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Single-Phase Non-Isolated DC-AC Converter Topologies Producing Boosted Outputs – An Overview

Dhanya Rajan[1], Pranav M S[2], Sruthi P K[3]

PG Student [Power Electronics], Dept. of EEE, Vidya Academy of Science and Technology, Thrissur, Kerala, India [1]

PG Student [Power Electronics], Dept. of EEE, Vidya Academy of Science and Technology, Thrissur, Kerala, India[2]

PG Student [Power Electronics], Dept. of EEE, Vidya Academy of Science and Technology, Thrissur, Kerala, India [3]

ABSTRACT: A classical voltage source inverter produces an instantaneous AC output voltage which is always lesser than the input DC voltage. There are cases where output AC voltage required is greater than the input DC voltage like uninterruptible power supplies (UPS), photovoltaic systems or grid connected systems. There are different approaches to obtain the boosted AC output voltage. Such requirements can be accomplished by single stage boost inverter topologies as well as multistage topologies. Single-stage topologies have only one stage of power conversion while multi-stage topologies have more than one stage of power conversion. The inverters can also be divided as isolated inverters or non-isolated inverters depending on whether isolation is provided between input and output. This paper gives a study of different non-isolated inverter topologies which are used to obtain an output AC voltage which is greater than the input DC voltage. Two single-stage and two multi-stage topologies are explained. Their working and applications are also mentioned. The multi-stage topologies mentioned in this paper are DC-DC-AC topologies. Finally, a comparison is done between the different topologies.

KEYWORDS: Boost inverter, voltage source Inverter.

I.INTRODUCTION

Inverters are DC-AC converters. Such a converter changes a dc input voltage to a symmetric ac output voltage of desired magnitude and frequency [1]. Inverters can be divided into voltage source inverters and current source inverters. Voltage source inverter is shown in fig. 1. V_{in} represents the input DC voltage and the AC output is obtained across load R_0.

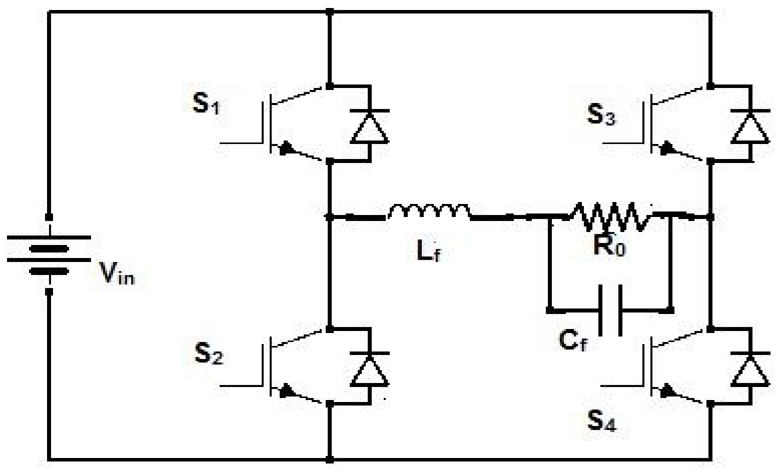

Fig. 1 Conventional voltage source inverter

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The classical VSIs have output voltage lesser than input voltage. This is because of the modulation strategies. In order to obtain an output AC voltage which is greater than input DC voltage, line frequency transformers can be used in the output stage of the voltage source inverter to step up the output voltage. Another solution is to use high frequency transformers with a multi-stage inverter. But these solutions can result in higher costs and volume. Also, by avoiding transformers and using power electronic devices we can have more compact designs with wide input ranges and improved overall efficiency [2]. Such non-isolated topologies can be single-stage or multi-stage. Single-stage inverters will have only one stage of power conversion. In this stage both stepping up as well as conversion to ac takes place. On the other hand, multi-stage inverters have more than one power conversion stage.

