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COUNTRY AREA AVERAGING APPROACH USED FOR STEADINESS OF THE TOPOLOGY IN ENHANCING GREENBACK MODES

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ABSTRACT

For a vehicle-to-grid (V2G) device, this study provides a switching bi-directional buck-boost converter (SBBBC). The architecture can provide a power bi-directional current path for power switching between the grid and the electrical car's Li-battery/super capacitor (SC) hybrid power garage machine (HESS). This architecture now has the capacity to control electricity as well as the ability to increase the value of a dollar. The country-area averaging method is utilized in this article to investigate the topology's stability in the boost and greenback modes. The control mechanism is provided in accordance with the power storage device's state of charge (SOC) to guarantee that the output voltage and current are steady. And constant current (CC) and constant voltage (CV) are used to charge the Li-ion battery (CV) mode. The voltage and current controllers are designed within side the frequency area primarily based totally on bode plots. Finally, the electric feasibility of the topology, thesuitability of the layout controller and manage method are tested with the aid of using simulation.

Keywords: Vehicles- to-grid (V2G), SBBBC, State ofcharge, CC, CV.

INTRODUCTION

Due to their cleanliness and minimal environmental effect, electric cars are often utilized [1]. Li-batteries play a crucial role in electric car energy storage systems [2]. Despite the fact that Li-batteries with high energy densities may deliver sufficient power during steady-state operation, their power densities are insufficient to satisfy peak power demand [3, 4]. The issue can be resolved by combining Li-batteries with super-capacitors to create a hybrid energy storage system (HESS). The load's need for transient power may be met by SC with greater power densities, which explains why [5][17]. It is important to utilize the dc-dc converter to boost the Li-battery voltage since the voltage source inverter's output voltage peak is lower than the dc-link side voltage. Figure 1 shows the block diagram of HESS. The SC is directly connected to the inverter, which can increase the dynamic response of the HESS during transient peak power demand, while the Li-battery is connected to the DC- link by a bi-directional DC/DC converter [19]. The effect of the bi-directional dc-dc converter in the HESS is to transformer the energy and keeps the dc bus voltage stability. More- over, the converter should provide bi-directional power flow because the energy storage system and the grid require energy exchange [20].

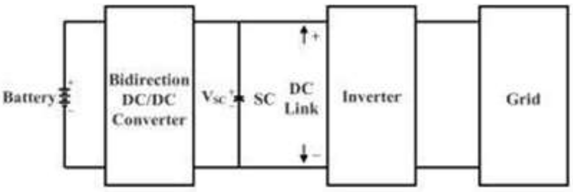


Fig.1. The block diagram of HESS

AHESS topology is mentioned in articles [3] and [5]. In the topology of [3] and [5], the Li-battery can be connected to the SC via a bi-directional dc-dc half-bridge or directly to the DC bus via a diode. This two-stage converter can make full use of the power capacity of the SC but the boost ratio is low. A buck-boost converter for a plug-in hybrid electric vehicle is proposed in paper [21] and [22], respectively. However, the converter mentioned in the paper [21] cannot achieve a bi-directional flow of energy between the grid and the energy storage device. The converter mentioned in the paper [22] has many switching devices, large losses and complicated control. A high voltage gain bi-directional dc-dc converter is given in article [23]. This topology can operate under zero voltage switching conditions and reduces switching and conduction losses. However, this topology has many switching states and the operation is complicated. In [13] and [24], hybrid energy storage systems for electric vehicles based on Z-source inverters (ZSI) and quasi-Z-source inverters (qZSI) were proposed. These two topologies have the boost capability, and provide a bi-directional energy flow path. Moreover, the reliability of the hybrid energy storage system is enhanced due to the characteristics that allow the inverter to shoot-through. These two topologies can increase power density [25]. The control strategies proposed in [13] and [24] is complex, and the topologies have multiple passive components between the SC and the DC bus, which will greatly increase the size of the device.

