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Sine-wave three phase resonance inverter for operation of renewable energy systemsR

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KEYWORDS- THD (ToltalHarmonic Distortion), RMS (Root Mean Square).

ABSTRACT*:* This paper proposes a high performance single-stage three phase inverter topology for the autonomous operation of renewable energy systems. The proposed configuration can boost the low voltage of renewable energy systems such as photo voltaic systems, fuel cells, and etc can also convert the output dc power, into high quality ac power to drive autonomous loads without any filters. It can also be useful in UPS (Uninterruptable Power Supplies) systems to convert low dc voltage of batteries into suitable amplitude and high quality ac voltage. The line current total harmonic distortion (THD) as it will be shown in the simulation results part, is quite reasonable in such different loads. The proposed topology has several desirable features such as low cost and compact size as it doesn't need to any filters in the output of the converter. In addition, the low number of switches in compare to multilevel inverters is noticeable. According to result, the operation of converter will produce and the performance will be acceptable in induction load. **© JASEM**

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Although fossil fuel based power generation is, and will still be the back bone of our world economy, such form of power generation significantly contributes to global CO2 emissions. In spite of that, renewable energies are clean, environmental friendly energy source for power generation. As fossil fuel prices have risen and concerns over greenhouse gases (Gh Gs) and global climate change have increased, alternative technologies for producing electricity have received greater attention [1]. As a matter of fact, usage of renewable energy sources such as photovoltaic systems, fuel cells, wind turbine systems and etc has been progressed rapidly [1]-[5]. Progression of these energy sources, necessitates, progression in power electronic systems which have duty of connect them to the ac load or the infinitive grid [6]. With the rapid progress of the power electronic techniques these types of energy sources can be used easier and much more suitable than before [7]. At the core of this system, the inverter unit plays an important role. However, one of the characteristics of the buck inverter is that the RMS (Root Mean Square) output voltage is often lower than the input dc voltage. This leads to increase in size of output transformer. As mentioned in previous paragraph it can be deduced, when an output voltage larger than the input is needed, a boost dc–dc converter must be used between the dc source and inverter as shown in Figure 1.

Generally, renewable energy sources produce Dc voltage at their terminal [8]. But, because of some technical reasons, this Dc voltage, is low and have to be amplified and then converted to suitable ac voltage through an inverter for connection to the load or ac grid. As a matter of fact usual systems have two units [6], first one is a dc-dc converter witch amplifies the output dc voltage of renewable energy source and the second one is a dc-ac inverter which has to produce suitable ac voltage (Low THD) at the final terminal [9].

Using two converters (DC/DC Boost + Dc/Ac Inverter) has lots of drawbacks such as reducing efficiency, increasing final cost and size and more importantly, reducing reliability of the system [10] , [11]. The question is whether it is possible to reduce the number of power processing stages in such systems or not. Two conventional and simple solution to this requirement are in the following [8].

Using conventional H-bridge inverter beside of a step-up transformer.
Using a renewable energy source with sufficiently large output voltage, which may be realized by a string of series connected modules followed by an H-bridge inverter [12], [13].

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While these options are feasible, they suffer from some drawbacks. Firstly adding a transformer (corresponding to the grid frequency) will add to the bulk and cost of the system and losses. Secondly, series connection of some renewable energy sources can damage them or at least decrease the net life of them. For example PV arrays with large dc voltage suffers from drawbacks such as hot-spots during partial shading of the arrays, reduced safety and increased probability of leakage current through the parasitic capacitance between the panel and the system ground.

A new method which is based on resonance method converter has been proposed and experimental results besides simulation one, represents a suitable performance in this application [8]. Also it was simulated and experimented on single phase system, while this paper, proposes a three phase generalized one, and analyze it by simulating in MATLAB/SIMULINK. In [14], Z-source inverters have been analyzed, however this converter doesn't deal with previous drawbacks such as low efficiency, it has some difficulties in their output THD. The proposed approach doesn't need to any filters in the output of the converter. According to result, the operation of converter will produce and the performance will be acceptable in induction load.

*Principle operation of the proposed method***.:** In this paper, a new three phase voltage source inverter (VSI) has been proposed, in the proposed method, by varying Duty cycle and also the capacitor and inductor of the converter we can control the output voltage of the converter. As it will be proved, we can deduce the Duty cycle have to be near to %50 because of cancelling the dc component of output voltage. As a matter of fact we can vary the output voltage mostly by variation of capacitor's and inductor's value [8]. Figure 2 shows the configuration of this method.

