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A High Voltage Gain DC-DC Converter Integrated with coupled Inductor and Diode Capacitor Techniques

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Abstract: A new high voltage gain dc-dc converter based on integrating coupled inductor and diode-capacitor topology is proposed. The proposed system has offer high voltage gain and is employed in many industry applications, photovoltaic systems, and fuel cell systems. The proposed converter achieves extremely large voltage conversion ratio with appropriate duty cycle and reduction of voltage stress on the power devices. The energy stored in leakage inductance of coupled inductor is efficiently recycled to the output, and the voltage doublers cell also operates as a regenerative clamping circuit. These characteristics make it possible to design a compact circuit with high static gain and high efficiency for industry applications. This paper presents a novel high step up dc-dc converter renewable energy applications. The MATLAB simulation of the converter is done using 24V input voltage and 380V/500W output. The lower stress on the switch and output voltage are verified by the simulation results.

Keywords: High step-up converter, low voltage stress, non-isolated, voltage clamping circuit, single switch, voltage doublers.

I. INTRODUCTION

The proposed converter can be used in Industrial applications such as Electric vehicles, fuel cell systems and high intensity discharge lamps..In recent years conventional boost converters are used in applications such as un interrupted power supplies, electric traction, photo voltaic systems etc. The conventional boost converter can achieve a high voltage gain and the voltage stress across the main switch is equal to the high output voltage with high duty cycle. Due to this reason high voltage rating switch with high on-resistance is required, there by inducing higher conduction losses and serious reverse recovery problems. In quadratic boost converter with single switch is another topology which will induce high voltage gain which is a quadratic function of duty cycle. However the voltage conversion of this converter is moderate The voltage across the main switch is equal to the output voltage .so for high voltage applications it requires high voltage rating switch.

A high voltage gain dc-dc converter integrating coupled inductor and diode capacitor achieves large voltage conversion ratio and reduce the voltage stress across the switch with appropriate duty cycle. The proposed converter using coupled inductor and voltage doublers cell minimizes the aforementioned problems. The energy stored in the leakage inductance of coupled inductor is recycled to the output and the voltage doublers cell operates as a regenerative clamping circuit, alleviating the problem of potential resonance between the leakage inductance and junction capacitance of the output diode. These characteristics make it possible to design a compact circuit with high static gain and high efficiency for industry applications. The validity of the study is verified using MATLAB simulations.

II. TOPOLOGY OF PROPOSED CONVERTER

A novel single switch dc-dc converter with high voltage gain and reduced switch voltage stress. The proposed converter has certain features 1) the voltage gain can be increased by coupled inductor and the secondary winding of coupled inductor is inserted in to a diode-capacitor of coupled inductor for again 2) A passive clamped circuit is connected to the primary winding of the coupled inductor to clamp the voltage across the switch to a lower voltage level, as a result active switch with low voltage rating and low on resistance can be selected, also diode-capacitor circuit is useful to increase the voltage conversion ratio3)

The leakage inductance energy of the coupled inductor can be recycled to the output thereby improving the efficiency.4)the potential resonance between the leakage inductance and the junction capacitor of output diode may be cancelled.

Fig 1(a) shows the proposed converter which consist of an active switch Input inductor L_1,coupled inductor T_1,diodes D_1,$D_2$and D_0,energy storage capacitor C_1 and output capacitor C_0.Clamped circuit consist of diode D_3 and capacitor C_2.Voltage doubler cell comprising of regeneration diode D_r, capacitor C_3 and secondary side of

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coupled inductor. The simplified equivalent circuit of the proposed converter is shown in fig 1(b) The dual-winding coupled inductor is modeled as an ideal transformer with a turn ratio N (n2 /n1), a parallel magnetizing inductance Lm, and primary and secondary leakage inductance Lk1 and Lk2 .

