MODELLING AND SIMULATION OF A NON-CONFINED BIDIRECTIONAL DC-DC CONVERTER WITH HIGH VOLTAGE PICK UP

VAISHALI[1], M.S.ASPALLI[2]
Department of Electrical and Electronics Engineering
Poojya Doddappa Appa College of Engineering, Kalaburgi, Karnataka, India

Abstract: This paper presents function of a non-confined bidirectional DC-DC converter with high voltage pick up. The proposed converter has a simple structure, low cost and ease of control. It consists of two boost converters to enhance the voltage pick up and efficiency to be high because the input current is divided to the inductors. The voltage pick up of the bidirectional dc-dc converter is more than the ordinary fell bidirectional buck/boost converter in the progression up mode. Furthermore, the voltage pick up of the bidirectional dc-dc converter is not as much as the traditional fell bidirectional buck/boost converter in the progression down mode. In order to charge and discharge the battery, a bidirectional converter is needed. The buck dc-dc converters are utilized as a part of the applications where the required yield voltage is lower than the source voltage. Plus, the lift dc-dc converters are utilized as a part of the applications where the required yield voltage is higher than the source voltage. The proposed converter can work in wide voltage range than the conventional cascaded bidirectional buck/boost converter and for better pick up performance of the proposed converter; it is compared with the conventional converter. The non-confined bidirectional DC-DC converter is assessed using MATLAB/Simulink (MLS) with the SimPowerSystem block set and the results of simulations are presented to evaluate the behaviour and feasibility of the proposed topology. The circuit is simulated with 25V input voltage for an output voltage of 250V in step-up mode and in step-down mode it is vice-versa. The task of proposed framework has been discovered palatable.

***Index Terms* - Non-confined bidirectional DC-DC converter, High voltage pick up converter, MOSFET (Metal-Oxide Semiconductor Field Effect Transistor), MATLAB/Simulink (MLS).**

I.INTRODUCTION

The massy usage of the fossil fuels, such as the gas, the oil and the coal, which causes a serious effect in greenhouse and pollution in the atmosphere. So the clean energy vehicle applications become worldwide. Nowadays, clean and renewable energies comprising wind energy, photovoltaic, fuel cell and so on, have been widely applied to obtain environment-friendly objectives [1].

Cold starting and battery discharging is used in battery-based energy storage systems because to reduce the pollution in the atmosphere and the development of bidirectional DC-DC converters has become important for clean-energy vehicle applications [2], [3].

Bidirectional DC-DC converters are relied upon to charge and discharge the battery. Bidirectional DC-DC converters trade essentialness between two sources in the two headings [4].

Bidirectional DC-DC converters structures are having some similar topologies. Soft switching techniques are generally used to reduce the switching losses and high conduction losses in isolated transformers because it requires four to nine power switches. Henceforth we favored non-disengaged converters. Basically bidirectional DC-DC converter are isolated into two sorts one is isolated converters and another is non-segregated converters. In non-segregated bidirectional DC-DC converters there is no transformer. Segregated bidirectional DC-DC converter is utilized for galvanic disengagement purposes. This will add additional size, weight and cost. So transformer-less type is preferred. Non-confined bidirectional DC-DC converter is used in high power, space craft applications and in applications where low weight and size is required. In order to reduce the disadvantages of isolated bidirectional DC-DC converter, here we are using a non-confined bidirectional DC-DC converter. The high rehash transformer based structure is an engaging one to get detachment between the source and load sides. Be that as it may, from the perspective of enhancing the effectiveness, size, weight and cost, the transformer-less write is substantially more alluring [5].

The bidirectional DC–DC converters are widely used for battery chargers aerospace power systems, photovoltaic hybrid power systems, many other industrial applications, fuel-cell hybrid power systems, uninterrupted power supplies (UPS), hybrid electric vehicle energy systems, and renewable energy systems [6]-[8].

The isolated types include flyback converters, forward-flyback converters, half-bridge converters. The flyback and forward converters can obtain high step-up voltage gain by adjusting the turns ratio of the transformer. High power dissipation of the converters and high voltage spike on the main switch cause the leakage-inductor energy of the transformer. In order to reduce the voltage spike and pursue high efficiency, non-dissipative snubber circuit and active-clamp circuit are used to recycle the energy of the leakage inductor. The flyback converters are simple in structure and ease of control. Vitality can't be reused in spillage inductor on account of high voltage stresses and it has switch recuperation issue on the optional side of the converters at the diodes. To lessen the voltage weights on the switches, voltage clip method is utilized. To increase the efficiency, recycle the leakage-inductor energy. The non-isolated types include the multilevel type, coupled inductor type, sepic/zeta type, conventional buck/boost type, switched capacitor types, three-level type converters[9],[10].

The multi-level types are having more switches and it have magnetic less converter. Control of the circuit in multilevel converter is more complicated when the voltage gain is needed to be lower in step-down mode and higher in step-up mode. Another converter is having a complicated structure i.e. coupled inductors. The voltage get is low in novel bidirectional DC-DC converter. It has a three power switches and common inductors [11]-[13].

