MODELLING OF RENEWABLE ENERGY SOURCE FED ACTIVE BUCK-BOOST INVERTER FOR GRID INTERFACE SYSTEMS

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In Renewable energy sources the voltage range is governed by environmental conditions, sunlight. The energy systems must be capable enough for large input voltage and have operation like boosting voltage and vice versa. This article illustrates a single-phase inverter topology as buck-boost inverter which suits with extensive range of variations in the input. The various operating modes, voltage gain, efficiency of inverter is to be properly investigated, with the selection for the turn's ratio with combined inductors, this inverter can be operated under both buck boost operations. In timely operation of duty ratio with AC/AC unit, coupled inductors voltage gain is achieved. Various control strategies of inverter are to be analyzed and compared. The power quality issues when renewable energy sources are integrated with grid through buck boost inverter are discussed. The mitigation of various power quality problems is to be designed and tested.

Keywords: AC/AC unit, Buck-Boost, Coupled inductors, efficiency

1. Introduction

With the progress of engineering technologies there is a enormous change industries and other wide spread zones. As a result, there is a big thrust for energy, it has become the important factor of human needs and management of energy is critical factor too. Consequently, as energy sources are exhausting, it is essential to make a focus towards renewable resources. Photo voltaic conveys prior attention compared to other sources because of availability and low maintenance cost. The power obtained from solar panel or PV cell is not fixed as it changes due to environmental conditions, availability of sun light, so in order to connect the power obtained from RES to grid is difficult.

In general, there are two conventional inverters: VSI and CSI. The VSI can only perform only voltage buck operation, whereas the CSI performs boost operation. The voltage value of photovoltaic cell varies rapidly. The inverter should carry out both buck and boost operations. When output is less with input fed DC source Full Bridge Inverter (FBI) is usually utilized. In order to get

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overcome from the complexity, the solutions are to append transformer, it increases the system size, expenditure. Latter one is employing 2 step structures. This configuration requires inductors and capacitors; it is not productive to the incorporation. This arrangement has instability and less efficiency [1]-[2]. In recent times different voltage regulation topologies had been discussed.

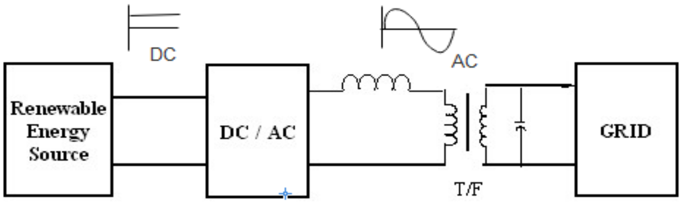

Fig. 1 Transformer fed Conventional Inverter.

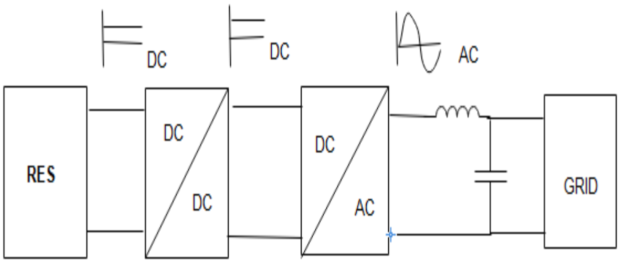

Fig. 2 Two stage converter structure.

The voltage can be boosted up with addition of passive elements to Z source inverter can [3]-[14]. Single step buck and boost inverter without a transformer is proposed [10]. With distribution of switches in the two step conversions, supplementary devices like active components and eliminated and passive components remain same.

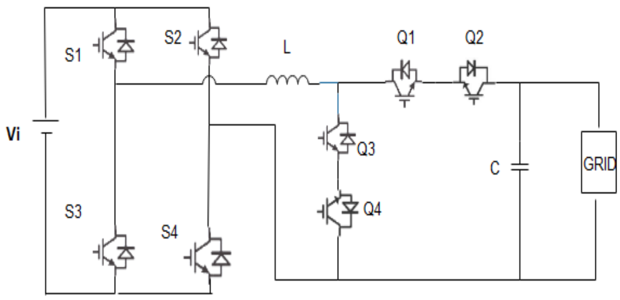

Fig. 3 Conventional inverter.