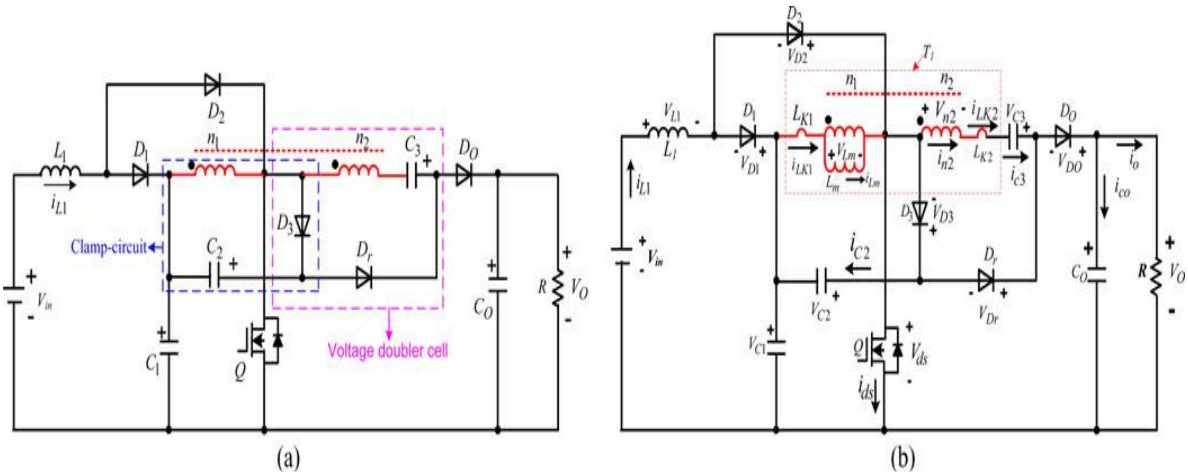


Fig 1: Circuit configuration of proposed converter

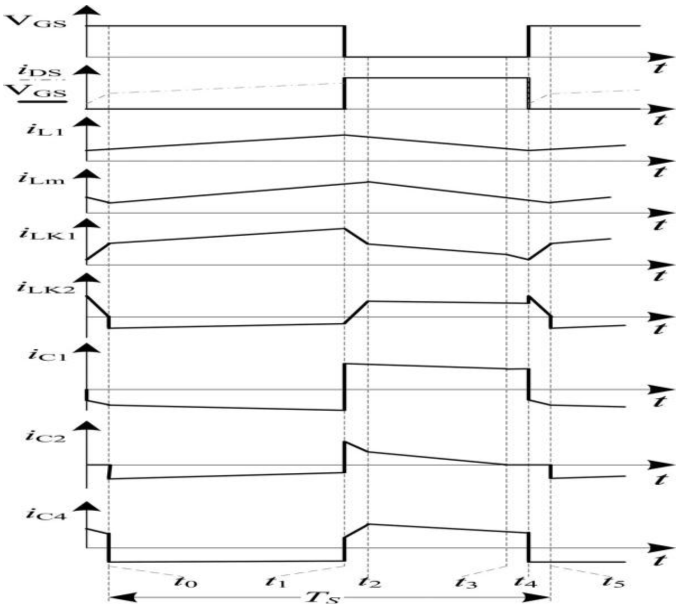


Fig 2 : theoretical waveform in CCM mode

III.OPERATIONAL PRINCIPLE

The converter switching period is subdivided into five operational modes as shown in Fig 3. It is operated in a duty ratio D. Certain assumptions are made in order to illustrate the steady state operation and are as follows:

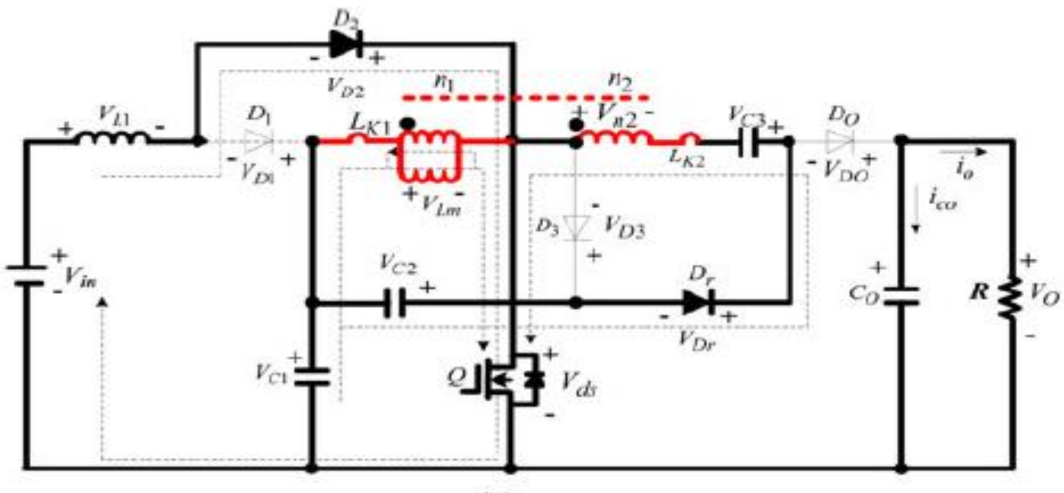
1) the input inductance L1 is assumed to be large enough so that iL1 is continuous; every capacitor is sufficiently large, and the voltage across each capacitor is considered to be constant during one switching period

