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SOFT-SWITCHING TECHNIQUE FOR NON-LINEAR SYSTEM

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ABSTRACT

In this paper a bidirectional non-isolated DC-DC converter using soft switching technique employing Zero-Voltage Switching (ZVS) technique for turn on and Zero-Current Switching (ZCS) technique for turn off of switches are utilized. In step-up mode, voltage source (V_L) acts as source and the current flows from source to load to get a high output voltage gain. In step-down mode, voltage source(V_L) act as load and the current flows in the opposite direction to get a low output voltage gain. The existing system is using hardswitching technique, which increases the switching loss and more heat is dissipated. In this technique, heat loss is less which increases the life span of switches. Moreover, the output voltagecan be increased. The proposed converter aims to reduce the switching current. It has higher step-up and step-down voltage gains than the conventional bidirectional dc-dc converter. For the same electric conditions, the converter and the conventional bidirectional converter efficiency, voltage gain, output voltage and switching current will differ. It uses an intermediate switching pattern to carry out seamless mode change.

Index Terms—Zero voltage switching (ZVS), Zero current switching (ZCS), Pulse width modulation (PWM), Continuous conduction mode (CCM), Bidirectional DC-DC converter (BDC).

I. INTRODUCTION

A DC-DC converter is an electronic circuit which converts direct current from one voltage level to another which is a type of power converter. The converter can be used in aero space applications, battery charging, battery operated Electric vehicle, telecom applications. Such electronic devices mostly contain several sub-circuits that are different from that supplied by the battery or any external supply may be higher or lower than the supply voltage. Moreover, the battery voltage decreases as its stored power is decreased. Switched DC-DC converters offer a method to increase voltage from a partially lowered battery voltage, thereby save the space instead of using a number of batteries. Most DC-DC converters will regulate the output. High efficiency light emitting diode (LED) power sources belong to the type of DC-

DC converters, which regulates the current through the LEDs, and the charge pumps will double or triple the input voltage [1].A bidirectional DC-DC converter is used for dc-dc conversion process. The power converter has two full bridge converters, one act as inverter and other as rectifier. This bidirectional DC-DC converter is suitable for electrical vehicle applications. It has advantages of simple circuit with soft switching implementation (ZVS and ZCS), without additional devices. It has high efficiency and simple control. These advantages make the converter applicable for low, medium and high power applications; mainly for auxiliary power supply in fuel cell vehicles and power generation. It is used in applications where high power density, low cost, low weight and high reliability power converters are required. Micro Controller is used to create pulses for switches. It triggers, operate and control Metal Oxide Semiconductor Field Effect Transistor (MOSFET) devices. Pulse Width Modulation (PWM) technique is used to reduce the harmonics and noises in the circuit [3] - [8].

Most of the existing Bidirectional DC-DC Converters (BDC) has a basic circuit structure, which is fed by a current or voltage on one side. Based on the auxiliary energy storage and conduction period, the bidirectional DC-DC converter can be classified into buck and boost converters. The buck type has energy storage placed on the high voltage with low conduction period and the boost type has it placed on the low voltage side with high conduction period. It is classified into two types:

- Isolated DC-DC Bidirectional Converter
- Non- Isolated DC-DC Bidirectional Converter

The converter has the following advantages [9]:

1) High voltage gains for both boost and buck operations;

2) Reduced voltage stresses of switches;

3) ZVS turn on and ZCS turn off of switches in Continuous Conduction Mode (CCM) operation;

4) Reduced energy volumes of passive components;

II. PROPOSED CONVERTER

The proposed converter consists of a general half-bridge converter as the main circuit and an auxiliary circuit that includes the capacitor C_a, inductor L_a, and four High-Voltage Side (HVS) switches as shown in fig1. It is assumed to regulate the HVS voltage, while allowing bidirectional power flow according to the direction of inductor current.The block diagram consists of BDC whose input is connected to a DC source and output is filtered by inductor-capacitor (LC) filter, which is fed to a battery. The switches used in the BDC are MOSFETS that are triggered using pulses generated by PIC controller and amplified by a power amplifier. The power supply is given separately to this control circuit.