The VSI diode assisted inverter can perform both buck –boost operations with incorporating active and passive components [11]. A switching inverter with boost conversion is proposed. with a analogous voltage gain compared to ZSI and fewer passive elements [13]. This configuration shows the similar two step conversions structure, although they are not considered as a single step inverters. The problems of conventional solution in buck-boost inverters can be overcome, a single stage converter is proposed an inverter with buck and boost operation incorporation of active components (ABI) and its controlling methodologies. This Inverter be capable of regulating the voltage in two modes.

2. Analysis of the circuit

The inverter is depicted in fig 4. A boost up AC unit is added to circuit instead of transformer to boost the voltage. whereas the inverter unit performs voltage regulation operation. This circuit has two parts, one is conventional H-bridge inverter part (DC/AC) and the latter is active part for AC/AC conversion depicted in fig. 5. The boosted output power which is obtained after ac unit is then converted to 3 phase which is suitable for grid.

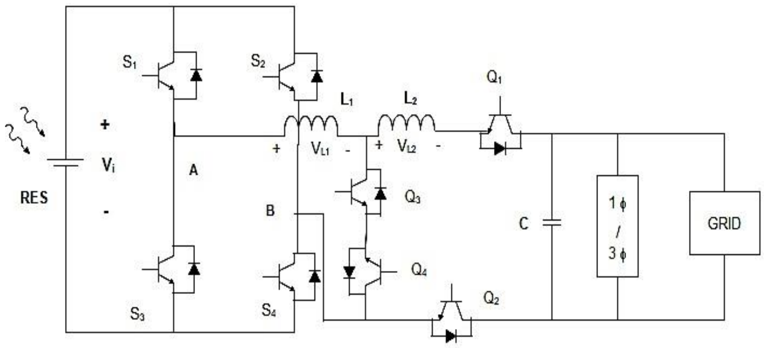

Fig. 4 Structure of proposed Inverter

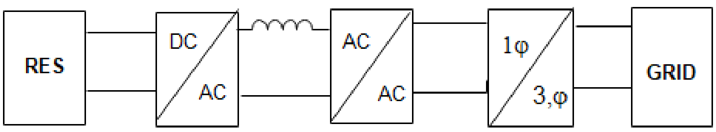

Fig. 5 Outline of work

Here first block converts the DC voltage to AC voltage and fed to sub sequent block of AC-AC to boost. The operation can be achieved by modifying switches duty ratio, and AC to AC unit able to be as transformer. SPWM technique applied to full bridge part and voltage amplitude is constant as shown in fig 3. The primary component of voltage output (Vo) peak is governed by degree of modulation, M.

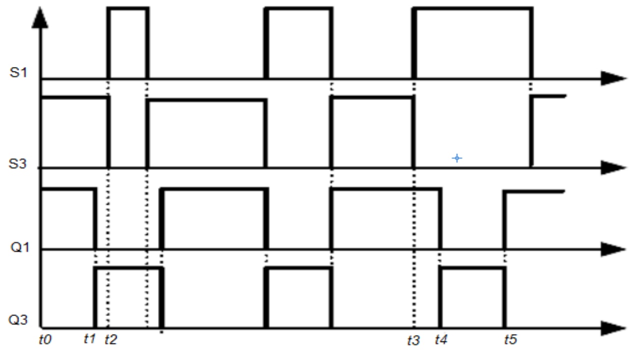

Fig. 6 Gating signals of switches

When voltage of full bridge inverter $V_{AB} > 0$, the switches Q2, Q4 are always on and Q1, Q3 are complementary on. Otherwise Q1, Q3 are always on and Q2, Q4 are complementary on and the respective equivalent circuits of both are indicated in Fig.7 (b).

