67%
26	69%

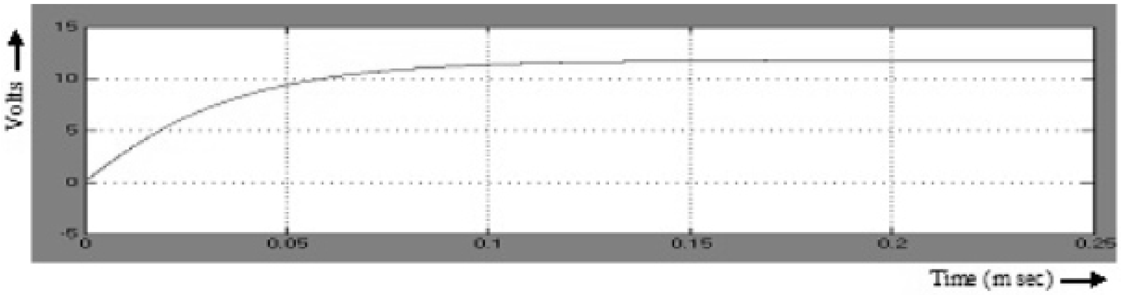

Fig. 7 Output Voltage

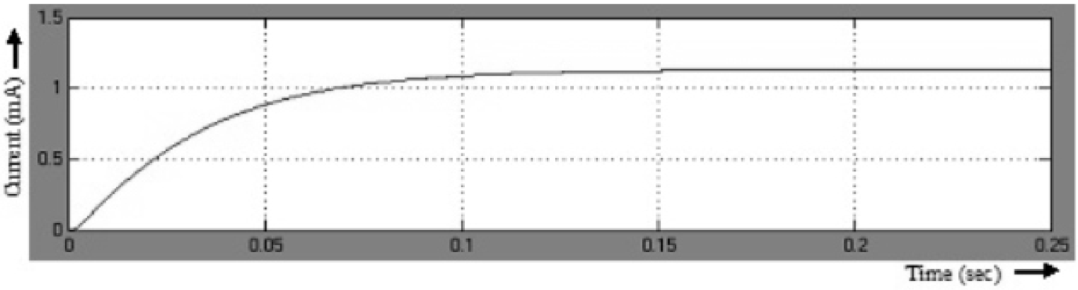

Fig. 8 Output Current

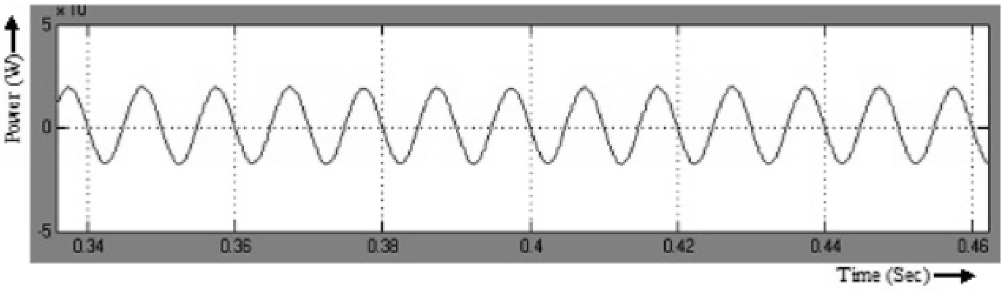

Fig. 9 Input Power

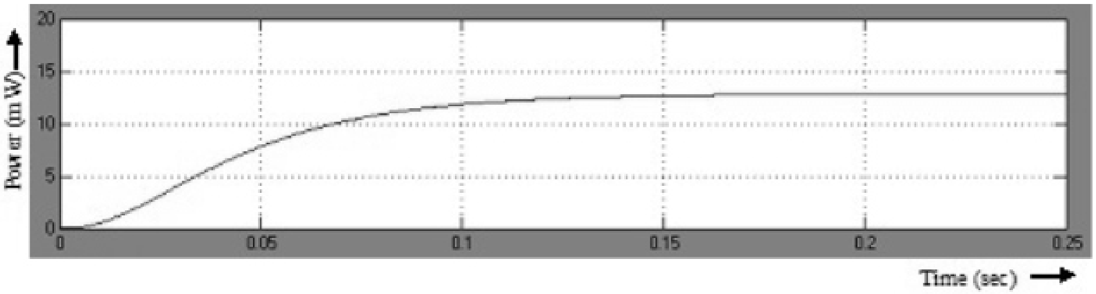

Fig. 10 Output Power

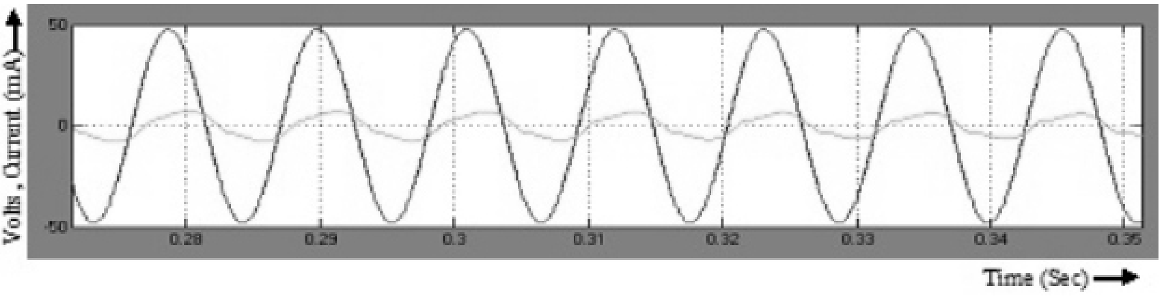

Fig. 11 Input voltage and current wave form for the modified circuit

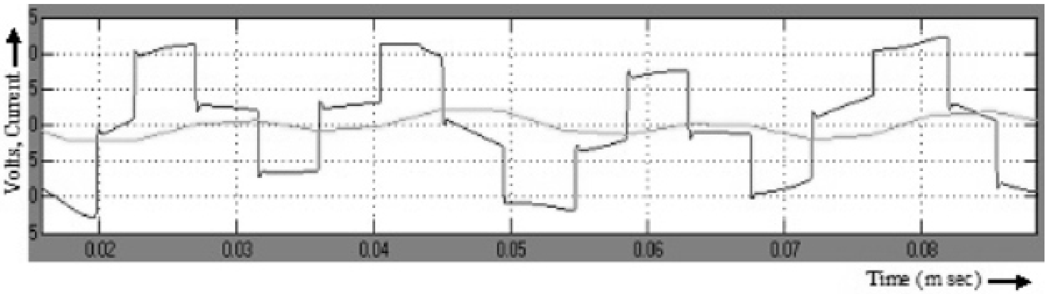

Fig. 12. Voltage and current wave form for the primary side of the transformer in the modified circuit

Input voltage and current waveform for the modified PFC converter is shown in fig.11. Input current waveform is almost in phase with the input voltage waveform. The phase angle difference between the voltage and current is very small. Results in improved power factor in the modified series resonant converter.

Voltage and current waveform at the primary side of the transformer is shown in fig. 12. Input voltage and percentage efficiency for the modified circuit is shown in fig. 13

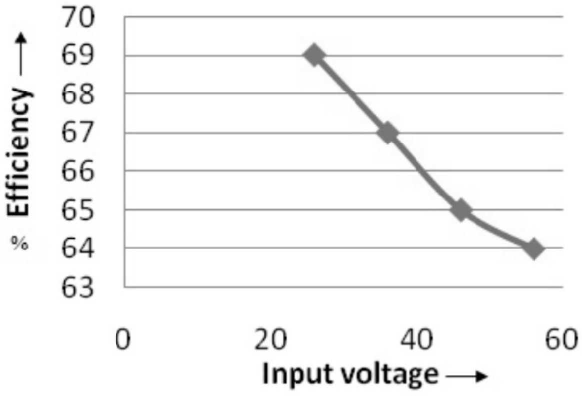

Fig. 13 Input voltage and percentage efficiency

VI. CONCLUSION

Half bridge series resonant PFC converter is simulated using Matlab simulink. The series resonant PFC converter has advantages like high power density, reduced EMI, reduced switching losses and stresses. Power factor improvement and high efficiency is achieved with a constant output voltage.

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