A Bidirectional Quadratic Boost Converter With Voltage Multiplier Cell To Increase Voltage Gain

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Abstract- *The high step up dc-dc converter with a bidirectional quadratic boost converter with voltage multiplier cell (VM) to achieve a high voltage gain in the continuous conduction mode (CCM). To increase higher voltage gain, lower voltage stress on diodes and capacitors and requiring smaller inductors with reduced number of components. Bidirectional DC-DC converters are mainly used in applications like HEVs and EVs where bidirectional power flow is required. The purpose of bidirectional converter is to charge a low-voltage (12 V) battery during boost mode and to assist the high-voltage 200V battery or bus in emergency situations like when a high-voltage battery has discharged buck mode operation. In this implementation, closed-loop control in high voltage side is implemented using PI controller.*

Keywords- Bidirectional, PI controller, Quadratic boost converter, voltage gain.

I. INTRODUCTION

Implementation of renewable energy resources like solar panels requires DC-DC converters for boosting their voltage [1-5]. The converters increase voltage gain and low voltage stress on the components. The used voltage multiplier cell in includes an extra coupled inductor and two additional capacitors that increase the number of components in the multiplier cell [1]. To conventional Z-source converter, it converts voltage with higher voltage gain and lower voltage stress on the switch, diodes and capacitors and it needs smaller inductors in comparison to the similar converters [2]. The integration of the quadratic-boost converter makes the system easier to lift up its voltage gain through slightly increasing the duty ratio of the single switch [3]. The non- isolated high gain converters with low input current ripple are preferred over isolated converters for PV applications [4]. Two or more basic DC-DC converters connected in cascade with the corresponding increase in power losses and voltage stress on the switching devices [5]. A novel high step-up non-isolated single switch DC-DC converter suitable for regulating DC bus in various micro sources especially for PV sources, the Quadratic boost and switched- capacitor technique are used as primary and secondary circuit[6].

To extend the range of voltage conversion and use of the cascade boost converters, because its voltage gain is higher with quadratic characteristic as a function of duty cycle [7].

The combinations of a quadratic boost converter and a voltage multiplier cell are used to increase output voltage. A designed controller is to validate the converter dynamic and stability. The advancements and increasing towards in Electric Vehicles would soon see increased influx of EVs on the road. This sudden increase in load would be affecting the traditional grid system that is present in India. So it is necessary to enable a smooth integration of the EVs to the grid. The EVs should act as act as an Auxiliary source to the grid rather than a load.

The proposed converter includes a quadratic boost converter and a voltage multiplier cell. The multiplier cell consists of two inductors, two diodes and one capacitor has been located instead of the second inductor of the quadratic boost converter. The proposed converter operates in bidirectional way to voltage gain. The proposed converter achieves higher voltage gain, higher efficiency. The PI controller to control the boost converter operation in closed loop. The modified bidirectional quadratic boost converter operates with a storage battery. The bidirectional quadratic boost converter is used for charging and discharging of the EV battery.

II. CONFIGURATION OF PROPOSED CONVERTER

The converter is a two switch DC–DC converter. Operation principle of the converter is continuous conduction mode (CCM). To give low voltage input to the converter and multiplier cell to gain the output voltage. The closed-loop control in high voltage side is implemented using PI (proportional integral controller). Switch one operates bidirectional way to restore the output voltage through switch 2 and L1 inductor. Switch two have two switching states turn on and turn off states. A PI Controller is a feedback control loop that calculates an error signal by taking the difference between the outputs of a system, in this case is the power being drawn from the battery and the set point. In this converter we use PI controller giving switching pulse switch 2 to operate boost converter.