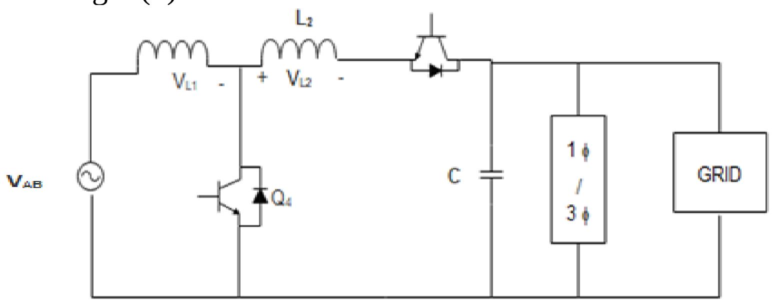

Fig. 7(a) Equivalent circuit when Vab> 0

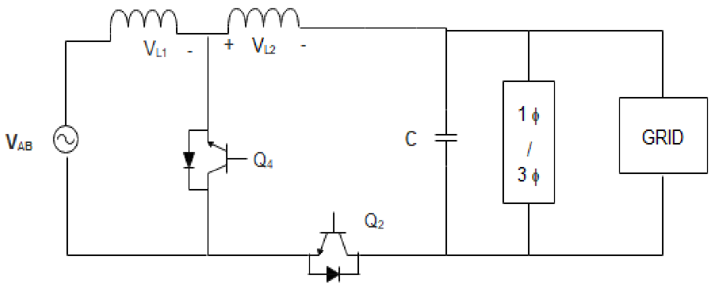

Fig. 7(b) Equivalent circuit when Vab<0

3. Operating modes

3.1 Buck Operation

If applied voltage V_i is larger compared to referred yield voltage V_{op}, the configuration works in buck mode as Q1, Q2 be always on where Q3, Q4 switches turned rotten. Here AC-AC unit will be in off state, coupled inductors forms of series. Hence the configuration is equals to single phase inverter with LC filter as depicted in Fig.8

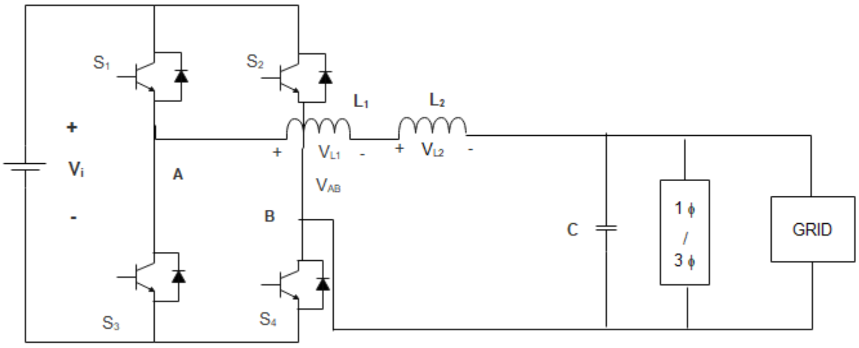

Fig. 8 Counterpart path in buck operation

Duly changing degree of modulation M, the system produces a preferred voltage:

$$V_o = V_{op}\,\mathrm{Sin}(wt) = V_i M\,\mathrm{Sin}(wt) \tag{1}$$

So,

$$M = \frac{V_{op}}{V_i} \tag{2}$$

3.2 Boost Operation

In case of applied voltage V_i is low compared with peak value of V_{op}. The configuration works in boost where AC-AC unit takes place by altering switching frequency and time duration of Q3/Q4. Fig shows corresponding operation circuits. The indicator forms L1, L2 are N1,N2. So turns ratio n=N2/N.

a) Mode1: Switches S3, S4, Q1, Q2 and Q4 are twisted to work and corresponding path is as below in Fig. 9(a).

