http://dx.doi.org/10.21172/ijiet.114.06

Modified Hybrid Switched-Inductor Converters For High Step-up Conversion

Anusha Abhayan[1], Annie P Oommen [2], Deena George [3]

[1]Post Graduate student, [2]Professor, Department of EEE, Mar Athanasius College of Engineering, Kothamangalam , Kerala India

[3]Professor, Department of Mathematics, Mar Athanasius College of Engineering, Kothamangalam, Kerala India

Abstract- The proposed High step up DC-DC converters have been developed for various applications, such as high-intensity discharge lamp ballasts for automobile headlamps, battery backup systems for uninterruptable power supplies, fuel-cell and solar-cell power conditioning systems. The voltage gain of traditional boost converter is restricted considering the problems like the system efficiency and current ripple. Two type Hybrid Switched Converters are proposed, Hybrid Voltage Lift Switched Inductor converter and Hybrid Self Lift Switched Inductor converter. These converters overcome those problems and it provide high step-up voltage gain. The operating principle and steady-state analysis of the proposed modified hybrid switched-inductor converters are simulated. The simulation is done using MATLAB/Simulink R2017 software. These converters provide low stress across the switches, low current ripple and low voltage ripple. So these Modified Hybrid Switched Inductor Converters increases the efficiency compared to conventional converters.

Index Terms— *Hybrid Voltage Lift Switched Inductor converter and Hybrid Self Lift Switched Inductor converter*

Introduction

Energy crisis is the most censorious issue in current world energy outline which can be settled down very effectively with green energy sources like solar, wind, tidal etc. Energy generation with solar power is most accepted and highly employed amongst all because of the availability of energy in affluence. To solve these problems many types High step-up DC-DC converters have been developed in various applications.

The traditional DC boost converter can attain an infinite conversion ratio as the duty cycle approaches 1 percentage in theory, but boost converter cannot be practically used for high duty cycles, because it leads a converter to instability.

Various topologies have been developed to provide a high step-up without an extremely high duty ratio. The isolated converters [2] can adjust the voltage ratio by increasing the turn's ratio of the transformers. The isolated voltage-type converters derived from the buck converter show high input a current ripple and high voltage stress across the secondary side diodes. The isolated current-type converters derived from the boost converter show inherent step-up capability, while the voltage spike across the switches caused by the leakage inductor should be considered carefully. Moreover, the cost in isolated topologies is high with multi-stage DC/AC/DC power conversion and isolated sensors or controllers.

Non-isolated high step-up converters are employed to achieve high efficiency and low cost, can be eneralized as the coupled inductor [6] type and non coupled inductor type. A number of coupled inductor based high step-up converters have been developed, by increasing the turns ratio of the coupled inductor which is similar to that in isolated converters, high voltage gain can be achieved. However, the leakage inductor of the coupled inductor is inevitable, which may cause high voltage spikes and add the voltage stress when the switch turns off.

Various switched-inductor and switched-capacitor structure to extend the voltage gain has been discussed in [10]. With the transition in series and parallel connection of the switched inductor, an inherent high voltage gain can be achieved. The switched inductor based boost converter is then derived, but the voltage gain is still limited and hard to deal with the 10 times voltage ratio to meet the demands of the inverter, in addition, the switch voltage stress is also high. Although more switched cells can be added to increase the voltage conversion ratio, the topology is very complex.

Hybrid switched-inductor converters (H-SLC) for high step-up conversion [1] can provide output with low duty ratio. The Modified Hybrid Switched Converters can provide high conversion ratio, which has the following advantages: high voltage-conversion ratio, low voltage stress across the switches, low conduction loss on switches, easy to control.operation with high input current and high output voltage, thus a careful study must be done to define the topology for a high step-up application.