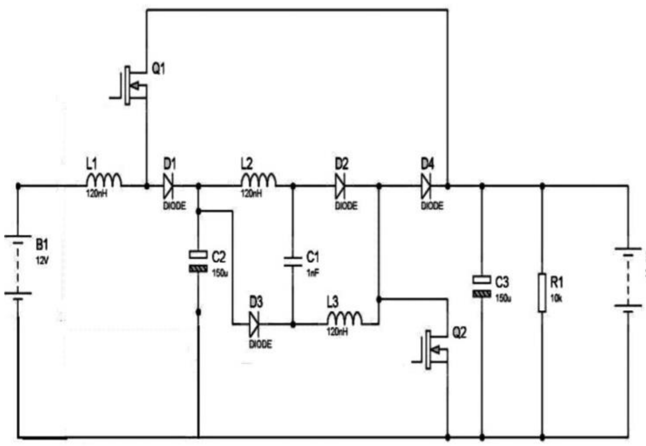

Fig.1 Configuration of the proposed converter

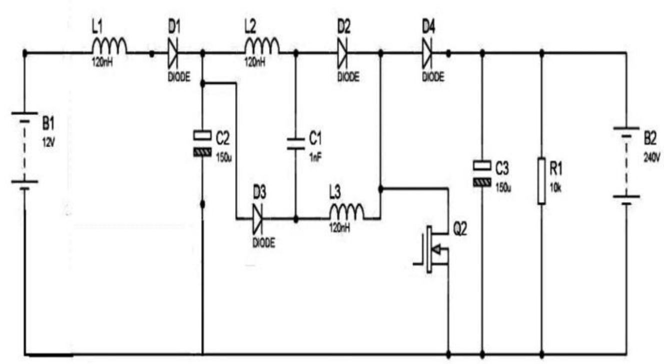

Fig.2a

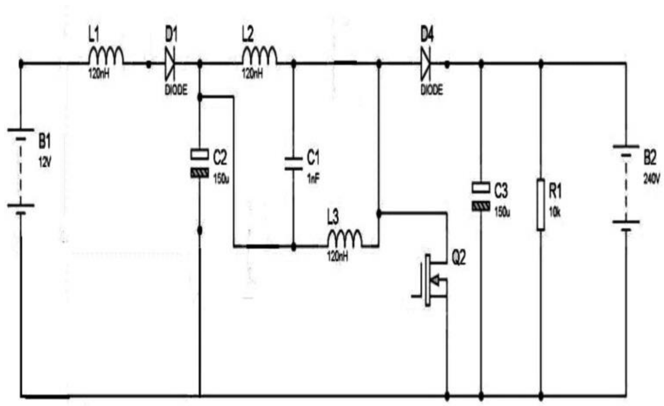

Fig.2b

Fig.2 Switch on and off states of the proposed converter (a) First state, switch is on,(b)Second state, switch is off

III. OPERATING STATES OF THE CONVERTER

The Bidirectional Quadratic Boost converter with voltage multiplier cell to increase voltage is shown in Fig.1. It comprises two active power switches (Q1 and Q2), four power diodes (D1-D4), three inductors (L1, L2 and L3) and three capacitors (C1-C3).

First Switching State: In this state, the switch 2 is turned on shown in fig.2a, the converter operates, the inductor L1 and diode D1 conducting, the energy given to the voltage multiplier cell. In addition, the capacitor C2 charges the inductors L2 and L3 and the capacitor C1 in the loops which contain D2 and D3. Through diode D4 and capacitor C3,the converter voltage given to the load resistor R. Then the high output voltage stored the battery. The defined loops on the equivalent circuit following equations is,

$$VL1 = Vin \qquad (1)$$

Second Switching State: In this state, the switch2 is turned off shown in fig.2b, the diodes D1 and D4 are conducting. The other diodesD2, D3 are blocking. The diodes D1 and D4 prepare the paths for the loops in the inductors L1, L2 and L3 and the capacitor C1 are discharged. The capacitor C2 is charged by Vin and L1 through D1.The discharge energy, stored the capacitor C3 through diode D4. Then voltage given to the R load and store the high voltage battery. The below equation is obtained,

$$VL1 = Vin - Vc2 \ (2)$$

The voltage gain of the converter equation is,

$$M = \frac{Vo}{Vin} = \frac{2}{(1-D)^2} \qquad (3)$$

The step time 0 to 0.1 the switch2 operate the converter to high output voltage stored battery. The step time 0.1 to 0.2 the switch1 operate, the quadratic converter operation will be stopped. The switch1 turned ON the high voltage stored battery discharge the energy, the energy stored in low voltage battery through inductor L1.

IV. SIMULATION EXPERIMENTAL PARAMETERS

The simulation parameters used in the proposed system with its specifications, input range, output ranges are represented in the following table1.