The proposed boost inverter facilitates dc–ac conversion as indicated in Fig. 3, by connecting the load differentially across two dc–dc converters and modulating the dc–dc converter output voltages sinusoidally. Blocks A and B represent dc–dc converters. These converters produce a dc biased sine-wave output for each phase, although each source produces only a unipolar voltage. The modulation of each converter is 120° out of phase with the other, which can produce, 120° differentiation in neighbor phases across the load. As figure 4 shows, the load is connected differentially across the converters.

Thus, whereas a dc bias appears at each end of the load, with respect to ground, the differential dc voltage across the load is zero. Thus a bipolar voltage at output is obtained by a simple push pull arrangement. One important requirement is that the dc–dc converter needs to have bidirectional current carry capability as it is shown in fig 4 [8].

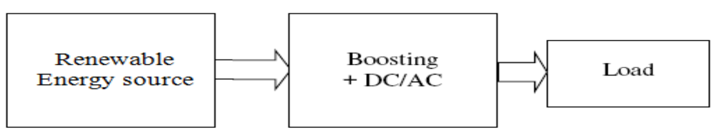

Fig1. Conventional method to connect renewable energy sources to Ac load

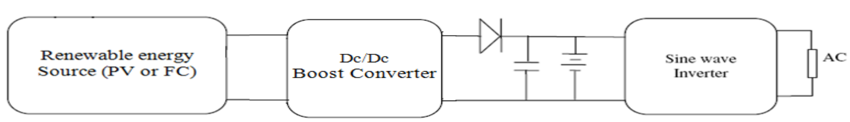

Fig 2. Conversion system with boost convertor

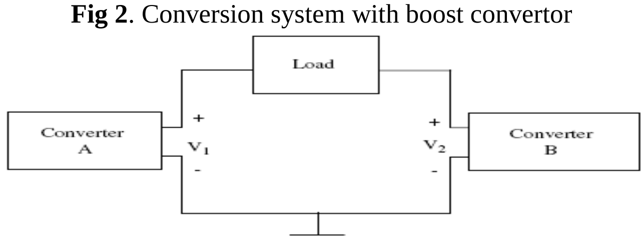

Fig. 3. Basic approach to achieve dc–ac conversion, with boost characteristics

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The principle of boost inversion with three dc–dc converters can be explained through the current bidirectional boost dc–dc converter shown in fig. 4. There are two modes of operation in every cycle of

output voltage. When switch S_1 is closed, the current of the inductor rises linearly. In this situation the loads current supplies by the capacitor C. As a matter of fact, capacitor's charge decreases exponentially due to its time constant. In the second situation, while switch S_1 is opened, the charged inductor forces its current throw D_1, the capacitor and the load. So the load's voltage will increase and the inductor discharges linearly. This is repeated for the consecutive switching periods to generate a capacitor voltage shown in fig. 4. The 180° phase shift for each converter can be achieved by triggering the neighbor switches by180° phase shift. A circuit implementation of the three phase boost dc–ac converter with two switches, two diodes, two inductors and two capacitors is shown in fig. 4. For a dc–dc boost converter, by using the averaging concept, the input–output voltage relationship for continuous conduction mode is given by equation (1), which is as same as a boost converter coefficient factor.

$$\frac{V_1}{V_{in}} = \frac{1}{1-D} \qquad (1)$$

Where, D is duty cycle.

As we discussed before, the output voltage of V_2 is 180° out of phase by V_1. As a matter of fact, the relationship with V_{in} & V_2 can be rewrite, just by changing D to $1-D$. Finally, the voltage gain, for the boost inverter, can be derived as follows.

$$V_o = v_1 - v_2 = \frac{v_{in}}{1-D} - \frac{v_{in}}{D} \Rightarrow \frac{v_o}{v_{in}} = \frac{2D-1}{D(1-D)} \qquad (2)$$

As it is mentioned before, the operation of three phase, proposed circuit, is based on single phase circuit method and the only differentiation between these two issues, is each resonance converter, operates by 120° out phase due to its neighbor one. So it is clearly obvious that the relationship between V_{in} &V_{out} in the three phase proposed method, is as same as equation (2). This algorithm has been represented in fig. 4.

