© 2017 IJEDR | Volume 5, Issue 2 | ISSN: 2321-9939

Grid-ConnectedPV-Wind SystemwithImplementation of Transformerless Inverter

C.MONICA, R.ARULMOZHIYAL
Department of Electrical & Electronics, Sona College of Technology, Salem, India
Corresponding author E-mails:cmonica.1993@gmail.com

***Abstract*— this project presents a single phase transformer less inverter topology for grid-connected photovoltaic (PV) and wind energy systems which is capable of solving leakage current issues. In this further work, the ground leakage current is controlled within the regulation limit by using LC filter. The proposed system can inject both active and reactive power into the utility grid without current distortion and leakage current. The MPPT algorithm control strategy is used in PV module to harvest the peak possible power from the module, even though they might be at divergent irradiance levels and operating temperature. Wind power module is also controlled by MPPT algorithm in an effective way.A detailed analysis is carried out on the hybrid system at desired conditional parameters such as irradiation, temperature etc.**

***Index Terms*—Converter,leakage current, PV array, tansformerlessinverter, wind turbine.**

1. INTRODUCTION

In order to ensure the safety, leakage currents must be the smaller the better in grid-connected PV systems. Using the transformers can make the galvanic connection between the grid and the PV array eliminated. But the transformer is large, heavy, and expensive. Thus, finding a way of high efficiency, low price, light weight, small volume is necessary. The transformer less inverter with low leakage currents can solve the problem in grid-connected PV systems, particularly in low-power single-phase systems. So various transformer less inverter topologies have been proposed to meet the point of reducing leakage currents by experts around the world.

The full bridge circuit high frequency common-mode equivalent model, and pointed out the way to eliminate leakage currents is the freewheeling voltage is half of the input voltage. Based on the conclusion, the leakage currents of the topologies can be diminished in the following aspects: a) Creating a freewheeling current path, b) Neutral point clamped. In fact, the freewheeling currentdirections is reversed in different half period of the utility grid. This paper proposes a novel structure based on the idea which is able to create a path can only flow the positive freewheeling current in the positive half period figure 1, and flow the negative freewheeling current in the negative half period respectively, so that it achieve the point of the freewheeling currents directions separation by the IGBTs and diodes.

This paper will first introduce the leakage path for transformer less PV systems. Then the comparative analysis on the proposed topology and Heric topology is described. Finally, the simulation results are presented to prove the well performance of the proposed topology in leakage currents.

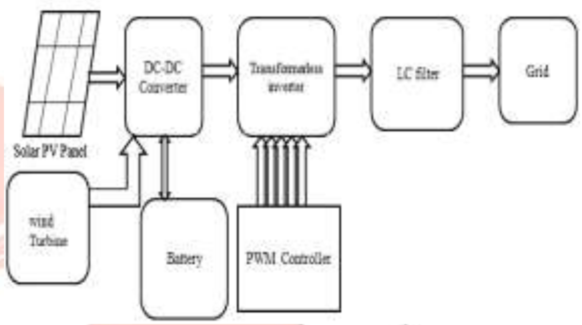


Figure 1. Block diagram of proposed system

2. LEAKAGE CURRENTS IN TRANSFORMERLESS PV SYSTEMS

Illustrations Fig. 2[16] shows the proposed transformer less inverter topologies consisting of six IGBT switches (S1-S6) and six diodes. It is a resonant circuit where the PV is grounded. Leakage current flows between the PV and the grid when the transformer is removed from the PV inverter. The behavior of leakage ground current is strongly subjective to the converter topology and the PWM strategy. It includes parasitic capacitance (CPE), each connected between the positive (P) and negative (N) of the PV to the ground, the filter inductance (Lc), and the ground resistance (Rf) [16]. In three-phase PV system, the common-mode (CM) and differential mode (DM) voltages between each phase are similar phase a and b, phase b and c, phase c and a. Therefore, the analysis of phase a and b is sufficient to represent the remaining of the phases.