To make the circuit analysis simpler, the following conditions are assumed:

(1) Inductors and capacitors are ignored in the equivalent series resistances and the ON-STATE resistances R_{DS}(ON) of the switches.

(2) Consistent voltages of the capacitors.

II. WORKING PRINCIPLE OF THE PROPOSED CONVERTER

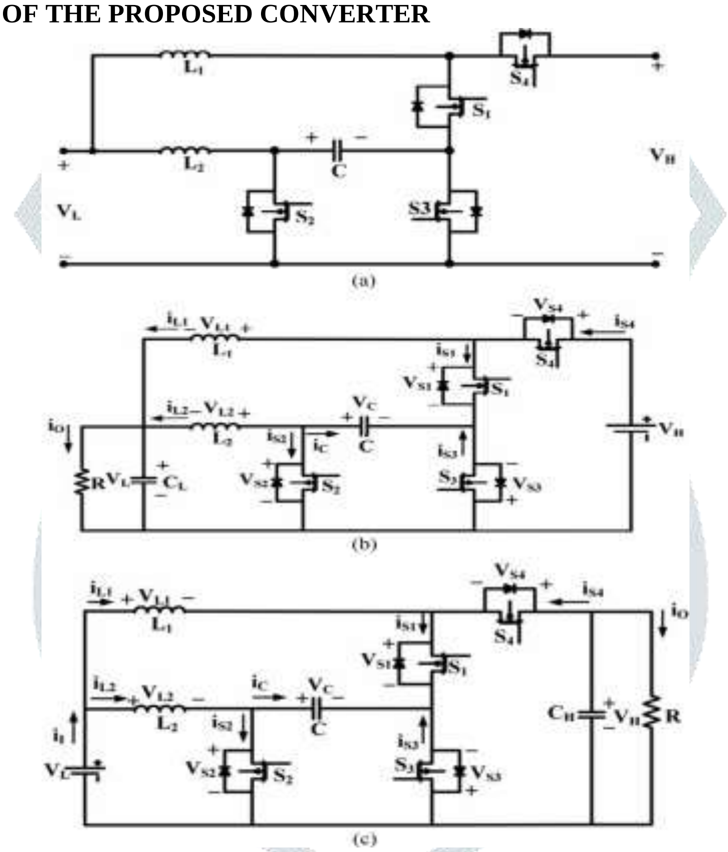

Figure 1.Proposed bidirectional DC-DC converter and its equivalent circuits in step-down and step-up modes. (a) Proposed converter. (b) Proportionate circuit in the step down mode. (c) Proportionate circuit in the step-up mode.

Figure 1 demonstrates the equal circuit of the proposed converter, which has a capacitor, two inductors, and four power switches. Two of the switches applied for synchronous rectifiers and other switches work as power switches.

Step-Down Mode of the Proposed Converter

The figure 1(b) demonstrates the proposed converter in step-down mode. In this step-down mode, switches S_1 and S_2 function as synchronous rectifiers and the S_3 and S_4 fill in as power switches. Figure 2 and 3 shows the flow of current in one switching period. The steady-state analyses are explained as follows.

Mode 1: Amid the mode 1 task [t_0, t_1], S_1 and S_2 are not leading and S_3 and S_4 are directing. Figure 2 shows the current stream way of the proposed converter. As seen in this figure, the energy of the DC source V_H is discharged to inductors L_1. Hence the inductor L_1 is charging during this mode. Vitality of the capacitor C is exchanged to inductor L_2 and capacitor C_L and the inductor L_2 is likewise charging. The following equations can be achieved in this mode:

$$V_{L1} = V_H - V_L \quad (1)$$

$$V_{L2} = V_C - V_L \quad (2)$$

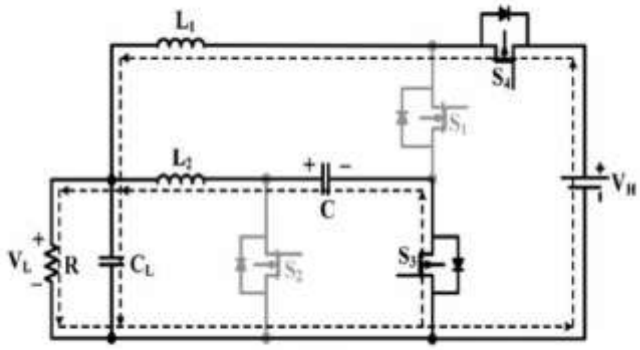

Figure 2.Current stream way in mode1.

