COUPLED-INDUCTOR BASED HIGH GAIN DC-DC CONVERTER

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Abstract: A high gain dc-dc converter with coupled inductor is proposed in this paper. This converter has high duty cycle and high gain .The energy stored in the leakage inductor of coupled inductor can be recycled. The voltage stresses on each switches are reduced. The operating principle and design of proposed converter has been discussed in the paper. The simulation has done using PSPICE software. The gate pulse for switches is generated in hardware model.
Keywords: High gain, Coupled inductor

I. INTRODUCTION

High gain dc-dc converter has many applications in various industries such as solar cell energy conversion, fuel cell etc. Usually dc-dc converter commonly, boost converter can be used to obtain high gain by operating it in high duty cycle. But by operating it in high duty ratio the voltage gain and efficiency are limited due straining effect of diode, switches and causes reverse recovery problem. But various types of dc-d c boost converters are available such as voltage doubler[1]-[3] circuit, switched inductor type[4],boost with cascaded topology These topologies provide high gain dc-dc converter with high gain than conventional boost converter. To obtain high gain they should cascade more power stage and results in low efficiency. By adjusting turns ratio of transformer fly back converter can operate in high gain mode and it has several advantages of low cost, easy control, simple topology. Its efficiency is reduced due to leakage inductor of the transformer cannot recycled. Thus voltage stress on switch is increased. In this paper coupled inductor [5]-[10] based high efficiency dc- dc converter topology [5]is presented. By using this topology voltage stresses on switches is reduced thus efficiency is increased. The features of this topology are (1) the voltage gain is increased (2)the leakage inductance can be recycled (3) voltage stresses on switches are reduced.

Fig 1. Show the proposed circuit diagram .It consists of coupled inductor, four diodes and two switches.

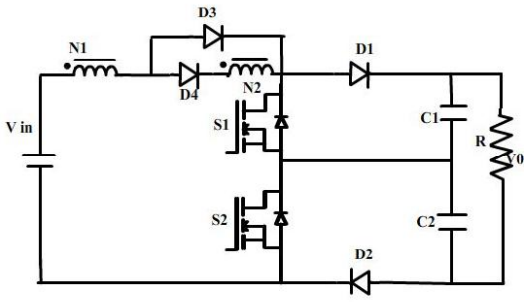


Fig 1.The proposed converter.

The output capacitors are used to obtain ripple free output voltage.

II. OPERATING PRINCIPLE

The proposed circuit consists of one coupled inductor, four diode D1-D4,two switches S1,S2 and two output capacitors C1 and C2.The coupled inductor is modeled as an transformer with primary and secondary inductance with proper turns ratio which obtained by appropriate design. For design, some assumptions are taken. Equivalent series resistance of inductance, capacitance are neglected. Forward voltage drop of diode and ON state resistance of switches are ignored. The values of output capacitances are taken as large in order to obtain constant voltage across capacitor during one period.

The operating principle can be explained in 4 modes. Fig 2(a), 2(b),2(c),2(d) shows the different modes of operation of proposed converter.

1) Mode I. Switch S1 is ON and S2 is OFF. The current flow path is shown in Fig 2.The dc source and primary inductor are serially connected to transfer the energies to secondary inductor, capacitor and load. Thus current through primary inductance increased and that of secondary inductor is decreased. The energy stored in capacitors is discharged to load. All the diodes are ON state.

2) Mode II. Both switches S1 and S2 are ON. The current path is shown in Fig 3.The dc source energy is transferred to switches through primary inductor and diode D3. Thus inductor current increased. The stored energy in the capacitors are discharged to load. Diode D4 is OFF which prevents the current to flow through secondary inductor. Diode D1 is OFF. Thus dc energy is transferred to switches and back to source

3) Mode III. Switch S1 is OFF and S2 is ON. The current path is as shown in Fig 4.The dc source, primary inductor, secondary inductor is connected in series to transfer energy to capacitor and load. The current through primary inductor iL1 decreased and iL2 increased. All the diodes are in ON state.

