ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization Vol. 4, Special Issue 1, March 2015

National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE 2015)

Organized by

Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India
On 26th & 27th March 2015

A Novel Transformer Less Boost/Buck DC-AC Converter with Current Control

Amrutha Mohan [1], Aswathy Rajan [2]

PG Student [Power Electronics], Dept. of EEE, Jyothi Engineering College, Thrissur, Kerala, India [1]

Assistant Professor, Dept. of EEE, Jyothi Engineering College, Thrissur, Kerala, India [2]

ABSTRACT: This paper introduces a new transformer less dc–ac converter with the feature that it produces an instantaneous output voltage higher or lower than the input dc voltage. The topology consists of two switching cells, well known dynamic response, does not have transformer or power conversion stage that saves us mass, losses, and volume of a transformer. The merits of step up/step down dc-ac converter includes operational reliability, reduced size of components and there by acquiring less mass for the whole converter. The advantages of buck-boost dc-ac converter when switching cells are used instead of a transformer, is also introduced. Current control takes the advantage of circuit protection from disturbance (fault). This technique can provide fast dynamic response, robust Performance. The current control of step up/step down dc-ac converter is easy to implement and provides high accuracy. The validity and performance of the discussed topology are verified by simulation using Matlab/simulink software.

KEYWORDS: Buck-Boost inverter, switching cell, Transformer less, current control

I.INTRODUCTION

One of the most commonly used converters in power electronics is the dc/ac converter (inverter) .It is used in applications such as uninterruptible power supplies (UPS), active filters, motor control, etc. Inverters can be classified as isolated or non isolated inverters based on the electrical isolation between the input and output [6].Electrical isolation is normally achieved using either line-frequency or high-frequency transformers [1-6]. The various dc voltages are applied to the input of the inverter because of the new energy sources, like solar batteries and fuel cells, which produce different dc-voltage levels. Depending on the input dc voltage range, to that of the output ac voltage, inverters can be classified as buck, boost and buck–boost inverters [3]. For single-stage inverters, the traditional H-bridge inverter has a simple circuit topology and a low component count. Thus low cost and high efficiency can be attained. [3-6].

One of the characteristics of the buck inverter is that the instantaneous average output voltage is always lower than the input dc voltage [11-17]. Buck inverter is a dc-ac converter which cannot produce an output voltage greater than the input voltage, but it is easy to be controled .This converter performs in a simplified way, turning on and off the switches to produce a bipolar square output voltage. The boost inverter provides an outstanding property. It produces an ac output voltage which is larger than the dc input voltage, based on its duty cycle [2-4]. This property is not found in the traditional full bridge buck inverter which produces an instantaneous ac output voltage always lower than the input dc voltage.

Z-source inverter provides the same features of a dc–dc boosted inverter (i.e., buck/boost). The Z-source inverter has two capabilities such as, shoot-through duty cycle and modulation index. But the drawback of Z-source inverter is that the Z-source inverter has lower average switching device power in low boost ratio range [9-12]. According to the principles of boost and buck–boost well known in dc–dc conversion, these inverters use dc inductors for energy storage or fly back transformers for both energy storage and electrical isolation as required for safety reasons. So instead of transformers, by using switching cells this topology is introduced.

Inverters are usually operated in step down condition. If an output voltage greater than input voltage is required. Then buck-boost inverters are used. But it requires an intermediate power stage or transformer. So dc-ac converters with this circuitry are complex. In order to solve this problem, Step up / Step down dc-ac converter with switching cells is

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization Vol. 4, Special Issue 1, March 2015

National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE 2015)

Organized by

Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India

On 26th & 27th March 2015

introduced. There by boost and buck conditions are satisfied with a transformer less system. The closed loop circuit naturally has a common voltage-loop-control circuit. But if there is any overloading condition or fault appears in the circuit. The current must be controlled. Therefore the circuit protection should be provided by implementing current control.

During the time of fault, to avoid distortion of current and voltage waveforms at high power levels, current control is required. Current control can reduce short-circuit currents, from the existing distribution equipment. They can also be used in high voltage electric power transmission grids for a similar purpose. This paper presents a scheme of current control for rejecting the disturbance (fault) effectively in a buck-boost topology. Closed loop control of step up/ step down dc-ac converter using the current control is presented with simulation of the dc-ac converter using current control.