Table 1

PARAMETERS	VALUES
Input voltage	40V
Switching frequency	4kHz
Inductance L1	200Mh
Inductance L2,L3	360µH
Capacitance C1, C2	47µF
Capacitance C3	470Mf

V. SIMULATED BIDIRECTIONAL QUADRATIC BOOST CONVERTER

The Simulink model for A Bidirectional Quadratic Boost converter with voltage multiplier cell is shown in the figure 4.1. The control of the converter is simple. The pulse generates with PI controller to give switching pulse.

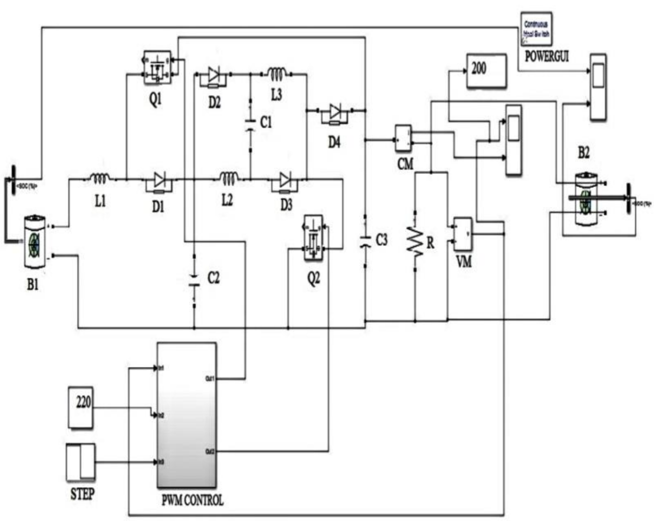

Fig.3 Simulation of Bidirectional Quadratic Boost converter with voltage multiplier cell to increases voltage gain

VI. EXPERIMENTAL RESULTS

A Bidirectional Quadratic Boost Converter with voltage multiplier cell to increase voltage gain. The simulated output voltage and current of the proposed system is shown in the below figures.

OUTPUT VOLTAGE

The simulated output voltage is represented in the fig.4, when the DC source input voltage is fed, after simulating it will provide the output value which will be boosted while comparing with the input value of voltage. Here we have set input voltage value as 40V,the resulted output voltage value is obtained as 200V to the bidirectional quadratic boost converter.

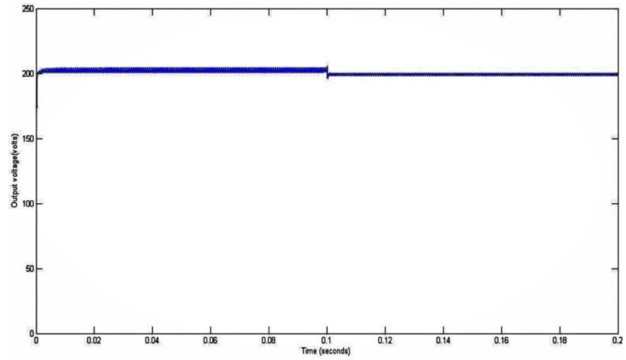

Fig.4 Output voltage waveform

OUTPUT CURRENT

The simulated output current is represented in the fig.5, when the DC source input voltage is fed, after simulating it will provide the output value which will be boosted while comparing with the input value of voltage.

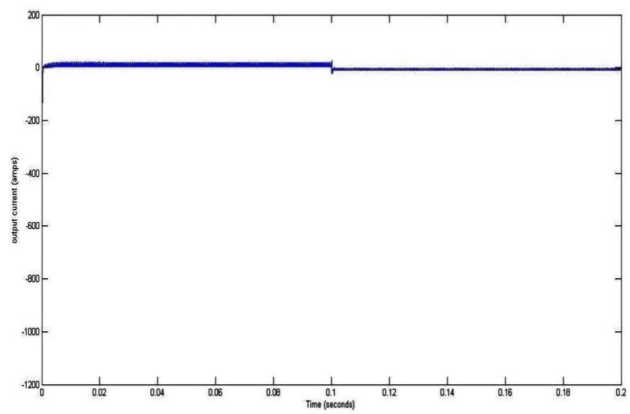

Fig.5 Output Current Waveform

BATTERY CHARGING AND DISCHARGING WAVEFORMS

The bidirectional quadratic boost converter operates charging and discharging batteries. The input battery gives low voltage to quadratic boost converter with voltage multiplier cell. The converter output voltage gain stored battery, the battery voltage charge to input battery through the switch one.

