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Comparison of Buck Converter and Resonant Buck Converter

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***Abstract:** The purpose of this paper is to compare the performance of the conventional buck converter and the resonant buck converter. The input supply given to the power electronics converter will be the battery of 48VThe resistive load is connected at the output of the converter. The dc-dc converter is controlled by using the PWM technique. In resonant converter with respect to the load the power electronics switches will not experience any current stress or voltage stress. Simulation outputs are provided. Simulation is done by MATLAB/SIMULINK software.*

***Index Terms:** Zero Voltage Switching (ZVS), Zero Current Switching (ZCS), Insulated Gate Bipolar Transistor (IGBT), Metal Oxide Semiconductor Field Effect Transistor (MOSFET), Pulse Width Modulation (PWM).*

I. INTRODUCTION

The major aims in the switching converters design are to achieve a higher power packing density and good conversion efficiency. In order to obtain an increase in power packing density the switching frequency has to be increased. This leads to the reduction in the size of the reactive components.

In conventional buck converter during the power transfer it suffers high switching losses. This high switching losses leads to usage of the large heat sinks.

In resonant converter as the load varies the power electronics switches will not experience any current stress or voltage stress.

II. BUCK CONVERTER

The conventional buck converter is shown in fig 1. The average output voltage is lesser than the input voltage in buck converter. The operation is classified into two modes interms of the switching action

Mode:1

When switch is turned ON mode the inductor current rises

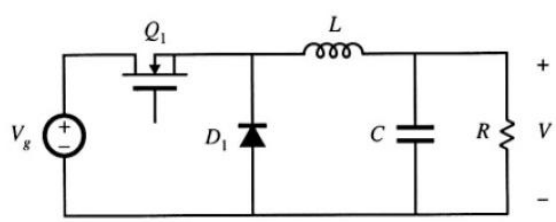

Fig. 1 Buck Converter

from I1 to I2.

$$V_L=\frac{di}{dt}L$$

$$V_S - V_a = \frac{L(I2-I1)}{t1}$$

$$t1=\frac{-L\Delta I}{t2}$$

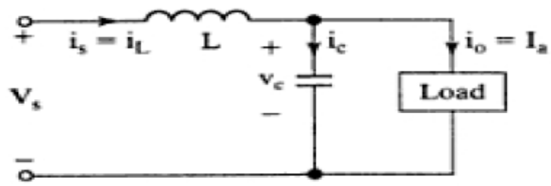

Fig. 2 mode 1 of Buck Converter

Mode:2

When Q1 is turned OFF the inductor current falls from I2 to I1.

$$-Va=-\frac{-L\Delta I}{t2}$$

$$\Delta I = \frac{(VS - Va)t1}{L}$$

$$\Delta I = \frac{(Va)t2}{L}$$

When we substitute t1=KT and t2=(1-k)T yields the average output voltage as

$$Va = V_S\frac{t1}{T}$$

$$V_a=kV_S$$

The switching period T can be expressed as,

$$T=\frac{1}{f}=t_1+t_2=\frac{\Delta ILVs}{Va(Vs-Va)}$$

which gives the peak to peak ripple current as,

$$\Delta I= V_a(V_S-V_a)/fLV_S$$

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III. RESONANT BUCK CONVERTER

The turn on instant of power switch occurs at zero voltage, it helps to reduce the switching losses, stress while switching, dv/dt and thus Electro Magnetic Interference. The capacitor Cr is connected across the switch to limit dv/dt of the power electronics switch, s. Because of this special feature resonant buck converter is suitable for high-frequency conversion applications. The circuit operation is classified into five modes.

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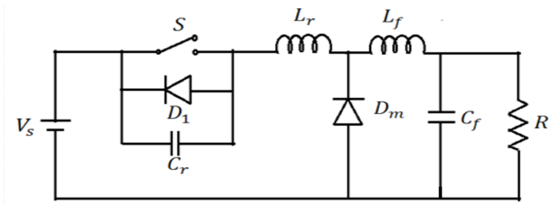

Fig. 3 Circuit Diagram of Zvs Resonant Buck Converter

Mode I:

This mode begins at time t_1. In this mode the switch and the diode are turned off and the capacitor charges to V_s .