II. OPERATION PRINCIPLE AND CONTROL OF CONVERTER

Transformer less buck-boost inverter is formed by connecting two switching cells. Circuit diagram of the converter is shown in Fig.1. Note that by referring to Fig.1, This structure consists of an input voltage source Vi, a high frequency filter formed by L_f and C_f, a load resistance R0, and two switching cells, whose elements are S1, D1, C1, S2, D2, and L1 and S3, D3, C2, S4, D4, and L2, respectively. When S1, S4 are turned on then L1 starts charging, L2 starts discharging, C2 starts charging, C1 starts discharging. When S2, S3 are turned on L1 starts discharging, C1 starts charging , L2 starts charging , C2 starts discharging.

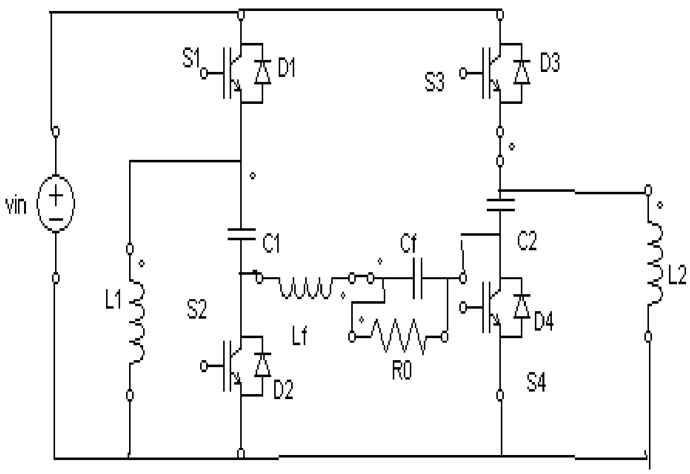

Fig.1. Transformer less buck-boost inverter

III. CURRENT CONTROL

In this paper, a current control method is used for controlling the transformer less buck-boost dc-ac converter. When a low impedance fault is applied to the network, the inverter output voltage will reduce. Then the outer voltage controller will increase the current reference to the inner controller in an attempt to maintain the system voltage. If the increase in current reference is above the maximum current which is allowed for the inverter. Then this current control will activate. This paper discusses a new control technique. This control has two control loops an outer voltage control loop and an inner current control loop. The output of the voltage control loop is the input of the current control loop. An advantage of this approach is that it can be adopted to control both single and three phase micro grids. In the Inner current control loop, the measured inverter current $i_o(t)$ is compared with the set value $i_{L^*}(t)$ of this current. Then the current error is given to a proportional-integral (PI) controller. It is an excellent method to eliminate the disturbance (fault), as well as voltage regulation. The output current has sensed. A reference current (desired current) has to be provided. If there is any overloading condition occurs then the increasing output current is controlled by using this current control technique. Then the resultant is given to a linearization function for maintaining the duty ratio.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization *Vol. 4, Special Issue 1, March 2015*

National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE 2015)

Organized by

Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India

On 26th & 27th March 2015

According to the duty ratio the resulting switching signal is given to the gates of the switches S1-S4. Thus by using this technique the over current through the circuit can be eliminated and thereby ensured safety.

In order to illustrate the equivalent circuits of the system, two cases were chosen. The first refers to the system operation with a duty cycle higher than 0.5, as shown in Fig. 2, and the second the system operates with a duty cycle lower than 0.5, as illustrated in Fig.3.