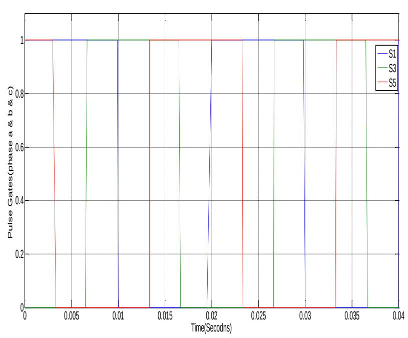


Fig.4 . Pulse gates of S_1 & S_3 & S

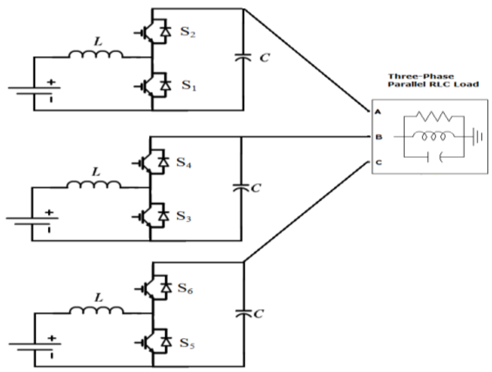


Fig. 5.The boost three phase inverter used in the proposed scheme.

The gain characteristics of the boost inverter are shown in Fig. 6. It is interesting to note that the feature of zero output voltage is obtained for D= 0.5. If the duty cycle is varied around this point, then there will be an ac voltage at the output terminals [8]. Noticeable that in Fig 5, that in three phase convertor we don't need three dc voltage source. But just one dc source is sufficient. In continue the results of simulation on different loads and conditions will be proposed.

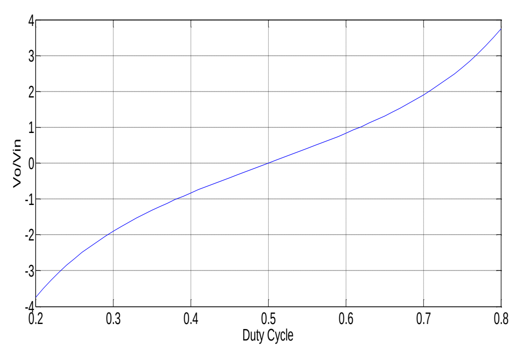


Fig. 6: Dc gain characteristic.

Simulation Results.: Figures 7 up to 11 represent results of simulation while the input voltage is 10 volt (Dc) and load is ohmic with resistance of 10 ohms per phase while connection of load is Wye. Figures 7 and 8, represents two capacitors voltage of each converter, respectively. As it has been discussed before, the differentiation between these two voltages, produces the output voltage of each phase which has been illustrated in fig.9. In continue, figure 10, illustrates the THD of produced voltage of the resonance converter, respectively. Figures 11 up to 18 represent results of simulation while the input voltage is 20 volt (Dc) and load is a three phase asynchronous motor with 150 volts (L-L) and the load power is 300Watt (3N.m in 1400 rpm). And connection of load is Wye. Figures 11 and 12 shows voltage of each phase and line - line voltage of the converter, respectively. In the continue, figures 13 and 14 illustrates the voltage and current harmonic spectrum of converter, while feeding an induction motor.

Figures 15-18, shows the voltage, current, torque and speed of rotor, during the starting. It is deducible from these figures, that the operation of converter, would produce and acceptable performance in induction load. Figures 19 and 20 shows the variation of voltage THD and current THD, due to the torque of the load. Figures 7 to 20 show that this convertor topology performance is suitable for renewable energy systems which have low dc terminal voltage. The simulation results represent low Voltage and Current THD at the output

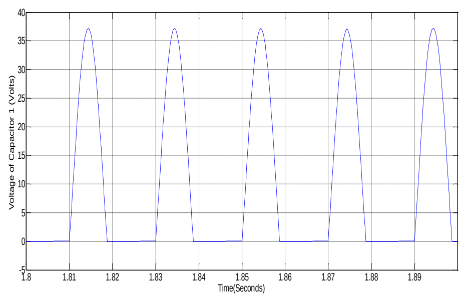


Fig.7. Voltage of $Capacitor_1$ (Converter A).

