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High Step-Up Bidirectional DC-DC Converter for Battery Storage System

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ABSTRACT

A non-isolated high voltage gain bidirectional DC-DC converter for battery storage system has been presented in this paper. The topology is composed of boost converter and traditional SEPIC converter. The proposed converter can achieve higher voltage conversion ratio with reduced voltage and current stresses in the switches. In additional, a reduced number of components are included in this topology. The PSIM simulation is carried to validate the analysis and operation of the converter.

1. Introduction

To address the challenges of fossil fuels as the primary energy source for transport, the battery storage system is a good way to solve this problem. A challenge for the BSS (battery storage system) is that the terminal voltage of battery is low, and varies over a wide range as they charged and discharged. Therefore, a bidirectional DC-DC converter with a wide voltage gain range is desired for the BSS to connect low-voltage battery with a high-voltage DC bus. A high step up non-isolated converter for PV application was proposed in [2]. The proposed converter can achieve high voltage gain with reduced voltage stress in the switches. However, this converter is unidirectional and the analysis is not detailed enough.

This paper present a Quasi-SEPIC bidirectional DC-DC converter for battery storage system based on [2]. Compared with the converter presented in [2], the proposed converter worked in the bidirectional mode. Compared with other bidirectional converters, the proposed converter can achieve high voltage conversion ratio with reduced voltage and current stress.

2. Contens

2.1 Operating Principle of the Proposed Converter

The configuration of the proposed bidirectional dc-dc converter is shown in Fig.1. It can be seen that the proposed converter

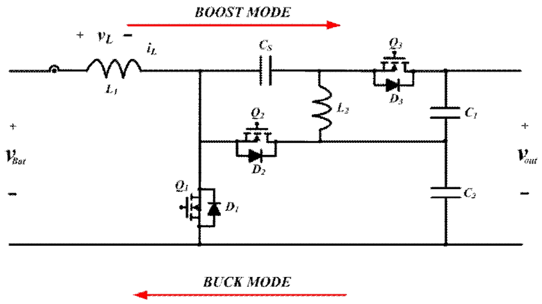


Fig. 1 Configuration of the proposed converter

consists of power awitch Q_1 , Q_2 and Q_3 inductors L_1 and L_2 , capacitors C_1 , C_2 and C_{cs} .The proposed converter can operate in the step-up or in the step-down mode, enabling the bidirectional power flow between the high-voltage and low-voltage sides.

2.1.1 Step-Up Mode of the Proposed Converter

When the proposed converter operates in the step-up mode. Q_1 operates as a main power switch and Q_2 and Q_3 are the synchronous rectifiers. The typical waveforms of the proposed converter continuous conduction mode (CCM) are shown in Fig 2(a).

When the converter operate in step-up mode, the current flow paths are shown in Fig3 . Accroding to the Fig.3, the voltage equations can be obtained. By applying the volt-second balance priciple on the inductors L_1 and L_2 ,the relationship between the voltage gain and the duty cycle in CCM can be obtained as equation (1).

$$M_{Boost} = \frac{1+d_{Boost}}{1-d_{Boost}} \tag{1}$$

2.1.2 Step-Down Mode of the Proposed Converter

When the proposed converter operates in the step-down mode. Q_1 operates as a main psynchronous rectifiers and Q_2 and Q_3 are the power switches. The typical waveforms of the proposed converter continuous conduction mode (CCM) are shown in Fig 2(b).Apply identical analysis with the step up mode . The current flow path are illustrated in Fig 4(a) and (b).

The relationship between the voltage gain and the duty cycle in CCM can be obtained as