II. TOPOLOGICAL DERIVATION OF MODIFIED HYBRID SWITCHED-INDUCTOR CONVERTERS

New class of DC-DC converter is proposed to attain high voltage conversion ratio via capacitor inductor based etworks such as Voltage Lift Switched Inductor (VL-SI) cell and Self Lift Switched Inductor (SL-SI). Combination of these etworks with active switched inductor to provide High step up voltage gain.

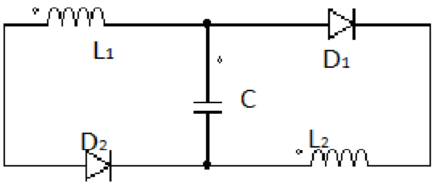

Fig. 1 Voltage Lift switched-inductor (VL-SI)

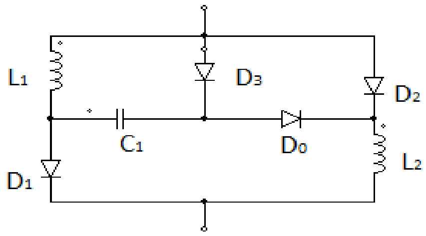

Fig. 2 Self Lift switched inductor (SL-SI)

The VL-SL unit (Fig.1) consists two inductors L_1 and L_2, three diodes D_1,D_2 and one capacitor C; when the applied voltage is positive D_1,D_2 become conduct whereas $L_{1,}$ L_2 and C are charged in parallel; when applied voltage becomes negative D_1,D_2 are reverse biased whereas $L_{1,}$ L_2 and C are discharged in series.

The SI-SL unit (Fig.2) consists two inductors L_1 and L_2, four diodes D_0, D_1, D_2, D_3 and one capacitor C_1; During the switching-on period of the main switch D_1, D_2 and D_3 conduct, whereas $L_{1,}$ L_2 and C_1 are charged in parallel. During the switching-off period of the main switch, D_0 conducts, whereas L_1 and L_2 are discharged in series.

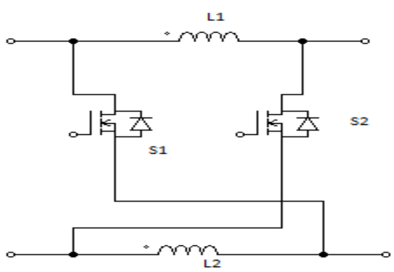

Fig. 3 The switched-inductor unit active switched inductor

A high voltage gain can be achieved by Modified Hybrid Switched Inductor Converters. Hybrid Voltage Lift Switched Inductor Converter developed by combining the VL-SI and A-SL unit (Fig.3) and Hybrid Self Lift Switched Inductor Converter developed by combining the SL-SI and A-SL unit. The inductors L_1 and L_2 in A-

SL unit can be substituted with VL-SI unit and SL-SI, then the proposed Hybrid Self Lift Switched Inductor Converter converters (H-SL-SI) and Hybrid voltage Lift Switched Inductor Converter converters (H-VL-SI) can be obtained, shown in fig.4 and fig.5.

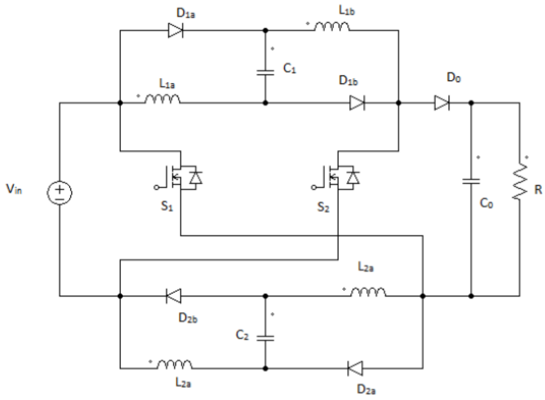

Fig. 4 Hybrid Voltage Lift Switched Inductor Converter.

