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Active Buck-Boost Inverter for Inverter Air Conditioner Applications

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ABSTRACT: This paper introduces an active buck-boost inverter with various line conditions and working in both buck and boost modes. Inverter is developed with full bridge and boost AC/AC unit. The circuit is composed of active switches and both stages share the same inductor and capacitor. This inverter gives a high efficiency and low cost. It is used in inverter air conditioner applications. This closed loop control scheme provides low power consumption. Operational analysis of both buck and boost modes are presented, and the modulation applied in the ABI(Active buck-boost inverter) is also developed. Simulation results are included to verify this topology.

KEYWORDS*:* Buck-boost inverter; AC/AC unit; inverter air conditioner.

I.INTRODUCTION

Nowadays the demand for air conditioner has grown significantly. So the amount of power consumption in houses and offices has increased rapidly mainly because of a change in the current lifestyles. In particular, power consumption is dominant in the summer season when the supply of electricity is tight. Thus, it is clear that the maximization of air conditioner efficiency can lead to significant energy saving. The traditional air conditioners regulate temperature by switched on or switched off entirely. It is done by using a compressor. Inverter air conditioners have a variable-frequency drive that incorporates an adjustable electrical inverter to control the speed of the motor and thus the compressor and cooling output. [1]-[3]

The inverter air conditioner uses a rectifier to convert the incoming alternating current to direct current and then uses an electrical inverter to produce AC of a desired frequency. The variable frequency AC drives an induction motor. And the line voltage is varying in a wide range [4],[5]. Inverter control is used towards the reduction of power consumption of the electrical air conditioner.

For the power conversion of dc-ac there are different types of inverters, like voltage source inverter, current source inverter etc. They perform either buck or boost conversion.

To overcome these limitations of only voltage buck conversion, or voltage boost conversion a number of modifications have been developed. Z-source inverter [6] employs an impedance network for connecting the power source main converter and the load. ZSI allows shoot through of the inverter switches. ZSI has a diode and an “X”-shaped impedance network between the dc source and the inverter. A one stage buck–boost inverter without a line frequency step-up transformer [7], has an isolated transformer to step up the voltage, this structure increases the system volume, weight, and cost. The diode-assisted buck–boost VSI can perform a wide-range buck-and-boost conversion with additional passive and active elements [8], has a unique X-shaped diode-capacitor network. The switched boost inverter is introduced with the Z source inverter and less inductors and capacitors [9], is composed of an active switch and diode. SBI has only one *L-C* pair which leads significant reduction in the size, weight and cost. The boost factor of SBI is (1-D) times that of ZSI it is the major drawback of SBI. In Trans-Z-source inverter, [10] the entire impedance network consist of a capacitor and transformer, it reduces the voltage stress. Switched inductor quasi Z source inverter, [11] has more number of inductors, capacitors, diodes and reduced passive components. These types of inverters create a double stage cascade structure. It is very complex and difficult to control. The cascade structure has low efficiency and stability.

The previous solutions introduce additional transformer or passive components to boost its voltage, which means reduced system compact and expensive cost. To overcome the problems of traditional solutions in buck–boost inverters, this thesis presents an active buck–boost inverter (ABI) and its control method. "Active Boost Network," is used to boost the voltage in ABI circuit. ABI performs the voltage buck and boost conversion in a quasi-single-stage inverter, and has the advantages of compact structure, improved power density, and efficiency.

In a control system, a sensor monitors the system output and feeds the data to a controller that adjusts the control to maintain the desired system output. A closed loop control has high reliability, easy implementation and output short circuit and overload protection.[21]-[25]

In this paper we are going to discuss about the control of active buck-boost inverter. Section II describes about the circuit and Section III describes about the operating principle. Section IV deals with the design and section V with the simulation results. Section VI deals with the conclusion.

II.NEW TOPOLOGY

Fig.1 shows the proposed inverter topology. The ac/ac unit performs the boost operation, which is composed of active switches only. And the buck operation is realized with the help of full bridge switches. Both the units sharing the same inductor and capacitor. Only one power processing stage is exists in the proposed topology; thus it can be seen as a quasi-single-stage buck-boost inverter.