This paper gives a study of single-phase transformer less DC-AC converter topologies which are used to obtain boosted or stepped up output AC voltage from an input DC voltage. Two multi-stage topologies and two single-stage topologies are taken into consideration. The paper is organised as follows. Section I explained about the conventional voltage source inverter and introduced the various methods which are used to obtain AC output which is greater than the input DC voltage. Section II is the literature survey. Section III explains a two stage inverter which uses a step-up or boost dc-dc converter in its first stage. Section IV also deals with a two-stage inverter which is used for grid connected systems [3]. Section V gives a boost inverter topology derived from boost dc-dc converter [4]. Section VI deals about topology which is similar to traditional inverter [5]. Finally section VII concludes the paper.

II.LITERATURE SURVEY

As mentioned previously, voltage source inverters have an instantaneous AC output voltage which is less than the input DC voltage. To obtain a boosted output, there are several approaches. They can be roughly divided as isolated and non-isolated methods. Isolated methods involve the use of transformers to provide isolation between input and output. These are multi-stage topologies as they involve an AC-AC conversion.

A popular method to obtain boosted output is the use of DC-DC converter in between input dc voltage and output voltage of inverter [1]. These topologies are hence DC-DC-AC topologies. They can also be buck-boost inverters [3][6].

Topologies for single-phase inverters which are used for small distributed power generators are mentioned in [2]. These involve isolated as well as non-isolated topologies. Inverters used for photovoltaic systems are mentioned in [7]. A comparison involving the number of components, costs and efficiency are also shown.

Another approach to obtain boosted outputs is the use of Z source structure in the inverter. Z source structure can be employed in single-phase and three phase systems [8]. The principle here involves using inductances and capacitances to produce single impedance between input and output of inverter.

This paper examines two single-stage and two-multi-stage topologies producing boosted outputs.

III.TWO STAGE INVERTER USING VSI AND BOOST DC-DC CONVERTER

As mentioned previously, the traditional VSI produces instantaneous average output voltage which is lesser than the dc input voltage. A boost dc-dc converter can be connected between the DC source and the inverter [2] [4] to step up the input voltage. So the DC input voltage is stepped up to a required value and given to the inverter. Hence it is a multistage process (DC-DC-AC). The inverter topology is given in fig. 2.

Operation: Switch S_A is used to charge the inductor L_A. When S_A is switched on, L_A gets charged. Opening S_A will force current through diode and output voltage is obtained across capacitor C. This voltage is the input to the inverter which produces corresponding AC output.

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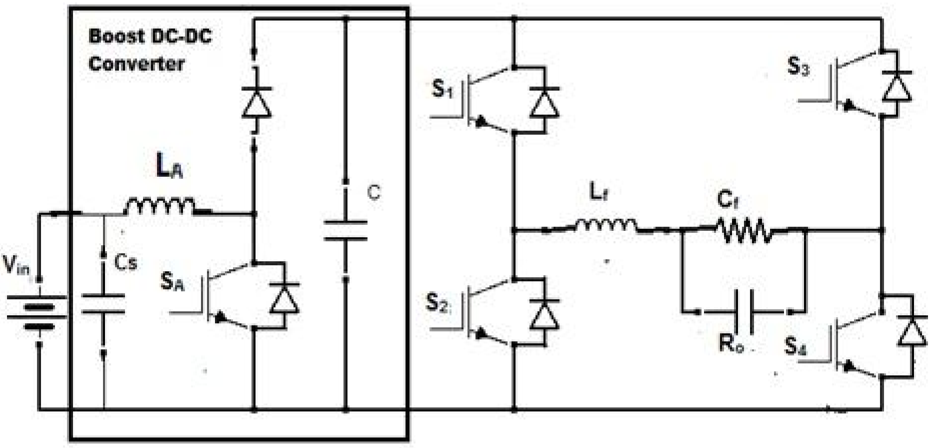

Fig. 2 Two Stage Inverter – a DC-DC-AC topology

Advantages and Disadvantages: This method is simple and is easy to design. But there is an addition of a switch when dc-dc converter was introduced to the inverter. Also, depending on the output requirement, the solution can result in high volume, weight and cost.