2) all components are ideal except the leakage inductance of the coupled inductor;

3) both inductor currents iL1 and iLm are operated in continuous conduction mode, which is expressed as C-CCM; the inductor current iL1 is operated in continuous conduction mode, but the current iLm of the coupled inductor is operated in discontinuous conduction mode, which is called C-DCM.

Stage 1 [to-t1] : In this mode, the switch Q is turned on. The leakage current Diodes D1,D3 ,and DO are reverse-biased by VC1, VC1+VC 2 and VO − VC1 − VC2 , respectively. Only Diodes D2 and Dr are turned ON.The dc source Vin energy is transferred to the inductor L1 through D2 and Q. Therefore, the current iL1 is increasing linearly. The primary voltage of the coupled inductor including magnetizing inductor Lm and leakage Lk1 is

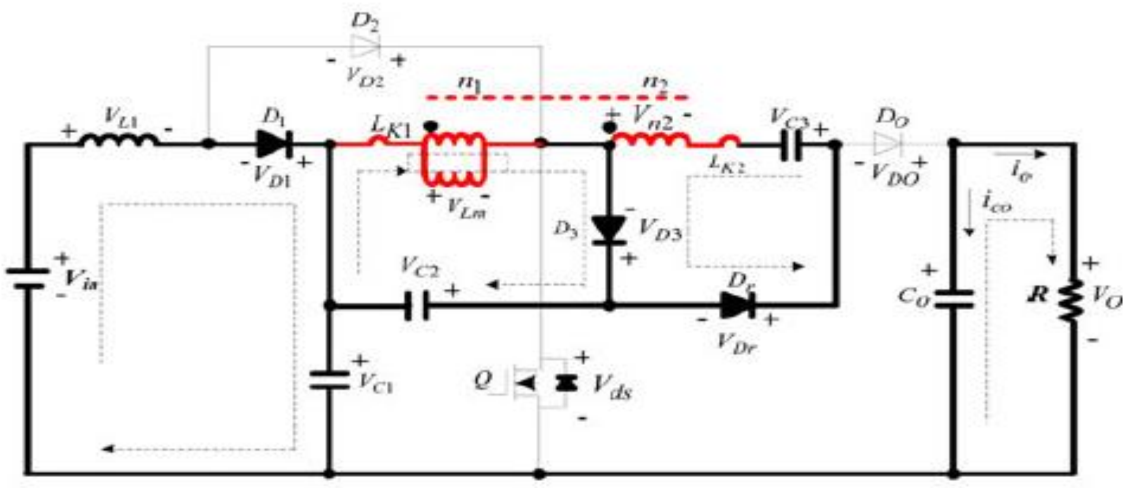
VC1 and the capacitor C1 is discharging its energy to the magnetizing inductor Lm and primary leakage inductor Lk1 through Q. Then currents iD2, iLm, and ik1 are increasing. Meanwhile, the energy stored inC2 and C1 is released toC3 through Dr. The load R energy is supplied by the output capacitor CO.



(a)

Fig 3 (a) operating Stage 1

Stage 2 [t_1–t_2]: The switch is turned off at t=t1, the current through Q is forced to flow through D3 .At the same time, the energy stored in inductor L1 flows through diode D1 to charge capacitor C1 instantaneously and the current iL1 declines linearly. Thus, the diode D2 is reverse biased by VC2 . The diode DO is still reverse biased by VO − VC1 − VC2 . The energy stored in inductor Lk1 flows through diodeD3 to charge capacitor C2 . Therefore, the energy stored in Lk1 is recycled to C2. The iLK2 keeps the same current direction for charging capacitor C3 through diode D3 and regeneration-diode Dr . The voltage stress across Q is the summation of VC1 and VC2 .The load energy is supplied by the output capacitors CO .This stage ends when iLK2 reaches zero at t = t2 ..