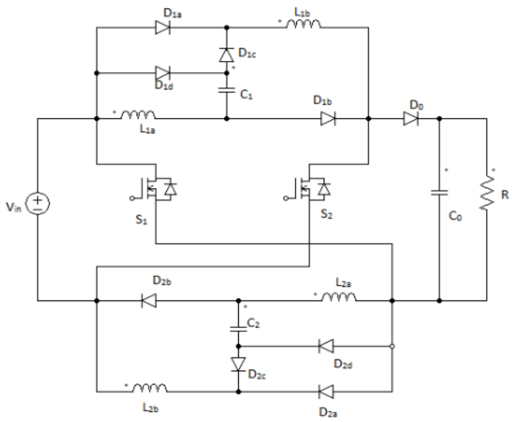

Fig. 5 Hybris Self Lift Switched Inductor Converter

III. OPERATING PRINCIPLE OF HYBRID VOLTAGE LIFT SWITCHED INDUCTOR CONVERTER

A. Mode I

S_1 and S_2 is turned ON in this mode. Here D_0 is reverse biased. The current low path is shown in Fig.VI. The inductors L_{1a}, L_{1b}, L_{2a}, L_{2b} and capacitors C_1 ,C_2 are charged by power source. The load is supplied by previously charged capacitor. The voltage across the inductors can be expressed as:

$$V_{L1a}= V_{L1b}= V_{L2a}= V_{L2b}= V_{ca}= V_{c2}= V_i \quad (1)$$

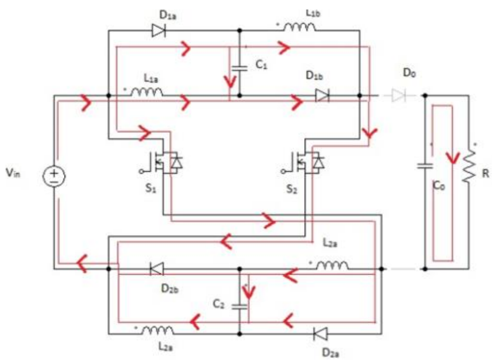

Fig. 6 Mode I Operation

B. Mode II

S_1 and S_2 is turned OFF in this mode. Here D_{1a}, D_{1b}, D_{2a}, and D_{2b} are reverse biased.The inductors L_{1a}, L_{1b}, L_{2a}, L_{2b} and capacitors C_1 ,C_2 are series connected to transfer the energy to output.

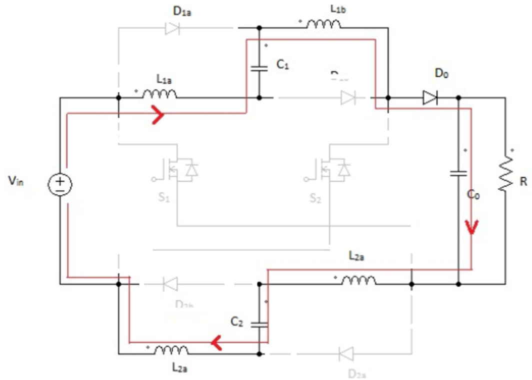

Fig. 7 Mode II Operation

IV. OPERATING PRINCIPLE OF HYBRID SELF LIFT SWITCHED INDUCTOR CONVERTER

A. Mode I

S_1 and S_2 is turned ON in this mode. Here D_1 is reverse biased. The current-flow path is shown in Fig.8. The inductors L_{1a}, L_{1b}, L_{2a}, L_{2b} and capacitors C_1 ,C_2 are charged by power source. The load is supplied by previously charged capacitor.

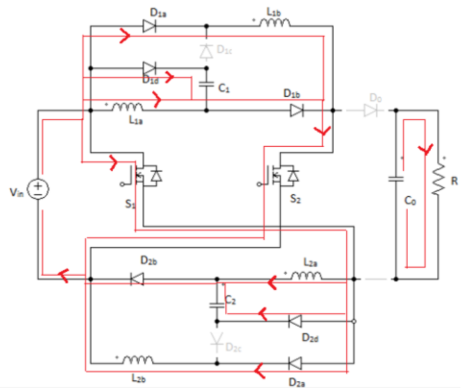

Fig. 8 Mode I Operation

B. Mode II

During this time interval, S_1 and S_2 are turned off. The inductors L_{1a}, L_{1b}, L_{2a}, L_{2b} and capacitors C_1 ,C_2 are in series and discharged to load.