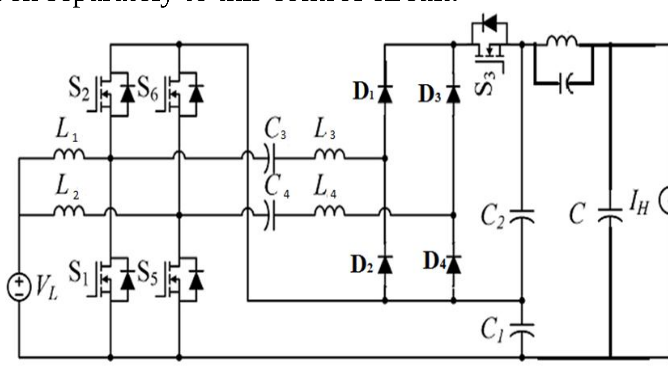

Fig 1: Circuit diagram of proposed converter

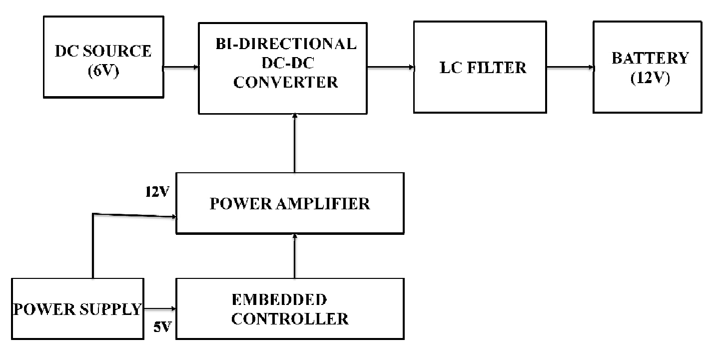

Fig 2: Block diagram of proposed converter

A. *Operating Principle*

The capacitances C_1, C_2 and C are large enough so that voltages V_{C1}, V_{C2}, and V_C across them are constant during the switching period T_S. In boost mode, Low-Voltage Side (LVS) switches S_1, S_2, S_5

and S_6 are operated with asymmetrical complementary switching with duty cycles of D (duty cycle) and 1−D respectively. Initially when S_1 is turned on, inductor currents i_{Lf}starts to increase and i_{La} starts to decrease respectively. The slopes are determined by the following equations:

$$\text{—— = —} \quad [1]$$

$$\text{—— = —} \quad [2]$$

$$\text{—— = ————} \quad [3]$$

$$\text{—— = ————} \quad [4]$$

To analyze the steady state operation of the converter, the following assumptions are made [10]:

1) The output capacitor C is large enough to assume that the output voltage V_o is constant and ripple free.
2) The main inductor Lf is large enough to be treated as a constant-current source I_{Lf}.
3) Main inductor L_f is much greater than resonant inductor L_r.
4) The semiconductor devices and the reactive elements are ideal.

B. *Voltage Conversion Ratio*

The HVS voltage is given by the following equation:

$$\text{= ——— .} \quad [5]$$

where the effective duty is defined as follows:

$$= \quad - \quad [6]$$

where d_3 means duty loss at switch S_3. The output voltage can also be expressed as follows:

$$\text{= —— .} \quad - \Delta \quad [7]$$

where ΔV is the voltage drop caused by the duty loss.

The voltage drop ΔV can be obtained as follows:

$$\Delta \quad = \frac{*}{(\quad)(\quad)} \quad [8]$$

Because the average current of C_3, C_4 and C_2 is zero, the average absolute currents of HVS switches can be expressed as follows:

$$- \int | \quad | \quad = \quad [9]$$

where $I_H = V_H / R_H$.

A. *Mode I operation*

The diode across switches S_1 and S_5 conducts initially as shown in fig. 3(a). The current flows through both L1, C_3, L_3, D_1 and L_2, C_4, L_4, D_3 to switch S_3 to C_1, C_2 and then to the load.

