

Comparison Between Conventional Buck Converter And Switched Inductor Converter

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Abstract : Conventional buck converter is used to step down the DC voltage. In conventional DC/Dc converters, conversion ratio depends on the duty cycle of the switch. In these converters, duty cycle varies to fix the load voltage. These converters have difficulty with operating in very high or very low values of conversion ratios. Extreme duty cycle impairs the efficiency of the converters. In order to tackle this problem, many methods, using transformer, series converters with one switch, soft switching, and switched capacitor converters are employed. In this paper, a modified buck converter formed by two inductors and two diodes is considered in discontinuous conduction mode is given. And a comparative study is done to assess the performance of the switched inductor buck converter with the conventional buck converter in the aspect of lower conversion ratio at higher efficiency. The simulation work is carried out using MATLAB-SIMULINK and the results are obtained.

Keywords : buck converter, inductor, choppers

I. Introduction

In classic DC/DC converters, conversion ratio depends on duty cycle of active switch. In these converters duty cycle vary to fix load voltage despite of changing in load current or input voltage [1]. Basic problem in these converters is producing very big or very small conversion ratio. In order to provide such a high or low voltage-conversion ratio, the basic converters would have to operate with an extreme value of the duty cycle, i.e. smaller than 0.1 in voltage-step-down converters, higher than 0.9 in voltage-step-up converters. An extreme duty cycle impairs the efficiency and imposes obstacles for the transient response. Solving these problems, researchers have proposed many methods, using transformer, series converters with one switch [1], soft switching [2], switched-capacitor converters [3] were the most important of these ways. Also, to generate such an extreme duty cycle, the control circuit must incorporate a very fast, expensive comparator. The extreme duty cycle may even cause malfunctions at high switching frequency due to the very short conduction time of the diode (self-driven transistor) in step-up converters, or of the active transistor in step-down converters. An obvious solution would be the use of transformers to get the desired voltage conversion ratio, like in forward or flyback converters. However, if the industrial application does not require for dc isolation, the use of a transformer would only increase the cost, the volume, and the losses.

II. Mathematical Analysis

Conversion ratio of a conventional buck converter is given by,

$$M_c = \frac{V_o}{V_d} = D$$

Where V_o is the output voltage and V_d is the input voltage.

The values of the circuit elements are given by

$$L = \frac{V_{out} * (V_{in} - V_{out})}{\Delta iL * f_s * V_{in}}$$

$$C = \frac{\Delta iL}{8 * f_s * \Delta V_{out}}$$

Here only one inductor is used in the conventional buck converter.

In the case of a switched inductor converter, the conversion ratio is given by,

$$\frac{(V_{in} - V_o)}{2} D - V_o(1-D) = 0$$

$$M_s = \frac{V_o}{V_d} = \frac{D}{2-D}$$

Where V_o is the output voltage and V_d is the input voltage.

The values of the circuit elements of the switched inductor converter are given by

$$L = \frac{(V_d - V_o)DR}{2V_o f}$$

$$C = \frac{\Delta iL}{8 * f_s * \Delta V_{out}}$$

Two numbers of inductors are used in the switched inductor converter.

III. Circuit Configuration And Modes Of Operation

Figure 1 shows the circuit diagram of the buck converter. The modes of operation give a clear comparison of the operation of the converters. A conventional buck converter has two modes of operation. In mode 1, when the switch is ON, the inductor is charged, as shown in figure 1 (a). In mode 2, when the switch is OFF, the load current freewheels through the diode, as shown in figure 1 (b). Capacitor is used to minimize the ripple in the output.

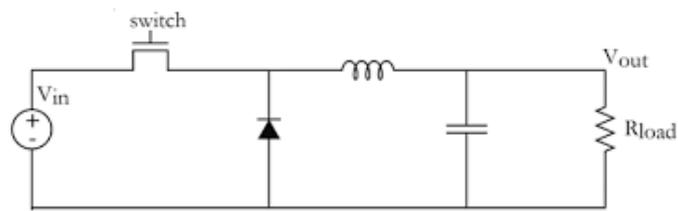


Fig 1

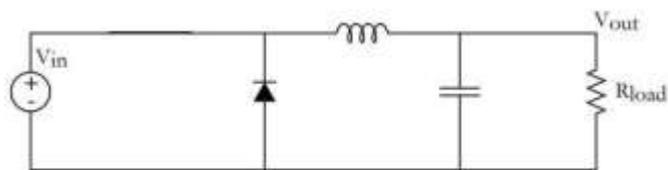


Fig 1 (a)