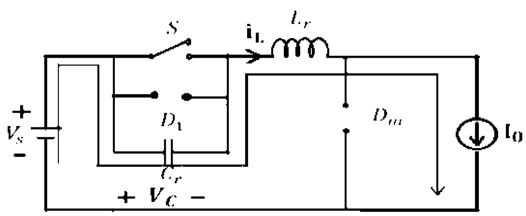

Fig. 4 Equivalent Circuit of Mode I

Mode II:

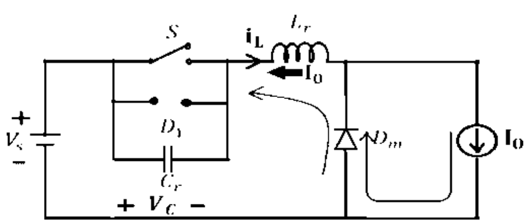

Fig. 5 Equivalent Circuit of Mode II

This mode begins at time, t_2. The switch is will be in off state, but diode is turned on. The capacitor voltage can be

$$V_c = V_m \sin \omega 0t + V_s$$

where$V_m = I_0\sqrt{\frac{L}{C}}$.

Mode III:

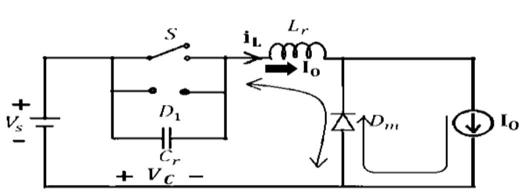

Fig. 6 Equivalent Circuit of Mode III.

This mode begins at time, t_3. The voltage in the capacitor gets fallen down to zero from V_S it can be,

$V_c = V_s - V_s \sin \omega_0 t$

Mode Iv:

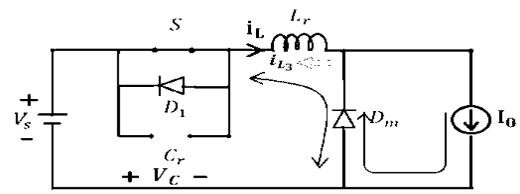

Fig. 7 Equivalent Circuit of Mode IV

This mode begins at time, t_4. Switch is turned on and diode will remains on state. The inductor current will rises linearly.

Mode V:

This mode begins at time t_5. Switch is turned ON but diode gets turned off. Now the switch carries the load current. The switch is off at the end of this mode, and the modes of operation is repeated.

$$t_5 = T - (t_1 + t_2 + t_3 + t_4)$$

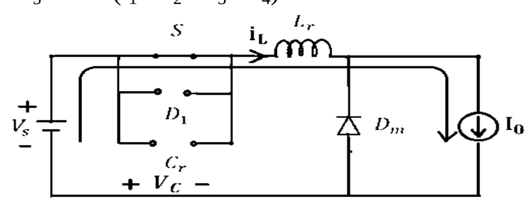

Fig. 8 Equivalent Circuit of Mode V.

IV. DESIGN SPECIFICATIONS

The below table gives the specification of components in the buck converter.

Table. 1 Buck converter design specifications

PARAMETERS	SPECIFICATIONS
Input Voltage	48V
Filter inductance	180µH
Filter capacitance	30µF
Load resistance	240Ω
Switching frequency	20KHz

The below table gives the specification of components in the resonant ZVS buck converter .

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Table. 2 Resonant Buck converter design specifications

PARAMETERS	SPECIFICATIONS
Input Voltage	48V
Filter inductance	180μH
Filter capacitance	30μF
Resonant inductance	103.157μH
Resonant capacitance	0.1007μF
Load resistance	240Ω
Switching frequency	20KHz
Resonant frequency	50KHz

V. SIMULATION RESULTS

Simulation Diagram of Buck Converter:

The FIG:9. gives the simulation model of the buck converter. The switch operates at the switching frequency of 20KHz.

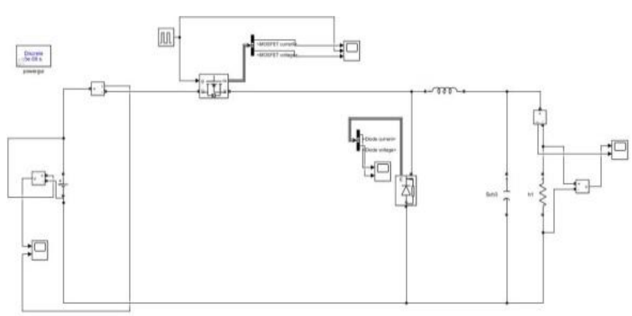

Fig. 9 Simulation Diagram of Buck Converter

Input Current:

In the FIG :10. the input current of buck converter is shown. It is plotted by time(secs) in x-axis and input current(mA) in y-axis.