To the full-bridge inverter, without transformer, a galvanic connection between the ground of the grid and the PV array exists. Therefore, the leakage current is flowing through path including L_1, L_2, C_{pv1}, C_{pv2}, $Z_g$and Bridge. As shown in Fig.2, The leakage current path is simplified to an LC resonant circuit. The common-mode voltage (u_{dm}) in the Fig.3 is defined as:

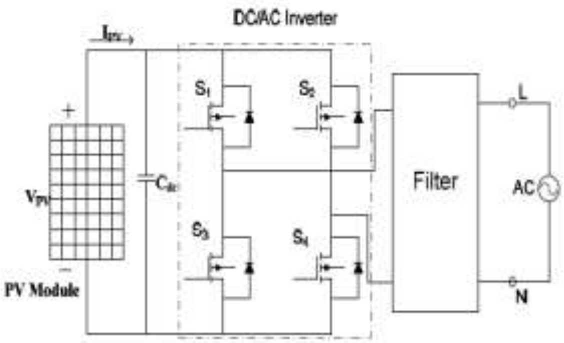


Figure 2. Proposed full bridge transformerless inverter

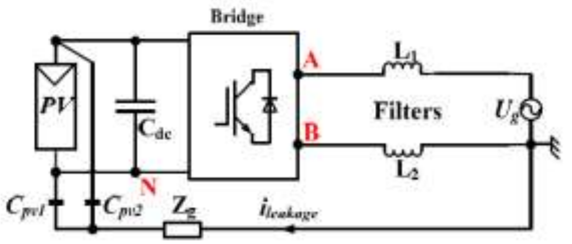


Figure 3. Leakage currents in a transformer less conversion stage

$$U_{dm} = \frac{U_{AN} + U_{BN}}{2} \quad (1)$$

uAN is the voltage between point A and point N, uBN is the voltage between point B and point N. The inductors L1 and L2 can be with the equal value easily. As a result, a conclusion can be given that when the CM voltage keeps constant, the leakage currents will be eliminated.

3. OPERATING PRINCIPLE

In this section, a comprehensive survey of state-of-the-art asymmetrical inductor based transformerless inverters (L1=0 or L2=0) is presented and discussed. The reviewed topologies are classified into the following sub-groups: half-bridge inverters, dual-buck inverters, virtual DC bus inverters, line-frequency unfolding topologies and Karschny transformer less inverter.

A. Half-Bridge Transformerless Inverters

Assuming L_2=0 and terminal *N* is directly connected to terminal *2* in Fig. 1, the total high-frequency common mode voltage is zero without high frequency leakage current. Generally speaking, the conventional two-level half-bridge inverter [in Fig. 3 (a)] can eliminate the leakage current with simplified configuration because only two power switches and one inductor are required [50]. However, the DC-link voltage should be twice of the grid peak voltage and the semiconductors should sustain the high DC-link voltage stress. Moreover, the bipolar inverter output voltage increases the filter size and cost.Fig 4[1], where G1, G2, G3, G4, G5, and G6 represent the gate drive signals of the switches S1, S2, S3, S4, S5, and S6, respectively. The circuit diagram for negative half cycle operation is depicted.

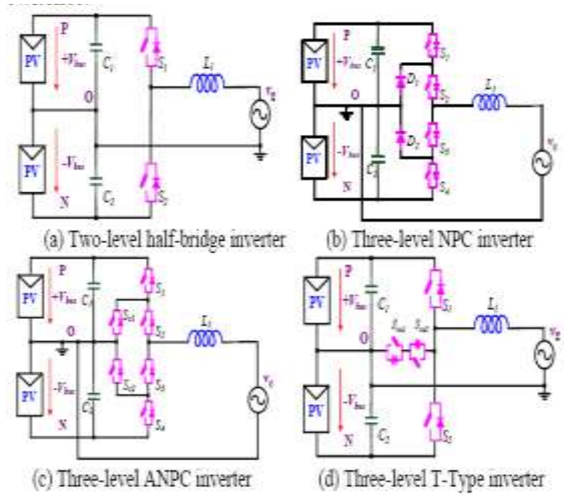
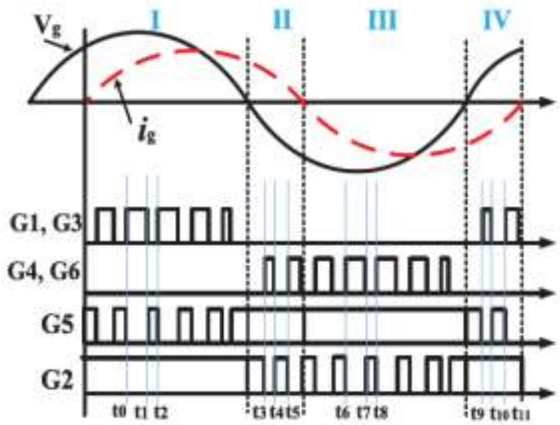


