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A Closed loop Single Stage Single Phase Bidirectional Buck-Boost Inverter (SSBBI)

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***Abstract* - This paper presents a closed loop control strategy for the operation of a single phase single stage bidirectional buck boost inverter.The boosting and inversion functions in a single power conversion stage based on buck boost inverter. The boosting is achieved by high frequency switching is about 20khz and inversion is done by fundamental switching frequency of 50hz.The single stage non- isolated inverter topology is more attractive features such as high efficiency, lower cost, less total harmonic distortion and reduced number of components. Analysis and Simulation results are presented to validate the performance of the proposed inverter topology.**

Index Terms:- ***Closed loop buck boost inverter, single stage buck boost inverter.***

I.INTRODUCTION

Voltage source inverters (VSIs) delivering AC power are commonly used in many applications such as uninterruptible power supplies (UPSs), AC motor drivers, and power Conditioning systems (PCSs) [1-3].

The conventional single-phase full-bridge inverter provides continuous and linear control capability of the output frequency and amplitude. However, the conventional VSI is capable to supply only a lower output voltage when compared with the input voltage. Therefore, when a low voltage source is available, a boost converter stage is required at the front-end before the inverter stage [4-7].

The typical solution of the two-stage conversion system, i.e. DC-DC followed by a DC-AC conversion stage, exhibits drawbacks such as being bulky, costly and inefficient due to its cascaded power conversion stages. Other recent developments include topologies that provide boosting and inversion functions in a single power conversion stage based on a Bi directional boost-inverter and a buck-boost-inverter [8-11].

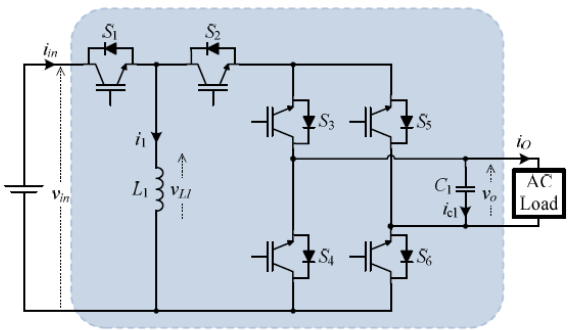
The single-stage non-isolated inverter topologies become more attractive because of the reduced number of components and power stages offering lower cost and more efficient conversion, unless the inverter requires isolation between the input/output. However, the single stage inverter topology [8-11] suffers from the following disadvantages. All the active switches are simultaneously hard switched at high frequency and such operation results in high switching losses. In addition, references [12-14] have proposed for the PV single-stage inverters based on a buck-boost inverter. However, the Topologies [12-14] are not suitable for the bidirectional power flow control.

The objective of this paper is to propose a compact single phase buck-boost-inverter topology providing boosting, inverting, and bidirectional power control capability. The proposed buck-boost-inverter utilizes a front-end bidirectional buck-boost dc-dc converter topology with a full-bridge block including only one inductor and one AC capacitor. The two main switches for the buck-boost stage operate at 20 kHz to produce a fully rectified sinusoidal waveform. The inductor and two buck-boost switches are followed by the fundamental frequency switched full-bridge block which converts the fully rectified sinusoidal waveform to a sinusoidal output. The proposed inverter provides the following features: covering the low and variable input voltage; offering a compact size, low switching losses, bidirectional power control capability; requiring a single inductor and capacitor, few voltage and current sensors, and finally resulting in a low cost solution.

II.OPEN LOOP SYSTEM SSBBI

The open loop single stage single phase bidirectional buck-boost inverter consisting of a single stage boosting and

inversion function. Fig. 1 shows the open loop single-phase bidirectional buck boost-inverter consisting of the front-end buck-boost converter with the full-bridge block. The full-bridge block provides the
Bipolar output capability.