(b)

Fig 3 (b) : operating stage 2

Stage 3 [t_2− t_3]: In this mode the switch Q is remains turned off. Since iLK2 reaches zero at t = t2, VC2 is reflected to the secondary side of coupled inductor T1 ; thus, regeneration-diode Dr is blocked by VC3 + NVC2 .Meanwhile, the diode DO starts to conduct. The inductance L1 is still releasing its energy to the capacitor C1. Thus, the current iL1 still declines linearly. The energy stored in Lk1 and Lm is released to C2 .Moreover, the energy stored in Lm is released to the output via n2 and C3.
The leakage inductor energy can thus be recycled, and the voltage stress of the main switch is clamped to the summation of VC1 and VC2 . This stage ends when current iLK1 = iLK2 ,thus the current iC2 = 0 at t = t3 .

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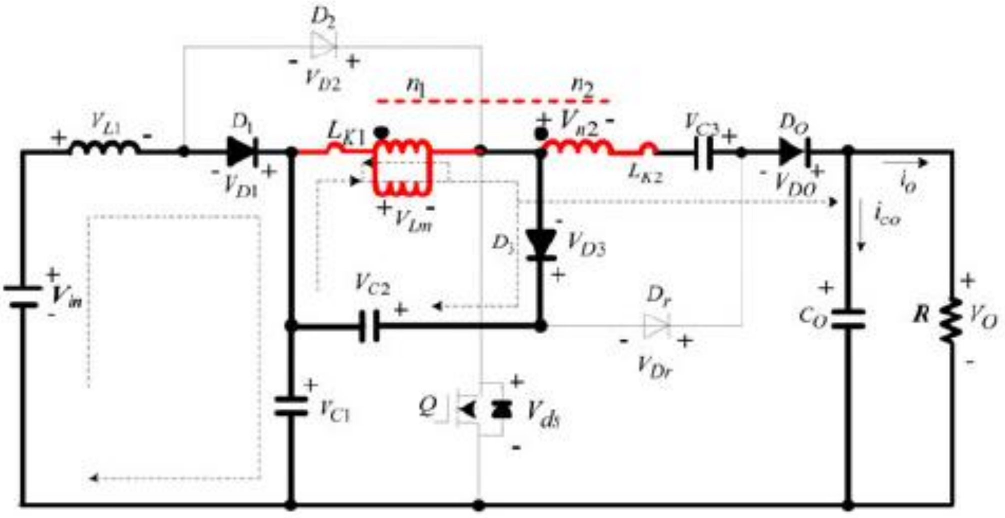
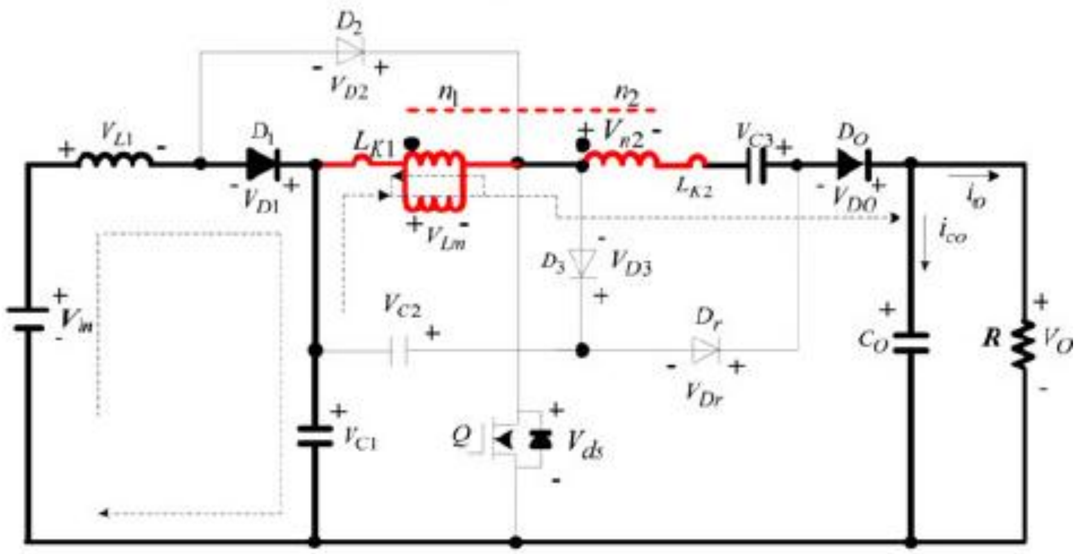