4) Mode IV. Both switches S1 and S2 are OFF. The current path is as shown in Fig 5.The dc source, primary inductor; secondary inductor is connected in series to transfer energy to capacitor and load. The stored energy in the capacitor is discharged to load. All the diodes are in ON state

III. ANALAYSIS OF PROPOSED CONVERTER

At CCM operation, modes I and II are considered and the following equations can be written

$$\frac{di_L}{dt} = \frac{K\,V_{in}}{L} \qquad (1)$$

where K is the coupling coefficient of coupled inductor.
coupling coefficient of coupled inductor K can be found by,

$$K = \frac{L_m}{L_m + L_K} \qquad (2)$$

Turns ratio N of the coupled inductor is given by

$$N = \frac{N_2}{N_1} \qquad (3)$$

Where N_2 is the number of turns of secondary inductor and N_1 is the number of turns of primary inductor.

$$v_{L2} = N^2 V_{L1} \qquad (4)$$

where N is the turns ratio of coupled inductor.
By considering four modes and integrating to their duty cycles

$$\int_0^{DT} V_{L1}dt + \int_0^{\frac{(1-D)T}{2}} V_{L2}dt + \int_0^{\frac{DT_S}{2}} V_{L3} + \int_0^{\frac{(1-D)T}{2}} V_{L4} = 0 \qquad (5)$$

Using volt -second balance principle on L1 ,gain equation can be written as

$$\frac{V_0}{V_{IN}} = \frac{2(1+N-ND+N^2+2NDK)}{(1-D)(1+N)} \qquad (6)$$

if K is substituted as 1 then (6) becomes

$$\frac{V_0}{V_{IN}} = \frac{2(1+ND)}{1-D} \qquad (7)$$

Normalizing magnetizing -inductor time constant

$$\tau_{Lm} = \frac{L_m f_s}{R} \qquad (8)$$

Magnetizing time constant for the boundary condition is

$$\tau_{LB} = \frac{KD(1-D)^2}{16(1+N-ND+N^2D2NDK)} \qquad (9)$$

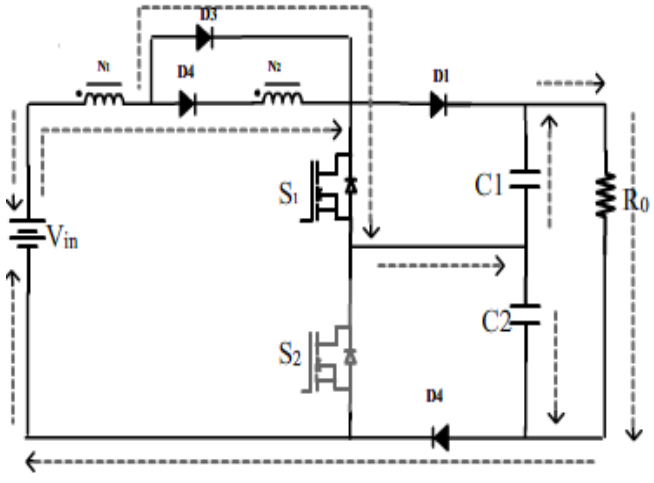


Fig. 2(a). Mode I. Switch S_1 is ON and Switch S_2 is OFF.