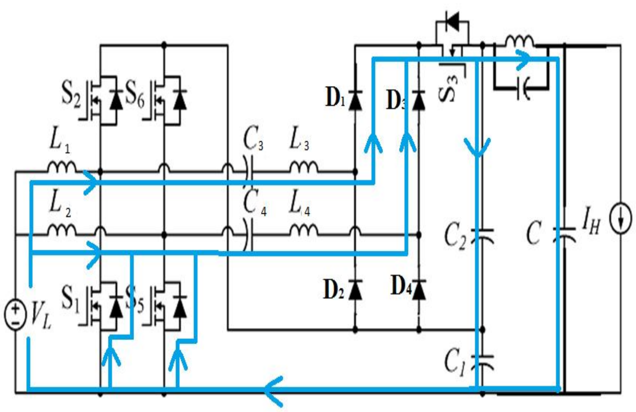

Fig 3(a): Mode I operation

B. *Mode II operation*

The switches S_1 and S_5 startconducting. The input voltage is fed to the input inductors L_1 and L_2 to store charge as well as to the load.

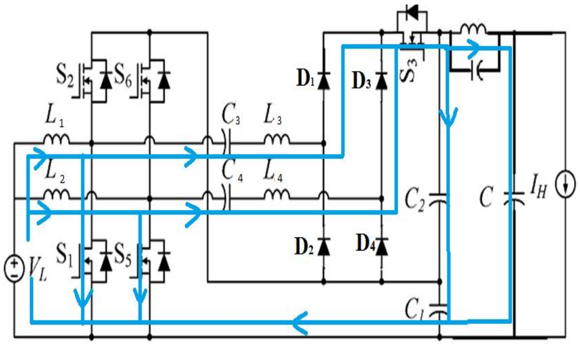

Fig 3(b): Mode II operation

C. *Mode III operation*

The capacitor C_1 starts discharging where the current flows load and input switches. The current through switches S_1 and S_5 is the sum of input current and current through capacitor C_1 respectively.

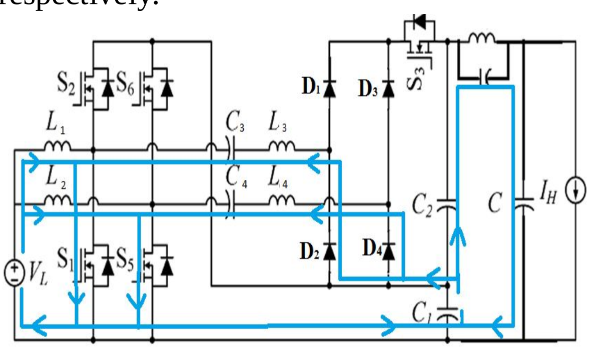

Fig 3(c): Mode III operation

D. *Mode IV operation*

The diodes across switches S_2 and S_6 allows current to flow from input to capacitor C_1. The HVS diodes D_2 and D_4conduct.

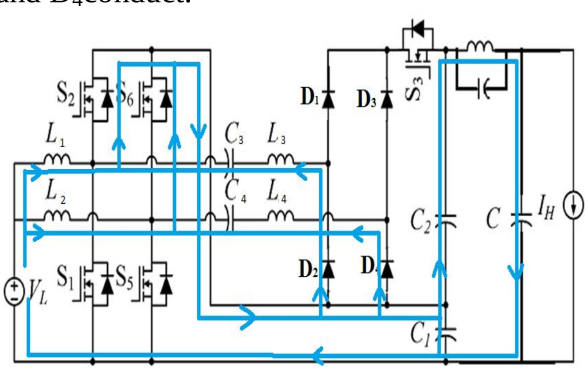

Fig 3(d): Mode IV operation

E. *Mode V operation*

The switches S_2 and S_6 are turned on which forward biases the diodes D_1 and D_3 respectively. Switch S_3 is turned on so that the current flows to the battery load.