Mode 2: Amid the mode 2 task [t_1, t_2], S_1 and S_2 are directing and S_3 and S_4 are not leading. Figure 3 shows the current stream way of the proposed converter. Inductor L_1 is demagnetized to capacitors C and C_L. Vitality of the Inductor L_2 is exchanged to capacitor C_L and gives vitality to the heap. The following equations can be achieved in this mode:

$$V_{L1} = -V_L - V_C \quad (3)$$
$$V_{L2} = -V_L \quad (4)$$

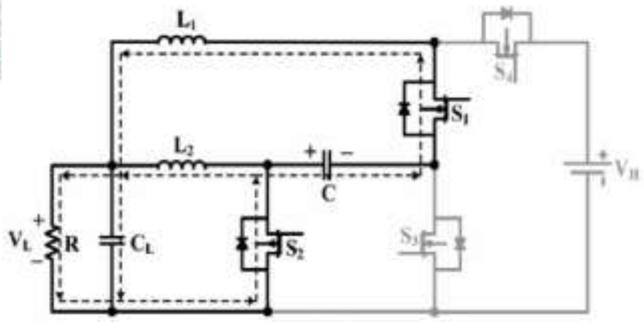

Figure 3.Current stream way in mode2.

By applying volt–second balance principle on the inductor L_1 and L_2, the equations can be written:

$$V_{L1} = D\,(V_H-V_L) + (1-D)\,(-V_L-V_C) = 0 \quad (5)$$
$$V_{L2} = D\,(V_C-V_L) + (1-D)\,(-V_L) = 0 \quad (6)$$

By simplifying (5) and (6), the following equations can be written as:

$$V_C/V_L = 1/D \quad (7)$$
$$V_H/V_C = 1/D \quad (8)$$

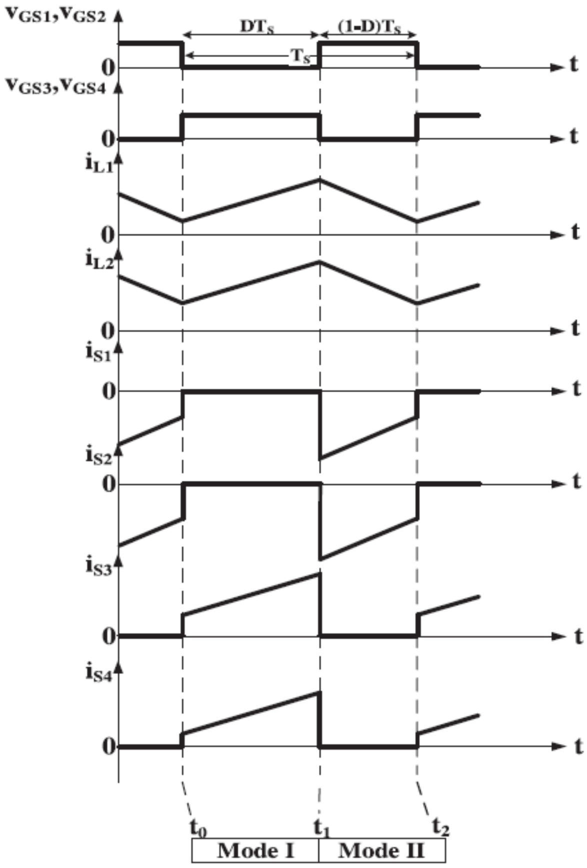

Figure 4.Waveform of the proposed converter in step-down mode (CCM).

Substituting (7) into (8), the voltage gain of the proposed converter in step-down mode can be written as

$G_{VCCM(step\text{-}down)}=D^2$ (9)

The voltage get of the standard buck converter is higher than the proposed converter.

The characteristic waveform of the proposed converter in continuous conduction mode (CCM) is shown in Figure 4.

Step-Up Mode of the Proposed Converter

The figure 1(c) demonstrates the proposed converter in step-up mode. In this operation mode, S_3 and S_4 function as synchronous rectifiers and S_1 and S_2 fills in as power switches. Figure 5 and 6 shows the flow of current in one switching period. The steady-state analyses are explained as follows.

Mode 1: Amid the mode 1 task [t_0, t_1], S_1 and S_2 are directing and S_3 and S_4 are not leading. As shown in Figure 5, in this interval the energy of the dc source V_L is discharged to inductor L_2. Inductor L_1 is polarized by the dc source V_L and the capacitor C put away the vitality. Capacitor C_H is additionally exchanged to the heap. The following equations can be written for this mode:

$V_{L1} = V_L+V_C$ (10)

$V_{L2} = V_L$ (11)

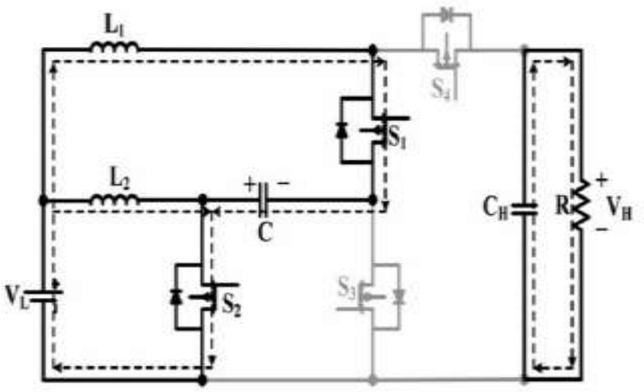

Figure 5.Current stream way in mode1.