The open loop system has a dc source of 60v input voltage. The switches S1 and S2 are operated at 20kz frequency and S3,S4,S5,S6 are at 50hz frequency which is a fundamental frequency. Capacitor and inductor values are taken based on our design of the output power the total harmonic distortion and efficiency are calculated. the main disadvantage of the open loop system is total harmonic distortion is more is about 4% .By using the closed loop technique the total harmonic distortion will be reduced.

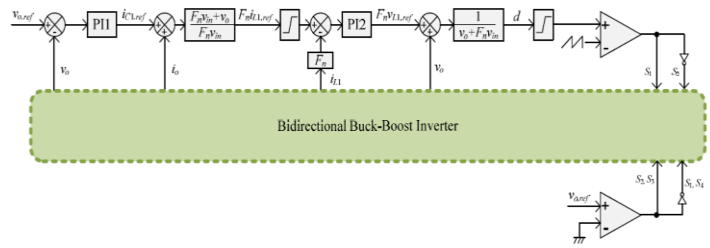
III.PROPOSED TOPOLOGY (CSSBBI) AND CONTROL SCHEME

shows the proposed single-phase bidirectional buck boost-inverter consisting of the front-end buck-boost converter with the full-bridge block. The full-bridge block provides the bipolar output capability and its operation is defined by

$$F_n = \begin{cases} 1, & \text{when } v_{o.ref} \geq 0 \\ -1, & \text{when } v_{o.ref} < 0 \end{cases} \qquad (1)$$

$$v_{o.ref} = A_o \sqrt{2} \cdot \sin(2\pi f_o t) \qquad (2)$$

The closed loop configuration is shown below by using PI controller. where Ao represent the amplitude of the output system. F is frequency of the system. T is the time period for a full cycle. By taking all the parameters the reference voltage is calculated.



The equivalent circuits including the function of the full bridge block (*Fn*) are illustrated in Fig. 2. Especially, Fig. 2(a) shows the negative half-cycle output while Fig. 2(b) shows the positive half-cycle output when the output voltage reference is negative and positive respectively. The power switches *S*1 and *S*2 operate at 20 kHz and the full-bridge switches operate at fundamental frequency. Due to the fundamental frequency full bridge square-wave control, a Thyristor-diode full-bridge can be used for the switches (*S*3-*S*6) to reduce system cost. Fig. 3 illustrates the relationship between the duty cycle and the output voltage reference signals. It also illustrates the relationship between the output voltage reference and the duty cycle to operate the buck-boost-inverter. Based on the averaging concept for the buck-boost-inverter [8, 11], the voltage relationship between the input and the output for the continuous conduction mode (CCM) is given by

$$Vo = \frac{d}{1-d}.Fn.Vin \qquad (3)$$

where *d* is the averaged continuous-time duty cycle. The control method for the buck-boost-inverter is expressed through the following equations. The output voltage *vo* depends on the current through the capacitor *iC*1 and is given by Kirchhoff's current law as:

$$i_{c1}=(1-d).Fn.i_{L1}-i_o=C_1\frac{dVo}{dt} \qquad (4)$$

Where *io* and *iL*1 are the output and inductor currents respectively. From (3) and (4), the inductor current reference *FniL*1*.ref* is expressed by

$$Fn.i_{L1.ref}=(i_{C1.ref}+i_o).\frac{Fn.Vin+Vo}{Fn.Vin} \qquad (5)$$

Which the control variable *iC1.ref* is the reference for the capacitor current [11]. Then, the output voltage of the buck boost-inverter *Vo* is derived from (4).

$$v_o = \frac{1}{C_1}\int i_{C1}dt = \frac{1}{C_1}\int \left((1-d)\cdot F_n i_{L1} - i_o\right)dt \qquad (6)$$