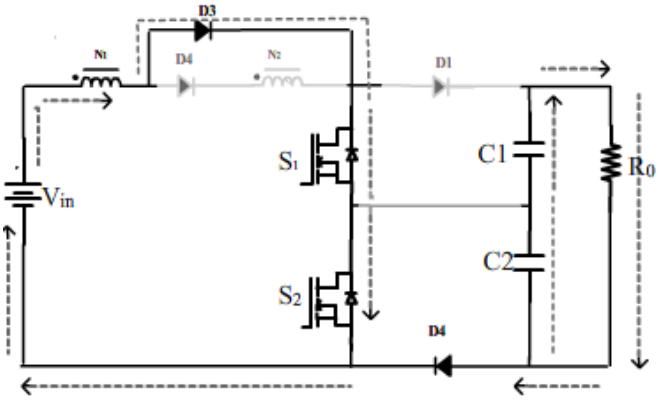


Fig 2(b). Mode II. Both switches S1 and S2 are ON

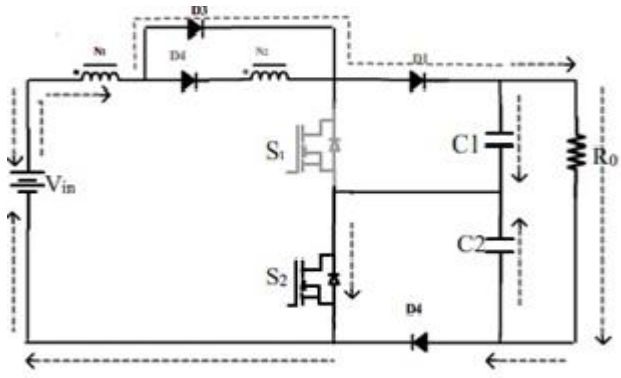


Fig.2(c). Mode III. Both switches S1 OFF S2 ON

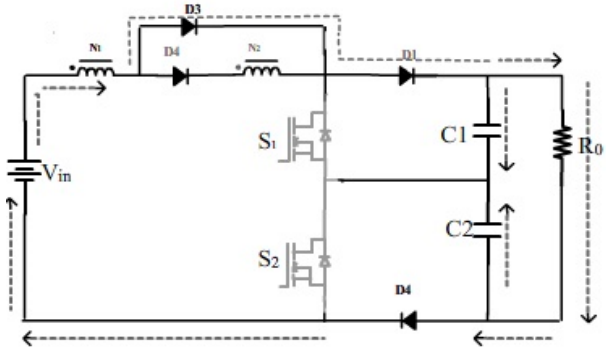


Fig2(4). Mode II. Both switches S1 and S2 are OFF.

IV. CIRCUIT SPECIFICATIONS

PSpice software is used to carry the simulation of proposed converter under following circuit specifications

TABLE I. Converter Specifications

Input Voltage(V_{in})	24V
Output Voltage	312V
Switching frequency	25kHz
Output Power(P_0)	250W

Coupled inductor(L_1,$L_{2)}$	12µH,108µH

Table I. shows the converter specifications

V. SIMULATION RESULTS

The simulation results of proposed converter is shown in Fig 3.Fig 3(a) shows the gate pulses of two switches and output voltage of 308.5V and power of 241 W is obtained which indicates boosting. As the duty cycle is taken as 0.61 there would be overlapping between them.

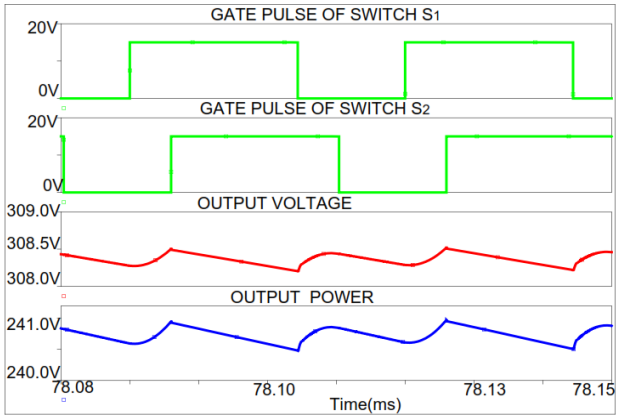


Fig 3(a).Gate pulse of switch S_1, Gate pulse of switch S_2, Output voltage and power.

Fig 3(b) shows the gate pulses of two switches and current across the primary and secondary inductor. As long as switch S1 is ON, the current through the primary inductor i L1 increases. When switch S1 OFF current through the secondary inductor increases and then decreases.

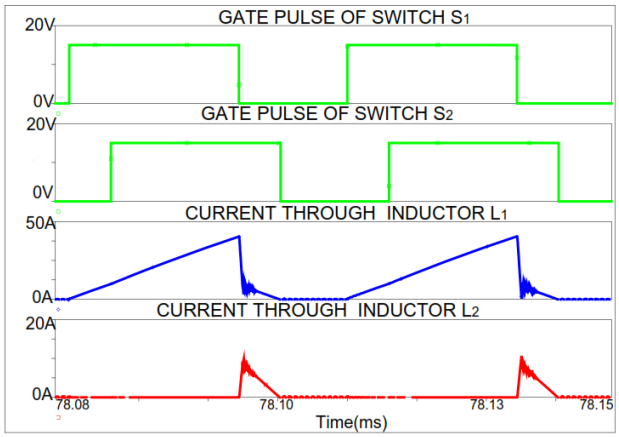


Fig3(b).Gate pulse of switch S_1, Gate pulse of switch S_2, Current through L_1 ,L_2.

Fig 3 (c) shows the voltage and current across the switch S1.When switch S 1 is ON, the voltage across the switch would be zero and there would be minimum current flowing through switch and if it is OFF then a blocking voltage of 300V is present.

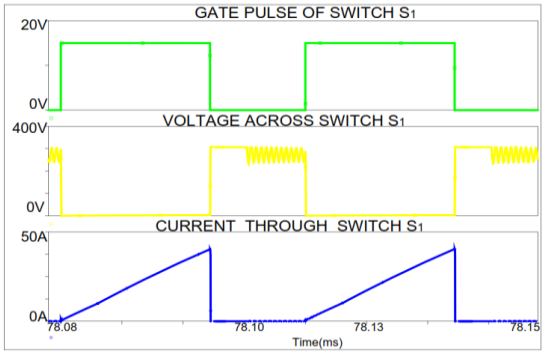


Fig3(c). Gate pulse of switch S_1 ,current and voltage across switch S_1.

