Transformer less MOSFET Inverter Topologies for PV Applications

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Abstract:

Recently, transformerless inverter has been found as one of the excellent solutions for grid-tied photovoltaic (PV) application because of its higher conversion efficiency, lower cost, smaller size, and light weight if compare with one's consist transformer. However, the main drawback of transformerless inverter is the leakage current issues that need to be addressed very carefully. On the other hand, the unipolar sinusoidal pulse width modulation full-bridge transformerless photovoltaic (PV) inverter can achieve high efficiency by using latest super-junction metal–oxide– semiconductor field-effect transistor (MOSFET) together with silicon carbide (SiC) diodes. The super-junction MOSFETs can avoid the fixed voltage drop and turn-off losses caused by tail current, thereby reducing the conduction and switching losses. However, due to poor reverse recovery of MOSFETs slow body diode, it is limited to use in transformerless inverter. In this work, a family of MOSFET-based transformerless topologies (HERIC, HBZVR, oH5,H6) for PV applications will be reviewed and discussed based on their circuit structure and common mode voltage clamping capability.

In this work, a family of MOSFET-based transformerless topologies (HERIC, HBZVR, oH5,H6) for PV applications will be reviewed and discussed based on their circuit structure and common mode voltage clamping capability. Based on that, a CMV clamped MOSFET transformerless inverter topology is proposed via super-junction MOSFETs and SiC diodes as no reverse-recovery issues are required for the main power switches for unity power operation. The proposed clamping branch clamps the freewheeling voltage at the half of dc input voltage during the freewheeling periods. As a result, the common-mode voltage kept constant during the whole grid period and hence reduces the common mode current (CMC) significantly. In addition, dead time is not necessary for main power switches at both the high-frequency commutation and the grid zero crossing instant, results low-current distortion at output. The theoretical findings are carried out via Matlab/Simulink. Furthermore, to show the effectiveness, the proposed topology is compared with the other transformerless MOSFET topologies interms of common-mode-voltage, leakage current and total harmonic distortion (%THD) respectively.

Keywords : *Common mode voltage, Turn on losses.*

INTRODUCTION

Sun is a major and an unlimited source of raw power which is available on our planet absolutely free. Today electricity has become the life line of all cities and even the rural areas. With depleting fossil fuel, sun light promises to be one of the major renewable source of energy that can be accessed directly from anywhere. Transformers as we all know are bulky, heavy and may become quite inconvenient for some applications. In the present design we tried to eliminate the use of a transformer by incorporating high voltage MOSFETS and by stepping up the voltage through series connection of solar panels. The electronic components to convert DC to high frequency AC, back to DC, and ultimately to standard-frequency AC. In a transformerless inverter, the process of stepping up voltage is achieved by means of a computerized multi-step process. A transformerless Inverter is lightweight, this allows installers the flexibility of rooftop installations without the need of reinforcement. Most modern inverter produced are transformerless simply because of superior efficiency. Transformerless inverter is an inverter which does not have transformer, since the function of stepping up the voltage is necessary, Transformerless inverter do not dispense with this function, rather the function is carried out in an entirely different manner. That manner is by using computerized multi-step process and electronic components which play a major role of a transformer. Transformerless Inverter has been found one of the excellent solutions for grid-tied photovoltaic (PV) applications because of its higher conversion efficiency, lower cost, smaller size and light weight if compare with one's consist transformer. Transformerless inverters are light, compact, and relatively inexpensive. Since transformerless inverters use electronic switching rather than mechanical switching the amount of heat and humidity produced by standard inverters is greatly reduced.