Application: This converter topology can be used in small wind systems. This topology can operate as grid connected as well as stand-alone unit.

IV.TWO STAGE BUCK BOOST INVERTER

Fig. 3 gives a two stage buck-boost inverter topology [3]. V_{in} represents the input and this inverter is a grid connected inverter. It has a first stage where the input is boosted up using a dc-dc converter as in case of III.

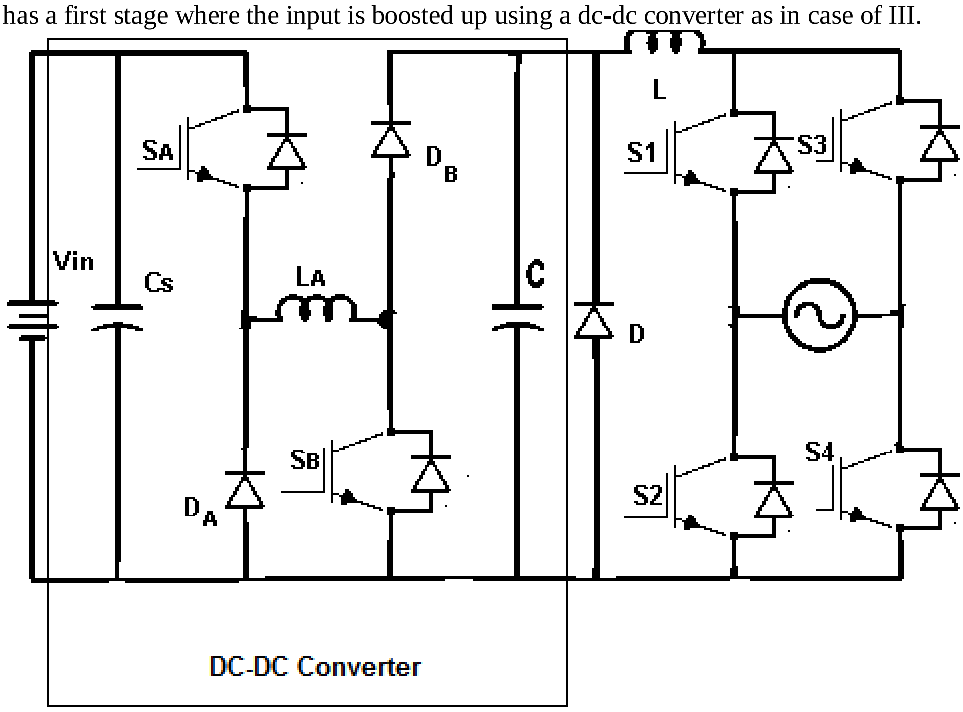

Fig. 3: Two Stage Buck-boost inverter for grid connected system

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Operation: There are two methods of operation for this circuit. For buck operation, switches S_A and S_B are first switched on to charge L_A. Next, both these switches are off and the diodes D_A and D_B get forward biased due to inductor polarity. The dc voltage is obtained across capacitor C. In case of boost operation, after inductor is charged by the switches, only switch S_B is switched off. Both the supply voltage and voltage in the inductor is obtained as output as the circuit is completed through S_A and D_B. This produces boosted DC voltage across C. This is the input to the inverter.

Advantages and Disadvantages: This inverter has a simple topology as in case of III. But there is an increase in switches. Also, this inverter can be used in grid connected system only.

Applications: This multistage topology can be used for photovoltaic systems.

V. SINGLE STAGE BOOST INVERTER

Fig. 4 shows the circuit diagram of a single stage boost DC-AC converter [4] which is derived from dc-dc converters. V_{in} represents the input DC source and the output is obtained across load R_0.