Based on the buck-boost converter characteristics and the inductor current reference equation given in (5), the voltage across the inductor *FnvL*1 is given by

$$Fn.V_{L1}=Fn.Vin.d-(1-d).Vo=L_1\frac{dFn.iL1}{dt} \qquad (7)$$

From (7), the duty cycle can be obtained as

$$d=\frac{Fn.VL1.ref+Vo}{Fn.Vin+Vo} \qquad (8)$$

To achieve the inductor voltage reference *vL*1*.ref* in (8), a PI controller is used based on the inductor transfer function. Eq.(8) also illustrates that the inductor voltage *vL*1 can be observed when the duty cycle *d* is applied to the inverter. Then the inductor current *FniL*1 can be expressed with the input and output voltages *vo* and *vin* by

$$F_n i_{L1}=F_n\frac{1}{L_1}\int v_{L1}dt=\frac{1}{L_1}\int\left(d\left(F_n v_{in}+v_o\right)-v_o\right)dt \qquad (9)$$

In this paper, a double-loop control scheme is used for the buck-boost-inverter control being the most appropriate to cover the wide range of operating points. This control method is based on the averaged continuous-time model of the buck boost topology and has several advantages with special conditions such as nonlinear loads, abrupt load variations and transient short circuit situations [11]. Using the control method the inverter maintains stable operating conditions by means of limiting the inductor current. Because of this ability to keep the system under control even in the situations mentioned earlier, the inverter achieves a very reliable operation [11]. The control block diagram for the proposed buck-boost inverter is shown in Fig. 5. The output voltage reference is compared with the measured output voltage to generate the error signal. The PI2 is for the inner current control loop that should be designed to allow at least 50 º phase-margins and a high bandwidth. The PI1 is dealing with the outer output voltage control loop that should be designed with the same phase-margin and lower bandwidth compared with the inner loop [9, 11].

IV. DESIGN AND CONTROL SYSTEM

The proposed inverter is designed for general home applications of 220v RMS output voltage and the boost/buck stage is operated at 20khz frequency and inverter is operated at normal frequency of 50hz.power electronic switches are taken based on the frequency and power ratings. the inductor and capacitor are designed based on the mathematical equations derived for closed loop operation .the control systems here used was two loops integrals .they are one is voltage controlled PI controller and other one is current controlled PI controller loop. Final system is designed for 1.5kw output power.

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A. Boost stage control

The boost converter is seen in the source to load operation .when source fed to load the first stage is boosting stage their by inverting stage of required output power. we are used to boost the voltage so it is called boost stage control.

B. Buck stage control

This is second stage control also called buck stage control. When the load fed to the source the inverting stage becomes rectifying the output voltage and that rectified voltage will be step down by using buck stage control.

V.SIMULATION RESULTS

In this section the simulation results are presented. The output voltage and the time for open loop and closed loop systems are perfomed.

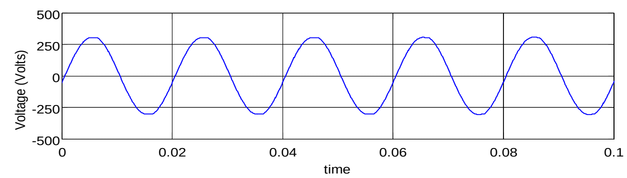

Fig. 6.output voltge for open loop system

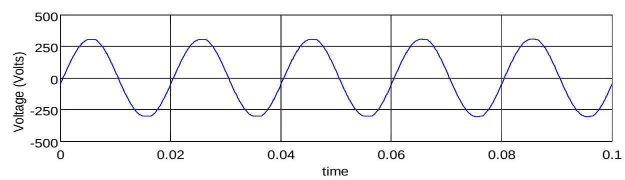

Fig. 7output voltage for closed loop system.

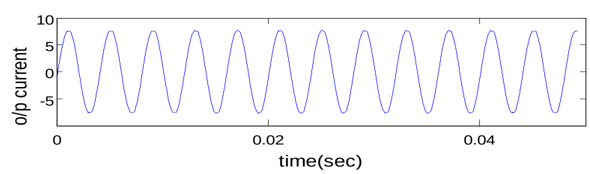

Fig 8.output current for open loop system

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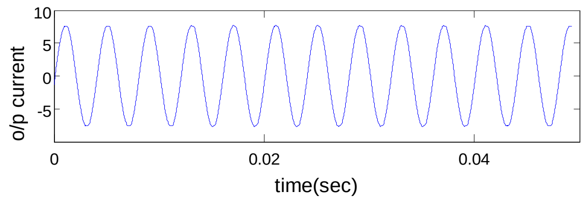