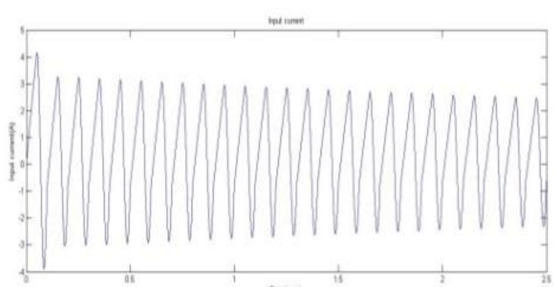

Fig. 10 Input Current of Buck Converter

Input Voltage:

In the FIG :11. the input voltage of buck converter is shown It is plotted by time(secs) in x-axis and input voltage(V) in y-axis.

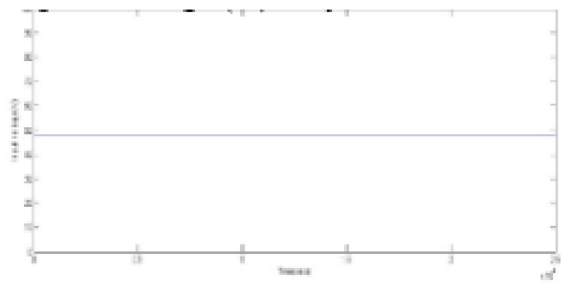

Fig. 11 Input Voltage of Buck Converter

MOSFET Voltage:

In the FIG :12 the MOSFET voltage of buck converter is shown. It is plotted by time(secs) in x-axis and MOSFET voltage(V) in y-axis.

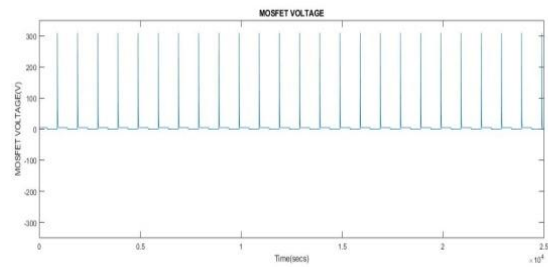

Fig. 12 MOSFET Voltage of Buck Converter

Output Current:

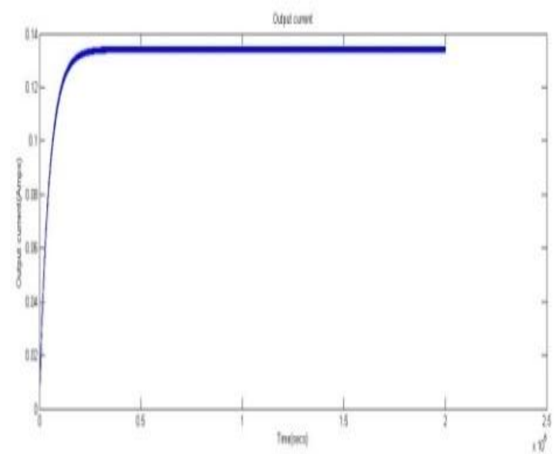

Fig. 13 Output Current of Buck Converter

The FIG.13gives the output current of buck converter. It is plotted by time(secs) in x-axis and output current(A) in y-axis.

Output Voltage:

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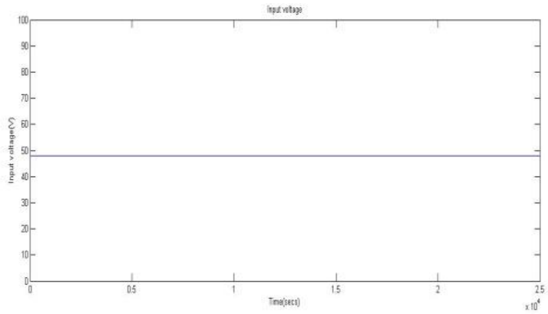

Fig. 14 Output Voltage of Buck Converter

The FIG:14. represents the output voltage of ZVS buck converter. The output voltage is plotted by time(secs) in x-axis and output voltage(V) in y-axis.

Simulation Diagram:

The FIG:15. represents the simulation diagram of the ZVS buck converter. The switch is the power MOSFET operates at the switching frequency of 20KHz.

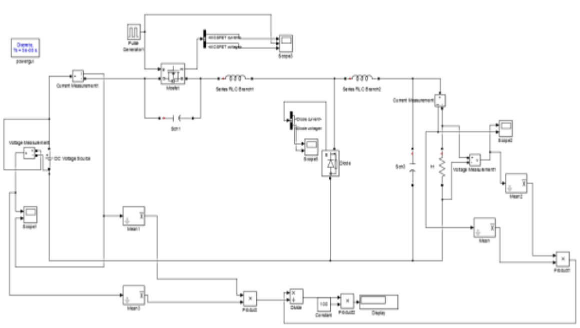

Fig. 15 Simulation Diagram of ZVS Buck Converter

Input Current:

The FIG :16. represents the input current of ZVS buck converter. The input current is plotted by time(secs) in x-axis and input current(mA) in y-axis.