Fig 3(d) shows the voltage and current across the switch S_2.When the switch S_2 is ON, the voltage across the switch should be zero. But in fig 3(d) voltage is non zero value and it has ripples. When the switch S_2 is OFF, voltage across the switch has a finite value. This finite value is known as blocking voltage. Fig 3(f) shows the voltage across the two capacitors. It is found that the output voltage is the sum of the voltage across two capacitors. The voltage across C1 is 305.6V and that of C2 is 3.44 V. Thus output voltage is 308.5V.

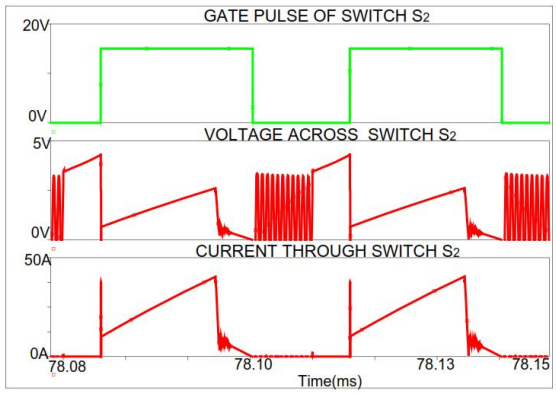


Fig 3(d)Gate pulse of switch S2 ,current and voltage across switch S2

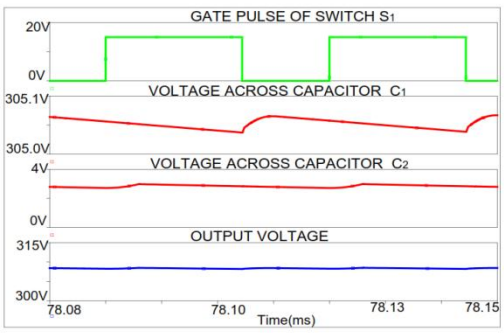


Fig 3(f). Gate pulse of Switch S1 ,Voltage across capacitors, Output voltage

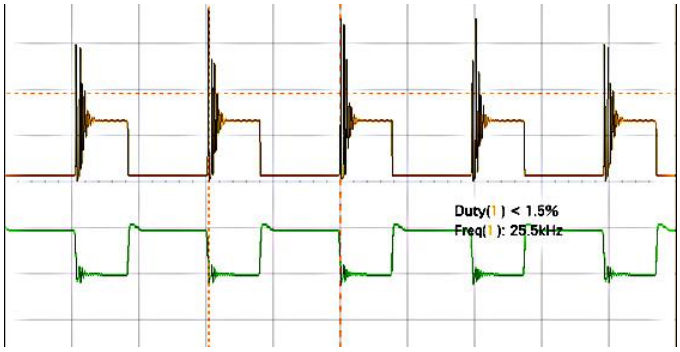
VI. EXPERIMENTAL SETUP

To verify the proposed converter hardware setup is provided. The circuit specifications are as follows .V in = 24 V, VO =314Vfs = 25kHz,P O =250W (R=395Ω). Coupling coefficient of coupled inductor is taken as 0.8.

Primary inductances is selected as 12µH. S1 and S2 are selected as IRFP250. Diodes D1 and D2 are selected as MUR1560 (600V,150A), and D3 and D4 are selected as SDB20D150 (150V,120A) is used. Substituting N=3, D=0.61 in (3) we get gain as 13.1Subsistuting in (6) r LB is obtained as 0.00045

$$\frac{L_m f_s}{R} > 0.00045$$

From this equation value of L_m should be greater than 11.52µH. for ease of accessibility L_m taken as 12µH.The gate pulse for the switch is obtained using programming in microcontroller PIC18F45K20.Driver IC TLP250 will provide required driving capabilities. Fig 4.shows the gate pulse obtained using TLP250 IC. Channel 1 shows the drain-source voltage of switch in order to show switching characteristics. Channel 2 shows the gate-source voltage of switch.



Channel 1-10V/div
Channel 2: 10V/div
Time -20µs

Fig 4. Gate source voltage and drain source voltage of switch S1 obtained using TLP250.

VII. CONCLUSION

High step-up dc-dc converter with high gain is presented in this paper. Gain is increased to 13 times. This topology uses only one coupled inductor. Thus cost reduces. Simulation of proposed circuit are shown .Simulation have done using PSpice software. Hardware for obtaining gate pulse obtained using TLP250 IC. The efficiency is improved compared to conventional boost converter.

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