Mode 2: Amid the mode 2 task [t_1, t_2], $S_1$and S_2 are not leading and S_3 and S_4 are directing. As shown in Figure 6, the energy of the input source V_L is transferred to capacitor C and the inductor L_2 stored the energy. The vitality of the information source V_L is exchanged to Capacitor C_H and the inductor L_1 put away the vitality. Therefore, the voltages across the inductors can be obtained as

$V_{L1} = V_L – V_H$ (12)
$V_{L2} = V_L − V_C$ (13)

Applying the volt–second balance principle on inductors L_1 and L_2 are

$V_{L1} = D (V_L+V_C) + (1-D) (V_L-V_H) = 0$ (14)
$V_{L2} = D (V_L) + (1-D) (V_L-V_C) = 0.$ (15)

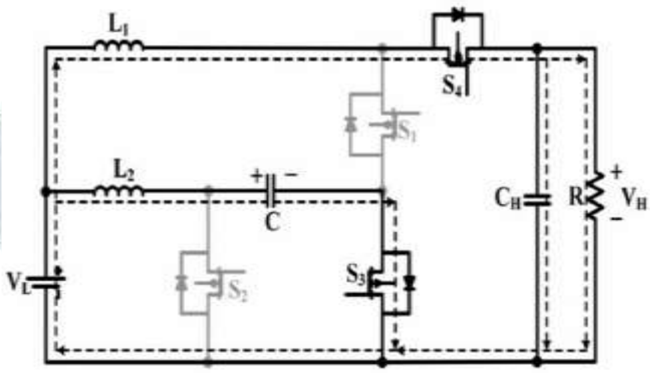

Figure 6. Current stream way in mode2.

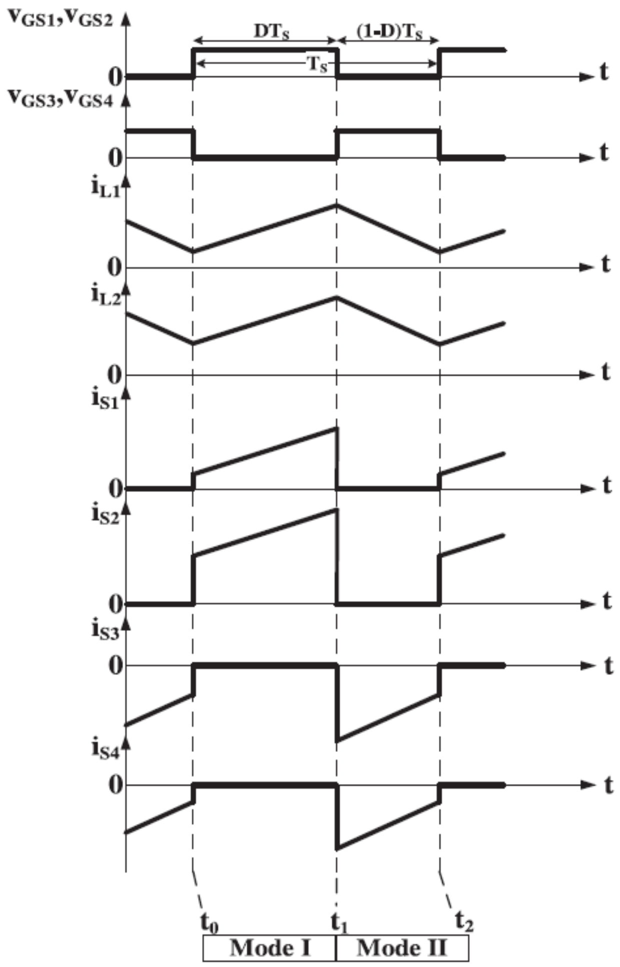

Figure 7.Waveform of the proposed converter in step-up mode (CCM).

Simplifying (14) and (15) and we get the following equations

$V_C/V_L = 1/ (1-D)$ (16)

$V_H/V_C = 1/ (1-D)$ (17)

By substituting (16) into (17), the voltage gain in CCM is

$G_{VCCM(step-up)}=1/(1-D)^2$ (18)

The voltage pick up of the ordinary buck converter is lower than the proposed converter.

The characteristic waveform of the proposed converter in continuous conduction mode (CCM) is shown in Figure 7.

III. SIMULATION RESULTS

Simulation was obtained for a non-confined bidirectional DC-DC converter with high voltage pick up using MATLAB/Simulink(R2014a) and Switching sequences have been provided using a pulse generator. By running the simulation, it is observed that in step-down mode for an input voltage of 250V, the output voltage is 25V and in step-up mode it is vice-versa.

The scheme of the block diagram describing the non-confined bidirectional DC-DC converter is shown in figure 8 and figure 9.