(c)

Fig 3 (c): operating stage 3

Stage 4 [t_3– t_4]: During this time interval, the switch Q, diodes D2 and Dr is still turned OFF. Since iC2 reaches zero at t = t3, the entire current of iLK1 flows through D3 is blocked. The energy stored in an inductor L1 flows through diode D1 to charge capacitor C1 continually, so the current iL1 is decreasing linearly. The dc source Vin, L1, Lm, Lk1, the winding n2, Lk2 and VC3 are series connected to discharge their energy to capacitor Co and load R. This stage ends when the switch Q is turned ON at t= t4.



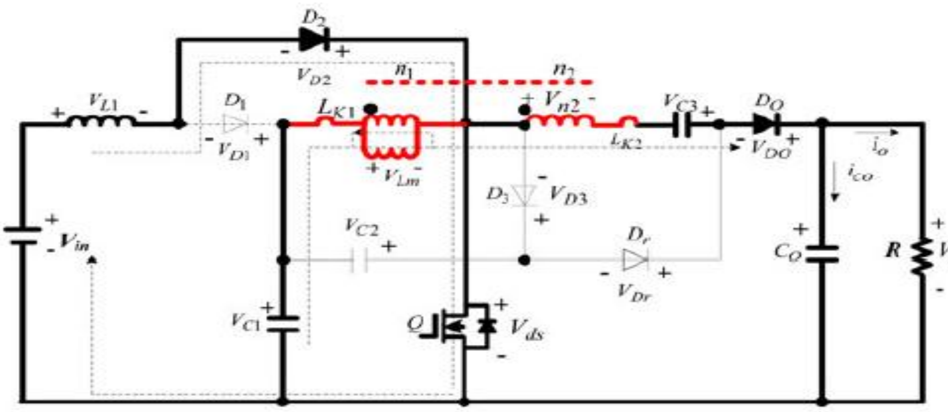
(d)

Fig 3 (d): operating stage 4

Stage 5 [t_4– t_5]: The main switch Q is turned ON at t4 .During this transition interval, diodes D1,D3 , and Dr are reverse-biased by VC1, VC1+VC 2 and VO − VC1 − VC2 , respectively. Since the currents iL1 and iLm are continuous, only diodes D2 and DO are conducting.

The inductanceL1 is charged by input voltage VIN, and the current iL1 increases almost in a linear way. The blocking voltages VC1 is applied on magnetizing inductor Lm and primary-side leakage Lk1, so the current iLk1 of the coupled inductor is increased rapidly. Meanwhile, the magnetizing inductor Lm keeps on transferring its energy through the secondary winding to the output capacitor CO and load R.

At the same time, the energy stored in C3 is discharged to the output. Once the increasing iLK1 equals the decreasing current ILM and the secondary leakage inductor current ik2 declines to zero at t = t5 , this stage ends.



(e)

Fig 3 €: operating stage 5

IV. SIMULATION ANALYSIS AND RESULT

The simulation analysis of a high voltage gain single switch dc-dc converter is carried out on the basis of the following assumptions:

1) Input voltage (V_{in}) = 24V
2) Output voltage (V_o)= 380V
3) Output power(P_o) = 500W
4) Switching frequency(f_s) = 40KHz
5) Duty ratio(D) = 60%
6) Leakage inductance(L_{lkg}) = 1.7μH
7) Magnetic inductance(L_m) = 200μH
7) Transformer turns(N_2:N_1) = 13:7
8) Output capacitor(C_o)=1000μF