Figure 4. Various types of bridge level converter

In order to keep the major advantages of the multi-level topologies and reduce the conduction losses in the low voltage systems, the T-type inverters can be adopted, which are also called as the conergy neutral point clamped (conergy-NPC) inverters or transistor-clamped (TCC) inverters [57] [in Fig. 3 (d)]. A bidirectional switches are inserted between the middle point of the half bridge inverters and the split capacitors to achieve the similar clamping function and three-level voltage generation in the ANPC inverters. The switch voltage stress in the T-type inverters is different. The two series switches in the upper and lower parts of the inverters should sustain the high DC-link voltage and the active clamping switches, which are employed to generate the zero voltage level, only suffer half of the high DC-link voltage. A detailed analysis and efficiency comparison among the two-level half-bridge, three-level NPC and T-type inverters for the low voltage applications is performed in [58]. It is concluded that the NPC and T-type inverters have higher conversion efficiency than the two-level half-bridge inverters. And above a certain switching frequency, the T-type topologies are superior to the NPC circuits due to the modern semiconductor properties.



Figures 4. The operating principle of Transformerless inverter (a) state 1 (b) state 2 (c) state 3 (d) state 6

4. HIGH FREQUENCY CM MODEL OF THE PROPOSED TOPOLOGY FOR LEAKAGE CURRENT ANALYSIS

The PV module generates an electrically chargeable surface area which faces a grounded frame. In case of such configuration, a capacitance is formed between the PV module and the ground. Since this capacitance occurs as an undesirable side effect, it is referred as parasitic capacitance. Due to the loss of galvanic separation between the PV module and the grid, a CM

Resonant circuit can be created. An alternating CM voltage that depends on the topology structure and control scheme, can electrify the resonant circuit and may lead to higher ground leakage current [6], [16], [22]. In order to analyze the CM characteristics, an equivalent circuit of the proposed topology as shown in Fig. 5 can be drawn, where V1N,V2N,V3N and V4N are the controlled voltage source connected to the negative terminal N, LCM and CCM are the CM inductor and capacitor,During the positive half-cycle, the switches S4 and S6 are always off. As a result, the controlled voltage sources V3N and V4N are zero and can be removed. According to the definition of common-mode and differential-mode voltage:

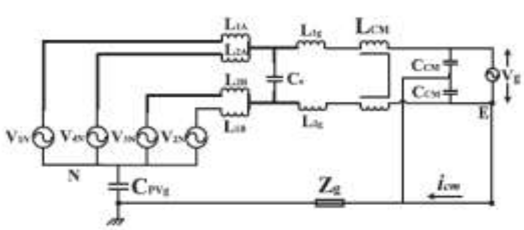


Figure 5.Equivalent CM model of the proposed topology

$$V_{cm} = \frac{1}{2}\,(V_{N1} + V_{N2}) \qquad (2)$$

$$V_{Dm} = V_{N1} - V_{N2} \qquad (3)$$

$$V_{N1} = V_{CM} + \frac{1}{2} V_{DM} \qquad (4)$$

$$V_{N2} = V_{CM} - \frac{1}{2} V_{DM} \qquad (5)$$

In order to illustrate the CM model at switching frequency, equation (4) and (5) could be replaced for the bridge-leg in Fig. 6. The grid is a low frequency (50–60 Hz) voltage source.

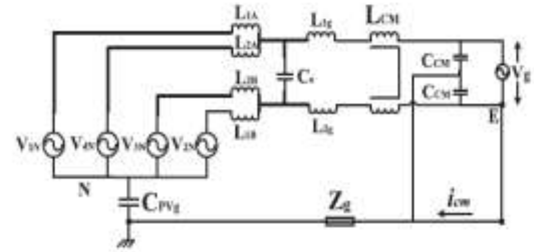


Figure 5. Equivalent CM model of the proposed topology

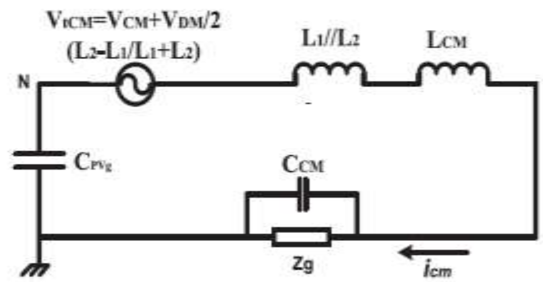


Figure 6.Simplified single loop CM model.