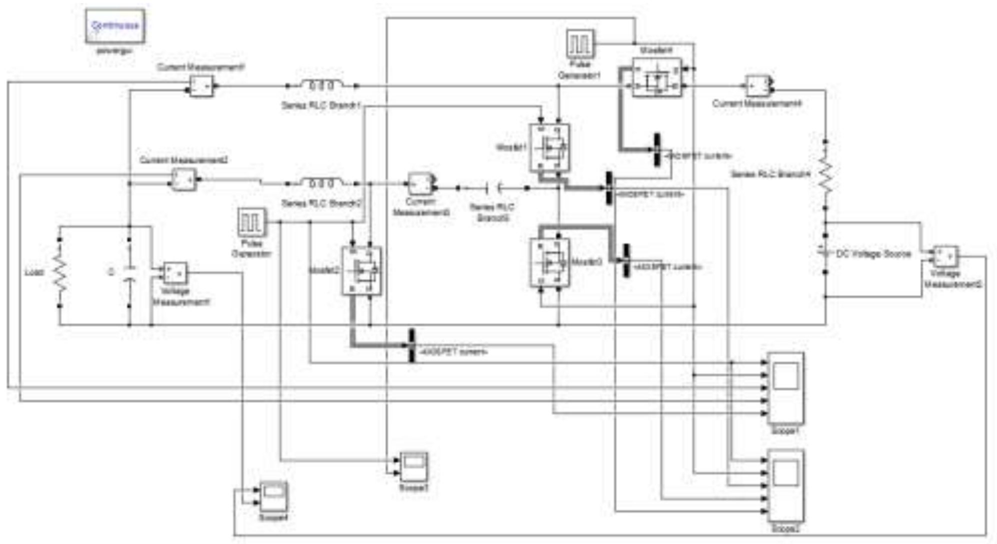

Figure 8.Simulation model for bidirectional DC-DC converter in step-down mode.

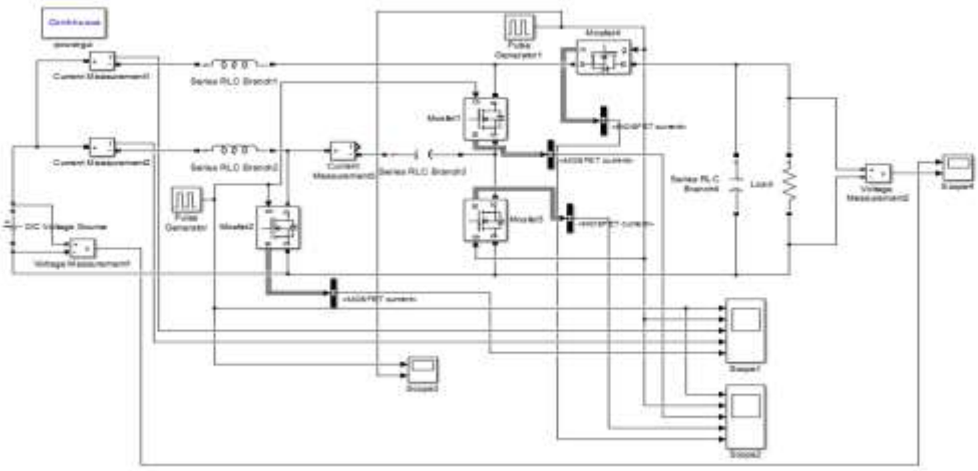

Figure 9.Simulation model for bidirectional DC-DC converter in step-up mode.

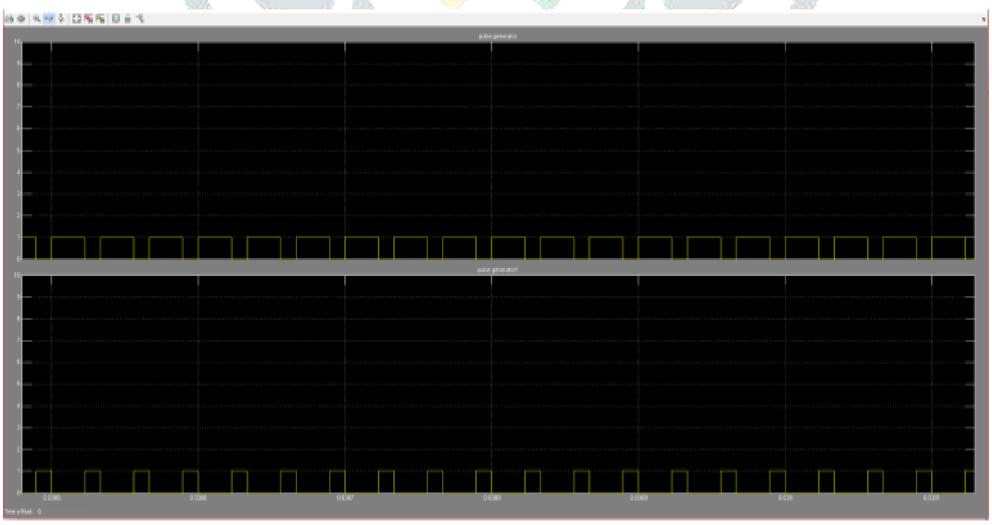

Figure 10.Yield waveform of the pulse generator.