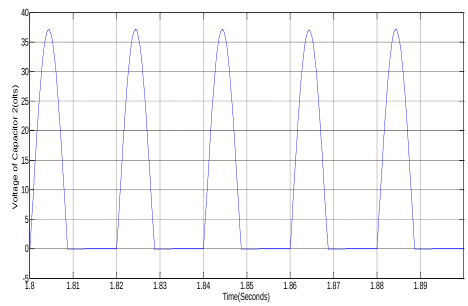


Fig.8. Voltage of $Capacitor_2$ (Converter A)

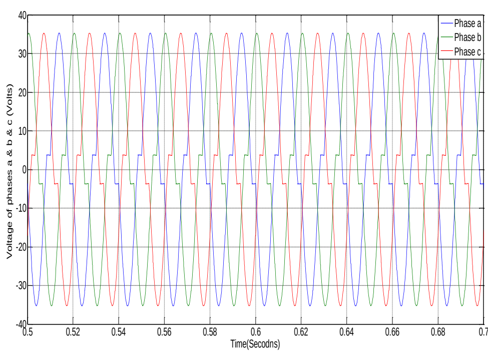


Fig. 9. Voltage of phases a & b & c.

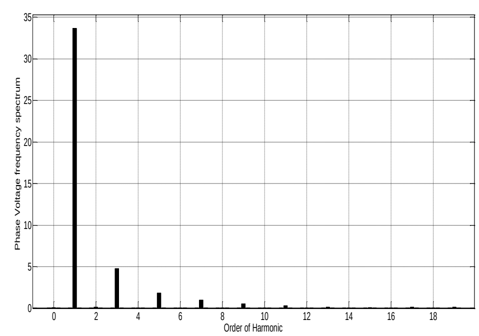


Fig. 10. Harmonic component of output voltage.(THD=16%).

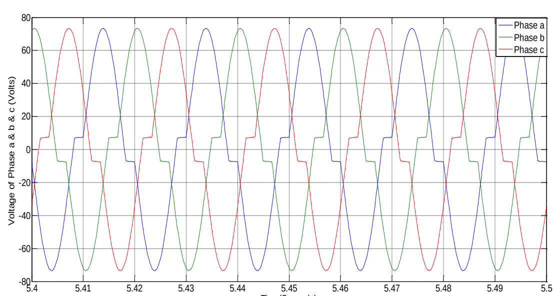


Fig 11.Voltage of phase a & b & c.

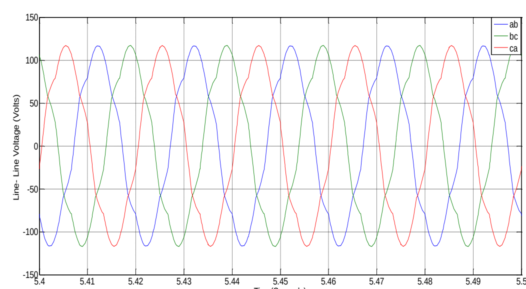
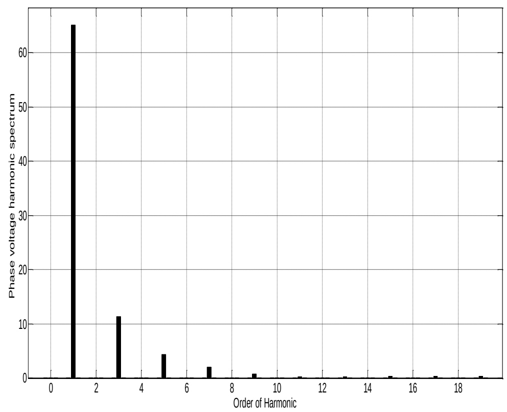


Fig.12. Line-Line voltage of phases



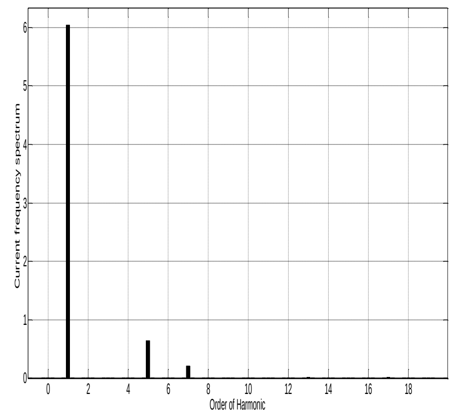


Fig. 13. Phase voltage harmonic component. (THD=16%)

