Full-Bridge Single-Inductor Based Buck-Boost Inverter

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Abstract- Single-stage buck–boost inverters have attracted the attention of many researchers, due to their ability to increase/decrease the output voltage in one power conversion stage. One of the most important uses of these inverters is in photovoltaic applications, where the voltage of the solar panels varies in a wide range. In recent years, many new inverters have been proposed to improve the performance of existing structures. In this paper, the state of the art of these single-stage buck–boost inverters are discussed. The advantages and disadvantages of each structure are examined from different perspectives, such as the number of components, losses, and performance. Finally, in a general comparison, the properties of all structures are discussed and summarized in a table. Single-stage buck–boost inverters are inverters capable of increasing/decreasing the output voltage in single power conversion. More attention of researchers to this type of inverters, in the last decade, various structures of these inverters have been presented. Although all of these structures have common features, they can be categorized.

I. INTRODUCTION

The output voltage of renewable energy sources is influenced by environmental conditions. To compensate for the variations of voltage, a buck-boost power conditioning system can be used. This paper presents a full-bridge single-inductor based buck boost inverter. Its output voltage can be greater or lower than the input voltage depending on the controllable duty ratio. This inverter features bidirectional and reactive power flow operations with no high frequency common-mode voltage. The unique feature of the proposed inverter is using a single inductor in the power train, which enhances power density. Moreover, only two switches can operate at high frequency. This enables to make the inverter with the high efficiency and simple circuit configuration. Based on the proposed full-bridge inverter, a novel cascaded buck-boost inverter is also presented. It retains all the benefits of the proposed full-bridge inverter. The theoretical analysis of the proposed full-bridge inverter is firstly explained in detail. It is then extended to a cascaded inverter. Thereafter, the practical effectiveness of the proposed inverters is verified with the experimental tests by implementing the hardware prototypes of 110 Vrms, 60 Hz and 500 W for full bridge single inductor-based buck-boost inverter, and 220 Vrms, 60 Hz and 1000 W for the cascaded inverter.

II. LITERATURE REVIEW

[1] "Kang, F.S. Cho, S.E Park, S.J. Kim, C.U. Ise, T. A new control scheme of a cascaded transformer type multilevel PWM inverter for a residential photovoltaic power conditioning system" Sol. Energy 2005.

From the viewpoint of high-quality output voltage generation in a residential photovoltaic system, a multilevel inverter employing cascaded transformers can become a good substitute for the conventional pulse width modulated inverters and other multilevel counterparts. However, to obtain more sinusoidal output voltage waves, it should increase the number of switching devices and transformers resulting in a cost increase. To alleviate this problem, an efficient switching pattern is proposed and applied to a multilevel inverter equipped with two cascaded transformers, which have a series- connected secondary.

[2] “Sahana, B. Araujo, S.V. Noeding, C. Zacharias, P. Comparative evaluation of three phase current source inverters for grid interfacing of distributed and renewable energy systems. IEEETrans. Power Electron.
Despite the rapid growth of self-commutated inverter technology, the well-known current source inverter (CSI) has not achieved significant practical application so far. This raised the question regarding the fundamental criteria that could either prevent or promote the use of such inverters, especially considering emerging fields of application such as grid integration of renewable sources. This paper will, thus, focus on a systematic comparison between circuits based on the CSI and voltage source inverter (VSI). The pulse width-modulated CSI with its inherent step-up capability alongside the indirect CSI (ICSI) with only two high frequency switches features very interesting characteristics in terms of low switching losses and high inductor power density.

[3] “Kumar, A. Sen Sarma, P. Operating modes-based review of single-stage buck-boost inverters. In Proceedings of the IECON 2019-45th Annual Conference of the IEEE Industrial Electronics Society, Lisbon, Portugal.
There is a need of buck-boost inverter (BBI) wherever the magnitude of source voltage is low as compared to the peak of ac output. Solar micro-inverter is most common application which requires BBI because of the low output PV voltage. Other major applications are uninterruptible power supply (UPS) and small wind turbine systems. Single stage BBIs are well known configurations which generally find demand in low power applications because of their claimed better efficiency profile as compared to two stage BBIs.

[4] “Operation of BBIs, their efficiency profile and the ease in controller design are the main aspects that are discussed in this paper”
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III. METHODOLOGY

The CSI topology it is necessary to maintain a DC link current which is greater than the peak of the current demand. The DC link current is dependent on the nonlinear load characteristic equivalent the rated power. It is necessary to maintain a DC bus voltage VC which is greater t then peek of the line voltage. The DC bus voltage is dependent only on the rated voltage and not the rated power as was the case with the CSI. In some cases, it may be possible to use CSI topology to achieve the same compensation. The CSI topology the AC side capacitor must approximately a short circuit for the switching frequency component bridge output current. The value is dependent on the line characteristic and is typically a few micro farads. The voltage-source inverter and current source inverter topologies for single-phase active power filter application.

