Performance Improvement of High Efficiency Bidirectional DC-DC Converter with High Voltage Conversion Ratio

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Abstract— This project proposes a high-efficiency power modulator a high voltage converter ratio for (Bi-directional dc-dc converter) with low voltage energy storage devices. For a step-up operation, the proposed converter operates with a high step-up voltage converter. a low voltage side power switches at It has low voltage stresses. a high voltage side output diode also has low switching losses. For a step-down operation, the proposed converter operates with the high step-down voltage conversion ratio. It features a zero-voltage switching of power switching at the high voltage side. At the low voltage side, a current doubler rectifier reduces the current ripples. This proposed work is designed and simulated by using MATLAB Simulink software. The necessary gating signals for switches in the converter are generated with the use of pulse width modulation. Simulation and results are presented and analyzed to verify the operation of the proposed converter.

Keywords: DC- DC Converter, High Efficiency, Zero Voltage Switching

I. INTRODUCTION

A high-efficiency bidirectional dc-dc converter is needed for bidirectional energy storage systems. Especially, in case of using low voltage energy storage devices like 48 V lead acid batteries [1], a high voltage conversion ratio is required for the interface with the grid-tied or stand-alone dc-ac inverter [2]. In order to develop a bidirectional converter with a high voltage conversion ratio, lots of efforts have been made [3]-[10]. First, non-isolated bidirectional dc-dc converters have been researched [3]-[5], which are based on the basic bidirectional buck-boost converter topology [3]. Several switching circuit techniques such as coupled inductor [4], switched-capacitor [5], and auxiliary switching circuits [6] have been utilized to improve the converter performance. The isolated bidirectional dc-dc converters have been developed [7]. Most of them utilize high-frequency linked converter topologies such as current-fed push-pull converter [7], current- fed full-bridge converter and dual-active bridge converter.

However, due to the high turns-ratio of the transformer, voltage stresses of power switches increase, resulting in high power losses. Also, the parasitic oscillations due to the high switching frequency operation restrict the practical use of the converter.

In this paper, a high-efficient bidirectional dc-dc conversion ratio is proposed, which has a high voltage conversion. For a high voltage step-up converter operates with a step-up voltage converter ratio. the low voltage stress of the power diode switch has been low voltage side. the low switching losses of the output diodes at the high voltage side. The high step-down converter operation of the proposed converter can operate the high step-down voltage conversion ratio. It zero voltage switching feature of power switch at the high voltage side and the low voltage side are current can be doubler rectifier can reduce the current ripples. The simulations and experimental results have verified and the operation of the proposed converter also verified.

II. PROPOSED CONVERTER

Fig. 1 shows the circuit diagram of the proposed dc-dc converter. VL is the battery voltage for a low voltage side. The low voltage side circuit consists of the switches S1 ~ S4 with diodes DS1 ~ DS4, capacitor Cc, inductors L1, L2, and transformer T. Two 180° out of phase angle pulses are equal to the supplied in drive the switches S1, S2. The switches S3, S4 are driven complete with switch S1, S2 with a short dead time, respectively. The high voltage side circuit consists of the switches SD1, SD2, and capacitors Cr1, Cr2, CH. The voltages Vc, VH is constant during one switching period Ts (1/fs) because the capacitors Cc, CH is sufficiently large.

The Fig.2 shows step-up operating modes proposed converter. Before Mode 1, the inductor current iL1 flows into the switch S3 and the inductor current iL2 flows into the switch S2. Mode 1 [t0, t1]: At t0, S1 is turned on. iL1 flows into S1 and iL2 flows into S2. Since both S1 and S2 are conducting, the primary voltage Vp is zero. Also, a primary current ip is a secondary current is also zero then il1 and il2 increase linearly mode 2 [t1 t2] at t1 and s2 is turned off. S4 is turned on while its body diode is conducting. iL1 increases continuously and iL2 decreases linearly. The low-voltage side power is transferred to the high-voltage side. The secondary winding voltage vs is – NVc where the turns-ratio N is given by N2/N1. Since SD1 is conducted, a series-resonance between Llk, Cr1, and Cr2 occurs. The switch current iSD1 becomes zero. After the series resonance converter is finished the switch sd1 is turn off to zero current modes 3 [t2 t3] at t2 s2 is turned on. This mode is analogous to Mode 1. Since S1 and S2 are conducting.