The DM capacitor Co can also be removed since it has no effect on the leakage current. Consequently, the simplified high frequency CM model of the proposed topology for positive half-cycle could be drawn as Fig. 5. Finally, the simplified single loop CM model of the proposed topology for positivehalf cycle is derived in Fig. 6.

$$V_{tCM} = V_{CM} + \frac{V_{DM}}{2}\frac{L_2 - L_1}{L_2 + L_1} \qquad (6)$$

Where,$VtCM$represent total CM voltage, and $L1 = L1A + L1g$ and $L2 = L1B + L2g$. In the proposed inverter if $L1A = L1B$ and $L1g = L2g$ for a well-designed circuit with symmetrically structured magnetics, equation (6)

5. Control of the proposed topology

The control system for the proposed topology is illustrated in Fig. 7, which contains an orthogonal signal generator (OSG) unit to calculate active and reactive power, two proportional integral (PI) controllers, a grid current controller and a SPWM generation block. Based on the OSG system, the active power P and reactive power Q for the proposed topology can be calculated by using the following equation which is shown in Fig. 8.

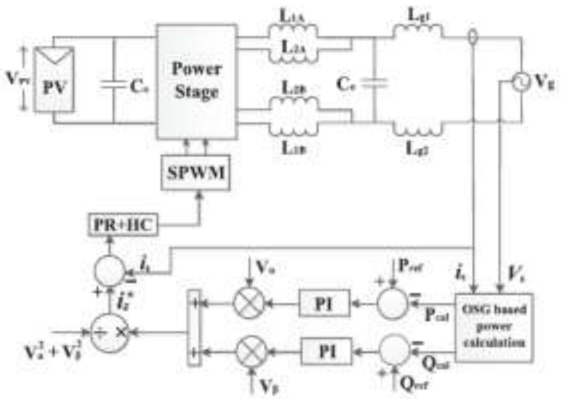


Figure 7. Control diagram of the proposed topology

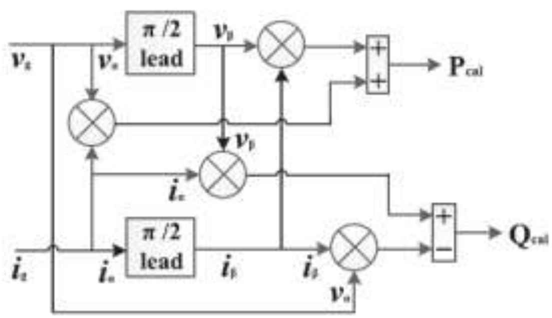


Figure 8. OSG based power calculation

In order to control the grid current, several existing control methods such as conventional PI controller, repetitive controller (RC), proportional resonant (PR) controller, and deadbeat (DB) controller can be adopted due to the capability of tracking reference signal without steady state error [27], [28]. Since the PR controller has better performance of tracking the reference signal if compared to the normal PI and RC controller, it is selected to control the output current of the proposed topology.

5. SIMULATION RESULTS

The transformer less inverter was simulated using MATLAB/SIMULINK tool. The PV cell and wind module were designed and simulated with the help of its equivalent circuit. Temperature and irradiation were considered as the changing parameters to change the output of the solar cell. The PV cells of 24V were taken as input for the transformer less inverter. The dc/dc boost converter is used to boost up the obtained dc input voltage to desirable value. The configured transformer less inverter network does boost operation and reduces the third level harmonic content. The inverter converts dc single in to ac. The switching circuit consists of six IGBTs and diodes which are taken from Simulink library. A LC filter is used to connect the inverter to the load side. The switching sequences were provided according to the operation described above. A 385V voltage and 20 A current waveform was obtained as output for the gird. The output voltage from PV array is obtained by keeping its irradiance value constant at 1000W/m^2.Fig 9 shows the output wave of PV array with MPPT controller of irradiance level 3W/m^2. Output power and voltage maintains at 28W and 20V respectively. Fig 10.1 & 10.2 shows the output waveform of wind output voltage is maintained at 15V along with the MPPT controller. Fig: 11 shows the boost converter output is maintained at 40V for which the battery current is 0.4A. Fig: 11 shows the increase of battery voltage to 21.98V for current decreases gradually below zero ampere.Transformerless inverter output voltage of 100V for which reduced leakage current of 21V is obtained as Output of phase and line voltage of inverter here the voltage value is 230V,50Hz nominal frequency . Input current and output voltage of the transformer less inverter is measured and the resultant waveform. From wind, the output power is 5W. Load receives 50kW supply. Thus the overall three phase output voltage is 320V and output current of 20A.