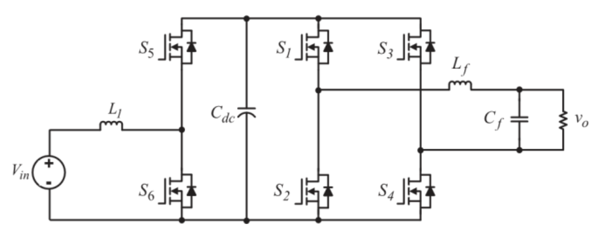


Fig. 1. Boost dc–dc converter cascaded with a VSI

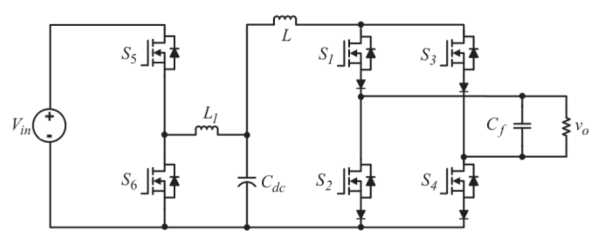


Fig. 2. Buck dc–dc converter cascaded with a CSI

Many renewable energy sources (RESs) require power inverters when they are connected to the grid. In general, they can be classified as the voltage source inverter (VSI) or current source inverter

(CSI). The full-bridge VSI is shown in Fig.1. It is a step-down inverter with the output peak voltage, which is always lower than the input voltage. The full-bridge CSI is shown in Fig. 2. It is a step-up inverter with the output peak voltage, which is always higher than the input voltage.

The output voltage of RESs is greatly influenced by environmental conditions. Thus, to compensate for the variations of voltage, the inverter system must make the buck–boost operation. To deal with this, a boost dc–dc converter is cascaded with a VSI, as shown in Fig. 2. It provides a boost function, and the VSI provides a buck function. Similarly, buck dc–dc converter is cascaded with a CSI, as shown in Fig, where the buck dc–dc converter provides a buck operation, and the CSI provides a boost operation. However, they require multiple inductors and capacitors in two high-frequency stages, and they might have the high-frequency common-mode voltage.

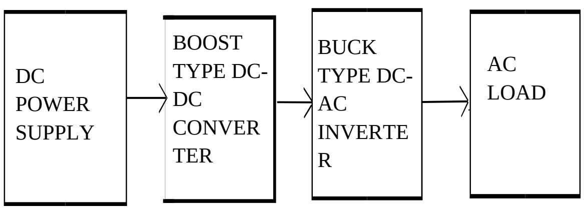


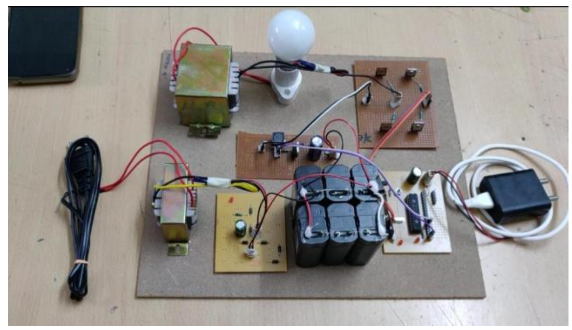
Fig.3. Block Diagram

A Working:

A full-bridge single-inductor-based buck-boost inverter. This inverter features bidirectional and reactive power flow operations with no high-frequency common-mode voltage. The unique feature of the proposed inverter is using a single inductor in the power train, which enhances the power density. Moreover, only two switches can operate at high frequency. A Buck-Boost converter transforms a positive DC voltage at the input to a negative DC voltage at the output. The circuit operation depends on the conduction state of the MOSFET:

On-state: The current through the inductor increases and the diode is in blocking state.

Off-state: Since the current through the inductor cannot abruptly change the diode must carry the current so it commutates and begins conducting. Energy is transferred from the inductor to the capacitor resulting in a decreasing inductor current and a voltage across the resistor with the opposite polarity compared to Vin. During steady state the circuit is said to operate: in discontinuous conduction mode if the inductor current reaches zero and in continuous conduction mode if the inductor current never reaches zero.



CONCLUSION

A new single-inductor based full-bridge buck-boost inverter and cascaded inverter are proposed. The detailed circuit analysis with its equivalent circuits is presented. Also, the modulation strategy for its proper operation is developed and discussed. A 500 W, 110 $Vrms$ and 1000 W, 220 $Vrms$ experimental prototypes was fabricated, and experimental studies were performed at 30 kHz to verify the practical effectiveness of the proposed full-bridge single-inductor based buck-boost inverter and proposed cascaded inverter. Peak efficiency 96.8 % was reported. The proposed single-phase buck-boost inverter generated an output voltage 155 Vpk for input voltages 85 V and 200 V, which verified the step up and step-down operations of the proposed inverter. The proposed cascaded inverter generated an output voltage 311Vpk for input voltage 50 V. The proposed inverters provide reactive power, which is verified through the operation with a partially inductive load consisting of inductance 50 MH and resistance 24 Ω. The unique feature of the proposed inverters is that it requires only a single inductor, and only two switches at a time are operated at high switching frequency. As the result, the power density and efficiency of the inverter can be improved while decreasing its control complexity.

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