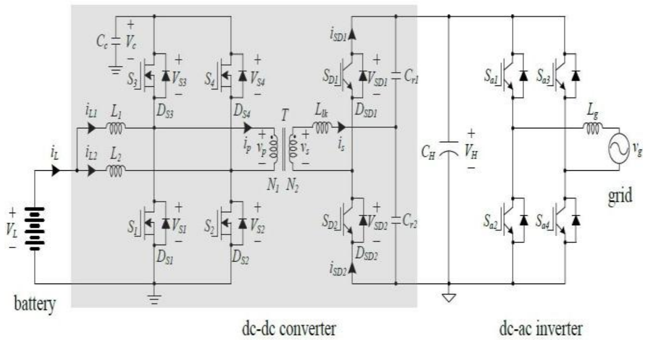


Fig. 1. Circuit diagram of the proposed dc-dc converter for bidirectional battery energy storage systems.

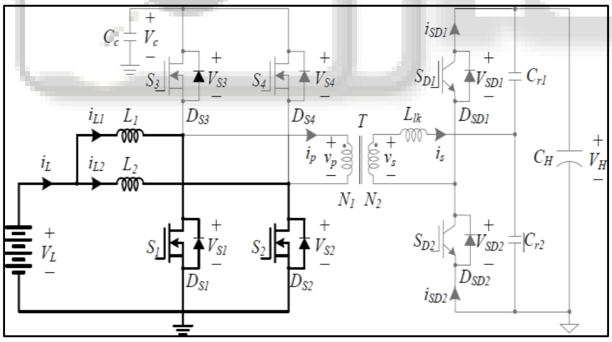
The primary voltage Vp is zero. Also, ip and is are zero. Then, iL1 and iL2 increase linearly. Mode 4 [t3, t4]: At t4, S1 is turned off. S3 is turned on while its body diode is conducting. iL2 increases continuously and iL1 decreases linearly. The low-voltage side power is transferred to the high-voltage side. The secondary winding voltage vs is NVc. Since SD2 is conducted, a series- resonance between Llk, Cr1, and Cr2 occurs. Then, the switch current iSD2 becomes zero. After the series resonance converter is finished sd2 is turned off to the zero current.

Fig. 3 shows the step-down operation modes of the proposed converter. Before Mode 1, the switch SD2 is turned on and the switch SD1 is turned off. Mode 1 [t0 and t1] at t0 sd2 is turned off to a secondary current and a primary current ip is zero. Also, the secondary voltage vs and a primary voltage Vp are zero mode 2 [t1 and t2] is t1 sd1 is turned on. The high-voltage side power is transferred to the low- voltage side. The primary winding voltage Vp is –Vc. A series resonance between Llk, Cr1, and Cr2 occurs. Mode 3 [t2, t3]: At t2, SD1 is turned off. This mode is analogous to Mode 1. Then, the secondary current is and the primary current ip is zero. Mode 4 [t3, t4]: At t3, SD2 is turned on. The high-voltage side power is transferred to the low-voltage side. The primary winding voltage vp is Vc. A series resonance between Llk, Cr1, and Cr2 occurs. The resonant capacitor voltage VCr1 is 0.5VH. Also, a resonant capacitor voltage VCr2 is 0.5VH. By the voltage-second balance law of the leakage inductance Llk of the transformer T during Ts, the clamping capacitor voltage Vc is Vc = VH /2N. By the voltage-second balance law of the inductor L1 during Ts, the relation between the low-voltage VL and the high-voltage VH is given by

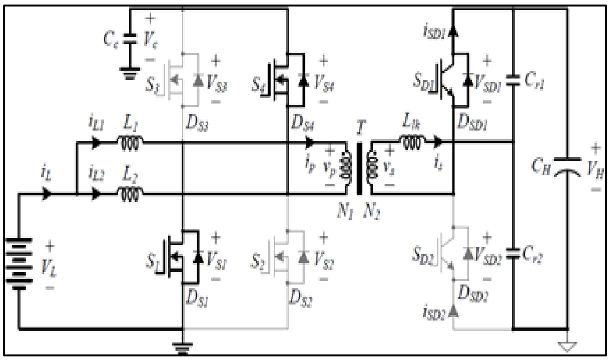
$$\frac{V_H}{V_L} = \frac{2N}{1-D} \qquad (1)$$