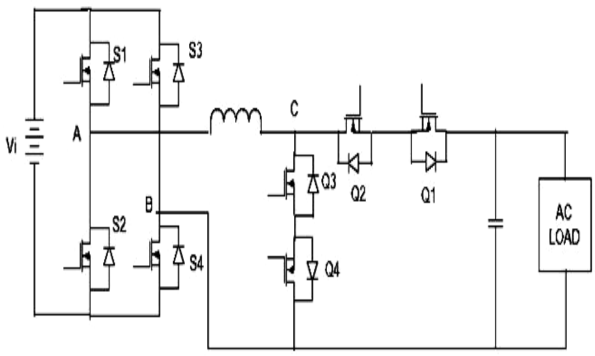

Fig. 1. Active buck–boost full-bridge inverter.

III. OPERATING PRINCIPLE

The proposed inverter consists of two modes of operation. One is the buck mode and the second is the boost mode. For buck operation sinusoidal pulse width modulation is applied on the full bridge switches, and the fundamental output voltage of the bridge is noted as,

$$v_{AB\_F} = MV_i \sin \omega t \quad \ldots(1)$$

Where *M* is the modulation ratio; the SPWM voltage is boost by the ac/ac unit, while sharing the same inductor with the dc/ac unit. The equivalent input voltage of the ac/ac unit can be represented as v_{AB_F}, and the operating principle of the ac/ac unit is the same as the boost ac/ac converter.

The output voltage of the ac/ac unit is given by,

$$v_o = \frac{v_{AB\_F}}{1-d} = \frac{MV_i \sin \omega t}{1-d} \quad \ldots(2)$$

where d is the duty ratio of Q_3 (positive half-cycle) or Q_4 (negative half-cycle); representing $(1 - d)$ with d', i.e., d' is the duty ratio of Q_1 (positive half-cycle) or Q_2 (negative half cycle), we can obtain

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$$\frac{v_o}{V_i} = \frac{M \sin \omega t}{d'} \quad \ldots(3)$$

As can be seen, the output voltage can be modulated with two parameters: *M* and d', and the ac/ac unit.

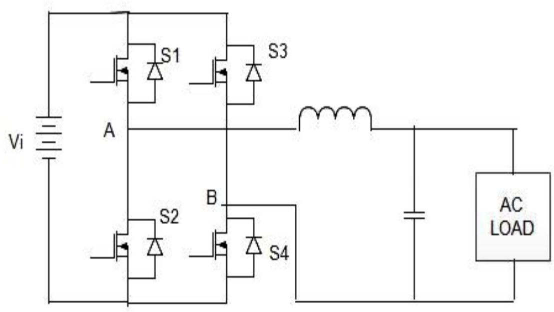

Fig. 2. Equivalent circuit of the ABI in the buck mode.

A.Buck Mode

When the input voltage is high enough to get the desired output, the ABI operates in the buck mode to realize the voltage step down. In this condition, d' is set to 1; therefore, Q_1 and Q_2 are always turned on, while Q_3 and Q_4 are switching in line frequency. The equivalent circuit of the ABI is the VSI, as shown in Fig. 2.

SPWM schemes can be adopted with,

$$v_o = M V_i \sin \omega t \quad \ldots(4)$$

B.Boost Mode

When the input voltage is low and not enough to get to the desired output, the ABI operates in the boost mode. In this condition, M is set to 1, d' is adjusted to boost the voltage; the output voltage can be calculated as

$$v_o = \frac{V_i \sin \omega t}{d'} \quad \ldots(5)$$

In the output positive half-cycle, Q_2 and Q_4 are always on, while Q_1 and Q_3 are modulated in complementary, as shown in Fig. 3(a). In the output negative half-cycle, Q_1 and Q_3 are always on, while Q_2 and Q_4 are modulated in complementary, as shown in Fig. 3(b).

SPWM schemes are adopted to modulate S_1–S_4, whereas Q_1–Q_4 are modulated the same as in the boost ac–ac converter discussed earlier. With a unipolarity SPWM scheme, in the positive half-cycle, the bridge output voltage v_{AB} is varied with V_i and 0, whereas the voltage after the inductor v_{CB} is varied with v_o and 0.