From the above assumptions, output current(I_o), time period(T_s), load resistance(R_o) and capacitors C_S and $C_B$are calculated as follows:

Time period, Ts $=\frac{1}{f_s} = \frac{1}{40\times1000} = 2.5e^{-5}$sec (4.1)

Output current, $I_o = \frac{P_o}{V_o} = \frac{500}{380} = 1.3$A (4.2)

Load resistor, $R_L = \frac{V_o}{I_o} = \frac{380}{1.5} = 300\Omega$ (4.3)

Input inductor $L_1 = \frac{V_{in}\,D}{\Delta I_{L1}\,F_s}$ (4.4)

ΔIL_1 = 15% of I_{in} (4.5)

$L_1 = 60\mu H$

Capacitor design, $C \geq \frac{2P_{max}}{Vc^2 * F_s}$(4.6)

$C \geq \frac{P_{max}}{Vc*\Delta Vc*F_s}$ (4.7)

$C_1 = 470\mu F$

$C_2 = C_3 = 47\mu F$

The simulation is done by using MATLAB2010.The focus was on the output voltage and voltage across the switch. The closed loop Simulink model of the proposed converter using a PI controller is shown in fig 4.

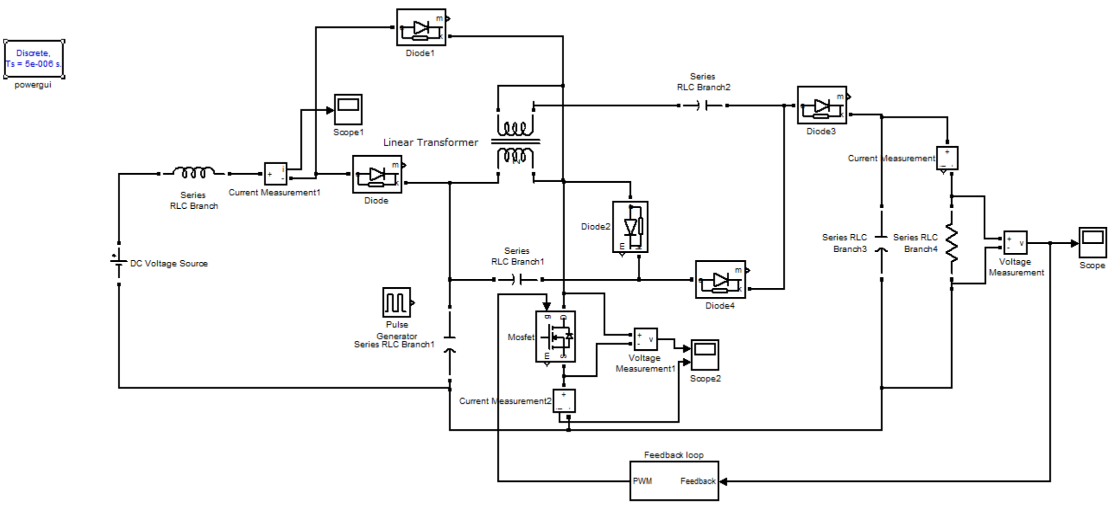


Fig 4: Closed loop simulation diagram of the proposed converter

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The simulation results are shown below.