The relation between the high-voltage VH and the low-voltage VL is the reciprocal of equation (1) as follows:

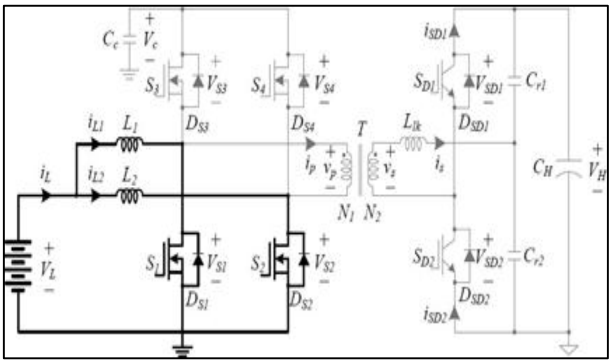
$$\frac{V_L}{V_H} = \frac{1-D}{2N} \qquad (2)$$



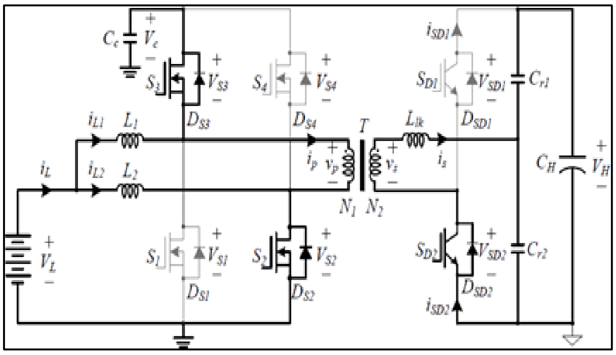
Mode 1



Mode 2

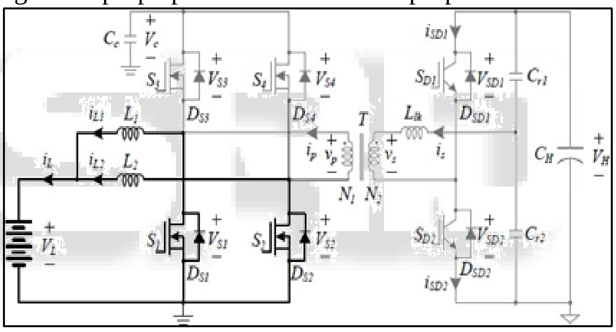


Mode 3

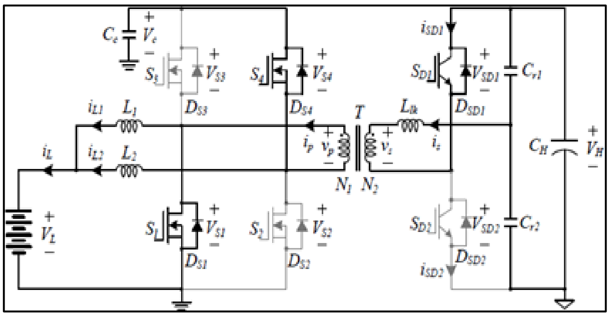


Mode 4

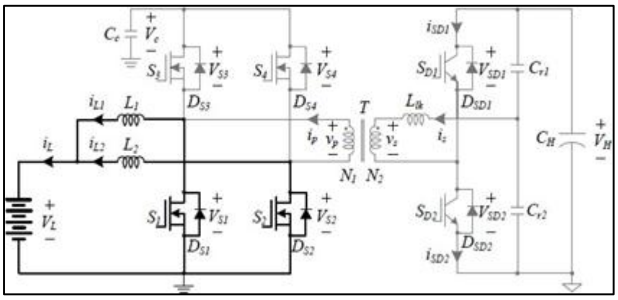
Fig. 2: Step-up operation modes of the proposed converter.