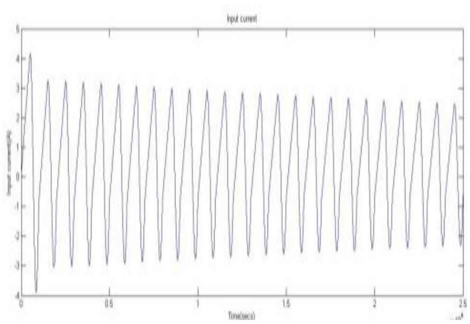

Fig. 16 Input Current of ZVS Buck Converter

Input Voltage:

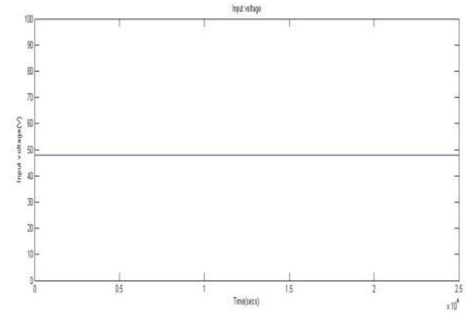

Fig. 17 Input Voltage of ZVS Buck Converter

The FIG:17. represents the input voltage of ZVS buck converter. The input voltage plotted by time(secs) in x-axis and input voltage(V) in y-axis.

MOSFET Voltage:

The FIG:18 represents the MOSFET voltage of ZVS buck converter. The MOSFET voltage is plotted by time(secs) in x-axis and MOSFET voltage(V) in y-axis

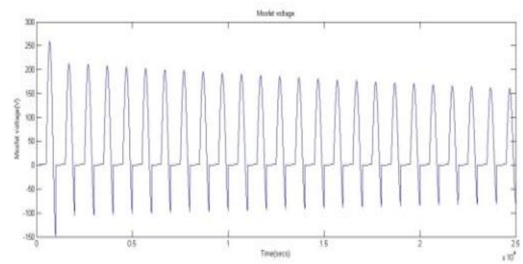

Fig. 18 MOSFET Voltage of ZVS Buck Converter

Output Current:

The FIG19. represents the output current of ZVS buck converter. The output current is plotted by time(secs) in x-axis and output current(A) in y-axis.

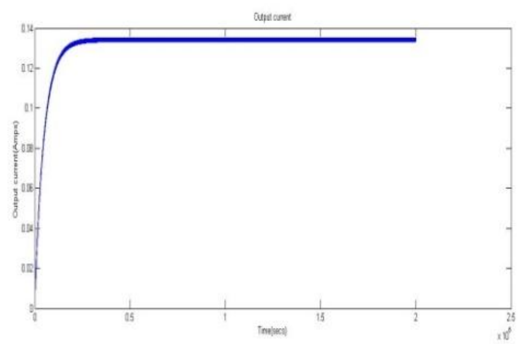

Fig. 19 Output Current of ZVS Buck Converter

Output Voltage:

The FIG:20. represents the output voltage of ZVS buck converter. The output voltage is plotted by time(secs) in x-axis and output voltage(V) in y-axis

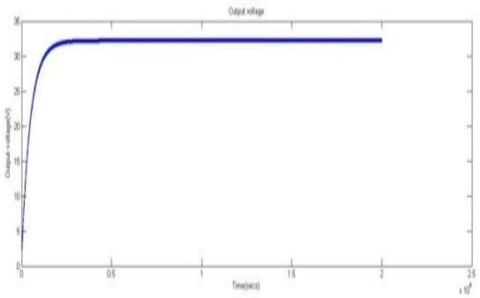

Fig: 20. Output Voltage of ZVS Buck Converter

VI. COMPARISON

In the conventional buck converter we can see some switch stress while turn ON the power MOSFET. This results in high switching losses and also the Electro Magnetic Interference. But this switch stress is eliminated in the resonant ZVS buck converter by connecting the resonant capacitor in parallel to the switch i.e., power MOSFET. Thus the switching losses can be reduced.

VII. CONCLUSION

Thus the modes of operation of the conventional buck converter and the ZVS resonant buck converter and also its design specifications are discussed. With the same component parameters the simulation is carried out in the MATLAB/SIMULINK software and the results are compared. The simulation results shows that the conventional buck converter experiences switch stress and it is reduced in ZVS resonant buck converter. Thus the switching loss in the resonant buck converter is less compared to the conventional buck converter.

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