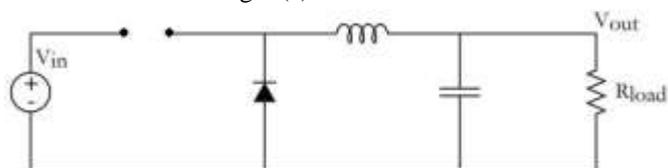


Fig 1 (b)

Figure 2 shows the circuit diagram of a switched inductor converter. In the switched inductor converter, it has two modes of operation. In mode 1, when the switch is ON, the two inductors are charged in series, as shown in figure 2 (a). In mode 2, when the switch is OFF, the load current freewheels through the inductors are diodes, shown in figure 2 (b). Inductor L1 is discharged through diode D1 and load and inductor L2 is discharged through diode D2 and the load. The inductors give their energy to the load in parallel. Load current boosting occurs here, as the load current is the sum of the two inductor currents.

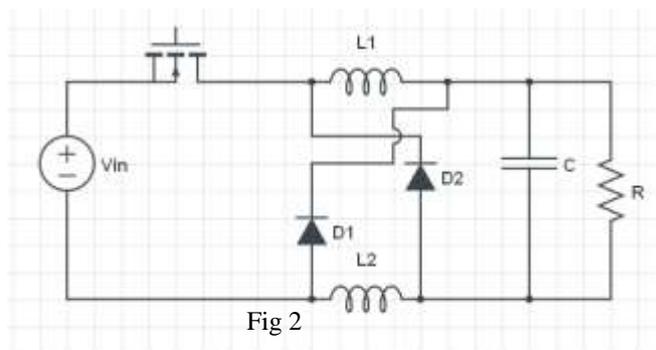


Fig 2

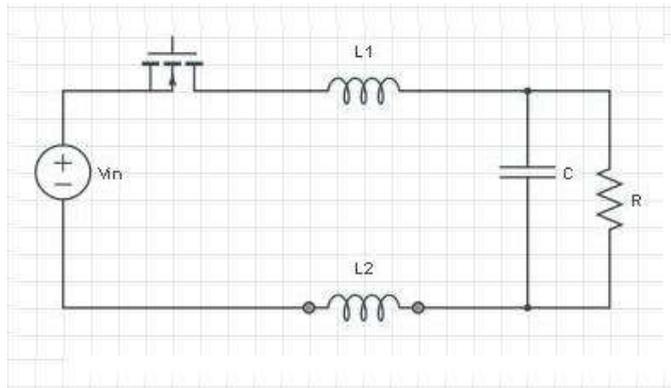


Fig 2 (a)

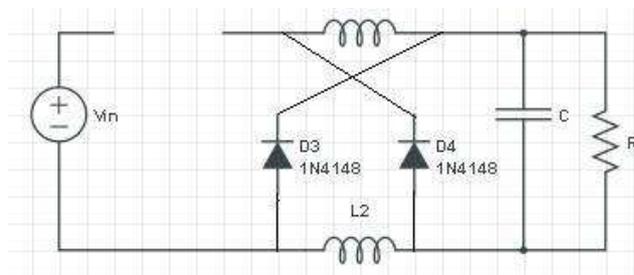


Fig 2 (b)

From this, it is observed that for the same duty cycle value of D , the conversion ratio of a switched inductor converter is smaller than that of a conventional buck converter. It is observed that, for lower values of conversion ratio, D will not go to extreme values.

IV. Simulations And Results

In order to analyze and compare the performance of the two converters, a model of the conventional buck converter and switched inductor converter is simulated in MATLAB-SIMULINK and the output waveforms and various parameters are observed. Figure 3 shows the MATALB-SIMULINK model of the switched inductor converter and figure 4 shows the MATALB-SIMULINK model of the buck converter. Waveforms of conventional buck converter and switched inductor converter are shown in figure 5 and figure 6 respectively.