Voltage across inductors is given by

$$V_{L1} + V_{L2} = -V_o \tag{3}$$

The voltage stress of Q3:

$$V_{Q3} = -V_{L1} = \frac{V_o}{1+n} \tag{4}$$

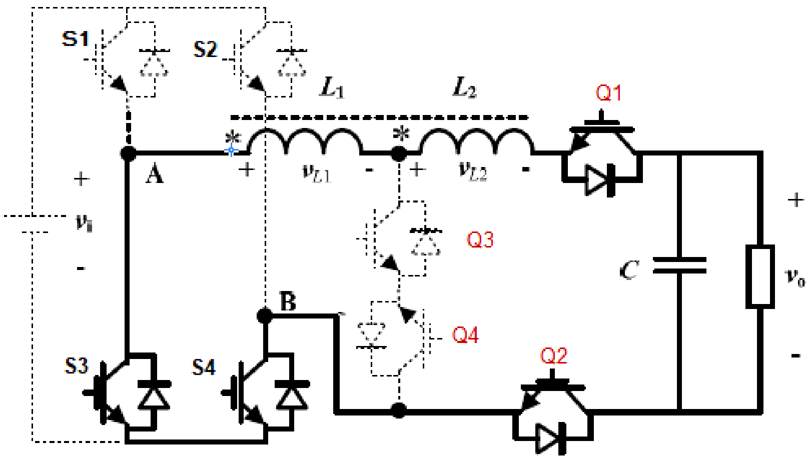

Fig. 9(a) Operating mode 1

b) Mode2: Switches S3, S4, Q2, Q3 and Q4 are on, corresponding path is below in Fig. 9(b).

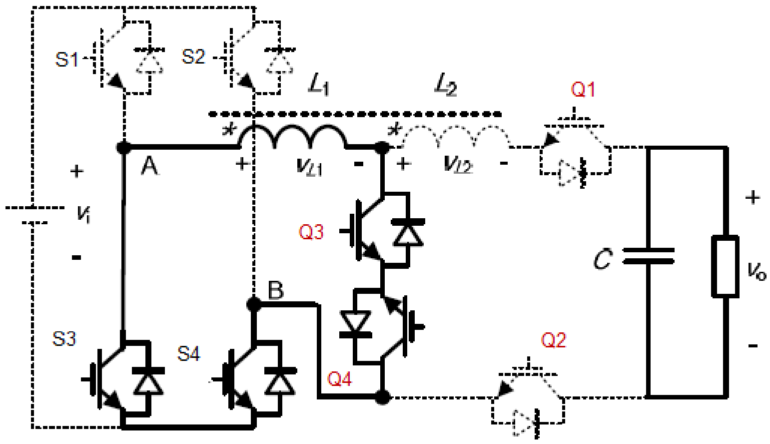

Fig. 9(b) Operating mode 2

The voltage of the inductors:

$$V_{L1} = V_{L2} = 0 \tag{5}$$

voltage pressure of Q1:

$$V_{Q1} = V_o \tag{6}$$

c) Mode 3: Switches S1, S4, Q1, Q2 and Q4 twisted to work and corresponding lane as below in Fig. 9(c).

Voltage across the inductors:

$$V_{L1} + V_{L2} = V_i - V_o \tag{7}$$

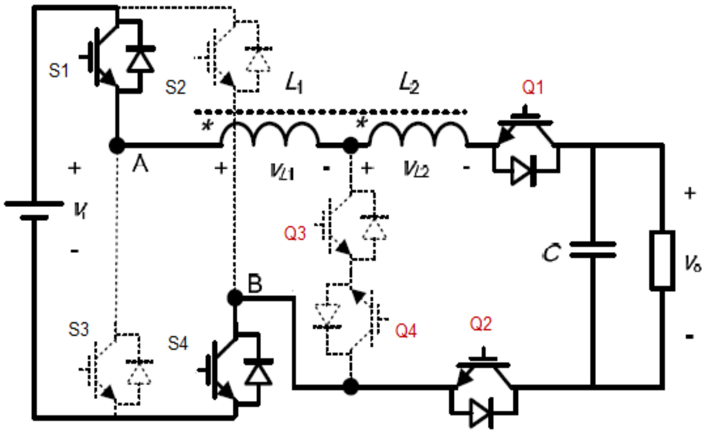

Fig. 9(c) Operating mode 3

The voltage pressure of Q3:

$$V_{Q3} = V_i - V_{L1} = \frac{V_o + nV_i}{1+n} \tag{8}$$

d) Mode 4: Switches S1, S4, Q2, Q3 and Q4 twisted to work and corresponding path is as below in in Fig. 9(d).