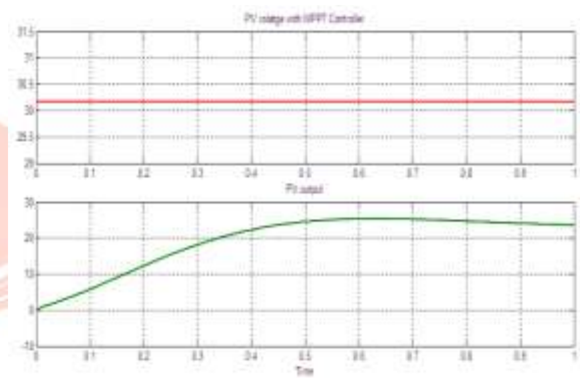


Figure 9. PV voltage with MPPT controller and PV output

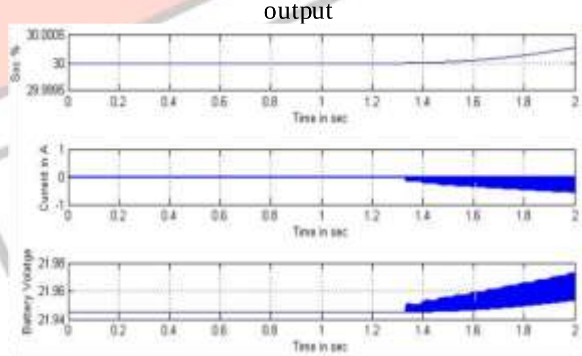


Figure 10.2. Output waveforms of battery and boost converter

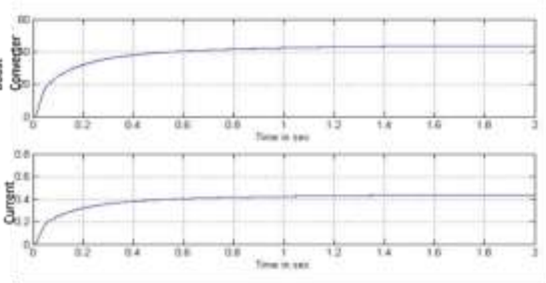


Figure 10.1. Output waveforms of battery and boost converter

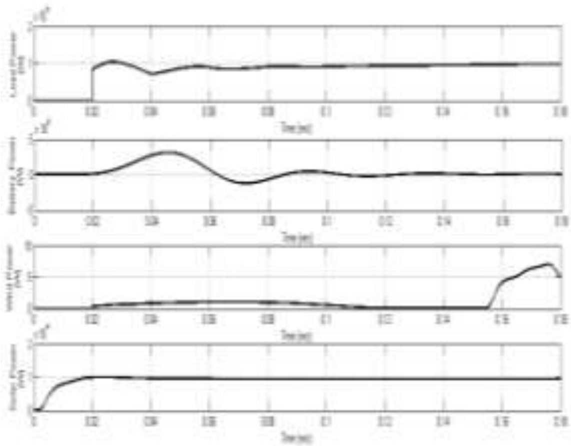


Figure 11. Waveforms of Output power from PV, Wind, Battery and Load

6. CONCLUSION

A transformer less inverter for grid connected hybrid system was simulated using MATLAB/SIMULINK tool. This three-phase transformer inverter was capable of obtain a maximum possible power from solar and wind module. Incremental conductance MPPT technique was used. Therefore, the PV string can be of different electrical parameters and working conditions. Transformerless condition of the inverter helped the system to convert maximum output power from the hybrid system to the gird by limiting pulsating power. Leakage Current was reduced by placing LC filter across the output of the inverter. LC filter also reduced the harmonics produce at inverter output voltage. Output power was subjected to active and reactive power compensation. Three phase output voltage of 320 V, 20 A was obtained. A 1kW prototype of PV and 7 W of wind was built and tested through simulation. The control scheme of transformer less inverter topology was described, and its detailed analysis was provided. Several experimental results were also shown to confirm the validity of the proposed inverter.