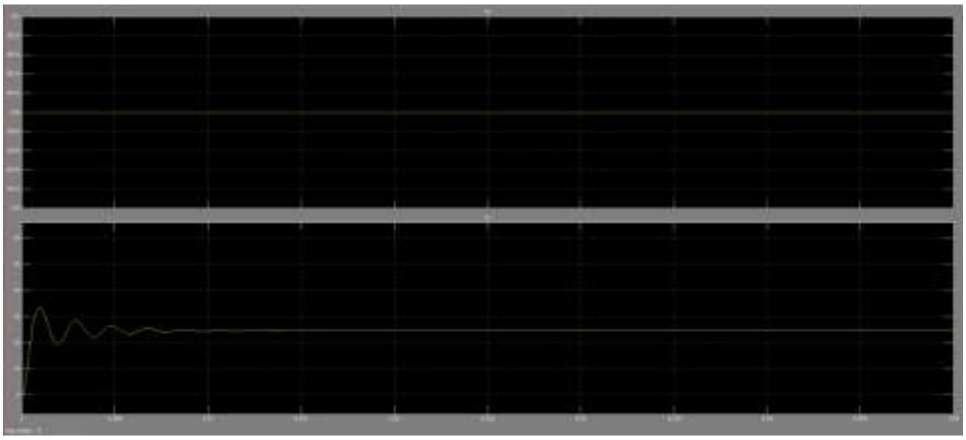

Figure 11.Yield voltage at an input voltage of 250V for step-down mode.

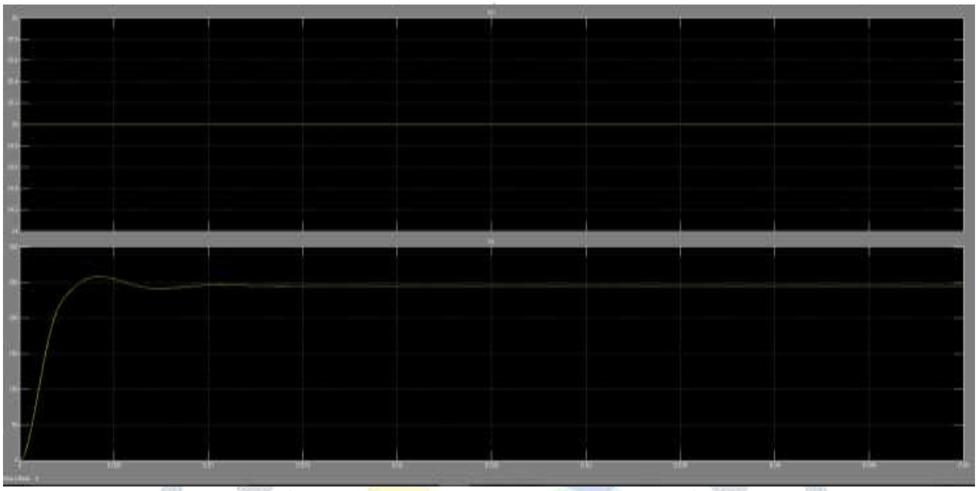

Figure 12.Yield voltage at an input voltage of 25V for step-up mode.

Figure 10 shows the output waveform of the pulse generator. Figure 11and 12 shows the yield voltage for step-down mode and step-up mode. Above is a graph which has been created by running the simulation and we getting these types of waveforms.

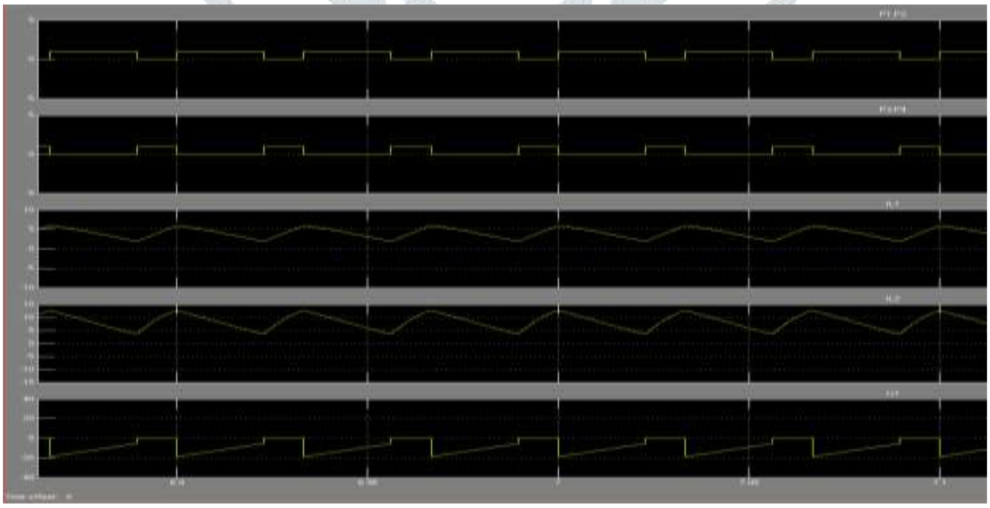

Figure 13.Waveforms for S_1, S_2, S_3, S_4, I_{L1}, I_{L2}, I_{S1} in step-down mode.