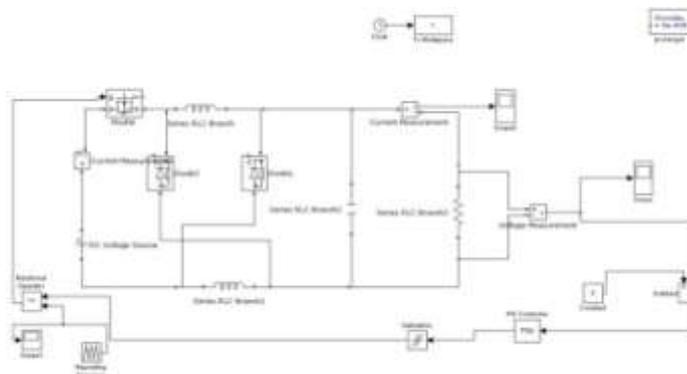


Fig 3

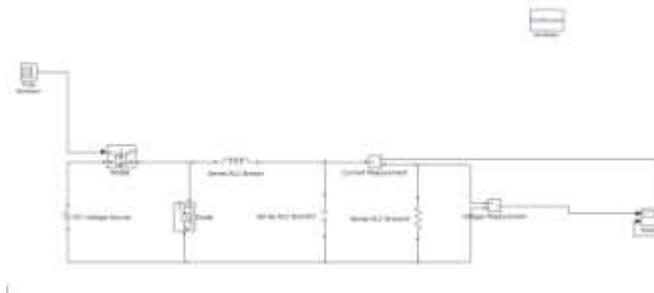


Fig 4

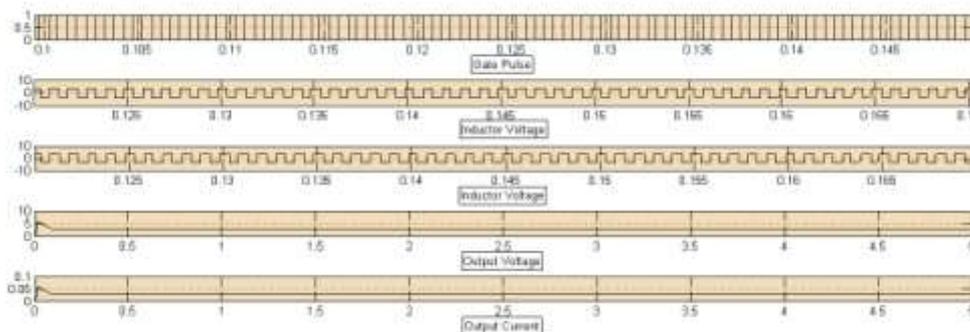


Fig 5

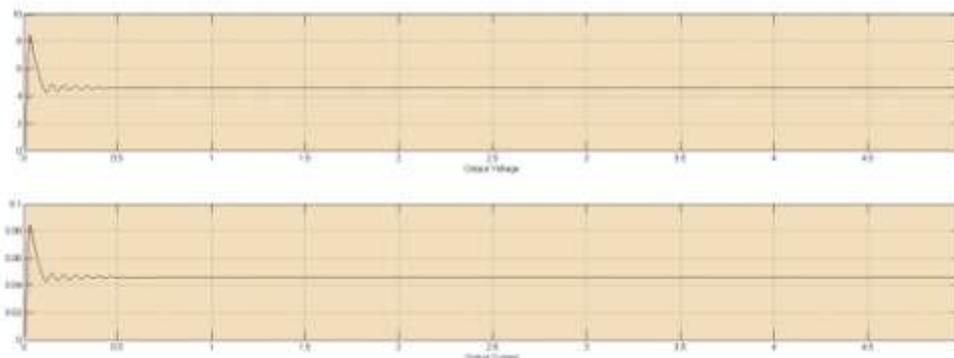


Fig 6

V. Conclusion

A switched inductor converter is analyzed and compared with a conventional buck converter. It is found that the switched inductor converter is able to achieve smaller values of conversion ratios than that of a conventional buck converter. Critical values of the circuit elements of both converters are analytically determined. The simulations of both converters were done and the results were compared and analyzed. A PI controller is employed to obtain better performance of the switched inductor converter.

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