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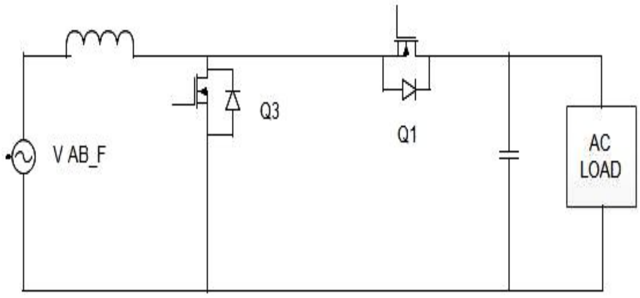
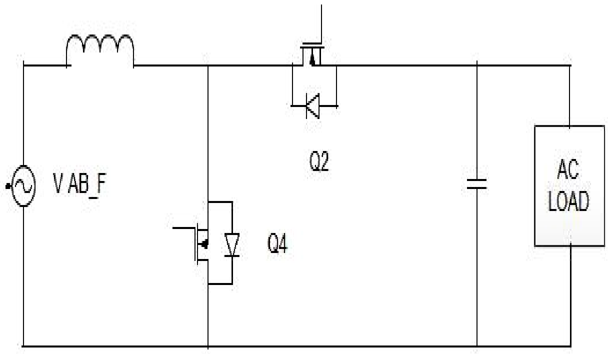


(a)



(b)

Fig. 3. Equivalent circuit of the ac/ac unit. (a) Output positive half-cycle.(b) Output negative half-cycle.

IV.DESIGN

The design of the proposed inverter is done at a power level of 1.5 KVA aiming at high power applications such as inverter air conditioner. The required output voltage is 230V. Various parameters of the inverter have been designed accordingly.

$$Z = R_L + jX_L \quad \ldots(6)$$

$$Z = 2\pi f L_f \quad \ldots(7)$$

$$Z = \frac{1}{2\pi f C_f} \quad \ldots(8)$$

From equation (6) R_L=32Ω and L_L=0.1 mH. And from equation (7) and (8) L_f=1.4 mh, and C_f=12µF.

V. SIMULATION RESULTS

Simulation has been done by using Matlab/Simulink model. The parameters are used as follows: Input voltage V_i = 100-300V dc, Output voltage V_o = 230V, the carrier frequency is set at 20kHz.

Figure.4. shows the switching signals of S_1-S_4. The control strategy used in switches (S_1-S_4) is sinusoidal pulse width modulation. Figure.5. shows the switching signals of Q_1-Q_4. . In this mode, Q_2 and Q_4 are always on in the positive half cycle; Q_1 and Q_3 are always on in the negative half cycle.

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Figure 6 shows the line regulation for the boost operation. Figure 6(a) shows the output voltage when V_i=120V and figure 6(b) shows the output voltage when V_i=160V.