Mode 1



Mode 2



Mode 3

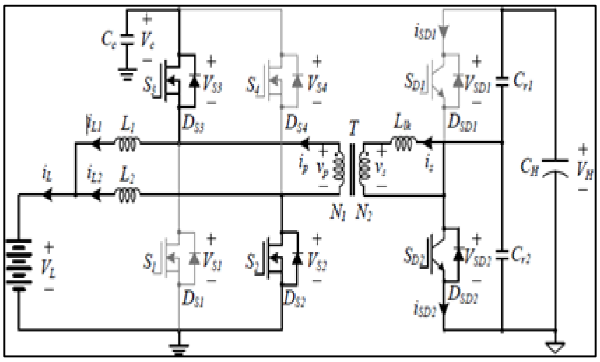


Fig. 3: Step-down operation modes of the proposed converter.

III. SIMULATION VERIFICATIONS

To evaluate the operation of the proposed converter, simulation verifications have been conducted for the following electrical parameters as VL = 48 V, VH = 380 V, and fs = 50kHz. The Fig.4 shows the simulation waveforms of a proposed converter for the step-up operation. Fig. 5 (a) shows the switch voltages VS1, VS2, VS3, and VS4. Switch voltages are clamped to Vc of 120 V, respectively. Fig. 5 (b) shows the switch voltages

VSD1 and VSD2 and currents iSD1 and iSD2. The currents iSD1 and iSD2 reach zero before SD1 and SD2 are turned off. Fig. 6 shows the simulation waveforms of a proposed converter for the step-down operation. Fig. 6 (a) shows the switch voltages VSD1 and VSD2 and currents iSD1 and iSD2. The switch currents iSD1 and iSD2 are zero before the switches are turned on, respectively. Fig. 6 (b) shows the switch voltages VS1, VS2, VS3, and VS4. Switch voltages are clamped to Vc of 120 V, respectively.

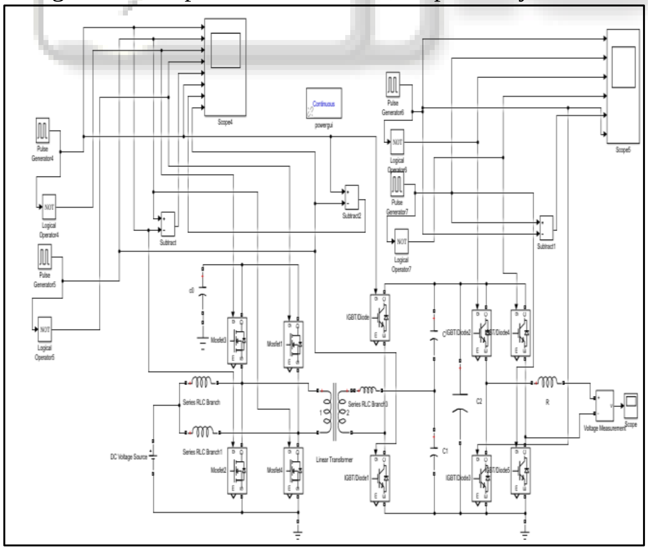
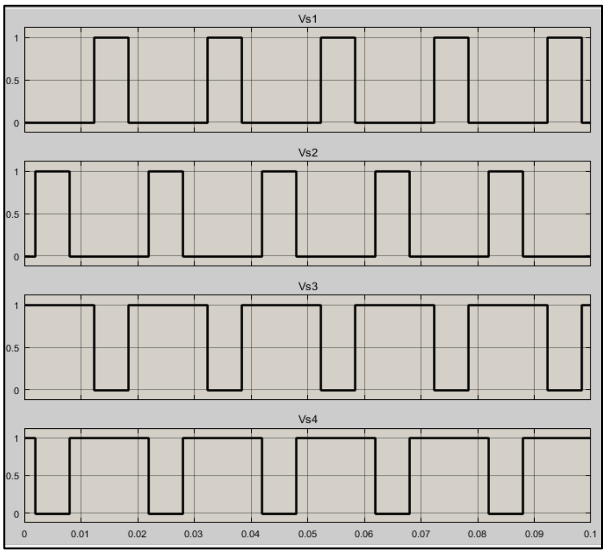
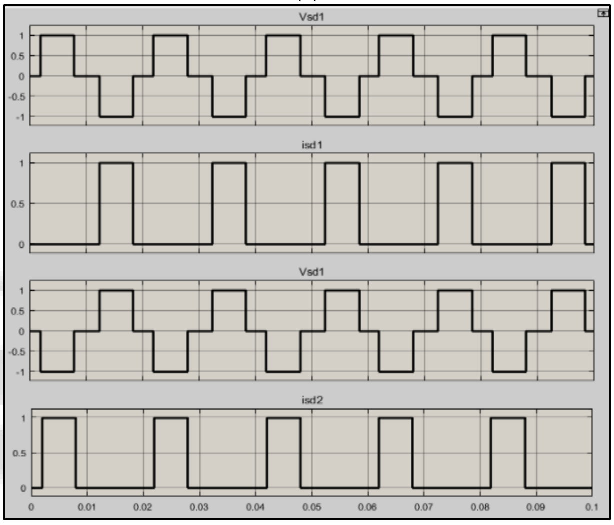