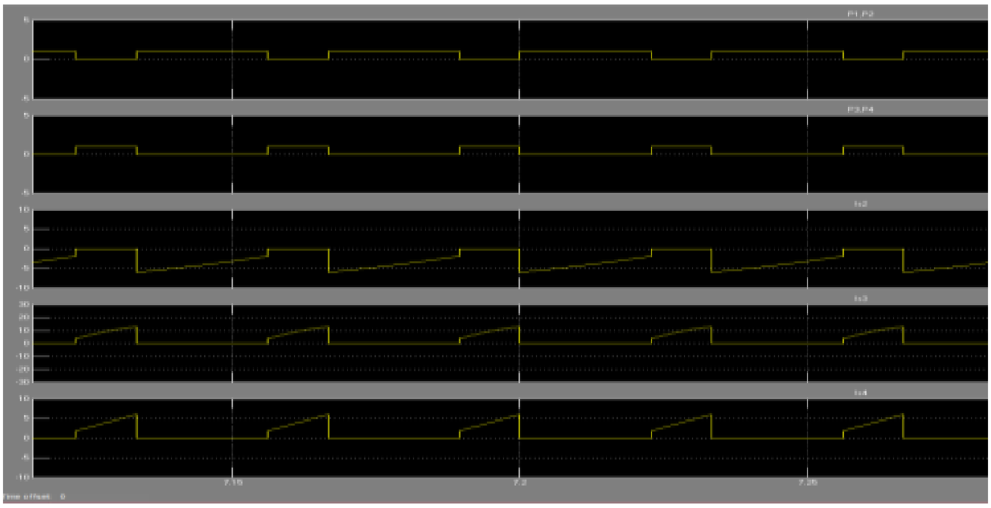

Figure 14.Waveforms for S_1, S_2, S_3, S_4, I_{S2}, I_{S3}, I_{S4} in step-down mode.

Figure 13 and figure 14 are the simulation waveforms for step-down mode. In this mode switch S_1 and S_2 functions as synchronous rectifiers and switch S_3 and S_4 fills in as power switches.

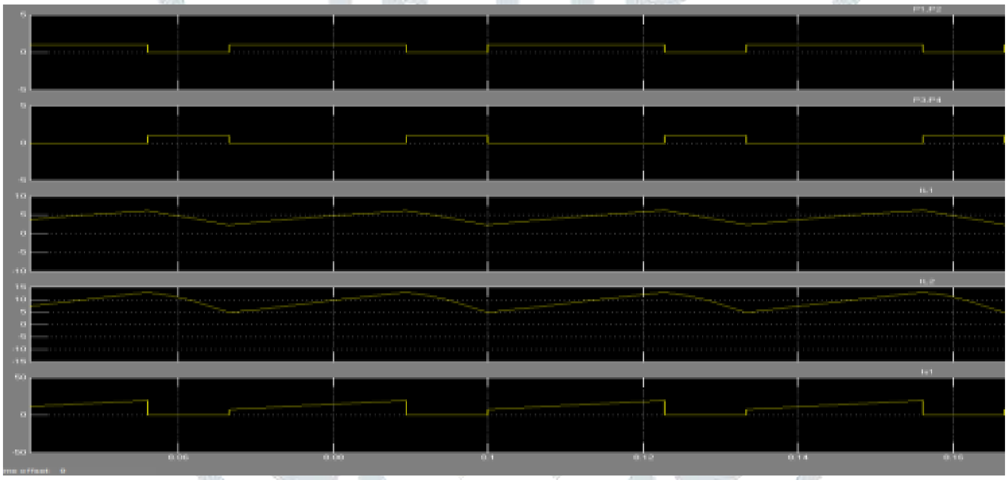

Figure 15.Waveforms for S_1, S_2, S_3, S_4, I_{L1}, I_{L2}, I_{S1} in step-up mode.