PROPOSED SYSTEM

This paper proposes a switching bi-directional buck- boost converter (SBBBC) and its appropriate control strategy, which is used in the HESS for vehicles-to-grid (V2G) sys- tem. The converter allows shoot-through of two switches of any phase, with anti- electromagnetic interference capability. Meanwhile, since there are three switches in the DC side, the SC and Li-battery can fulfill bi-directional power flow. Furthermore, the small-signal model of the topology is established by state space averaging method and the stability of the system is analyzed. The control strategy is given according to the state of charge (SOC) of the energy storage system and the operating state of the circuit. The performance of the proposed converter and control strategy are verified through simulation results.

PROPOSED TOPOLOGY

Figure 2 shows the proposed SBBBC with HESS, which consists of five parts: Li- battery, switching bi-directional buck-boost circuit, SC, full bridge inverter and gird. The switching bi-directional buck-boost circuit has an inductor, a SC and the additional three switches (SD1, SD2, SD3). Since the gate signals of switches SD2 and SD3 are the same and complementary to the gate signal of switch SD1, one gate signal can control these three additional switches. This unique SBBBC network allows the system works on the buck and boost modes, and it can provide bi-directional power flow.

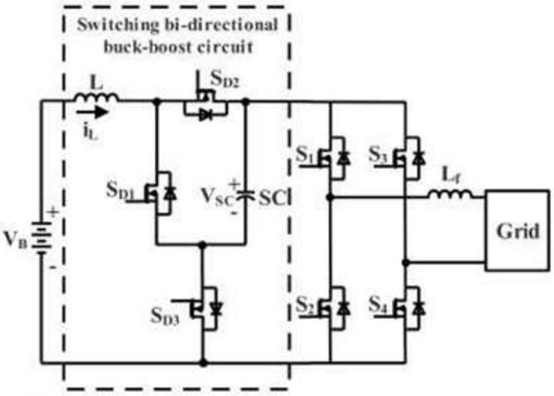


Fig.2. The proposed SBBBC

Table.1. Switch combination and inverter output voltage

N	U_{AC}	S_{D1},S_{D2},S_{D3}	S_1,S_3	S_2,S_4	state
1	0	0 1 1	0 0	1 1	zero state
2	0	0 1 1	1 1	0 0	zero state
3	$-U_{SC}$	0 1 1	0 1	1 0	active state
4	U_{SC}	0 1 1	1 0	0 1	active state
5	0	1 0 0	1 1	X X	shoot-through state
6	0	1 0 0	X X	1 1	shoot-through state

Note:X is 0 or 1.

MODULATION METHOD

In the proposed converter, there are three switching-states include active state, zero state and shoot-through state respectively, asshown in Table 1. All switches of full bridgeinverter are operated in the

SPWM mode to modulate output volt- age. The switching bi-directional buck-boost circuit uses the shoot-through duty to achieve buck-boost voltage. The duty cycle is calculated by:

$$\begin{cases} d = m\sin(\theta) \\ d_s = const \\ d_0 = 1 - d - d_s \end{cases} \qquad (d_s \le 1 - d) \qquad (1)$$

Where m is the modulation index of the
inverter; ϴ is the vector angle of the outputvoltage; d, ds, d0 are the duty cycles of the output voltage active state, shoot-through state and zero voltage state, respectively.

MODELING AND ANALYSIS OFTHE PROPOSE CONVERTER

The proposed converter can provide bi- directional power flow among SC, Li-battery and grid, as shown in Figure 2. And the converter can work in boost mode and buck mode.

BOOST MODE

During boost mode, the proposed converter boosts the low Li- battery voltage to high dc-link voltage. There are three work states: zero state, active state and shoot-through state.

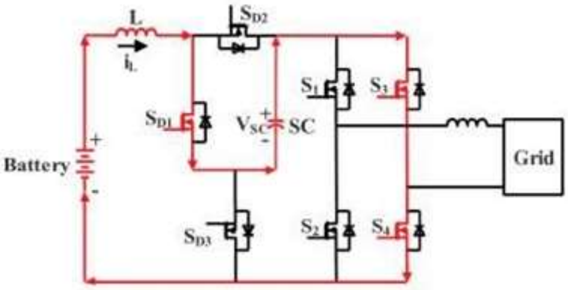


Fig.3. Flow path shoot through state of boost mode

SHOOT-THROUGH STATE

In shoot-through state, the switches SD1 andS3 &S4 (S1 &S2) are turned ON while switches SD2 and SD3 are simultaneously turned OFF, as shown in Figure 3. In this state, the power is transferred from the Li- battery and SC to the inductor L. The state equation is given by:

$$\begin{cases} L\dfrac{di_L}{dt} = -(R_L + R_C)i_L + V_{SC} + V_B \\ C\dfrac{dV_{SC}}{dt} = -i_L \end{cases} \qquad (2)$$