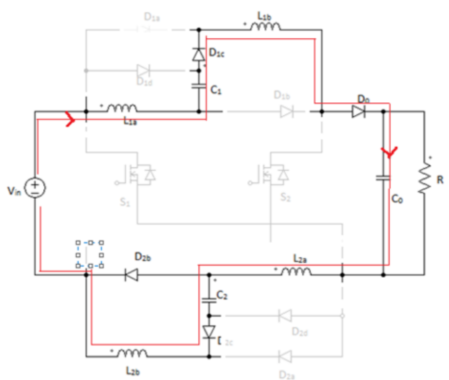

Fig. 9: Mode II Operation

http://dx.doi.org/10.21172/ijiet.114.06

V. DESIGN OF COMPONENTS

The simulation of a converter rated at 300 W with V_{in}=30 V and V_o=250 V is simulated. So the Output current *Io*=1.2A. Switching frequency f_{sw} =50KHz. The design is done so as to get a voltage gain of 8.33. Duty ratio D=58 % is chosen.

A. Inductor Design

The inductor value is selected such that the boost stages operate in continuous conduction mode(CCM). The minimum inductor value for the CCM operation of the boost stages is given by,

$$L = \frac{V_{in}(vout - vin)}{\Delta I_L * Fs * Vout} \quad (2)$$

B. Capacitor Design

The output capacitor is choosen based on the quantity of charge that's transferred to the output for a desired output voltage ripple. Assuming a voltage ripple of 0.03% of output voltage, the required capacitance is given by,

$$C_0 = \frac{I_L * D}{F_S * \Delta V_{out}} \quad (3)$$

The capacitors C_1 and C_2 are selected such that the a voltage ripple of 0.01% of output voltage, the required capacitance is given by,

$$C_1 = \frac{V_0 * (1-D)}{D * R * F_S * \Delta V_{C1}} \quad (4)$$

VI. SIMULATION RESULTS

The simulation parameters used for multiple input DC-DC converter are shown in Table I.

TABLE I

Simulation parameters

Components	**Rating**
Input Voltage	30V
Output Voltage	250V
Load Resistance	200Ω
Duty Ratio	58%
Inductors	500µH
Switching Frequency	50Khz
Capacitor C_0 C_1, C_2	 470µF 170µF

VI. Simulation Model and Result

A 300W model of converter is simulated in MATLAB/ SIMULINK environment. The simulation diagram is shown in Fig. 10 and Fig.11.