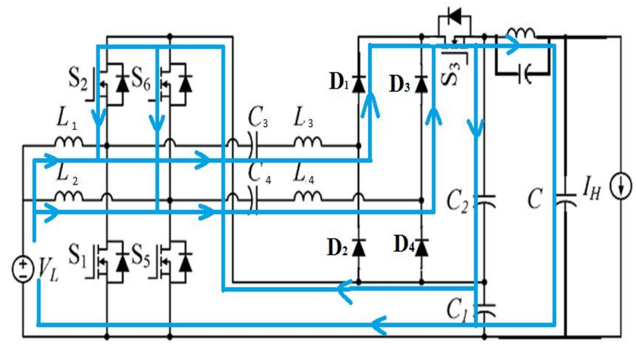

Fig 3(e): Mode V operation

III. SIMULATION RESULTS

The interleaving technique can be applied to reduce the size of passive components and current stresses. A 5.9W prototype of the BDC shown in Fig.1 has been simulated according to the following specification:

P_o = 5.92 W, f_s = 1 kHz, V_H = 14.21 V, V_L = 6 V, L_f = 50 μH, L_a = 50 μH, C_a = 10 μF, C_1=C_2 = 10 μF.

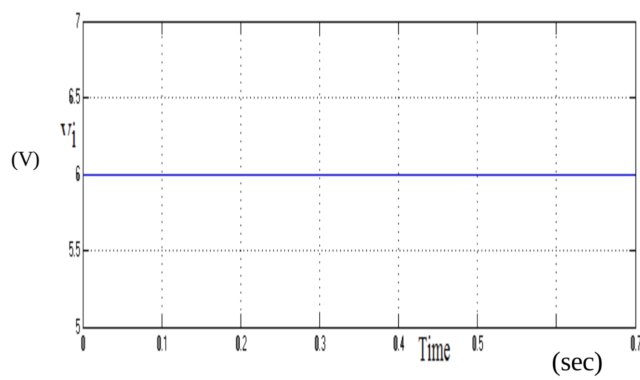

Fig 4: Input voltage waveform

(rpm)

(Nm)

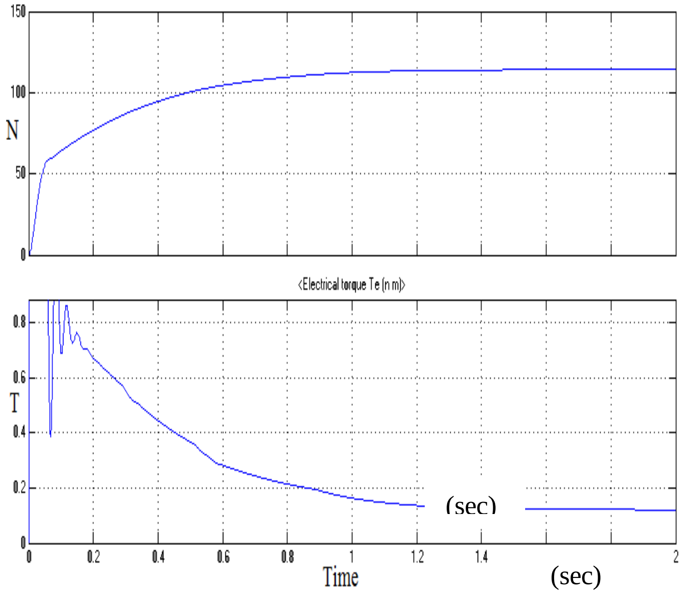

Fig 5: Speed and Torque waveform

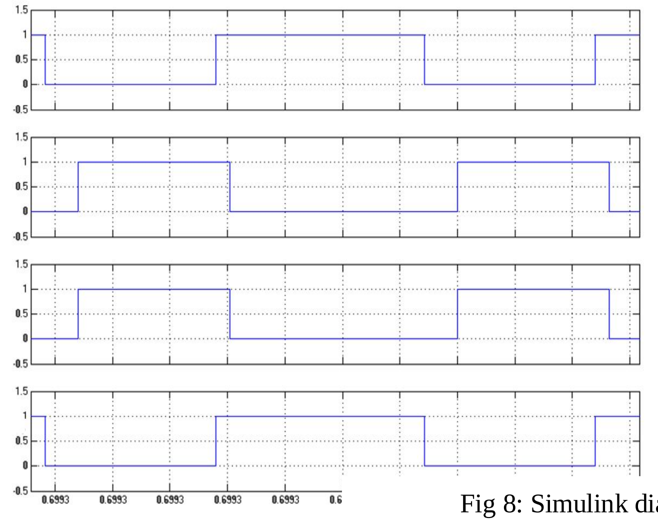

Fig 7: Switching pulses to four switches

applied to each MOSFET switch is 10V.