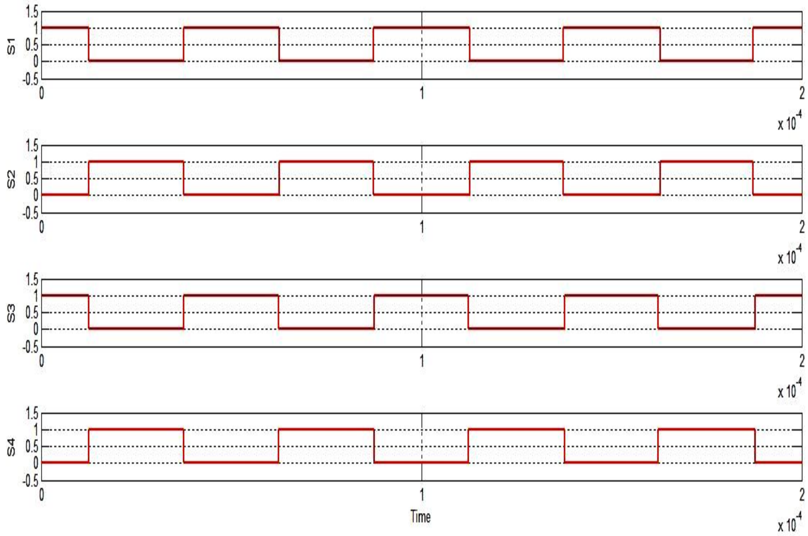

Fig. 4. Switching signals of S_1-S_4

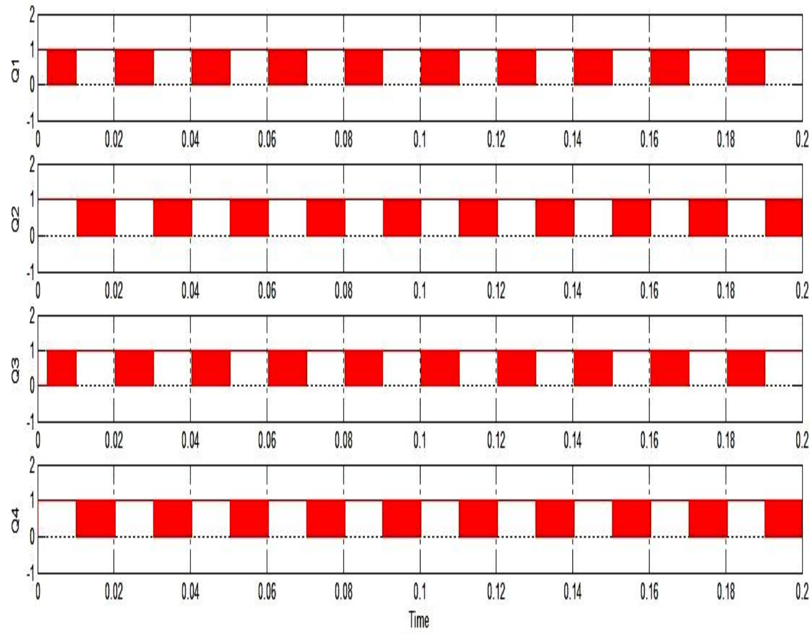

Fig. 5. Switching signals of Q_1-Q_4

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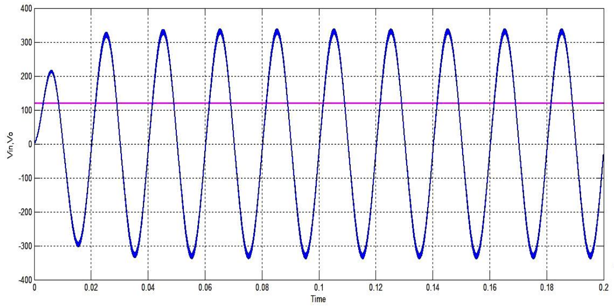
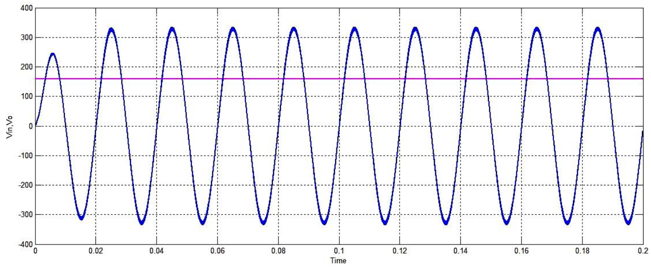
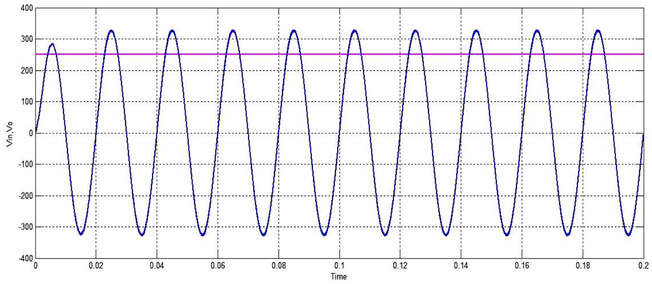


(a)

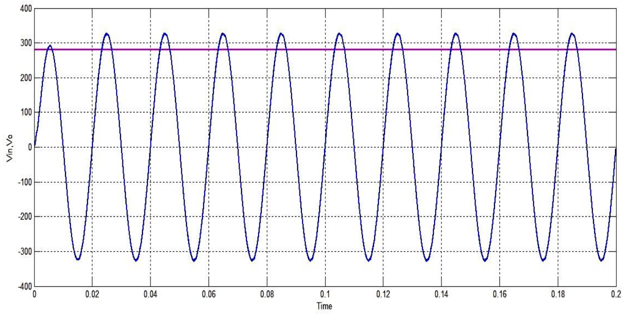


(b)

Fig. 6. Line regulation for boost operation. (a)V_i=120V, (b)V_i=160V



(a)



(b)

Fig. 7. Line regulation for buck operation. (a)V_i=250V, (b)V_i=280V

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Figure 7 shows the line regulation for the buck operation. Figure 7(a) shows the output voltage when V_i=250V and figure 7(b) shows the output voltage when V_i=280V.