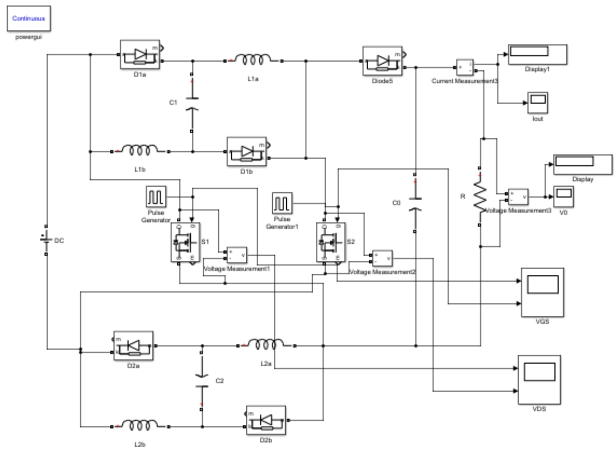

Fig. 10: Simulation model of the Hybrid Voltage Lift Switched Inductor Converter

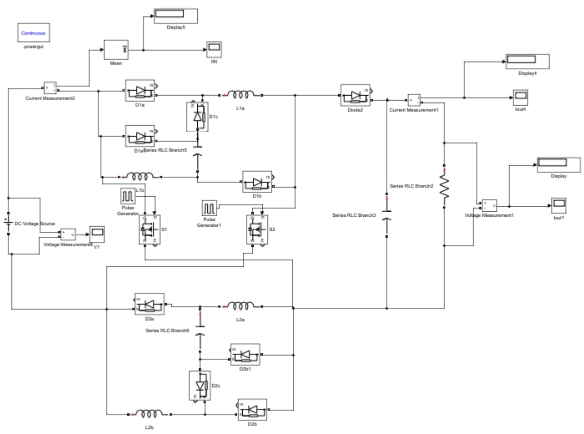

Fig.11: Simulink Model of Self Lift Switched Inductor Converter

A. Simulation Result of Hybrid Voltage Lift Switched Inductor Converter

The switching sequence for S_1, S_2 are same.

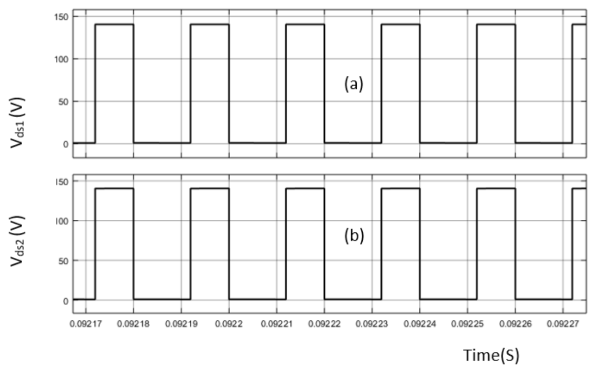

Fig. 12: Voltage Stress across switch (a) S_1 (b) S_2

Fig.12 shows the voltage stress across the switches. A voltage stress of 140V is experiences by the switches. Compared to the output voltage of 250V the value is small (56%). So the switching stress is comparatively low.

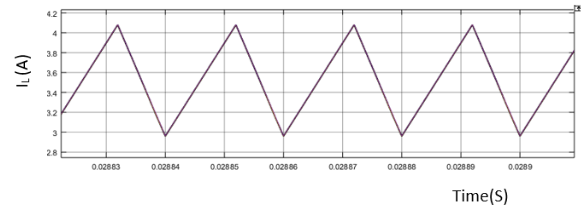

Fig. 13: Current through inductor L_{1a}, L_{1b}, L_{2a}, L_{2b}

The inductor current and the input current are the same.

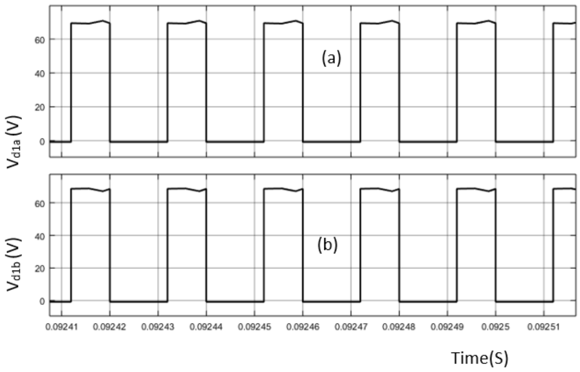

Fig. 14: Voltage across (a) diode D_{1a},D_{2a}(b) diode D_{1b},D_{2b}

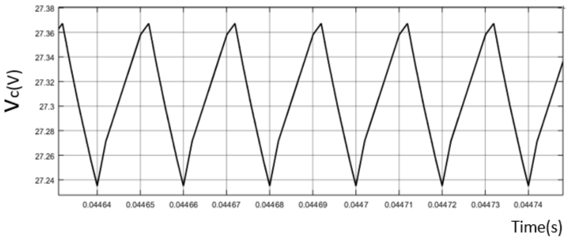

Fig. 15:*Voltage across Capacitors C_1, C_2*

Fig. 16 shows the output waveforms of obtained in the simulation. Output voltage is 250V and the output current is 1.2A.