REFERENCES

[1] Monirul Islam, Nadia Afrin, and SaadMekhilef "Efficient Single Phase Transformerless Inverter for Grid-Tied PVG System With Reactive Power Control" IEEE transactions on sustainable energy, vol. 7, no. 3, July 2016

[2] Yi Tang ,Wenli Yao , Poh Chiang Loh , and FredeBlaabjerg "Highly Reliable Transformerless Photovoltaic Inverters with Leakage Current and Pulsating Power Elimination" IEEE transactions on industrial electronics, vol. 63, no. 2, February 2016.

[3] Wuhua Li , YunjieGu , HaozeLuo , Wenfeng Cui , Xiangning He and Changliang Xia "Topology Review and Derivation Methodology of Single-Phase Transformerless Photovoltaic Inverters for Leakage Current Suppression" ieee transactions on industrial electronics, vol. 62, no. 7, July 2015

[4] AbhishekGarg, Rajasekar.S,and Rajesh Gupta,"A New Modulation Technique to EliminateLeakage Current in Transformerless PV Inverter"

[5] K. S. F. Tan, N. A. Rahim, H. Wooi-Ping, and C. Hang Seng, "Modulation Techniques to Reduce Leakage Current in Three-Phase Transformerless H7 Photovoltaic Inverter," Industrial Electronics, IEEE Transactions on, vol. 62, pp. 322-331, 2015.

[6] T. Kerekes, R. Teodorescu, and U. Borup, Transformerless photovoltaic inverters connected to the grid," in Proc. APEC, Feb. 25–Mar. 1, 2007, pp. 1733–1737.

[7] E. Ün, and A. M. Hava, "A near-state PWM method with reduced switching losses and reduced common-mode voltage for three-phase voltage source inverters," IEEE Trans Ind. Appl., vol. 45, no. 2, pp.782-793 , Mar./Apr. 2009.

[8] Y. Bo, L. Wuhua, G. Yunjie, C. Wenfeng, and H. Xiangning, "Improved transformerless inverter with common-mode leakage current elimination for a photovoltaic grid-connected power system," IEEE Trans. PowerElectron., vol. 27, no. 2, pp. 752–762, Feb. 2012.

[9] E. Gubía, P. Sanchis, A. Ursúa, J. Lopez, and L. Marroyo, "Groundcurrents in single-phase transformerless photovoltaic systems," Prog. Photovolt., Res. Appl., vol. 15, no. 7, pp. 629–650, 2007.

[10] Lopez.O, Teodorescu.R, Freijedoy.J, "Eliminating ground current in a transformerless photovoltaic application," IEEEPowerdo.F, Doval-Gan Engineering Society General Meeting, 2007. , vol., no., pp.1-5, 24-28 June 2007.

[11] Agelidis.V.G, Baker.D.M, Lawrance.W.B, Nayar.C.V, "A multilevel PWM inverter topology for photovoltaic applications," Proceedingsof the IEEE International Symposium on Industrial Electronics, 1997.ISIE '97, vol.2, no., pp.589-594 vol.2, 7-11 Jul 1997.

[12] S. Dasgupta, S. K. Sahoo, and S. K. Panda, "Single-phase inverter control techniques for interfacing renewable energy sources with micro grid partI : Parallel-connected inverter topology with active and reactive power flow control along with grid current shaping," IEEE Trans. PowerElectron., vol. 26, no. 3, pp. 717–731, Mar. 2011.

[13] F. Blaabjerg, R. Teodorescu, M. Liserre, and A. V. Timbus, "Overview of control and grid synchronization for distributed power generation systems," IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1398–1409, Oct. 2006.

[14] W. Yong and L. Rui, "Novel high-efficiency three-level stacked-neutralpoint- clamped grid-tied inverter," IEEE Trans. Ind. Electron., vol. 60, no. 9, pp. 3766–3774, Sep. 2013.

[15] F. Bradaschiaet al., "Modulation for three-phase transformerless Z-source inverter to reduce leakage currents in photovoltaic systems," IEEE Trans.Ind. Electron., vol. 58, no. 12, pp. 5385–5395, Dec. 2011.