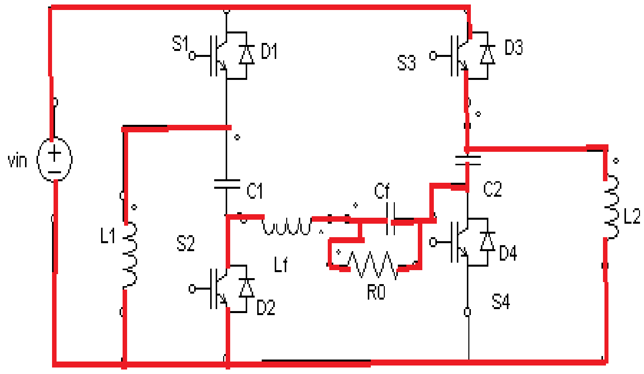

Fig.2. Equivalent circuit for duty cycle higher than 0.5

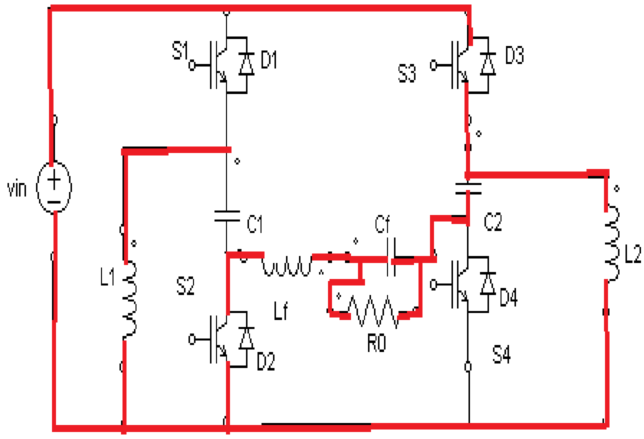

Fig.3. Equivalent circuit for duty cycle lower than 0.5

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization | Vol. 4, Special Issue 1, March 2015

National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE 2015)

Organized by

Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India

On 26th & 27th March 2015

IV. DESIGN

a) High frequency filter

The high frequency filters formed by Lf and C_f are the important elements in the discussed buck-boost topology. Since their values greatly influence the quality of output voltage and current. Thus, the ripple current through inductor L_f and ripple voltage through capacitor C_f is given as follows.

$$\Delta i_{Lf} = \frac{V_i}{L_f \times f_s} \quad (1)$$

$$\Delta V_{cf} = \frac{1}{8} \times \frac{V_i}{L_{f} \times C_f \times f_s^2} \quad (2)$$

$$\Delta i_{L1}(\theta) = \frac{V_i}{L_1 \times f_s} \times d(\theta) \quad (3)$$

$$\Delta i_{L2}(\theta) = \frac{V_i}{L_2 \times f_s} \times (1 - d(\theta) \ ) \quad (4)$$

b) Static gain

The static gain of the new inverter topology is defined as follows:

$$d(\theta) = \frac{((q(\theta))T_s - 2)}{2.(q(\theta))T_s} \pm \frac{\sqrt{(4 + (q(\theta))^2 T_s}}{2.(q(\theta))T_s} \quad (5)$$

Manipulating (3) the duty cycle, as a function of the static gain, is presented as follows:

$$F(\theta) = \frac{((q(\theta))T_s - 2)}{2.(q(\theta))T_s} + \frac{\sqrt{(4 + (q(\theta))^2 T_s}}{2.(q(\theta))T_s} \quad (6)$$

As the duty cycle increases the static gain increases. The above equations show the steps applied to obtain the representation of a sinusoidal output voltage with low distortion, independently of the desired voltage gain. The static gain can be obtained by the relation between the average voltage and the input voltage. The linearization function in (6) is sufficient to establish a linear relation between the real and the reference static gain.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization Vol. 4, Special Issue 1, March 2015

National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE 2015)

Organized by

Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India

On 26th & 27th March 2015

V. ANALYSIS AND RESULTS

The transformer less buck-boost dc-ac converter with current control has been simulated using Matlab/Simulink for the following input and output data specifications:

Vin = 96V, Vo = 110Vrms, Pout = 1000W, and f_s = 20 kHz. The circuit components used in the simulation are shown in Table I.

The topology chosen here is the easiest one. So the design of the step up/step down dc-ac converter with two switching cells is much simplified. The battery input voltage is 96V. The output voltage is regulated at 110Vrms. A higher switching frequency of 20 kHz is also chosen. Thus the values of the different parameters required for the introduced step up / step down dc-ac converter were calculated and found out through the above said equations. The design data obtained for the step up/step down dc-ac converter with two switching cells is given in the table I.

Table I

Simulation parameters and values

Components used in simulation	
Inductor L1	255 µF
Inductor L2	255 µF
Capacitor C1	1 µF
Capacitor C2	1 µF
High frequency filter L_f	1.5 mH
High frequency filter C_f	5µF

The new topology of step up/step down dc-ac converter has been introduced with two switching cells. It is having the feature that it provides an instantaneous output voltage higher or lower than the input dc voltage without an intermediate power stage or transformers. This peculiarity is provided by using two switching cell including two switches, two diodes, one inductor, and one capacitor on each inverter leg to get the required power (1000W). The advantage is that the ripples are reduced. The output ripple can be reduced without increasing device stress.

Fig.4. (a) shows the simulated output voltage and current. It can be observed from Figure that the output current is in phase with the output voltage. Fig.4. (b) shows the current of high frequency filter Lf. Fig.4(c) shows the voltage and current of capacitor C1. V_{c1}, ic1. Fig.4 (d) shows the voltage and current of capacitor C2. V_{c2}, i_{c2}.Whereas the inductor voltage, V_{L1}, i_{L1} V_{L2}, i_{L2} are illustrated in Fig.4.(e).