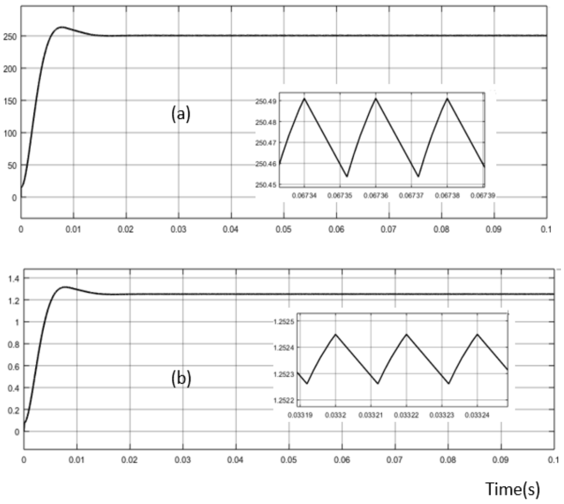

Fig. 16: Output (a) Voltage and (b) Current

B. Simulation Result of Hybrid Self Lift Switched Inductor Converter

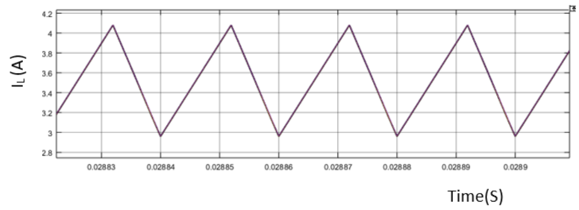

Fig. 17: Current through inductor L_{1a}, L_{1b}, L_{2a}, L_{2b}

The inductor current and the input current are the same.

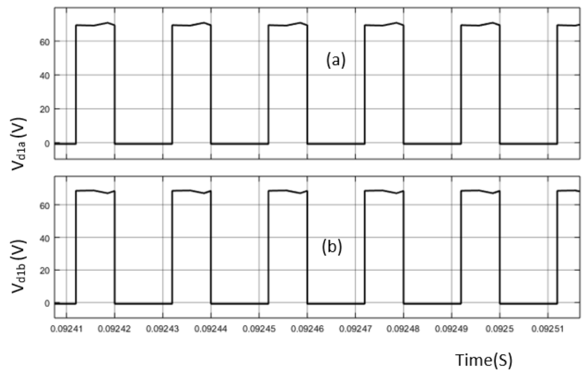

Fig. 18: Voltage across (a) diode D_{1a},D_{2a}(b) diode D_{1b},D_{2b}

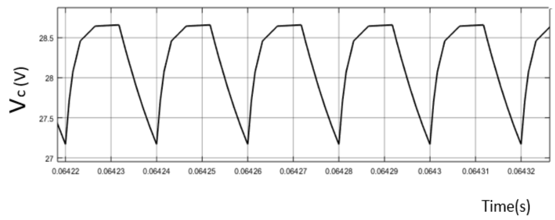

Fig. 19:*Voltage across Capacitors C_1, C_2*

Fig.20 shows the output waveforms of obtained in the simulation. Output voltage is 250V and the output current is 1.2A.