Fig. 4: Simulink Model

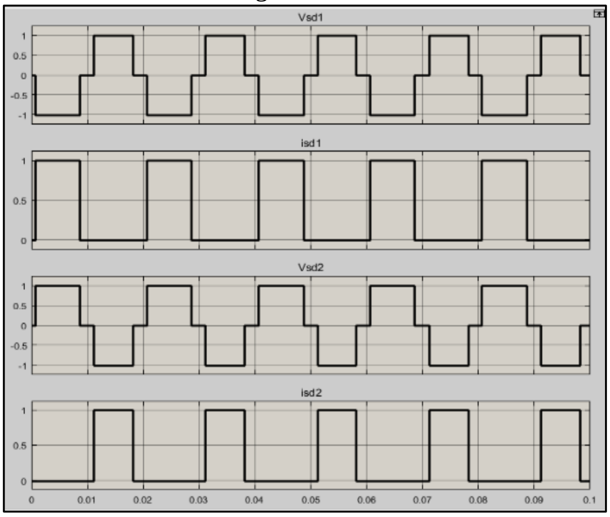


(a)

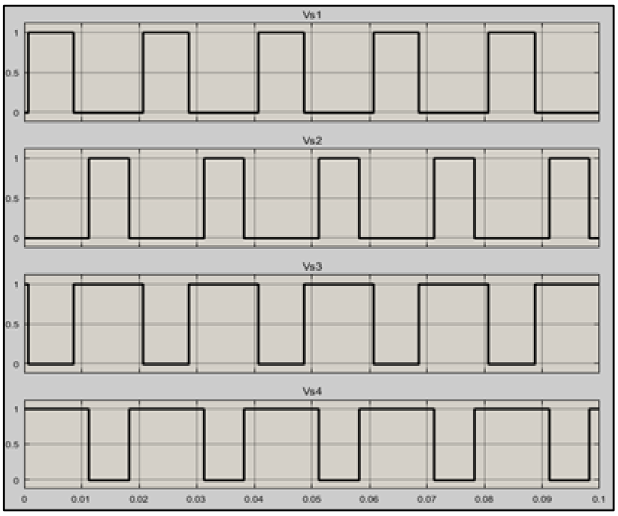


(b)

Fig. 5: Simulation waveforms step-up operation (a) Voltage across the switches in converter Circuit (b) The switch voltage and current



(a)



(b)

Fig. 6: Simulation waveforms step-down operation (a) Voltage and current across the switches in converter Circuit (b) The switch voltages and switch voltages are clamped to Vc.

IV. CONCLUSION

The performance of a high-efficiency power modulator a high voltage converter ratio for (Bi-directional dc-dc converter) with low voltage energy storage devices has been studied. For a step-up operation, a proposed converter operates with the high step-up voltage conversion ratio. It has low voltage stresses of the power switches with a low voltage side. It has low voltage stresses of the power switches at the low voltage side. it also has low switching losses for output diodes at the high voltage side. For a step-down operation, a proposed converter can operate with a high step-down voltage conversion ratio. The proposed circuit is simulated is MATLAB and the result are presented. The performance analysis of the proposed bidirectional dc-dc converter has been analyzed. Zero-voltage switching of power switches at the high voltage side can be implemented. At the low voltage side, the current doubler rectifier reduces the current ripples.

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