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization *Vol. 4, Special Issue 1, March 2015*

National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE 2015)

Organized by

Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India

On 26th & 27th March 2015

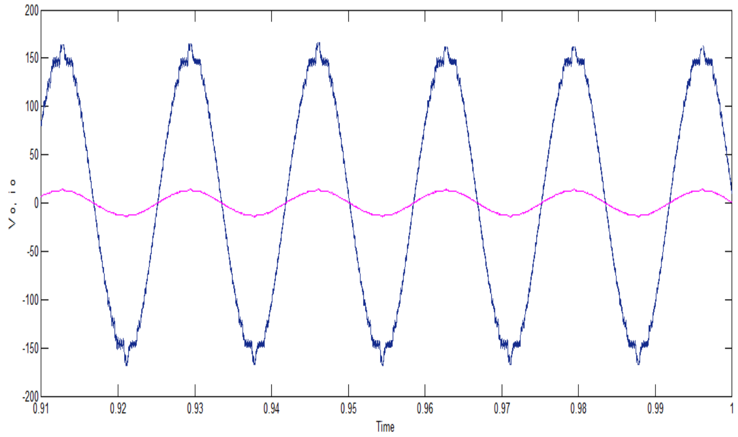

Fig.4 (a) Output voltage and current waveform

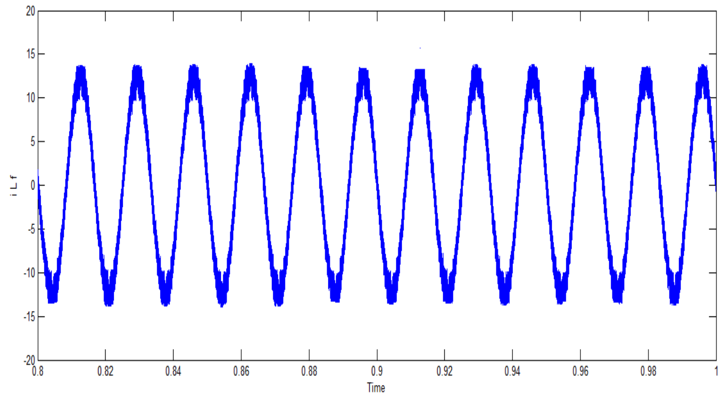

Fig.4 (b) current waveform of inductor L_f , i_{Lf}

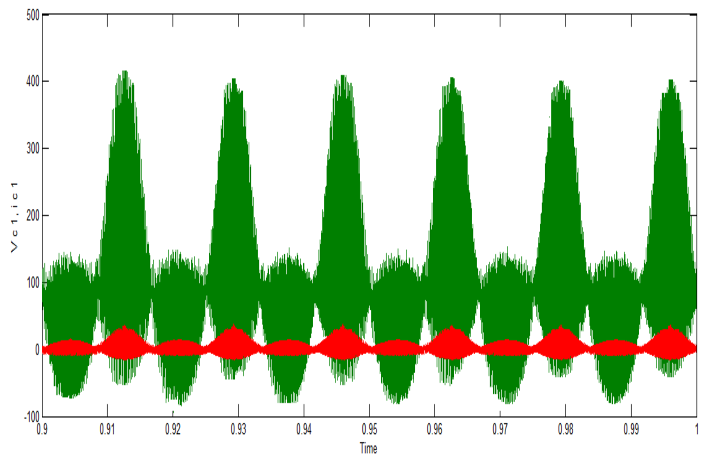

Fig.4(c) voltage and current of capacitor C1 V_{C1}, i_{c1}

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization *Vol. 4, Special Issue 1, March 2015*

National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE 2015)