The pulses given to the gate of each switch is shown in fig.10. The gate pulses to switches S_1 is complement to switch S_2. The gate pulse given upper switches S_2 and S_6 and the gate pulse given lower switches S_1 and S_5 are identical.

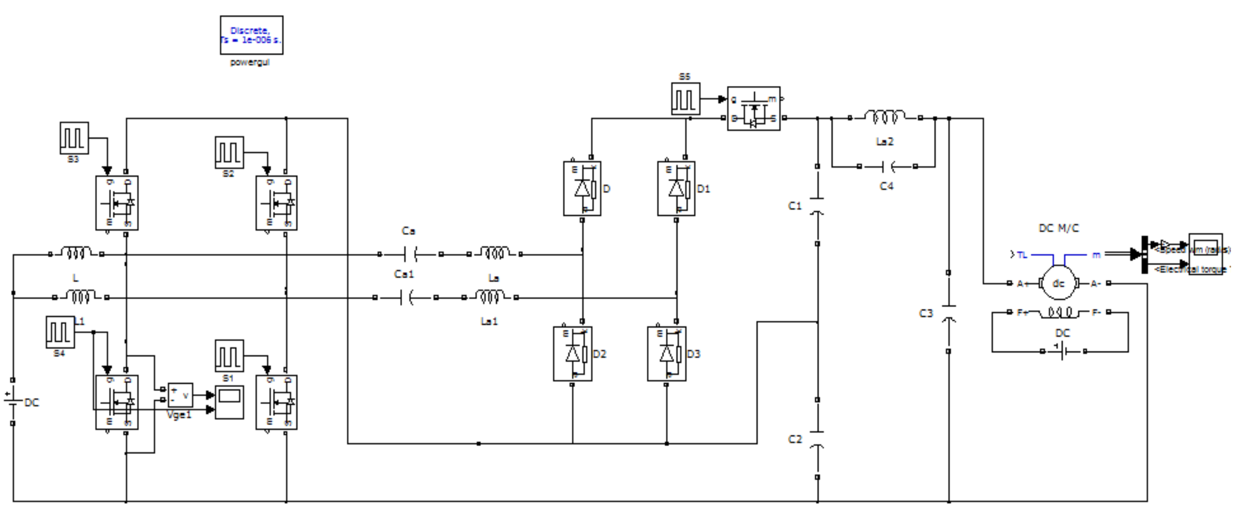

Fig 8: Simulink diagram of

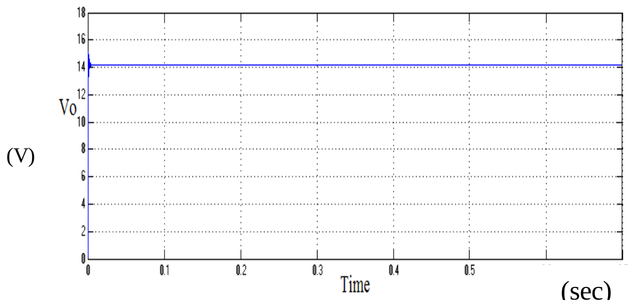

Fig 8: Output voltage waveform

IV. CONCLUSION

In this paper, a non-isolated soft switching BDC has been proposed for high-voltage gain and low-power applications. The proposed converter can achieve ZVS turn on of all switches and ZCS turn off some switches in both boos (sec) ck operations. An optimized switching sequence has been presented along with an intermediate switching pattern to carry out seamless mode change.ZVS reduces the switching current and frequency and a high output voltage is obtained.A 5.9W prototype of the proposed cor (sec) been simulated to justify the proposed o 6V DC input voltage is boosted to 14V and fed to the motor load. The converter used for low power applications can be modified by isolating the LVS and HVS using a transformer for high power applications.

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