LITERATURE REVIEW

In Inverters, transformers are bulky so we tried to investigate on replacing the circuit with electrical parameters. Our project is on utilization of largest renewable energy available called solar energy. Transformer-less inverters are generally more efficient than conventional inverters because they able to avoid internal energy losses and extra component costs. Due to the absence of a transformer, Transformerless inverters are light, compact and relatively cheaper than conventional inverters. Main objective of this project is to design a new topology with less MOSFET count having greater efficiency and low leakage current losses. Project concentrates on investigation on various MOSFET based transformerless topologies to eliminate the leakage current via CMV clamping method and propose a low switching count MOSFET Configuration via clamping method. Finally simulation of existing and proposed configurations by comparing the performance characteristics of proposed structure with existing topology in terms of CMV, leakage current and %THD respectively.

DETAILED INFORMATION

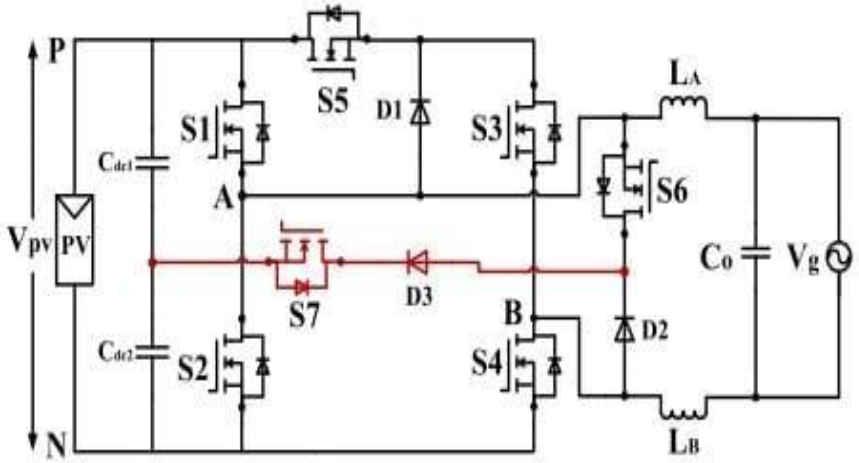
Recently, transformerless inverter has been found as one of the excellent solutions for grid-tied photovoltaic (PV) application because of its higher conversion efficiency, lower cost, smaller size, and light weight if compare with one's consist transformer. However, the main drawback of transformerless inverter is the leakage current issues that need to be addressed very carefully. Due to the loss of galvanic isolation between the PV module and the grid, a direct path is formed to flow leakage current which generally depends on the nonnegligible parasitic capacitance between the PV module and the ground, and the amplitude of fluctuating common-mode (CM) voltage. The fluctuation of CM voltage depends on the

topology structure and the control scheme. As a result of leakage current flowing through the system, the grid current harmonics and system losses increases. Another important concern of transformerless inverter is the efficiency that can be improved by the optimal design. Most of the transformerless inverter efficiency is the range of 96%−98%.

The most attractive transformerless topology is the highly efficient and reliable inverter concept (HERIC) topology where two switches are added in the ac side of a full-bridge topology to decouple the PV module from the grid during the freewheeling period. Another topology which has been proposed in replaces the two switches freewheeling branch with one bidirectional switch and four diodes called H-bridge zero-voltage rectifier (HB-ZVR) topology. It is also called Proposed topology. One more transformerless topology is called H5 topology, made up by adding an extra switch in the dc side of an FB inverter. An investigation has been conducted to calculate the device power losses and to make a detail comparison with the topologies. At last, a comparison table has been summarized based on the experimental data to show the effectiveness of the proposed topology.
HERIC transformer less inverter consists of conventional H - bridge inverter in addition to two switches in the AC side.

H5 topology is one of the most efficient topologies of the transformer less inverter family is H5 topology. This inverter extracts a discontinuous current from the PV panel, which conflicts with the operation at maximum power point tracking (MPPT) conditions while the utilization factor of the PV degrades.

H6 Topology is further advancement of H5 topology. H6 transformer less full bridge inverter topology with low leakage current that can be used in PV grid tied applications with higher efficiency. The PROPOSED topology is an hybrid combination of HERIC AND H6 kind where the efficiency is more and leakage currents are less when compared to the existing topologies.