Operation: The circuit is a four switch topology and can be considered as two dc-dc converters connected in back-to-back manner with its load connected between the two output terminals as in fig. 5. Each dc-dc converter produces a dc biased sine wave output which is unipolar. The modulation to each converter is 180° out of phase with the other.

$$V_1 = V_{dc} + V_m \sin\omega t$$
$$V_2 = V_{dc} - V_m \sin\omega t \qquad (1)$$

The load is differentially connected across the converters. Therefore, the output voltage is given by:

$$V_0 = V_1 - V_2 = 2V_m \sin\omega t. \qquad (2)$$

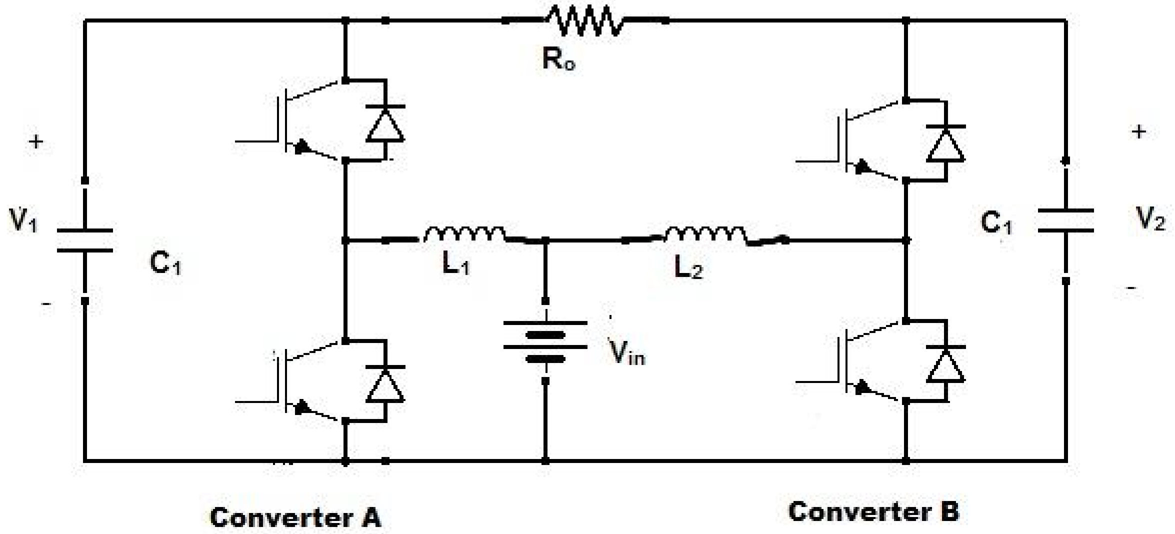

Fig. 4: Single Stage Boost Inverter

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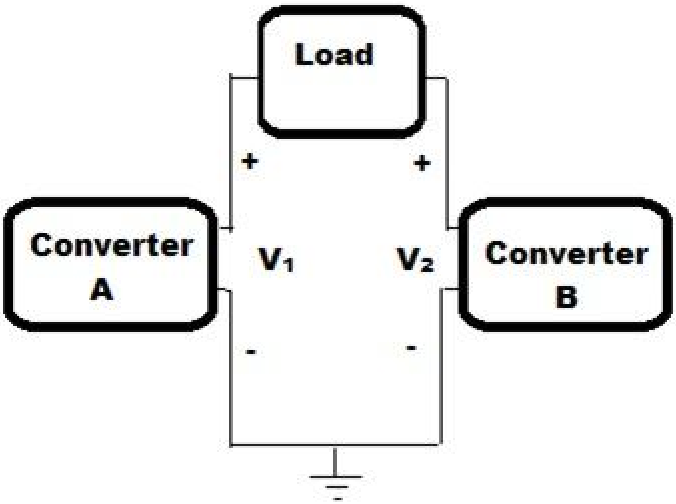

Fig 5: Principle of operation – Boost Inverter

The dc component of each of the dc-dc converter output (V_1 and V_2) must be equal so that there will be no dc component in the output [9]. Here the duty ratio of the two converters A and B are varied so that the V_1 and V_2 follow the sinusoidal reference voltage. The duty ratio is varied symmetrically around 0.5 to obtain the output voltage.

Advantages and Disadvantages: In this circuit the number of switches remains the same as for the traditional inverter. There is no intermediate boosting stage. But the difficulty faced in this circuit is its control. Mostly used control for this circuit is the sliding mode control.