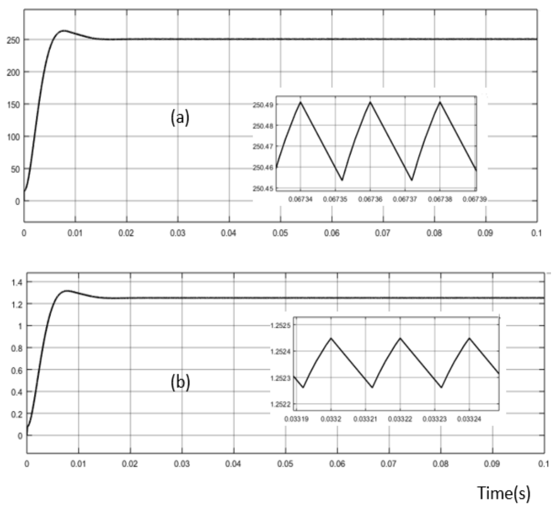

Fig. 20: Output (a) Voltage and (b) Current

VII. COMPARISON

Table II shows the comparison between the converters. For input voltage of 30V, all the converters are simulated. Voltage across switch, output voltage ripple and current ripple is reduced. Efficiency of modified converter is improved. Number of componets in Voltage Lift Switched Converters is less than Self Lift Switched Inductor Converter and efficiency also improved. So prototype is designed and implemented for Hybrid Voltage Lift Switched Inductor.

TABLE III

Comparison between different Converters

	Conventional Boost Converter	Hybrid Switched Converter	Modified converters	
			Hybrid Voltage Lift Switched Inductor Converter	Hybrid self lift switched inductor converter
Number of components Diode Inductor Capacitor	 1 1 1	 7 4 1	 5 4 3	 9 3 3
Output Voltage	80 V	200 V	250 V	250 V
Votage gain	2.6	6.66	8.33	8.33
Voltage stress across MOSFET	29 V	114.9 V	140 V	140 V
Voltage ripple	.12 V	0.025 V	.035 V	.045 V
Efficiency	76 %	83.33 %	92 %	85 %

IX. EXPERIMENTAL SETUP AND RESULTS

A 5 W, 10KHz prototype of the DC-DC converter with high voltage gain input 12V is implemented. Table III shows the specification.

TABLE III

Components used for prototype

Components	**Rating**
Inductors	1.5mH
Capacitor C_0 C_1,C_2	 2μF 60μF
Diode	IN5819
Controller	PIC16F877A
MOSFET	IRF540
Driver IC	TLP250

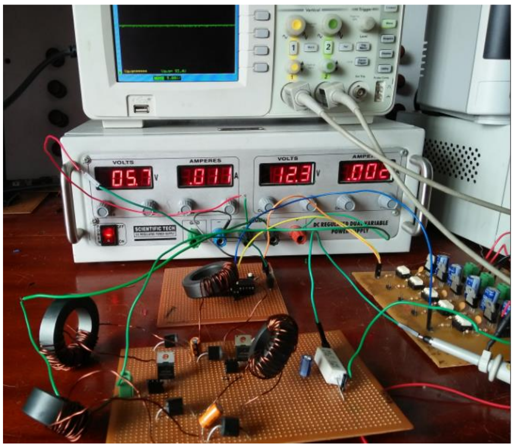

Fig.21: Experimental setup

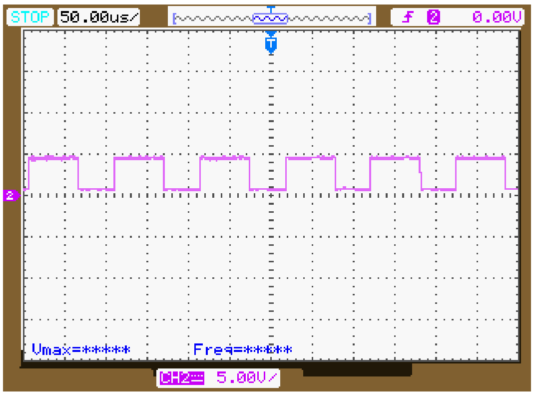

Fig.22 : Switching Pulses

Switching pulses for S_1 and S_2 are same.