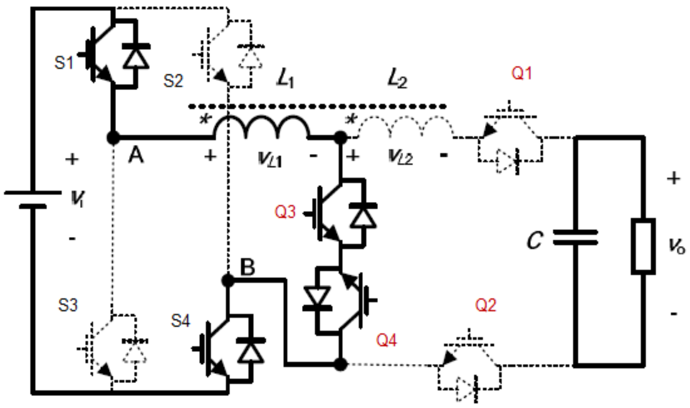

Fig. 9(d) Operating mode 4

The voltage of the inductors:

$$V_{L1} = V_i \tag{9}$$

The voltage stress of Q1:

$$V_{Q1} = V_o + V_{L2} = V_o + nV_i \tag{10}$$

4. Single phase to three-phase conversion

Difficulty in conversion of 1ϕ AC to 3ϕ AC exists for a long time. In various departments like railway, industrial power systems engineering. In some areas like hill station it is necessary to convert into 3 phase for supply to machines, and railway, electric power locomotives. Two stage inverters are largely used but disadvantage is of high cost, less reliable, maintenance difficult. There is urgent need to find alternate sources to solve 1ϕ to 3ϕ conversion technologies, based on research works a new technology were developed in some way. The conversion circuit for 1ϕ to 3ϕ if power factor < 60^0 be shown below in fig.10 is known as capacitor and inductance converting way.

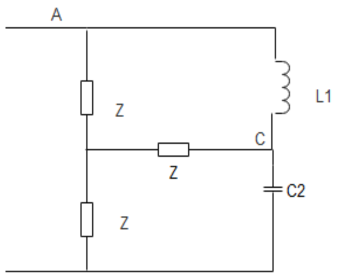

Fig. 10 Conversion circuit

Here output voltage degrees are equal and phase angle is also 120^0 there are following formulas:

$$\frac{1}{wL1} = \frac{\sin\varphi(\sqrt{3}\cos\varphi - \sin\varphi)}{3X} \quad (11)$$

$$wC2 = \frac{\sin\varphi(\sqrt{3}\cos\varphi + \sin\varphi)}{3X} \quad (12)$$

The controlling method of 1Φ to 3Φ conversion are given by equations (11) and (12), the SIMULATION is as below in fig. 11 at power factor ϕ > $60^{0.}$

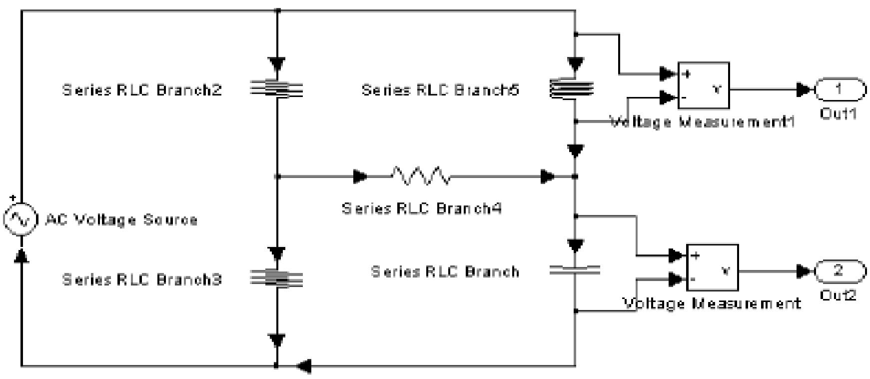

Fig. 11 Simulation of 1Φ to 3Φ

5. Simulation results

The simulation parameters and its values range are tabulated as below in Tab.1

Table 1

Simulation parameters

S.No	Constraint	Range
1	Input voltage (*V*i)	50-200V
2	Output voltage (*V*o)	110V/415V
3	Inductors $L1$: $L2$	$300\mu H : 300\mu H$
4	Capacitor C	$30\mu F$