Organized by

Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India

On 26th & 27th March 2015

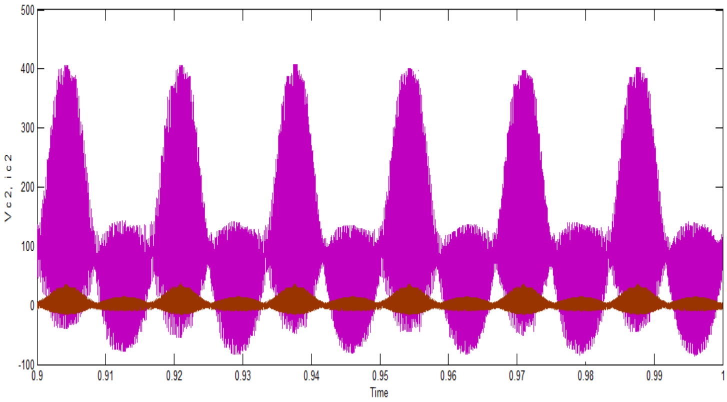

Fig.4 (d) voltage and current of capacitor C 2 V_{C2}, i_{C2}

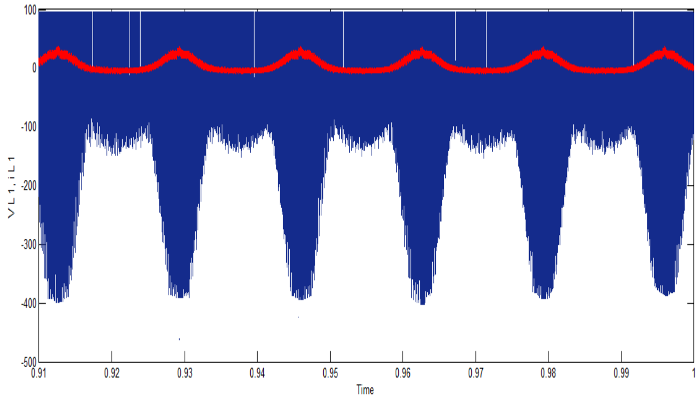

Fig.4 (e) voltage and current of inductor L1 V_{L1}, i_{L1}

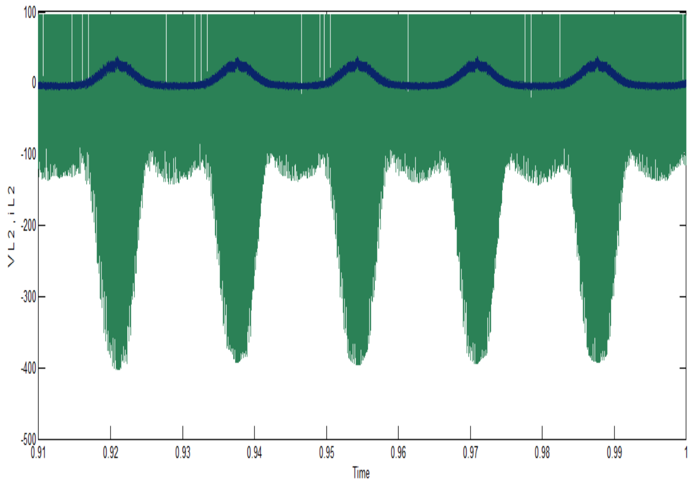

Fig.4 (f) voltage and current of inductor L2 V_{L2}, i_{L2}

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization Vol. 4, Special Issue 1, March 2015

National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE 2015)

Organized by

Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India

On 26th & 27th March 2015

VI. CONCLUSION

New transformer less dc-ac converter based on buck-boost topology with two switching cells is presented in this paper. The advantages of step up/step down dc-ac converter includes system reliability, reduction of size of components and there by acquiring less mass for the whole converter. This dc-ac converter operates with the step-up/step-down feature without transformer. This peculiarity is provided by using two switching cells including two switches, diodes, one inductor, and capacitor on each leg of the inverter. The main advantage of the new inverter topology is that it generates an ac output voltage larger than the dc input one, based on the duty cycle. This property is not found in the normal VSI, which produces an ac output instantaneous voltage always lower than the dc input one. The reduced number of switches that is required (only four) and the quality of the output voltage sine wave are the additional advantages. Further, by using current control the controlling of over current, fault isolation and better network protection, can be achieved by taking care of most of the distribution system situations which result in power quality issues. Simulation is done using MATLAB and the simulation results show that step up/step down dc-ac converter with current control is attained.

REFERENCES

[1] R. O. Caceres and I. Barbi, “A boost DC–AC converter: analysis, design, and experimentation,”IEEE Trans. Power Electron., vol. 14, no. 1, pp. 134–141, Jan. 1999.

[2] N. Vazquez, J. Villegas-Saucillo, C. Hernandez, E. Rodriguez, and J. Arau,“Two-stage uninterruptible power supply with high power factor,”IEEE Trans. Ind. Electron., vol. 55, no. 8, pp. 2954–2962, Aug. 2008.

