An Efficient Step-Up DC-DC Converter

Kshemada Devi .V
Electrical dept. VAST
Thrissur, India.

Reshma . M
Electrical dept.VAST
Thrissur, India.
.

Abstract—**Step Up DC-DC converters has got crescent demand because of its varied applications.Here through this paper a highly efficient Step Up DC-DC converter with simple topology is introduced.The converter could provide high efficiency as the leakage energy is recycled.The diodes and coupled windings provide similar and better function than active clamp counter parts.**

Keywords— DC-DC boost converter, Clamp Mode, Coupled inductor ,.

I. INTRODUCTION

A DC-DC converter converts an unregulated DC input voltage to a regulated DC output having magnitude and possibly polarity differs from input.DC-DC converters can be used to regulate the output DC voltage to the required levels.DC-DC power converters has got a variety of applications.It can be used for charging battery banks in off-grid systems such as remote telecommunication site,security camera,portable solar power system for military,in UPS systems,insulation testing,to drive DC motors,wind energy systems,insulation testing,to drive DC motors,wind energy system for HVDC transmission.It can also be used in office equipment,power supplies for personal computers,laptops,telecommunication equipments,spacecraft power,battery powered equipments,dc motor drives etc.

So the development of a DC-DC converter with high efficiency has got its own importance and hence it is an important research area.

Conventional boost converter can boost the low input voltage several times,but the boost level is restricted due to duty ratio and device characteristics.Inorder to supply a high output voltage,the conventional boost converter must operate at extremely high duty ratios.High duty ratio will create small off time for the semi-conductor devices which leads to reverse recovery problems,low switching frequencies which may in turn increase the size of passive components,correspondingly the size and cost of converter.To realize an efficient system the converter must operate with moderate duty ratio.

Different kinds of DC-DC converters are now available.Many converter topologies have been introduced to avoid the problems associated with the conventional ones.But most ended up with certain another drawbacks.

High boost converter implemented with capacitor diode voltage multiplier in [2]-[3] has less energy in the magnetic elements but it cannot achieve ultra voltage gain at moderate duty ratio.Converter with cascaded network of multiplier cells described in [4] can multiply the voltage to required value.But due to several multiplier cells the cost and circuit complexity has increased by several folds.Two level and three level boost converter[1] has got improved voltage gain but they are associated with problems such as high power, device voltage stress,high switching condition,severe output diode reverse recovery problems,complexity etc.Even though the cascade boost converters are well suited for high step up applications it is associated with problems such as switch voltage stress and current stress which will result in conduction loss and reduced circuit efficiency.The limitation of high step-up converters with switched capacitor is that it require a lot of power devices for having high gain. The increased circuit complexity results in high system cost.Converters with coupled inductors can have high gain but it is associated with high voltage stress,large losses and also with severe EMI problems.Active clamp circuit can recycle the leakage energy with low voltage stress but it is of high cost.Also complexity as well as the losses of that circuit is high.Hence efficiency improvement is limited. The other major concerns related to efficiency are large input current,severe reverse recovery problem in output rectifier due to high output voltage.

So it is well clear that certain requirements are normally necessary for a Step Up converter.And those requirements normally include reduced losses,high power density,low weight and volume.Also a high efficiency operation is desirable for battery powered systems and high cost power sources.And this paper aimed at developing a converter by satisfying these basic requirements.

The converter mentioned in this paper is suitable for high step up applications with low input voltage having high efficiency.Most of the renewable energy sources produce only low DC voltage.So the proposed converter has got a wide scope in the field of renewable applications. .Also the converter is good in producing high efficiency while reducing extreme duty cycle and no.of components. Which may help in reducing power device cost and conduction losses.Also the converter has got fast recovery diodes which can eliminate the reverse recovery problems. It could provide high gain and non-isolation. Non isolation converters could provide high gain without much increase in duty ratio.

II. PROPOSED CONVERTER

The proposed is Clamp mode Coupled inductor converter.It is meant to achieve high efficiency and high Step Up without extreme duty ratio.

The major parts of this converter are diode,capacitor,coupled winding,clamp circuit and leakage inductor.