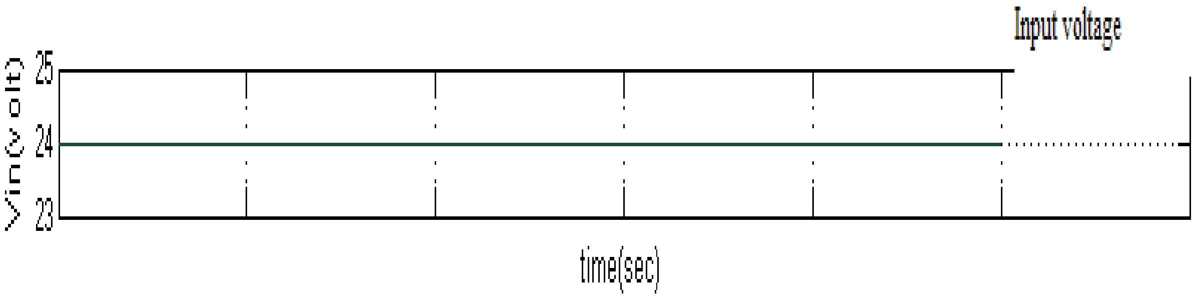

Fig 5(a):Input voltage of 24V DC

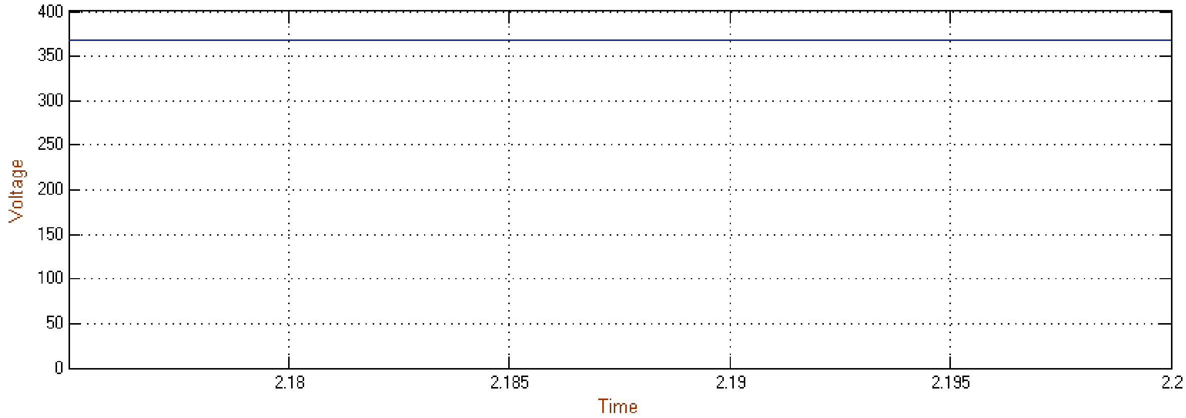

Fig 5(b):Output voltage of 380V DC

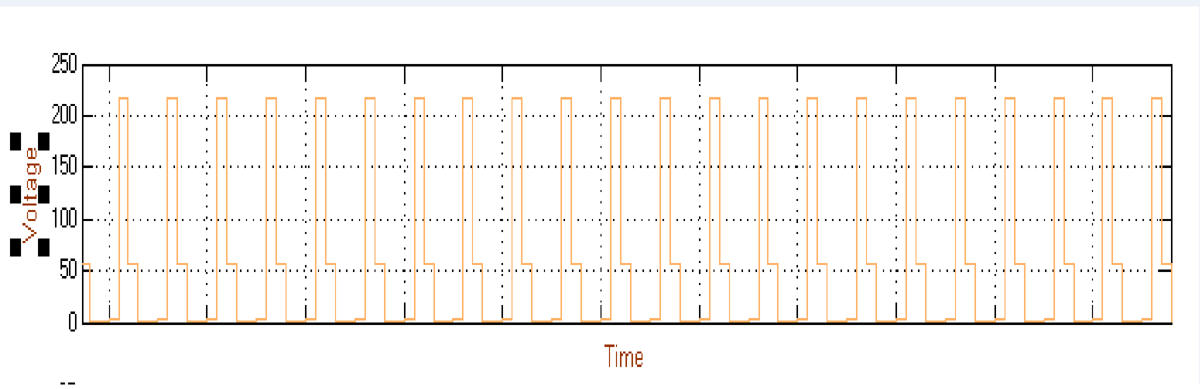

Fig 5(c): Voltage across the switch

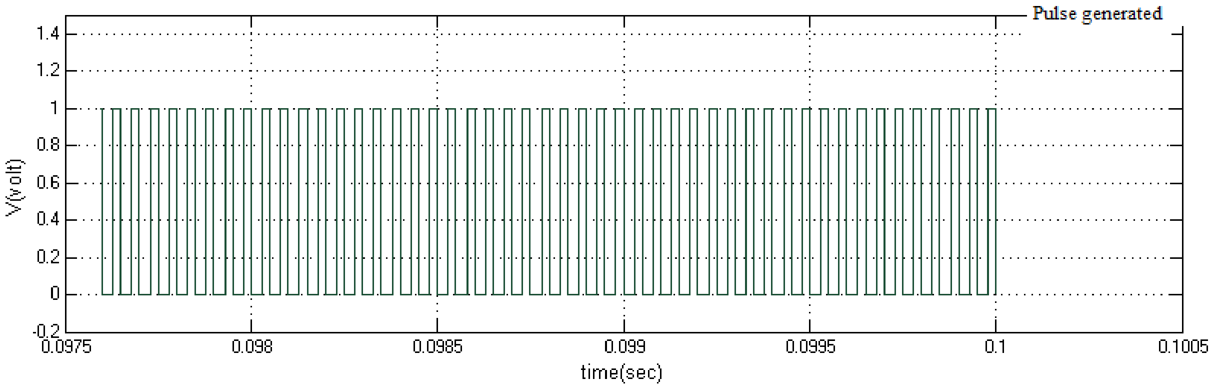

Fig 5(e): Pulse generated

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V.CONCLUSION

The experimental analysis of a non-isolated single switch high step-up converter is presented in this paper. The validity of the basic operational principle is verified by the MATLAB simulation using 12V DC input and 120V/60W output. The proposed converter has a low voltage stress across its switch and diodes. Hence the converter has lower conduction losses and reduced reverse recovery problem which lead to attain higher efficiency. Thus the converter has a high output voltage with lower voltage stress and duty ratio on comparing with the conventional circuits.

REFERENCES

[1] J F. Boico, B. Lehman, and K. Shujaee, "Solar battery chargers for NiMH batteries," IEEE Trans. Power Electron., vol. 26, no. 5, pp. 1600–1609, Sep. 2007.
[2] M. Prudente, L. L. Pfitscher, G. Emmendoerfer, 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.
[3] H. Kanchev, D. Lu, F. Colas, V. Lazarov, and B. Francois, "Energy management and operational planning of a micro grid with a PV-based active generator for smart grid applications," IEEE Trans. Ind. Electron., vol. 58, no. 10, pp. 4583–4592, Oct. 2011.
[4] 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.
[5] A. Vaccaro, G. Velotto, and A. F. Zobaa, "A decentralized and cooperative architecture for optimal voltage regulation in smart grids," IEEE Trans. Ind. Electron., vol. 58, no. 10, pp. 4593–4602, Oct. 2011.