[3] N. Vazquez, J. Almazan, J. Alvarez, C. Aguilar, and J. Arau, “Analysis and experimental study of the buck, boost and buck–boost inverters,” inProc. 30th Annu. IEEE Power Electron. Spec. Conf., 1999, vol. 2, pp. 801–806.

[4] B. S. Prasad, S. Jain, and V. Agarwal, “Universal single-stage grid connected inverter,”IEEE Trans. Energy. Convers.,, vol. 23, no. 1, pp. 128– 137, Mar. 2008.

[5] M. Jang and V. G. Agelidis, “A minimum power-processing-stage fuel cell energy system based on a boost-inverter with a bidirectional backup battery storage,”IEEE Trans. Power Electron., vol. 26, no. 5, pp. 1568– 1577, May 2011.

[6] M. Kaliamoorthy, R. M. Sekar, and I. G. C. Raj, “Solar powered single stage boost inverter with ANN based MPPT algorithm,” inProc. IEEE Int. Conf. Commun. Control Comput. Technol., 2010, pp. 165–170.

[7] H. Patel and V. Agarwal, “MPPT scheme for a PV-fed single-phase single stage grid-connected inverter operating in CCM with only one current sensor,”IEEE Trans. Energy. Convers., vol. 24, no. 1, pp. 256–263, Mar. 2009.

[8] F. Z. Peng, “Z-source inverter,” IEEE Trans. Ind. Appl., vol. 39, no. 2, pp. 504, 510, Mar./Apr. 2003.

[9] D. Vinnikov, I. Roasto, and T. Jalakas, “An improved high-power DC/DCconverter for distributed power generation,” in Proc. 10th Int. Conf. Elect. Power Quality Utilisation (EPQU), 2009, pp. 1–6.

[10] K. Beer and B. Piepenbreier, “Properties and advantages of the quasi-Zsource inverter for DC–AC conversion for electric vehicle applications,” Proc. Electr. Power Train Emobility, pp. 1–6, 2010.

[11] A. Florescu, O. Stocklosa, M. Teodorescu, C. Radoi, D. A. Stoichescu, and S. Rosu, “The advantages, limitations and disadvantages of Z-source inverter,” inProc. 2010 Int. Semicond. Conf. (CAS), Oct. 2010, vol. 2, pp.483, 486.

[12] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, “A review of single-phasegrid-connected inverters for photovoltaic modules,”IEEE Trans. Ind. Appl., vol. 41, no. 5, pp. 1292–1306, Sep./Oct. 2005.

[13] A. S. Khlebnikov and S. A. Kharitonov, “Application of the Z-source converter for aircraft power generation systems,” in Proc. 9th Int. Workshop Tuts Electr. Devices Mater. (EDM), 2008, pp. 211–215.

[14] M. Calais, J. Myrzik, T. Spooner, and V. G. Agelidis, “Inverters for singlephase grid connected photovoltaic systems-an overview,” inProc. IEEE 33rd Annu. Power Electron. Spec. Conf. (PESC’02), pp. 1995–2000 .

[15] X. Yaosuo, C. Liuchen, K. Sren Baekhj, J. Bordeaux, and T. Shimizu, “Topologies of single-phase inverters for small distributed power generators: An overview,”IEEE Trans. Power Electron., vol. 19, pp. 1305– 1314, 2004.

[16] W. Rong-Jong, W. Wen-Hung, and L. Chung-You, “High-performance stand-alone photovoltaic generation system,”IEEE Trans. Ind. Electron., vol. 55, pp. 240–250, 2008.

[17] M. Calais and V. G. Agelidis, “Multilevel converters for single-phase grid connected photovoltaic systems-an overview,” in Proc. IEEE Int. Symp.Ind. Electron. (ISIE’98), vol. 1, pp. 224–229.

[18] S. Miaosen and F. Z. Peng, “Operation modes and characteristics of the Zsource inverter with small inductance,” in Proc. 40th IAS Annu. Meeting.Conf. Rec. Ind. Appl. Conf., 2005, vol. 2, pp. 1253–1260.

[19] G. Buja, R. Keshri, and R. Menis, “Characteristics of Z-source inverter supply for permanent magnet brushless motors,” in Proc. 35th Annu. Conf.IEEE Ind. Electron. (IECON’09), pp. 1234–1239.

[20] A. M. Salamah, S. J. Finney, and B. W. Williams, “Single-phase voltage source inverter with a bidirectional buck–boost stage for harmonic injection and distributed generation,” IEEE Trans. Power Electron., vol. 24, no. 2, pp. 376–387, Feb. 2009.