Diode and capacitor helps in providing operation similar and better than that of active clamp counter part.Where the diode act as the body of active clamp switch.Coupled winding and output rectifier together could act as a switch similar to magnetic switch.It helps in reducing the cost as well as complexity.Along with that it provides reliable operation.The clamp circuit recovers the leakage energy.Also it develops only a low circulating current.Leakage inductor is good in controlling the the current decrease rate at output rectifier.Thereby the reverse recovery problem could significantly be alleviated.

Fig 1 shows the basic circuit model of the proposed converter.The key idea behind the operation of this converter is that, it store required amount of energy in inductors by assembling the input voltage and output voltage in such a way that they are in series during switch ON.

This converter operates through six stages.Assuming all semiconductor devices as ideal ones and all capacitors as voltage sources, the modes of operation can be described as follows.

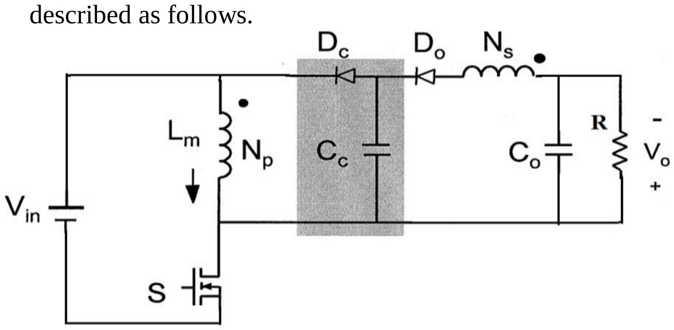

Fig 1:Basic circuit model.

Mode I:Fig 2 shows mode I of operation.This mode is from t_0-t_1.During this mode switch,S is made ON.D_O got reverse biased.At that time inductors Magnetizing inductor,L_m and Leakage inductor,L_k is charged by supply voltage,V_{in}.

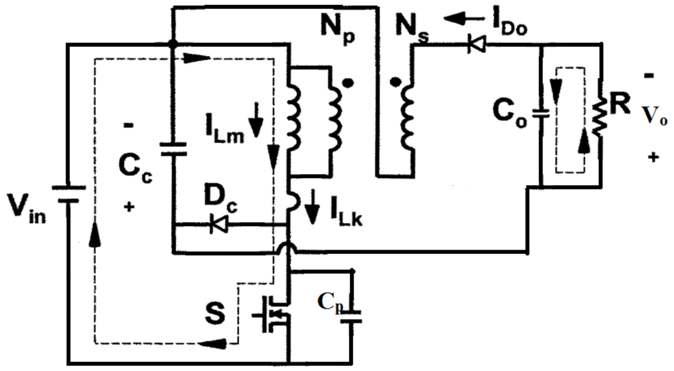

Fig 2:Mode I

Mode II: Fig 3 shows mode II of operation.This mode is from t_1-t_2.At t_1 switch,S is made OFF.So the parasitic capacitor of switch,S is charged by the magnetizing current.

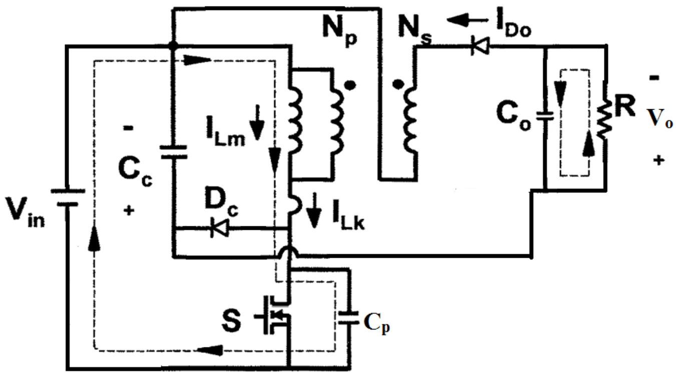

Fig.3:Mode II

Mode III: Fig 4 shows mode III of operation.This mode is from t_2-t_3.Parasitic capacitor of Switch,S charges to V_{in}+V_{CC}. Diode D_C conducts.The magnetizing current then charges capacitor,C_C.