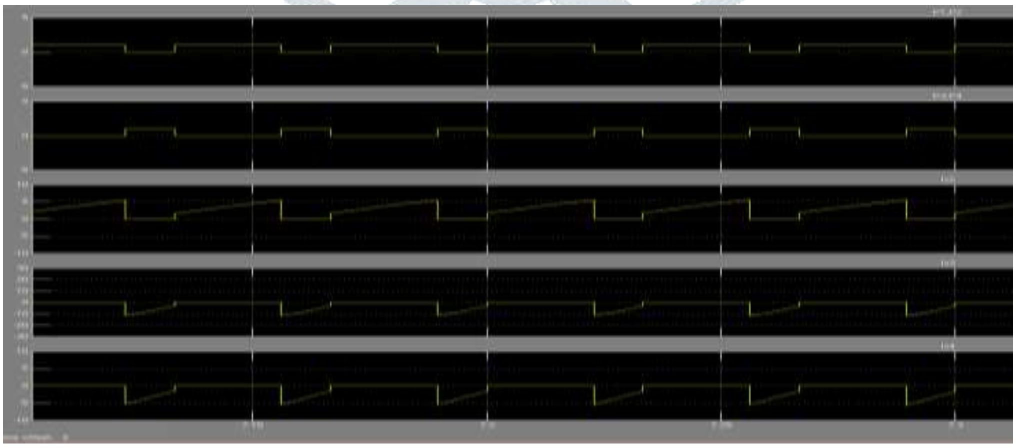

Figure 16.Waveforms for S_1, S_2, S_3, S_4, I_{S2}, I_{S3}, I_{S4} in step-up mode.

Figure 15 and figure 16 are the simulation waveforms for step-up mode. In this mode switch S_3 and S_4 functions as synchronous rectifiers and switch S_1 and S_2 fills in as power switches.

IV. CONCLUSION

In this paper, operation and simulation of a non-confined bidirectional DC-DC converter with high voltage pick up has been elucidated. Using MATLAB/simulink (R2014a), simulation outputs were observed for an input voltage of 250V and the output voltage of 25V in step-down mode and in step-up mode it is vice-versa. With switching frequency of 30kHz to confirm the predicted performance of the proposed topology.

The voltage pick up of the proposed converter is lower than the ordinary fell bidirectional buck/boost converter in advance down mode and the voltage pick up in venture up mode is higher than the customary fell bidirectional buck/boost converter. The MOSFETs are used as the main power switching device due to its high power applications and fast switching frequency for fine control.

REFERENCES

[1]. H. Ardi, Ali Ajami, Faezeh Kardan, and Shahla Nikopour Avilagh, "Analysis and implementation of a nonisolated bidirectional dc-dc converter with high voltage gain" IEEE Transactions on industrial electronics, vol. 63, no. 8, Aug. 2016.

[2]. H. Ardi, R. Reza Ahrabi, and S. N. Ravandanagh, "Non-isolated bidirectional DC–DC converter analysis and implementation," IET Power Electron., vol. 5, no. 12, pp. 3033–3044, Dec. 2014.

[3]. Z. Zhang, O. C. Thomsen, M. A. E. Andersen, and H. R. Nielsen, "Dual-input isolated full-bridge boost dc–dc converter based on the distributed transformers," IET Power Electron, vol. 5, no. 7, pp. 1074–1083, Aug. 2012.

[4]. Y. P. Hsieh, J. F. Chen, T. J. Liang, and L. S. Yang, "Analysis and implementation of a novel single-switch high step-up DC–DC converter," IET Power Electron., vol. 5, no. 1, pp. 11–21,Jan. 2012.

[5]. C. C. Lin, L. S. Yang, and G. W. Wu, "Study of a non-isolated bidirectional DC–DC converter," IET Power Electron., vol. 6, no. 1, pp. 30–37, Jan. 2013.

[6]. R.Y.Duan and J. D. Lee, "High-efficiency bidirectional DC–DC converter with coupled inductor," IET Power Electron., vol. 5, no. 1, pp. 115–123, Jan. 2012.

[7]. 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.

[8]. P. Xuewei and A. K. Rathore, "Novel bidirectional snubberless naturally commutated soft-switching current-fed full-bridge isolated DC/DC converter for fuel cell vehicles," IEEE Trans. Ind. Electron., vol. 61, no. 5, pp. 2307–2315, May 2014.

[9]. L. R. Chen, N. Y. Chu, C. S. Wang, and R. H. Liang, " Design of a reflex based bidirectional converter with the energy recovery function," IEEE Trans. Ind. Electron., vol. 55, no. 8, pp. 3022–3029, Aug. 2008.

[10]. A. Nasiri, Z. Nie, S. B. Bekiarov, and A. Emadi, "An on-line UPS system with power factor correction and electric isolation using BIFRED converter," IEEE Trans. Ind. Electron., vol. 55, no. 2, pp. 722–730, Feb. 2008.

[11]. R. J. Wai and R. Y. Duan, "High-efficiency bidirectional converter for power sources with great voltage diversity," IEEE Trans. Power Electron., vol. 22, no. 5, pp. 1986–1996, Sep. 2007.

[12]. R.-J. Wai, R.-Y. Duan, and K.-H. Jheng, "High-efficiency bidirectional dc–dc converter with high-voltage gain," IET Power Electron., vol. 5, no. 2, pp. 173–184, Feb. 2012.

[13]. L. S. Yang and T. J. Liang, "Analysis and Implementation of a novel bidirectional DC–DC converter," IEEE Trans. Ind. Electron., vol. 59, no. 1, pp. 422–434, Jan. 2012.