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Control and Designing of Bidirectional DC-DC Converter

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ABSTRACT

This paper explains designing and control of bidirectional converter step-by-step and simulation of the full circuits of a battery control system and connected together starting from the AC input source to the battery control and storage system. The bidirectional dual switch converter is designed to control and convert the DC power in different ranges. The output and input voltage levels ratio are used to calculate the pulse generator signals duty cycle. Therefore, the duty cycle indicates the operation mode of the converter in steady-state operation. In this study, we analyze and control of a bidirectional converter with the duty signal. Besides, the bidirectional DC/DC converter has been achieved and optimized by open loop control to control the battery charging and discharging modes. The simulation has been applied via the MATLAB/Simulink. The results show the activity of each part of the designed circuits starting from the converters and the battery control system in charge and discharge modes. The proposed converter has the ability to work in both bidirectional step-up (boost) and step-down (buck) modes. The main features of the proposed converter are the low components count, the low peak voltage of the main switches and low losses. Moreover, only two power switches are utilized in the proposed converter, which makes it easy to transfer the power between the sources. The suggested converter can be worked in energy storage system (ESS) due to the ability of step-up and step-down operation principles. Thus, it can charge and discharge the ESS with high voltage conversion ratio.

Keywords: DC-DC Converter, bidirectional DC-DC converter, pulse generator, non- isolated dc dc converter, Renewable power generation.

1. Introduction

Bidirectional DC-DC converters are used in many applications when bidirectional energy transfer between input side to output side or output side to input side as per requirement. They are used as an interface circuit between ultra-capacitor and DC bus in a Hybrid Electric Vehicle (HEV). Since the voltage levels of the ultra-capacitor and DC bus are different, the circuit must be able to increase or decrease the voltage level in each power flow direction while limiting the current. BDCs are being increasingly used in many applications such as UPS, hybrid electric vehicles, fuel cell power systems, and solar cell power systems (Amjadi and Williamson, 2010; Tsurata et al., 2009; Jin et al., 2010; Shen et al., 2018). These power converters allow transfer of power between two sources in either direction. The BDCs are divided into non-isolated and isolated circuits. When both sides do not need to be grounded simultaneously and high voltage ratio is not needed, non-isolated bidirectional converters are used for their simple structure and control scheme (Inoue and Akagi, 2007; Yu et al., 2010). The bidirectional DC–DC converter is one of these converters that can transfer the energy between the load and energy supplies (Shakib and Mekhilef, 2016). There are different kinds of bidirectional DC–DC converters such as conventional bidirectional buck–boost converters (Chaoping et al., 2021). Besides, the voltage stress of the semiconductors in these converters is high that causing an increase in the losses of the converter. The multi-port converters with the bidirectional feature are divided into two types, isolated and non-isolated converters (Dusmez et al., 2015). In isolated type, a high voltage conversion ratio can be achieved by adjusting the transformer conversion ratio. Such converters are composed of a large number of components, because of this increase in the cost and the conduction losses of the converter (Jin and Liu, 2015). Besides, these types of converters control is also difficult. Advantages of non-isolated converters over isolated converters include low component count and also less stress across switches, high voltage conversion ratio and simple structure. Basic DC-DC converters such as buck and boost converters (and their types) do not have bidirectional lower flow capability. This limitation is due to the presence of diodes in their structure which prevents reverse current flow. In general, a unidirectional dc-dc converter can be turned into a bidirectional converter by replacing the diodes with a controllable switch in its structure. The structure of classical bidirectional converter is shown in Fig.1. This converter has two operation modes. At the step-up mode, the input voltage in low voltage side (LVS) is increased and the voltage of output filter capacitor C2 is equal to increased output voltage. At the step-down mode, the high voltage in high voltage side (HVS) is decreased and the low voltage is obtained on the C1 capacitor. So, the converter can be operated as bidirectional according to need. In this paper, a new bidirectional dc-dc converter is introduced. In this new converter, dual switch is used for voltage conversion and filter capacitor is added as parallel to input side to the different from the classical bidirectional converter. This converter also has two operation modes. At the first mode, the input voltage in converter is increased and in second mode the input voltage is decreased.