Fig.12 and Fig.13 shows the simulation result under buck state during V_i is 200V. The Q1, Q2 switches are in on state all the time and Q3, Q4 are correspondingly on resulting in AC/AC unit with coupled inductors is off state. Fig.14 and Fig.15 shows simulation results under boost operation at V_i 50V during which Q1-Q4 are turned on to boost the input Fig. 18 and Fig.19 shows the THD parameters for both conventional and proposed models of boost operation.

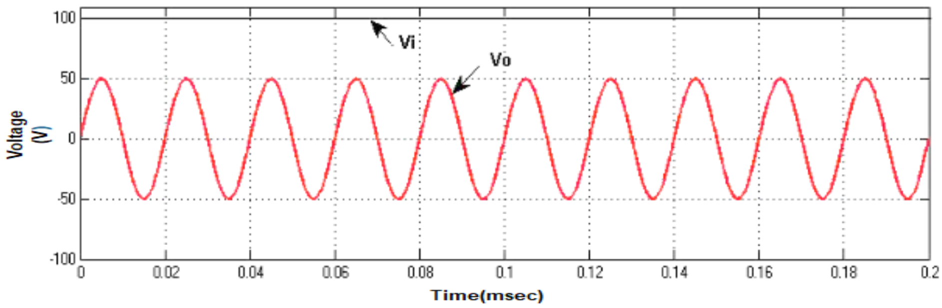

Fig. 12 Vo and Vi in Buck mode

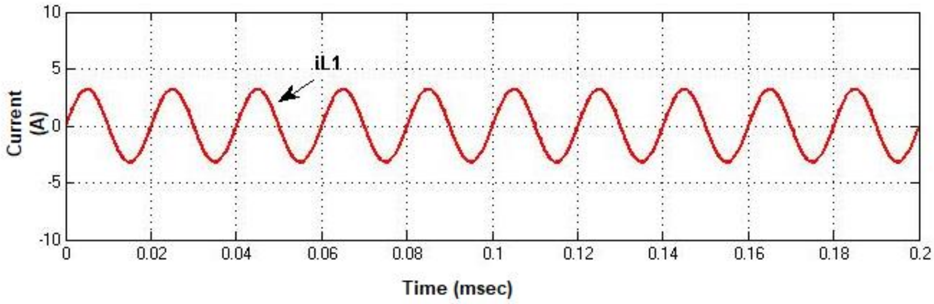

Fig. 13 Inductor current (i_{L1}) in Buck Operation

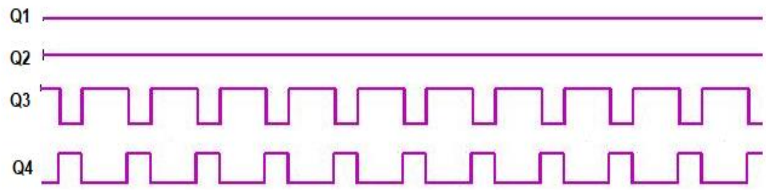

Fig. 14 Gating signals in Buck Operation

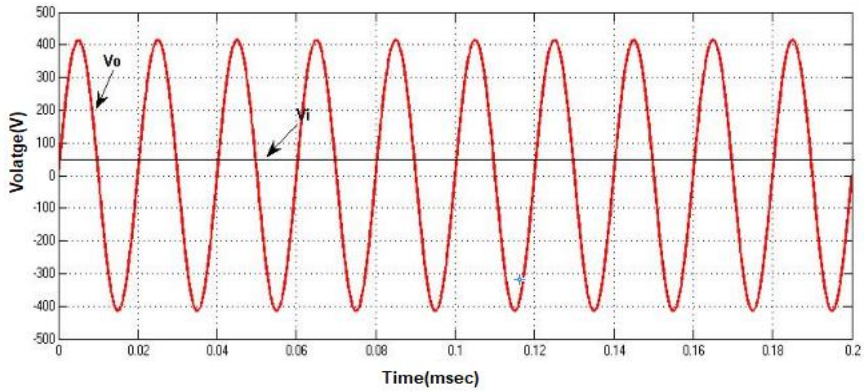

Fig. 15 V_o and V_i in Boost Operation

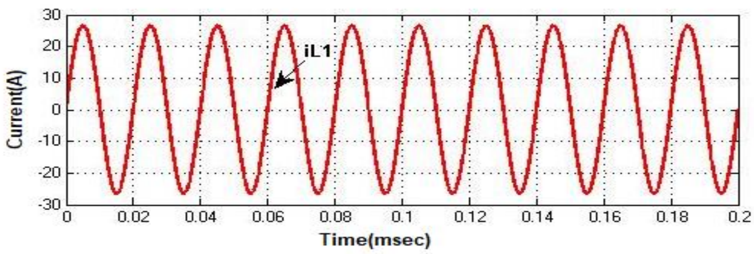

Fig. 16 Inductor current (i_{L1}) in Boost Operation

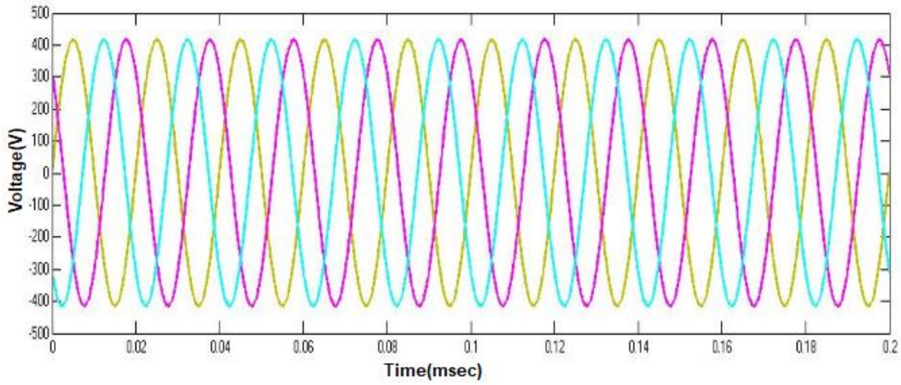

Fig. 17 Three phase power conversion

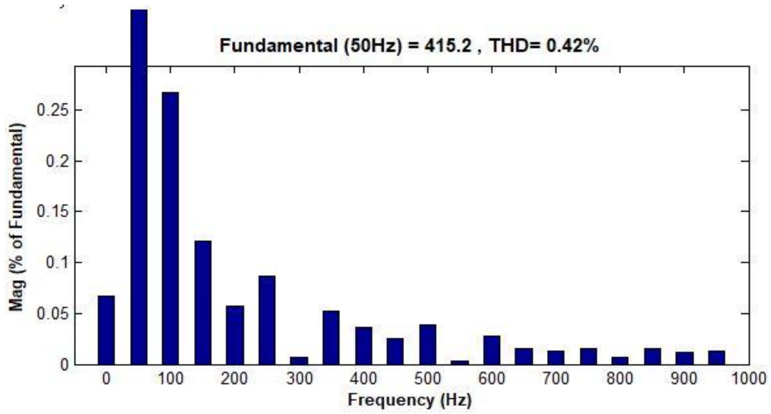

Fig. 18 THD of Conventional Boost model

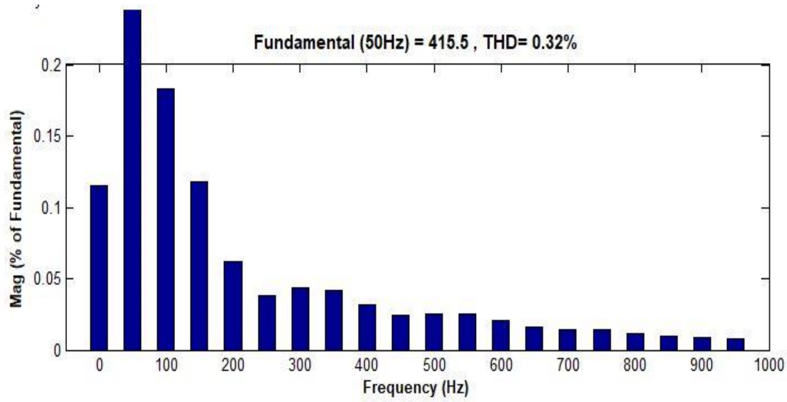

Fig. 19 THD of Proposed Boost model

Table 2

THD parameters

Parameter	Conventional	Proposed
Boost Model - THD	0.42%	0.32%

The above table 2 shows the THD values for buck and boost modes of proposed model.

6. Conclusions