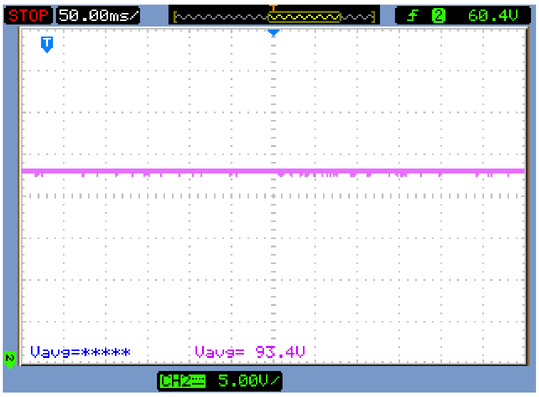

Fig. 23: Output voltage waveform

The power supply consist of a step down transformer, full bridge diode rectifier, filter capacitor and a regulator IC (7812). IRF540 MOSFET is used as the switches. TLP250 driver is used to drive the MOSFET. To generate the switching signal PIC16F8771A was programmed in the laboratory and necessary waveforms were obtained. The Switches are working in 10KHz frequency and have a duty ratio of 0.58.

X. CONCLUSIONS

Modified Hybrid switched inductor converters (both VL-SI and SL-SI) are capable of producing to output voltages of 250 V for an input voltage of 30 V. The positive output voltage has a high gain of 8.33. The output voltage waveform obtained from simulation result. The ripple in output voltage and current is low. Voltage Ripple and current ripple is less than 1% . The voltage Stress across S1 and across S2 is 140V. From this circuit, we get continous and discontinous mode of operation. Hybrid voltage Lift Switched Inductor Converter is more suitable than Hybrid Self Lift Switched Inductor Converter, because of the number of components in VL-SI converter is less.

XI. REFERENCES

[1] Yu Tang, Dongjin Fu , Ting Wang, and Zhiwei Xu, "Hybrid Switched-Inductor Converters for High Step-Up Conversion", *IEEE,pp.* 1480 - 1490,March 2015.

[2] P. H. Tseng,J. F. Chen, and Y. P. Hsieh, "A novel active clamp high step-up DC-DC converter with coupled-inductor for fuel cell system", *IEEE IFEEC*,pp.326-331,2013.

[3] Y. Zhao,W. H. Li, and X. N. He, "Single-Phase Improved Active Clamp Coupled Inductor-Based Converter With Extended Voltage Doubler Cel"l, *IEEE Trans.Power Electron.*, vol. 27, no. 6, pp. 2869-2878, Jun. 2012.

http://dx.doi.org/10.21172/ijiet.114.06

[4] Y. P. Hsieh,J. F. Chen, T. J. Liang, L. S. Yang, "Novel High Step-Up DC-DC Converter With Coupled-Inductor and Switched-Capacitor Techniques", *IEEE Trans. Ind. Electron.*, vol. 59, no. 2, pp. 9981007, Feb. 2012.

[5] B. L. Narasimharaju,S. P. Dubey, and S. P. Singh, "Coupled inductor bidirectional DC-DC converter for improved performance" in Proc. *IEEE IECR*, pp. 28-33, 2010.

[6] L. S. Yang,T. J. Liang,and J. F. Chen, "Transformerless DCDC Converters With High Step-Up Voltage Gain" , *IEEE Trans. Ind*. Electron, vol. 56, no. 8, pp. 31443152, Aug. 2009.

[7] Y. Axelrod, Berkovich, and A. Ioinovici, "Switched-capacitor/ switched-inductor structures for getting transformerless hybrid DCDC PWM converters", *IEEE Trans. Circuits Syst. I* , Reg. Papers, vol. 55, no. 2, pp. 687696, Mar. 2008.

[8] Y. Jiao, F.L. Luo, M. Zhu, "Voltage-lift-type switched-inductor cells for enhancing DC-DC boost ability: principles and integrations in Luo converter" , *IET Power Electronics,* April. 2014.

[9] Mahajan Sagar Bhaskar, Sanjeevikumar Padmanaban,Frede Blaabjerg, "4Nx Non-Isolated and Non-Inverting Hybrid Interleaved Multilevel Boost Converter Based VLSIm Cell and Cockroft Walton Voltage Multiplier for Renewable Energy Applications", IEEE Trans. Circuits Syst. I , 2016.