2. Bidirectional dc to dc Converter

A conventional buck-boost converter can management the power flow in one direction only but power can flow in both the direction in bidirectional converter. Bidirectional dc-dc converters are the device for the purpose of step-up or step-down the voltage level with the capability of flow power in either forward directions or in backward direction. Bidirectional dc-dc converters work as regulator of power flow of the DC bus voltage in both the direction. In the power generation by renewable power systems, output vary because of the changing environment condition. These energy systems are not reliable to feed the power as a steady system because of the large fluctuations in output and hence these energy system systems are always connected with energy storage devices such as batteries/super capacitors. These energy storage devices store the energy during low load demand and provide backup in case of system failure and when the output of energy system changes due to weather conditions. Thus, a bidirectional dc-dc converters are important to allow power flow in both forward and backward the directions [12]– [18]. A conventional dc-dc converter can be converted into a bidirectional converter using bidirectional switch by using diode in anti-parallel with MOSFET or IGBT allowing current flow in both the direction using controlled switching operation.

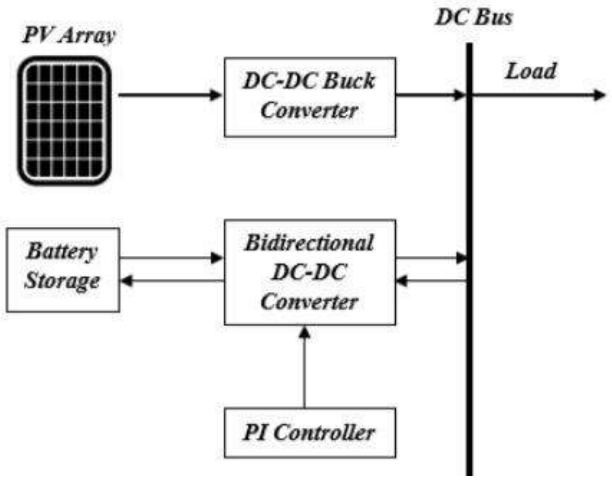

Figure 1. Dc grid with bidirectional dc-dc converter

2.1 Types of Bidirectional Converter

There are two types of Bidirectional dc-dc converter on the basis of isolation between input and output side.

- Non isolated bidirectional converter
- Isolated bidirectional converter

2.2 Non-Isolated Bidirectional Dc- Dc Converter (NIBDC)

NIBDC is a converter which does not use high frequency trans-former to provide any electrical isolation between source and load. Hence these converters are not used in high power applications due to safety reasons but in low power application theses convert-er are more efficient because these are easy to control and light weight due to absence of transformer [20].

2.3 Isolated Bidirectional dc- dc Converter (IBDC)

NIBDC are not capable to provide the safety standards of galvanic isolation. Hence in many applications, IBDC is used in place of NIBDC. In IBDC, high frequency transformer is used to provide galvanic isolation. Galvanic isolation is necessary in many applications for safety of source in overload condition, for noise reduction, for voltage matching between conditions. This converter works in two stages. In first stage dc is converted to ac and second stage ac is converted into dc and both the stages are connected through high frequency transformer.

3. Methodology

This work present bidirectional dc-dc converter with open loop control using pulse generator for duty cycle. we are using two Mosfet two capacitors and one inductor or bidirectional converter designing. The designing of converter is in MATLAB Simulink which are shown in figure2