Fig. 14. Line Current Harmonic Component.
(THD=7%)

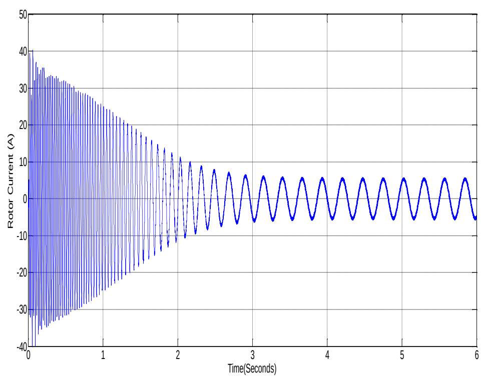


Fig. 15. Rotor Current (A)

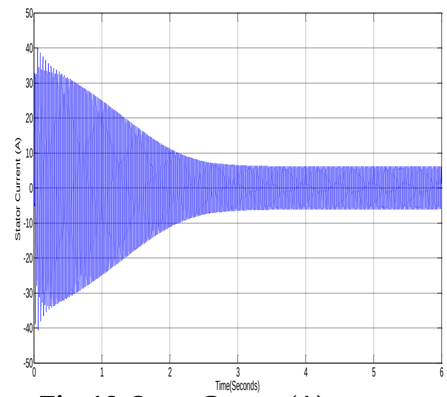


Fig. 16. Stator Current (A**)**

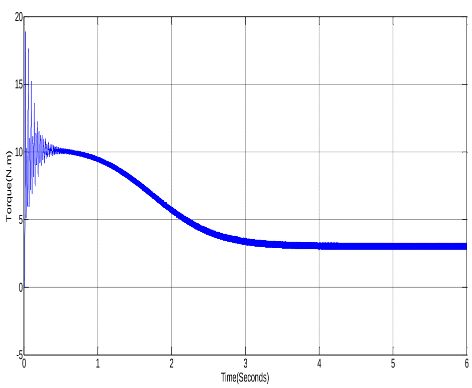


Fig.17. Torque (N.m**)**

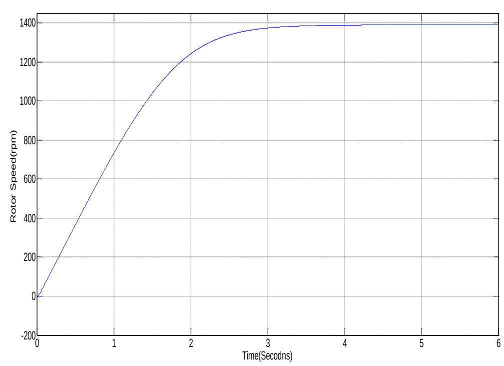


Fig 18. Speed of rotor (rpm**)**

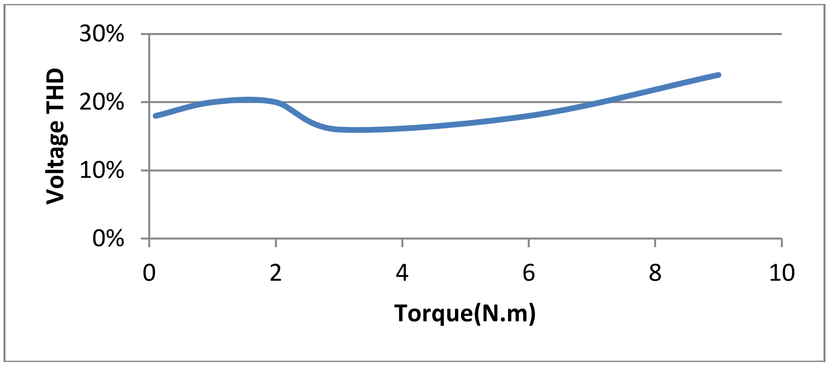


Fig 19. Variation of Voltage THD due to Torque

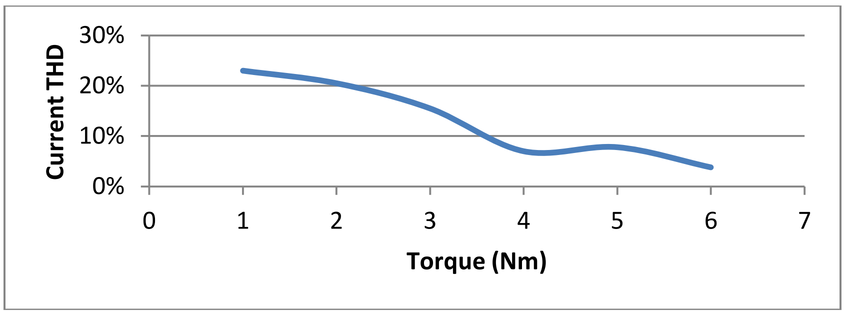


Fig 20. Variation of current THD due to Torque

Conclusion: In this paper, a high performance three phase boost inverter topology for the autonomous operation of renewable system is presented. The ease with which the inversion and boosting has been achieved in the simulation to supply power to an isolated three-phase load confirms the feasibility, operational simplicity and effectiveness of the proposed scheme. Further, adoption of a simple control strategy should make the inverter more reliable. The cost of this inverter will also be relatively low as the conventional converter doesn't need any filter and boost converter. As shown in Fig.4 it can be deduced the low size and cost of converter because of the low number of switches (six switches for three phase converter). It is also evident from the results, that the total harmonic distortion of the output inverter current waveform at different voltage levels can be maintained close to the specified regulation limits of the utility. All the above advantages have made the inverter configuration highly suitable for any type of autonomous load. However, the ideal buck-boost topology has yet to be found. This provides motivation for research into high efficiency, low cost inverters for DG applications. It is noted that further research efforts are continuously being made toward increasing the operational input voltage and power ranges, reducing converter component counts, cost and size, and improving efficiency, reliability, and robustness.

REFERENCES

Alireza Payman, Serge Pierfederici, Farid Meibody-Tabar." Energy control of supercapacitor/fuel cell hybrid power source" Energy Conversion and Management 49 (2008) 1637–1644.Elsevier.