There are two issues while we are working with Transformerless inverter.

1.Common Mode voltage

2.Leakage current issues

Common-mode voltage is one-half the vector sum of the voltages from each conductor of a balanced circuit to local ground or common

A leakage current is an electric current in an unwanted conductive path under normal operating conditions. Leakage current can be an indicator of the effectiveness of insulation on conductors. High levels of leakage current may be present in circuits where electronic equipment with filters is used, and can cause voltages that disrupt normal operation of equipment.

Transformerless inverters do not have electrical isolation between DC and AC circuits. This may raise some grounding and / or lightning protection concerns. In order for transformerless inverters to comply with NEC specifications specially designed and more expensive PV Wire must be used. Transformerless inverters have been developed for use with Grid-Tie Solar PV Systems, so Off-Grid systems users will not necessarily achieve the same benefit yet. To over come leakage current there are 3 methods. They are:

1. DC bypass Method
2. AC bypass Method
3. CMV clamping Method

If the switches are added on the DC side then the method is called DC bypassing or DC decoupling method. If the switches are added on the AC side, then the method is called AC bypassing or AC Decoupling method. CMV method is done by clamping the voltages and the method is called Neutral point clamping method. In this method in order to send the voltage to grid the capacitors should have a voltage withstanding capacity. Common mode Voltage clamping method is best suited because in this method the voltage fluctuations are maintained constant which finally results in low leakage currents.

WORKING :

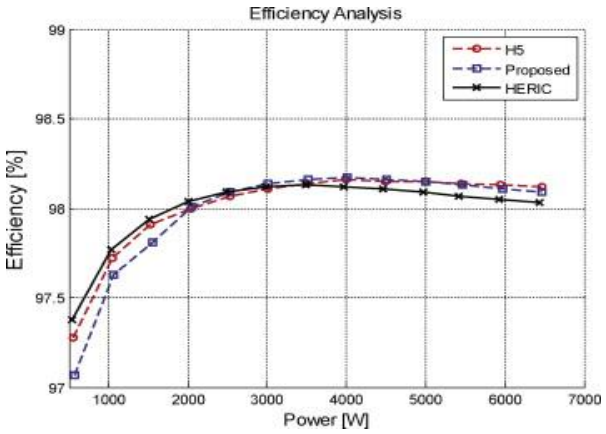
The above circuit shows the conventional H5 transformerless inverter topology. In this circuit, the conventional H-bridge inverter is connected to the PV panel using the fifth switch. The switch operates at the same frequency as the utility grid's frequency.

Moreover, it works to disconnect the PV array from the grid in zero state, something which cuts off the path for leakage current. As a result, system leakage current is greatly decreased. The following main operation principles for the H5 inverter are:

• The upper group switches (Q1 and Q3) operate alternately at the grid frequency. (Q1) is on during the positive half cycle, while (Q3) is on during the negative half cycle. The control signals of switches (Q1 and Q3) are pure square waves at the supply frequency.

• The lower group switches (Q2 and Q4) operate alternately at the grid frequency. (Q4) is on during the positive half cycle, while (Q2) is on during the negative half cycle. The control signals of switches (Q2 and Q4) are square waves at the supply frequency, but are modulated with PWM as shown in circuit.

RESULTS



The efficiency for the H5, HERIC and proposed topologies is calculated 97.59%, 98.16%, 98.24%. HERIC topology shows better efficiency with high leakage current. It is clear that only the **proposed** topology presents high efficiency with low leakage current. Therefore, the proposed topology can combine the superior performance of CM characteristics and efficiency.

In this project a new topology of transformerless inverter will be developed based on existing MOSFET model will be modified and proposed with low switching count MOSFET transformer less inverter namely LS-MTI. To overcome thE issues of transformerless inverter, this project introduces MOSFET's in PROPOSED topology with this one can terminate leakage current issues and CMV fluctuations. The efficiency of the newly based transformerless inverter can also be increased by 2-3% by maintaining constant Common mode voltage and also reducing the leakage current as low as possible.