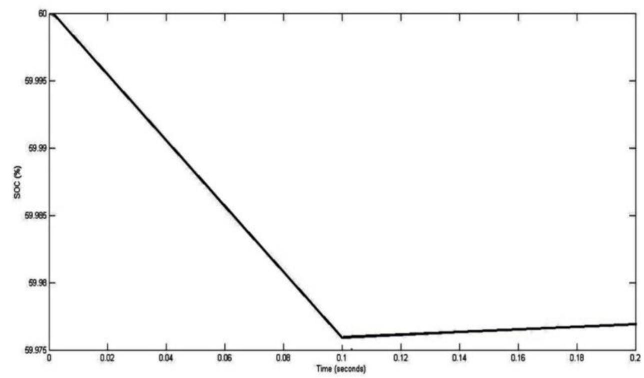

Fig.6a LV Battery Discharging and Charging Waveform

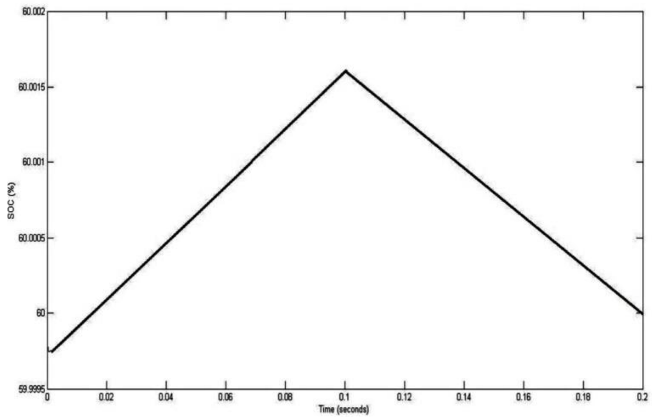

Fig.6b HV Battery Charging and Discharging waveform

VII. CONCLUSION

The proposed converter is composed of a Bidirectional quadratic boost converter and a voltage multiplier cell. The converter has higher voltage gain in comparison to the quadratic boost converter. The bidirectional converter operates to charging and discharging the battery voltage.

The proposed converter requires smaller inductors in comparison to the converter in which can be introduced as an important advantage. In similar voltage gains, power losses of the proposed converter are lower in comparison to the converter in which has less number of the used components.

REFERENCES

[1] MiladRezaie., VashidAbbasi., ‘Effective combination of quadratic boost converter with voltage multiplier cell to increase voltage gain’, IET Power Electronics,2020.
[2] Rostami, S., Abbasi, V., Kerekes, T., ‘Switched capacitor based Z-source DC–DC converter’, IET Power Electron., 2019.
[3] Wang, Y., Qiu, Y., Bian, Q., et al.: ‘A single switch quadratic boost high step up DC–DC converter’, IEEE Trans. Ind. Electron., 2019.
[4] Revathi, B.S., Mahalingam, P.: ‘Non- isolated high gain DC–DC converter with low device stress and input current ripple’, IET Power Electron., 2018.
[5] Leyva-Ramos, J., Mota-Varona, R., Ortiz- Lopez, M.G., et al.: ‘Control strategy of a quadratic boost converter with voltage multiplier cell for high voltage gain’, IEEE J. Emerging Sel. Topics Power Electron., 2017.
[6] Saadat, P., Abbaszadeh, K.: ‘A single-switch high step-up DC–DC converter based on quadratic boost’, IEEE Trans. Ind. Electron., 2016.
[7] Cabral, J.B.R., Tiago Lemes, D.S., Oliveira, S.V.G., et al.: ‘A new high gain non-isolated DC-DC boost converter for photovoltaic application’. Proc. Int.conf. Brazilian power Electronics, Gramado, 2013.
[8] Mahmoudi, M., Ajami, A., Babaei, E.: ‘A non-isolated high step-up DC-DC converter with integrated 3 winding coupled inductor and reduced switch voltage stress’, Int. J. Circ. Theor. Appl., 2018.