[6] L Yan and B Lehman, "An integrated magnetic isolated two-inductor boost converter: Analysis, design and experimentation," IEEE Trans. Power Electron., vol. 20, no. 2, pp. 332–342, Jan. 2005 [8] C.-S. Leu and M.-H. Li, "A novel current-fed boost converter with ripple reduction for high- voltage conversion applications," IEEE Trans. Ind.Electron., vol. 57, no. 6, pp. 2018–2023, Jun. 2010.
[7] Q Li and PWolfs, "A review of the single phase photovoltaic module integrated converter topologies with three different DC link configurations," IEEE Trans. Power Electron., vol. 23, no. 3, pp. 1320–1333, May 2008.
[8] A. Reatti, "Low-cost high power-density electronic ballast for automotive HID lamp," IEEE Trans. Power Electron., vol. 15, no. 2, pp. 361–368, Mar. 2000.
[9] S. S Lee, S. W Choi, and G. O. Moon, "High efficiency active-clamp forward converter with transient current build-up (TCB) ZVS Technique," IEEE Trans. Ind. Electron., vol. 54, no. 1, pp. 310–318, Feb. 2007.
[10] E. S. da Silva, L. dos Reis Barbosa, J. B. Vieira, L. C. de Freitas, and V. J. Farias, "An improved boost PWM soft-single-switched converter with low voltage and current stresses," IEEE Trans. Ind. Electron., vol. 48, no. 6, pp. 1174–1179, Dec. 2001.
[11] H. S. H. Chung,W. C. Chow, S. Y. R.Hui, and S. T. S. Lee, "Development of a switched-capacitor DC–DC converter with bidirectional power flow," IEEE Trans. Circuits Syst. I, Fund. Theory Appl., vol. 47, no. 9, pp. 1383– 1389, Sep. 2000.
[12] L. S. Yang, T. J. Liang, and J. F. Chen, "Transformerless dc–dc converters with high step-up voltage gain," IEEE Trans. Ind. Electron., vol. 56, no. 8, pp. 3144–3152, Aug. 2009.

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