Where VB is the Li-battery voltage; VSC is the SC voltage; IL is the current through the inductor L; RL and RC are parasitic resistances of the inductor L and SC, respectively.

ACTIVE STATE

In active state, both switches SD2 and SD3 are turned ON while switches SD1 is simultaneously turned OFF, as shown in Figure 4. In this state, the Li-battery VB and inductor L charge SC and power is transferred from the Li-battery VB and inductor L to the grid. The state equation can be calculated as follows:

ZERO STATE

In zero state, both switches SD2 and SD3 and S1 & S3 (S2 &S4) are turned ON while switches SD1 is simultaneously turned OFF,as shown in Figure 5. The state equation canbe calculated as follows.

$$\begin{cases} L\dfrac{di_L}{dt} = -(R_L + R_C)i_L - V_{SC} + V_B \\ C\dfrac{dV_{SC}}{dt} = i_L \end{cases} \qquad (4)$$

From equations (2) to (4), due to the averagevalue of the inductor voltage and the capacitor current should be zero in one switching period of Ts, the voltage gain and current gain of the proposed converter inboost mode are as follows [26]:

$$\frac{V_{SC}}{V_B} = \frac{(1-2D_{boost})Z_H}{(1-2D_{boost})^2 Z_H + (2D_{boost}R_C + R_L)m} \quad (5)$$

$$i_L = \frac{m}{1-2D_{boost}} i_O \quad (6)$$

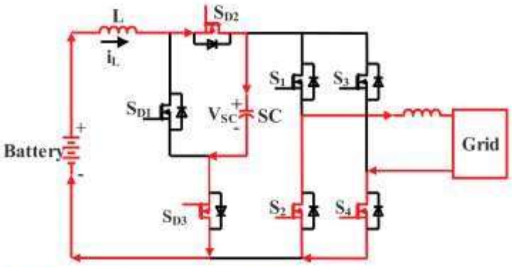


FIGURE 5. Flow path in zero state of boost mode.

SIMULATION RESULTS

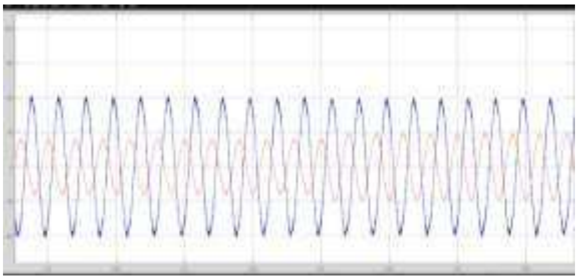
The SBBBC was simulated to verify the feasibility and dynamic performance. The simulation parameters are shown in Table 2.

TABLE 2. Design papameters.

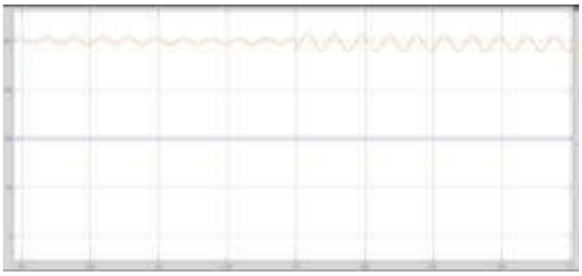
Parameter	Value	Unit
Li-battery voltage V_B	100	V
SC voltage V_{SC}	200	V
grid voltage V_G	100	V
grid voltage frequency	50	Hz
inductor L	2	mH
filter inductor L_f	2	mH
supercapacitor SC	2	F
parallel capacitance of the Li-battery C_l	470	μF
parasitic resistors R_L	800	mΩ
parasitic resistors R_C	25	mΩ
parasitic resistors R_{Cl}	51	mΩ
internal resistance of the Li-battery R_B	100	mΩ
switching frequency f_s	5	kHz