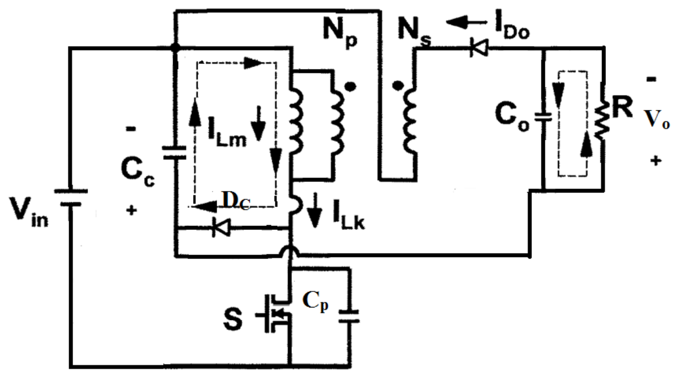

Fig 4:Mode III

Mode IV: Fig 5 shows mode IV of operation.This mode is from t_3-t_4.At t_3,V_{CC} is charged to make output diode,D_O forward biased.Reflected voltage from secondary,N_S clamps primary,N_P.L_k and C_C begins to resonate.

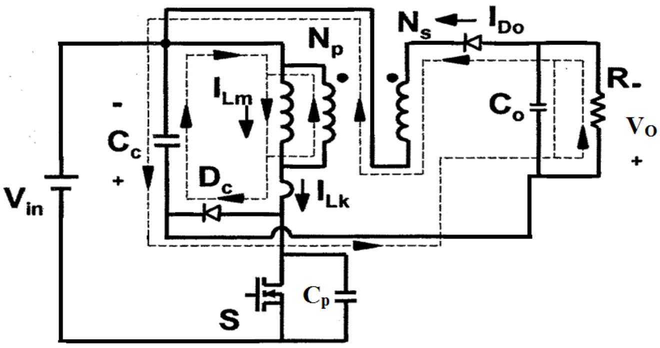

Fig 5:ModeIV

Mode V: Fig 6 shows mode V of operation.This mode is from t_4-t_5.During this mode resonant current reaches zero.Magnetizing current got reflected from N_P to N_S.Clamp capacitor current is discharged by output rectifier current.

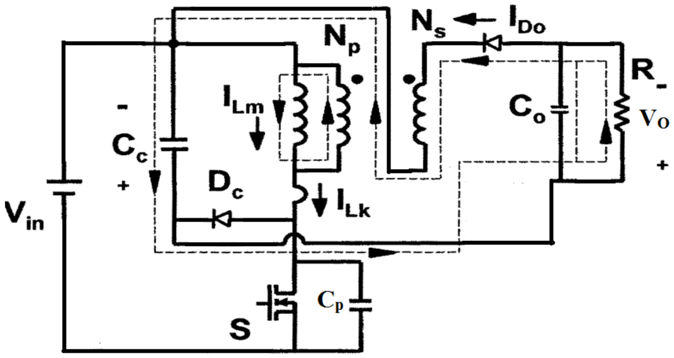

Fig 6:Mode V

Mode VI: Fig 7 shows final mode,mode VI of operation.This mode is from t_5-t_6.Here again the switch is made ON..L_k is charged by supply voltage and $(V_O-V_C) / N$.This continues until leakage inductor current,I_{Lk} equals the magnetizing current,I_m.After that D_O become reverse biased.Next switching cycle happens after then.

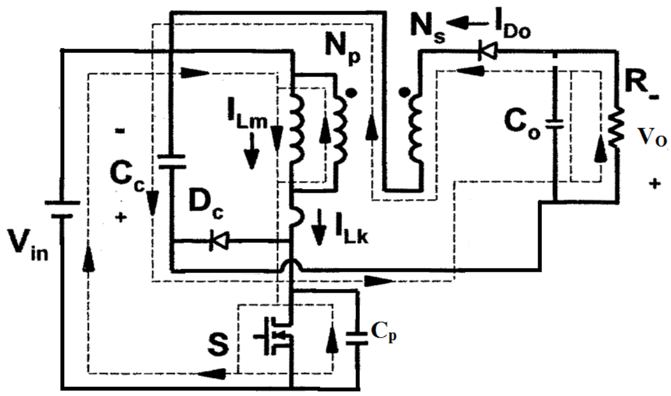

Fig 7:Mode VI

In short the leakage energy instead of wasting is stored in clamp capacitor and is then given to output thereby increases efficiency and gain of the converter.