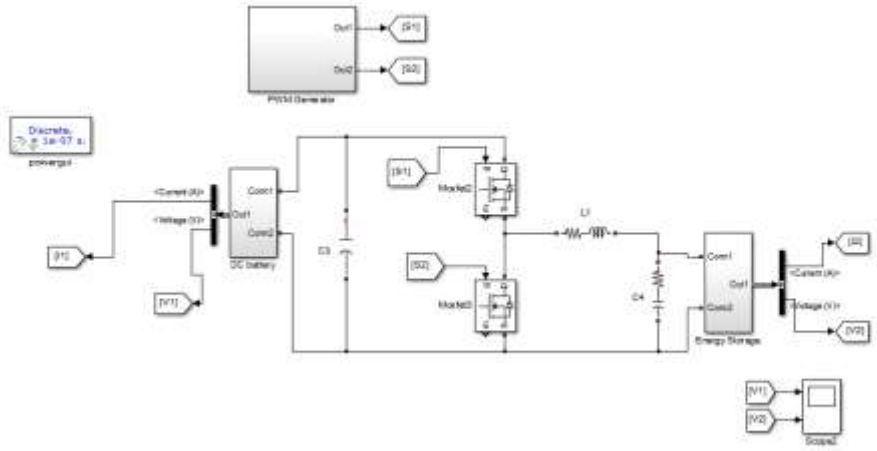

Figure 2. new proposed bidirectional dc -dc converter

4. Simulation result

The proposed bidirectional dc-dc converter is simulated in MATLAB Simulink for buck and boost operation. When converter operates in boost operation the values of input side in 24v and output side is 48v as shown in figure 3. there is only work done for boost operation.

Table 1 – Design parameter

Symbol	Values
V1	24V
V2	48V
L1	350mh
C1	1000 μ F
C2	20 μ F

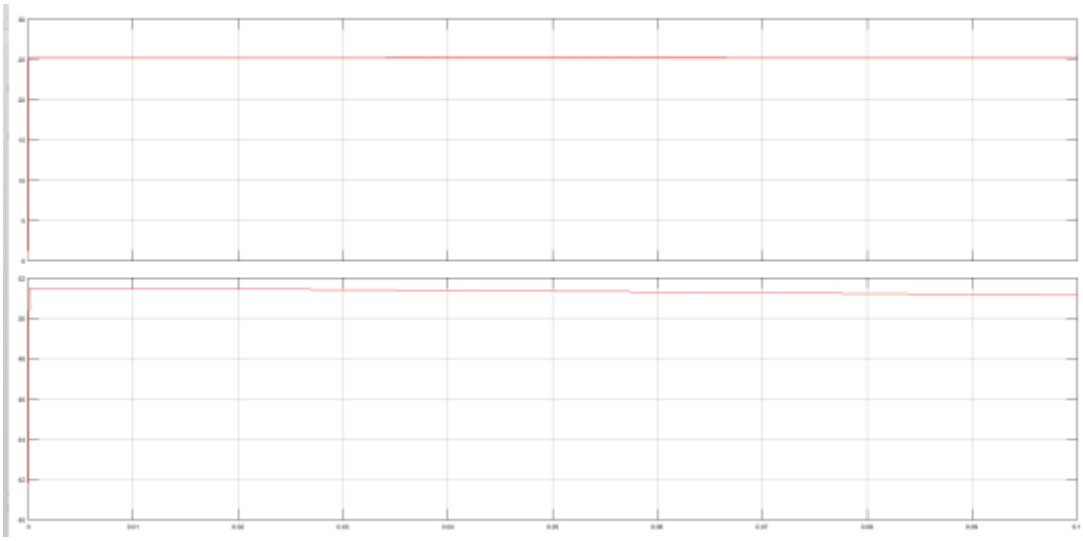

Figure 3. simulation result for step up operation of converter

5. Conclusion

In this paper, a new bidirectional converter is proposed. In the proposed converter, the place of HVS filter capacitor is changed different from classical bidirectional converter. The voltage across capacitor is equal to the high voltage value in the classical bidirectional converter. This structure has an advantage because the voltage across the filter capacitor is less than classical structure. So, the cost is reduced. Additionally, the converter can be operated as bidirectional by two modes. While the voltage is increased at first mode, the voltage is both increased and decreased according to duty cycle. Another advantage of these converters have is, they can have multiple input with versatile voltage profile and the diversified output voltage can be generated as per the load demand.

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