Applications: It can be used as uninterruptible power supplies.

VI. STEP-UP/STEP-DOWN DC-AC CONVERTER

Fig. 6 shows a step-up/step-down DC-AC Converter [5]. The circuit has a topology which is similar to traditional inverter. V_{in} is the input and output is obtained across R_0.

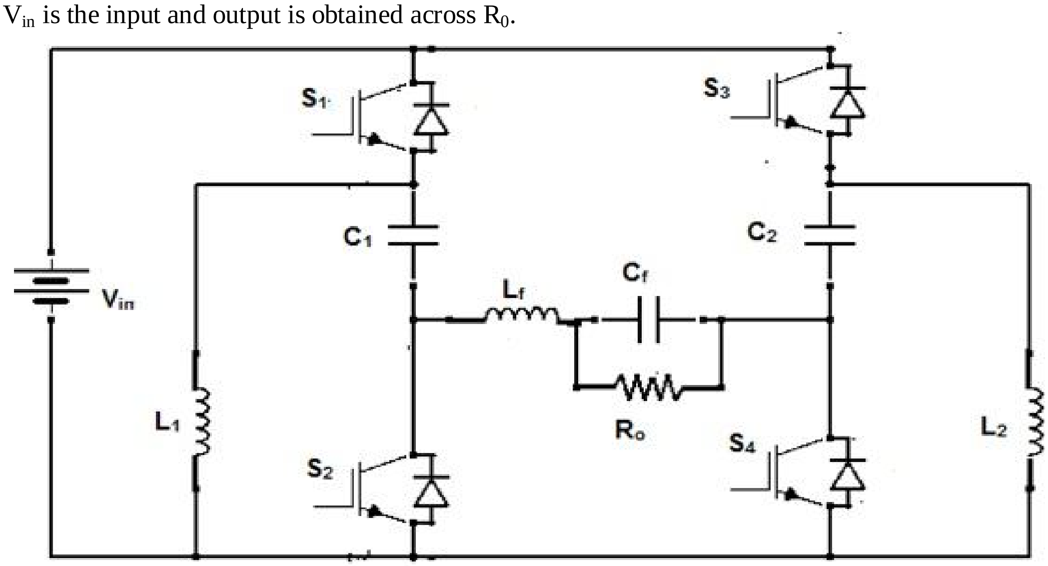

Fig. 6: Step-Up/Step-Down DC AC Converter

Operation: There are two stages of operation for this circuit. The switches S_1 and S_4 are on in stage 1 and S_2 and S_3 are off. In stage 2, switches S_1 and S_4 are off and S_2 and S_3 are on. The duty ratio is defined the time switch S_1 (and S_4) divided by the switching period. For each duty ratio, output voltage of certain magnitude is obtained. For duty ratio greater than 0.5, positive output voltage is obtained and for duty ratio lesser than 0.5, negative output voltage is obtained. Hence duty ratio can be varied symmetrically around 0.5 as in case of boost inverter mentioned in section V. Pulse width modulation is used for the switching of signals. The duty ratio can be changed in a range according to the output requirement.

Advantages: The circuit involves only four switches. The topology is similar to voltage source inverter. The control is easier as the required gain can be used to vary the duty ratio. The control involves only output voltage control.

Applications: This single-stage topology can be used for industrial applications like induction heating as high frequency output can be obtained by using proper modulation.

VII.CONCLUSION

The paper explained about the DC-AC converter (single-stage and multi-stage) topologies used to obtain an output AC voltage which is greater than input DC voltage.

Section I explained about the multi-stage and single-stage topologies and section II covered about the works done in the area. Section III and section IV dealt about the multistage (DC-DC-AC) converters to obtain the desired output. And sections V and VI explained the single stage topologies. Multistage topologies showed an increase in the number of switches while single stage topologies require minimum number of switches. But multistage topologies are easier to design and control. However, the inverter mentioned in section VI is easier to control as compared with that in section V.

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