The main theoretical waveforms of the proposed converter is displayed in fig.7.The waveforms are drawn in accordance with each mode of operation.Magnetizing inductor current increases during switch ON and decreases during switch OFF.Leakage current rises and drops before capacitor current equals zero.Always there will be a fixed voltage across capacitor.

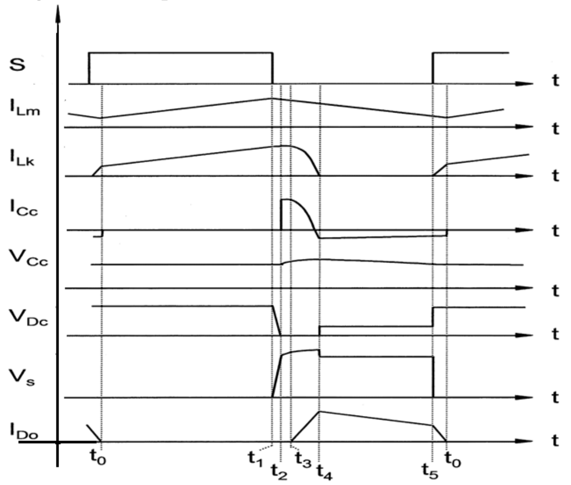

Fig 8:Theoretical Waveforms

The voltage gain [5] of the proposed converter is

$$V_O / V_{in} = ((d/1-d)(N+1)(1+k)) / 2$$

Where,

$k=L_m / (L_m+L_k)$

And,

$N=N_s / N_p$

III. ADVANTAGES AND APPLICATIONS

The key advantages of this converter are;it has got high efficiency and step up.Reverse recovery problem can be alleviated.Leakage energy can be recycled instead of merely wasting.Voltage stress of the switch is minimum for this converter.It is of low cost and less complexity.It has got high reliability.Moreover conduction loss for this converter is less.

This converter has got wide applications. Specifically it is applicable in those powered by batteries,industries,traction motor control in electric auto mobiles,trolley cars,marine hoists,fort lift trucks,mine haulers etc.

IV. DESIGN AND SIMULATION

A. Design:

The design part of the proposed converter is presented here. The assumptions made here are:

a)Output Power,P_o=1 kW
b)Input Voltage,V_i=60 V
c)Output Voltage,V_o=380 V
d)Switching frequency,f_s=100 kW

[1] Duty Ratio,D:

$D=1/\{[(Vi/V_o).(N+1)((1+k)/2)]+1\}$

Take N=5 and k=0.99

So,

$D=1/\{[(60\ V / 380\ V)(5+1)(1+0.99)/2]+1\}$

$=0.514$

[2]Mutual Inductor value :

We have,

$V_L=L(di_L / dt)$

$=L(\Delta i_L/\Delta t)$

$=L(\Delta i_L / D.t_s)$

From that,

$L=(V_L.D.t_s) / \Delta i_L$

Also we have

$V_L=V_s=60\ V$

$D=0.514$

$t_s=(1 / f_s) = (1/ 100kW) =10\ \mu s$.

Take $\Delta i_L=5\ A$

So,

$L = (60V*0.514*10\ \mu s) / 5A$

$= 61.68\ \mu H$.

Hence,

The primary inductance,$L_p=61.68\ \mu H$.

So,

The secondary inductance,$L_s=N^2 L_p$

$=4^2x61.68\ \mu H$

$=986.88\ \mu H$.

And,

Mutual inductance,$L_s=k*sqrt(61.68\ \mu H*986.88\ \mu H)$

$=244.25\ \mu H$.

[3]Capacitor,C_C value:

$V_c=[(D/(1-D)).V_i.[((1+k)+(1-k).N))/2]]$

$=[(0.514/(1-0.514)).60.[((1+0.99)+(1-0.99).5))/2]]$

$=64.75\ V$.

Consider the voltage ripple of capacitor as ΔV_C.And it is equal to 15% of nominal capacitor voltage.

i.e. ΔV_C=15% of nominal capacitor voltage.

$=(15/100)*64.75$

$=9.71$.