Figure 1 shows the simulation waveforms when the SBBBC is operating in boost mode. To make the grid cur- rent clear, the amplitude of the grid current is amplified 10 times. The current injected into the grid is in phase with the grid voltage to achieve a unit power factor. As shown in Figure 19(b), when the shoot-through duty cycle ds is 0.25, the proposed converter boosts the 100V Li-battery voltage to 200V SC voltage, which meets the voltage gain given by equation (5). At t D 0:5, the reference current IG_ref of the grid current controller changes from 4A to 5A. At this time, the Li-battery current increases and the output power of the Li-battery increases, this can achieve a fast response of the grid current. The capacitor voltage remains constant and the energy required by the grid is provided by the Li-battery.

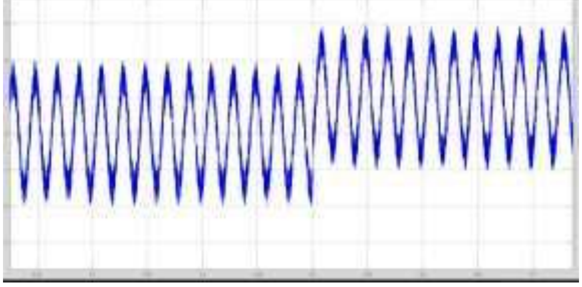
Case_1:V2G Mode



(a)



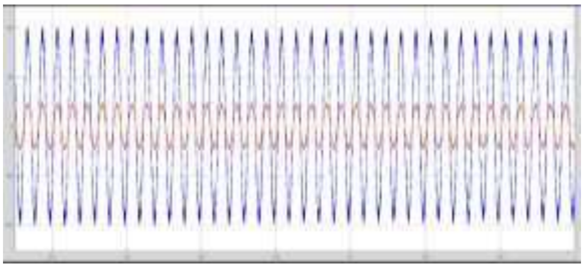
(b)



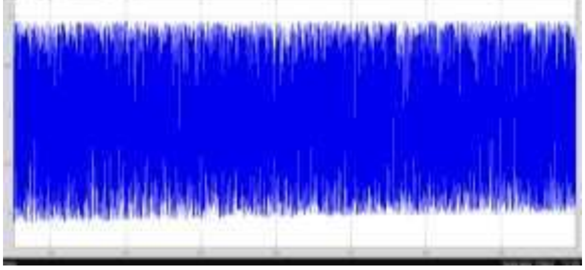
(c)

Fig.1. Simulation results of the proposed system. (a) Grid voltage and grid current. (b) Battery discharge voltage and SC voltage.
(c) Battery discharge current.

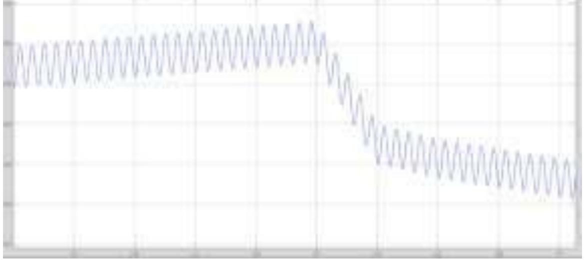
Case_2 G2V Mode



(a)



(b)



(c)Simulation results of the proposed system.
(a) Grid voltage and grid current. (b) Batterycharging current. (c) SC voltage.

CONCLUSION

In this work, an SBBBC for V2G system is shown. The suggested converter includes a bidirectional energy flow channel in addition to a high voltage gain and immunity to electromagnetic interference.

The SBBBC's many operating modes are covered in detail in this article, and the converter's tiny signal model is constructed. The system's zero-pole diagram was created, its dynamic properties were examined, and its stability was established. In this study, control algorithms are proposed for the HESS's V2G and G2V modes, which implement energy management. In order to have strong dynamic performance, the controller is developed in the frequency domain. Finally, simulation findings have been used to validate the theory's accuracy and the control strategy's viability.

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