Martin Barry, Ralph Chapman." Distributed small-scale wind in New Zealand: Advantages, barriers and policy support instruments". Energy Policy 37 (2009) 3358–3369.

Eric Hua, YongPing Yang, Akira Nishimura, Ferdi Yilmaz, Abbas Kouzani." Solar thermal aided power generation". Applied Energy 87 (2010) 2881–2885.

Ezio Sesto, Claudio Casale." Exploitation of wind as an energy source to
meet the worldÕs electricity demand". Journal of Wind Engineering and Industrial Aerodynamics 74Ð76 (1998) 375Ð387.

Severin Borenstein.” The Market Value and Cost of Solar Photovoltaic Electricity Production”. CSEM WP 176. January 2008.

Ram´on O. C´aceres, Ivo Barbi.” A Boost DC–AC Converter: Analysis, Design, and Experimentation”. IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 14, NO. 1, JANUARY 1999.

F. Liccardo, P. Marino, M .Triggianese.” Interleaved dc-dc Converters for Photovoltaic Modules”.

G. Saravana Ilango, P. Srinivasa Rao, A. Karthikeyan, C. Nagamani.” Single-stage sine-wave inverter for an autonomous operation of solar photovoltaic energy conversion system” . Renewable Energy 35 (2010) 275–282.

G. Beinhold, R. Jakob, and M. Nahrstaedt, “A new range of medium voltage multilevel inverter drives with floating.

Yeong-Chau Kuo, Tsorng-Juu Liang, and Jiann-Fuh Chen.” A High-Efficiency Single-Phase Three-Wire Photovoltaic Energy Conversion System”. IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 50, NO. 1, FEBRUARY 2003.

T. Kerekes, R. Teodorescu, U. Borup.” Transformerless Photovoltaic Inverters Connected to the Grid”. 1-4244-0714-1/07/$20.00 C 2007 IEEE.

Chen Y, Ma-Smedley K. A cost-effective single-stage inverter with maximum power point tracking. IEEE Trans Power Electron Sep. 2004;19(5):1289–94.

Blaabjerg F, Chen Z, Kjaer SB. Power electronics as efficient interface in dispersed power generation systems. IEEE Trans Power Electron Sep. 2004;19(5):1184–94.

capacitor technology,” in Proc. 9th European Conf. Power Electronics (EPE), Graz, Austria, 2001, CD-ROM.

Fang Zheng Peng," Z-Source Inverter ". IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 39, NO. 2, MARCH/APRIL 2003.