CONCLUSION:

In this article, new efficient transformerless inverter for a grid-tied PV power generation system is presented using MOSFETs as main power switches. The main advantages of the proposed topology are as follows:

1) High efficiency over a wide load range is achieved by using MOSFETs and SiC diodes.
2) CM voltage remains constant during all operation modes due to the added clamping branch, results low leakage current.
3) Like as isolated FB inverter, excellent DM characteristics are achieved with unipolar SPWM.
4) PWM dead time is not required for main power switches, results low distortion at output.
Therefore, it can be concluded that the **PROPOSED** inverter topology is best suitable for a single-phase grid-tied PV application.

REFERENCES

Journal Articles

[1] M. Islam, S. Mekhilef, and M. Hasan, "Single phase transformerless inverter topologies for grid-tied photovoltaic system: A review," Renew. Sustainable Energy Rev., vol. 45, pp. 69–86, 2015.

[2] I. Patrao, E. Figueres, F. Gonzalez-Esp ´ ´ın, and G. Garcera, "Transformer- ´ less topologies for grid-connected single-phase photovoltaic inverters," Renew. Sustainable Energy Rev., vol. 15, pp. 3423–3431, 2011.

[3] Z. Li, S. Kai, F. Lanlan, W. Hongfei, and X. Yan, "A family of neutral point clamped full-bridge topologies for transformerless photovoltaic grid-tied inverters," IEEE Trans. Power Electron., vol. 28, no. 2, pp. 730–739, Feb. 2013.

[4] M. Islam and S. Mekhilef, "H6-type transformerless single-phase inverter for grid-tied photovoltaic system," IET Power Electron., vol. 8, pp. 636– 644, 2015.

[5] H. Xiao, X. P. Liu, and K. Lan, "Zero-voltage-transition full bridge topologies for transformerless photovoltaic grid-connected inverter," IEEE Trans. Ind. Electron., vol. 61, no. 10, pp. 5393–5401, Oct. 2014.

[6] X. Huafeng, K. Lan, and L. Zhang, "A quasi-unipolar SPWM full-bridge transformerless PV grid-connected inverter with constant common-mode voltage," IEEE Trans. Power Electron., vol. 30, no. 6, pp. 3122–3132, Jun. 2015.

[7] J. Baojian, W. Jianhua, and Z. Jianfeng, "High-efficiency single-phase transformerless PV H6 inverter with hybrid modulation method," IEEE Trans. Ind. Electron., vol. 60, no. 5, pp. 2104–2115, May 2013.

[8] D. Barater, G. Buticchi, E. Lorenzani, and C. Concari, "Active commonmode filter for ground leakage current reduction in grid-connected PV converters operating with arbitrary power factor," IEEE Trans. Ind. Electron., vol. 61, no. 8, pp. 3940–3950, Aug. 2014.

[9] X. Huafeng, X. Shaojun, C. Yang, and H. Ruhai, "An optimized transformerless photovoltaic grid-connected inverter," IEEE Trans. Ind. Electron., vol. 58, no. 5, pp. 1887–1895, May 2011.

[10] T. Kerekes, R. Teodorescu, P. Rodriguez, G. Vazquez, and E. Aldabas, "A new high-efficiency single-phase transformerless PV inverter topology," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 184–191, Jan. 2011.

[11] B. N. Alajmi, K. H. Ahmed, G. P. Adam, and B. W. Williams, "Singlephase single-stage transformer less grid-connected PV system," IEEE Trans. Power Electron., vol. 28, no. 6, pp. 2664–2676, Jun. 2013.

[12] G. Bin, J. Dominic, L. Jih-Sheng, C. Chien-Liang, T. LaBella, and C. Baifeng, "High reliability and efficiency single-phase transformerless inverter for grid-connected photovoltaic systems," IEEE Trans. Power Electron., vol. 28, no. 5, pp. 2235–2245, May 2013.