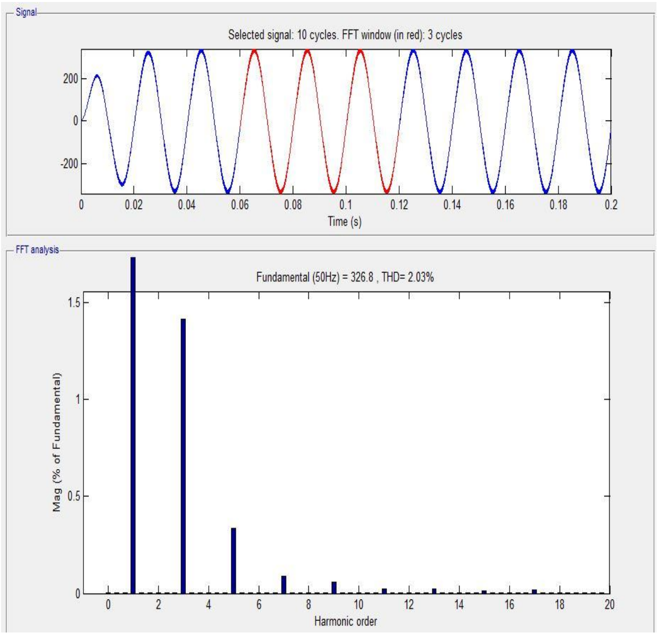

Fig. 8. THD and harmonic order of the output voltage.

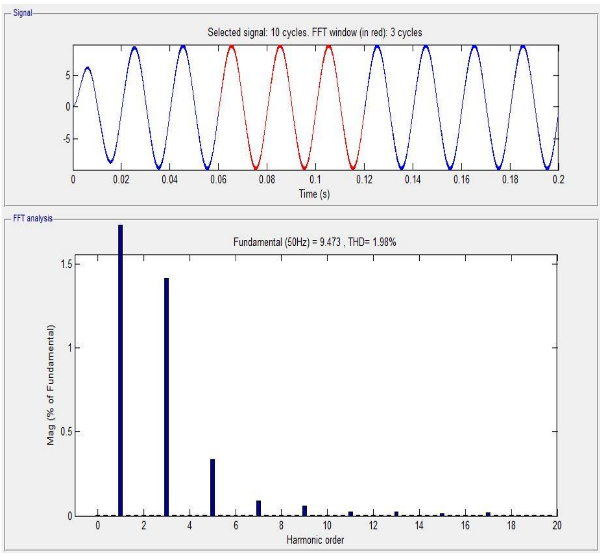

Fig. 9. THD and harmonic order of the output current.

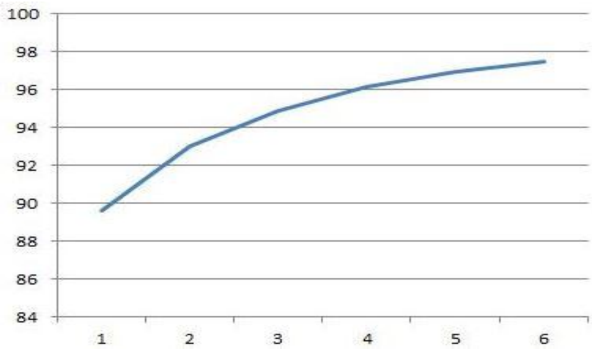

Fig.10. Efficiency curve

Figure.8. shows the THD (total harmonic distortion) and harmonic order of the output voltage and it shows that THD=2.03%. Figure.9. shows the THD and harmonic order of the output current and it shows that THD=1.98%. Figure.10. shows the efficiency curve versus input voltage.

VI.CONCLUSION

This paper has suggested a new active buck-boost inverter which is suitable for inverter air conditioner applications. This inverter achieves both buck and boost mode of operation with a wide range of input. The boost ac-ac unit performs the voltage boost mode. This control scheme achieves good voltage regulation. It is useful in reducing system volume, increasing the system efficiency, reducing the cost and also increasing the system power density. The simulation results of buck and boost modes of operation are developed. This result shows that the ABI can operate in both buck and boost mode.

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