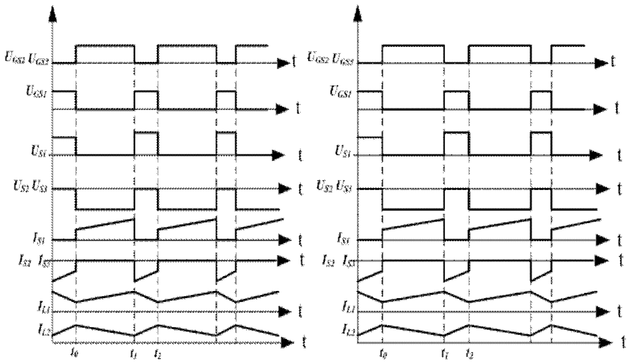
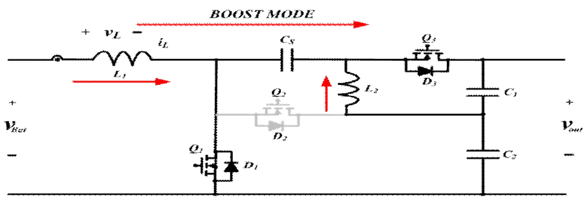
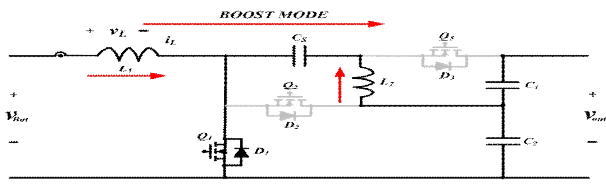


Fig. 2 Typical waveforms of the (a)step up mode.(b)step down mode

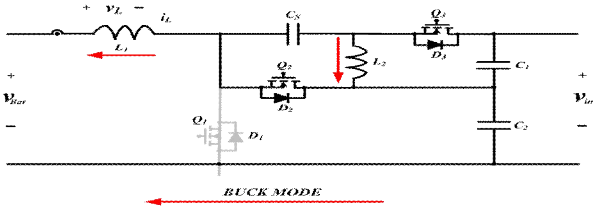


(a)

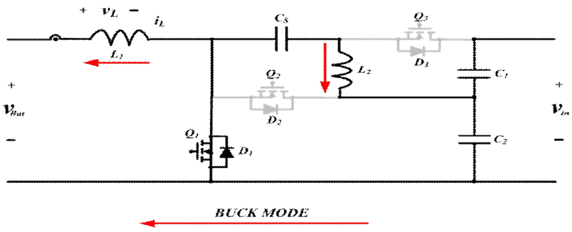


(b)

Fig.3 Current flow path of the proposed converter in the step up mode. (a) State 0.(b) State 1.



(a)



(b)

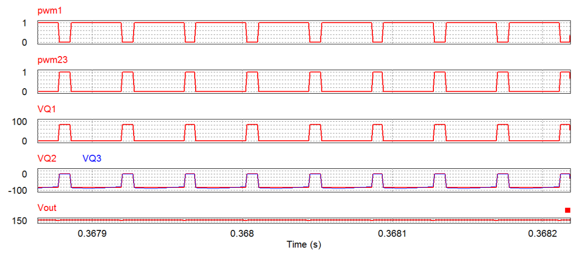
Fig. 4 Current flow path of the proposed converter in the step up mode. (a) State 0.(b) State 1.

$$M_{Buck} = \frac{1-d_{Buck}}{1+d_{Buck}} \quad (2)$$

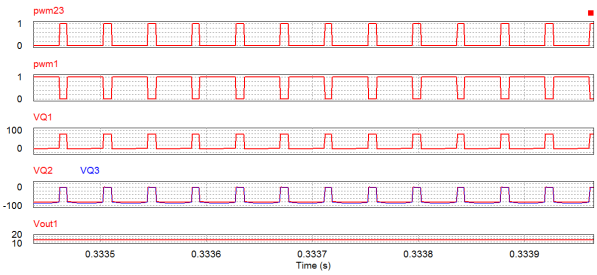
2.2 Simulation of the proposed converter

Table I. Parameters of the test converter

Battery voltage	15 [Vdc]
Output voltage	150 [Vdc]
L_1 L_2	102 [uH]
C_1 C_2	50 [uF]
C_S	3.37 [uF]
Outout power	100 [w]



(a)



(b)

Fig.5 simulation results. (a) step up mode.(b) step down mode.

The experimental result of the bidirectional DC DC converter proposed in this study is shown in Figure 5. As shown in the experimental results, when the duty cycle is setted to 0.81, the voltage gain can be attained to 10 in step up mode and 0.1 in the step down model. In addition, the voltage on the switch is half of the high voltage side.

3. Conclusion

A nonisolated Quasi-SEPIC bidirectional DC-DC converter for battery storage system was proposed in this paper. The proposed converter benefits from a wide voltage gain range in step up and step-down model. In addition, the bidirectional converter has a simple structure with three power switches, and their voltage stress is lower.

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References

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