A novel Inverter is projected in this article. The circuit, working theory, strategies are discussed. Switches are used in order to have voltage regulation exclusive of passive elements. Hence maximum density of power and regulation are gained. Simulation results are presented with buck and boost operation for input voltage are presented.

REFERENCES

[1] *S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg*, "A review of single-phase grid-connected inverters for photovoltaic modules," IEEE Trans. Ind.Electron., vol. 41, no. 5, pp. 1292–1306, Sep. 2005.
[2] *Z. Zhao, M. Xu, and Q. L. Chen*, "Derivation analysis and implementation of a boost–buck converter-based high-efficiency PV inverter," IEEE Trans. Power Electron., vol. 27, no. 3, pp. 1304–1313, Mar. 2012.
[3] *P. C. Loh, F. Blaabjerg, and C. P.Wong*, "Comparative evaluation of pulse width modulation strategies for Z-source neutral-point-clamped inverter," IEEE Trans. Power Electron., vol. 22, no. 3, pp. 1005–1013, May 2007.
[4] *P. C. Loh, D. M. Vilathgamuwa, and Y. S. Lai*, "Pulse-width modulation of Z-source inverters," IEEE Trans.Power Electron., vol. 20, no. 6, pp. 1346–1355, Nov. 2005.
[5] *ZHANG Ge-xian*, "The theory scheme and comparing analysis of one phase AC to three phase AC,", Shengyang: Transformer, 1991, 28(9):24-26