Fig.9. output current for closed loop system

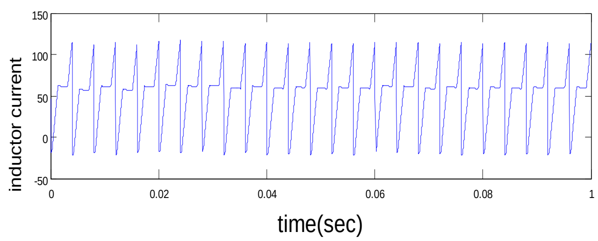

Fig.10.inductor current for both systems

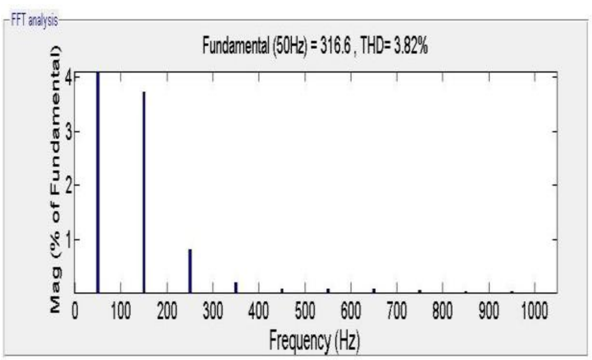

Fig.11 THD for open loop system

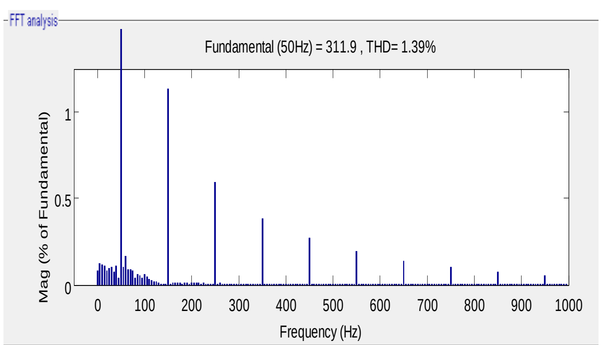

Fig 12.THD for closed loop system

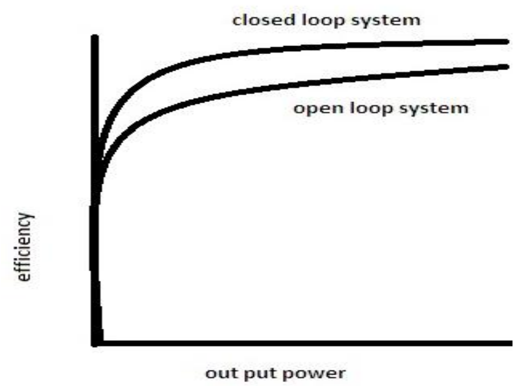

Fig13. Efficiency of the open and closed loop systems

The efficiency and total harmonic distrtion for both open and closed loop system are simulate and results are shown above figures.efficiency of closed loop loop system is incresed and total harmonic distrtion is improved from 3.8% to 1.39 % value.

VI. CONCLUSION

A compact closed loop single-phase bidirectional buck-boost-inverter has been proposed in this paper. The simulation results presented in this paper have verified the operation characteristics of the proposed inverter. The results of the proposed buck-boost-inverter from the laboratory prototype operating at 20 kHz for the two main switches and fundamental frequency for the additional full-bridge switches have confirmed its satisfactory performance for delivering boosting and inversion functions to generate 220VAC from 60VDC. In summary, the proposed buck-boost-inverter has a number of attractive features, such as covering the low and variable input voltage; offering a compact inverter size, low switching losses, boosting and inversion functions, bidirectional power flow control capability, low count of passive components, few voltage and current sensors, less THD value, more efficiency and finally resulting in a low cost solution.

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