We have,

The capacitor voltage ripple(ΔV_C)=NI_o/Cf

From that $C =NI_o /(\Delta V_C f) =C_C$

$C_C=(5*2.63A) / (9.71*100*10^3\ W)$

$=13.54\ \mu F$.

[4]Output Load,R_o

Input Current,$I_i=(P/V_i)$

$=(1\ kW / 60\ V)$

$=16.67A$.

Output Current,$I_o=(P_o/V_o)$

$=(1\ kW / 380\ V)$

$=2.63\ A$.

Output Load,$R_o=(V_o / I_o)$

$=(380 / 2.63)$

$=144.49\ \Omega$.

B. *Simulation:*

Simulation of the work is done to get an idea of end result.Fig 9 shows the simulation diagram.Basic circuit model shown in fig 1 is considered for simulation.Fig 10.shows the obtained output voltage waveform.

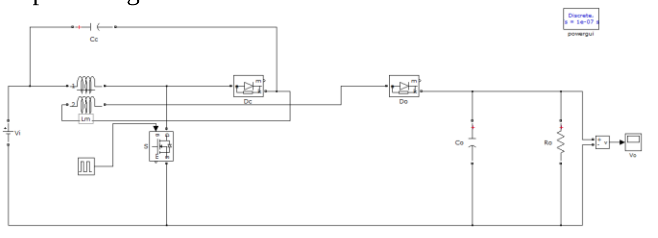

Fig 9:Simulation diagram

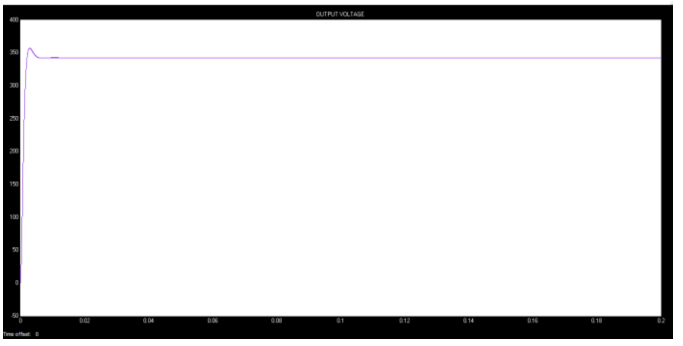

Fig 10:Output waveform

V.CONCLUSION

The paper is all about clamp mode coupled inductor converter.The converter is meant for providing high Step Up with high efficiency of about 92.03% without requiring extreme duty ratio

This converter with coupled inductor and clamping circuit helps in realizing high voltage gain at moderate duty ratio by the transformer action of coupled inductor.The circuit has got improved efficiency by effectively recycling the inductor leakage energy using capacitor diode clamping circuit.

VI.REFERENCES

(1) C. W. Li and X. He, "Review of non-isolated high step-up DC/DC converters in photovoltaic grid-connected applications," *IEEE Trans. Ind.Electron.*, vol. 58, no. 4, pp. 1239–1250, Apr. 2011.

(2) D. Zhou, A. Pietkiewicz, and S. Cuk, "A three-switch high voltage converter", IEEE Trans. Power Electron., vol. 14, no. 1, pp. 177183, Jan. 1999.

(3) B. Axelrod, Y. Berkovich, and A. Ioinovici, "Switched capacitor/ switched-inductor structures for getting transformer less hybrid DC-DC PWM converters",IEEE Trans. Circuits Syst. I, Reg. Papers, vol. 55, no. 2,pp.687-697,Mar.2008.

(4) M. Prudente, L. L. Pfitscher, G. Emmenderfer, E. F. Romaneli, and R. Gules," Voltage multiplier cells applied to non-isolated DC DC converters",IEEE Trans. Power Electron., vol. 23, no. 2, pp. 871 -887, Mar. 2008.

(5) Q. Zhao and F. C. Lee, "High-efficiency, high step-upDC–DCconverters,"*IEEE Trans. Power Electron.*, vol. 18, no. 1, pp. 65–73, Jan. 2003.

(6) N. Mohan, T. Undeland, and W. P. Robbins, Power Electronics: Converters, Applications, and Design, 3rd ed. New York, Wiley, 2003.