[6] *CHEN Shi-long, LI Qun-zhan*, "The one phase to three phase converter based on TCR," China, applilied and new patent: CN2904464.
[7] *F. Z. Peng*, "Z-source inverter," IEEE Trans. Ind. Appl., vol. 39, no. 2, pp. 504–510, Mar/Apr. 2003.
[8] *T. Kerekes, R. Teodorescu, P. Rodriguez, G. Vazquez, and E. Aldabas*, "A new high-efficiency single-phase transformer less PV inverter topology," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp.184–191, Jan. 2011.
[9] *A. R. Borges and I. Barbi*, "Three-phase single stage AC-DC buck-boost converter operating in buck and boost modes, " in Proc. Brazilian COBEP , Sep. 11-15, 2011, pp. 176-182.
[10] *Jain S and Agarwal V*, "A single-stage grid connected inverter topology for solar PV systems with maximum power point tracking," IEEE Trans. Power Electronics, vol.22, no.5, pp.1928-1940, Sept. 2007.
[11] *Rong-Jong Wai and Rou-Yong Duan*, "High Step-Up Converter with Coupled-Inductor," IEEE Trans. Power Electronics, vol.20, no.5, pp.1025-1035, Sept. 2005.
[12] *T. Kerekes, R. Teodorescu and U. Borup*, "Transformer less Photovoltaic Inverters Connected to the Grid," in APEC, Anaheim, 2007, pp. 1733-1737.
[13] *Yu Tang, Yaohua He, Xianmei Dong and Shaojun Xie*, "Research of a Single-stage Buck-Boost Inverter under Dual Mode Modulation," in IECON, Vienna, 2013, pp. 1230 - 1235.