

FULL-BRIDGE PV-GRID TIED GENERATION SYSTEM BY USING H6 TRANSFORMERLESS

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Abstract-- MATLAB based single-phase three-level topology for a transformerless photovoltaic system is presented in this paper. Compared with the conventional H-bridge topology, it only needs two additional asymmetrically distributed switches, and the system common-mode voltage can be kept constant with a simple modulation scheme. Family of H6 transformer less inverter topologies with low leakage currents is proposed and highly efficient and reliable inverter concept (HERIC) topology is also presented in this paper. The proposed inverter can also operate with high frequency by retaining high efficiency which enables reduced cooling system. Finally, the proposed new topology is simulated by MATLAB/Simulink software to validate the accuracy of the theoretical explanation.

Index Terms— Solar PV, Transformerless inverter, Common-mode voltage, Leakage current, Current Ripples, Switching control, PWM

I. INTRODUCTION

The interest in renewable-energy sources is successively increasing because of rising demand of the world's energy and increasing price of the other energy sources, together with considering the environmental pollution. Many renewable energy sources are now available; among them, PV is the most up-to-date technique to address the energy problems. Photovoltaic (PV) power generation systems are received more and more attention in recent years. Due to the large-scale manufacturing capability of the PV module, it is becoming increasingly cheaper during these last years. So the attempt to decrease the total grid-tied PV system cost is mostly depend on the price of grid-tied inverter [1-3]. Grid tied PV inverters which consists a line frequency transformer are large in size; make the entire system extensive and difficult to install. It is also a challenging task to increase the efficiency and reduce the cost by using high frequency transformer which requires several power stages [4, 5]. On the other hand, transformer-less grid-tied inverters have the benefits of lower cost, higher efficiency, smaller size, and weight [6-12]. However, there exist a galvanic connection between the power grid and the PV module due to the exclusion of transformer which form a CM leakage current. This CM leakage current increases the grid current harmonics and system losses and also creates strong conducted and radiated electromagnetic interference. However, the

transformerless inverter creates a common-mode resonant circuit including the filter, the inverter, the impedance of the grid and the DC source ground parasitic capacitance as illustrated in Figure 1. In this case, a common-mode current is generated and superimposed to the grid, hence increasing its harmonics content [7, 12-16] and causing an electromagnetic interference (EMI) between the PV system and the grid. In addition, the leakage current through the parasitic capacitance can reach considerable levels affecting therefore the safety when a human touches the PV system. To eliminate these currents, topologies that do not generate variant common-mode voltage are necessary for implementing transformerless PV inverter.

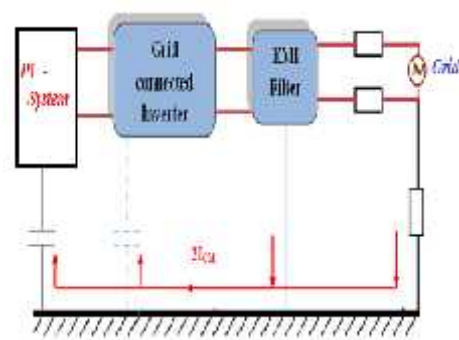


Fig.1. Ttransformerless PV system

On the other hand, the transformerless PV systems have been received more attention due to cost and size reduction, as well as efficiency improvement compared with the conventional transformer ones. A number of technical challenges may arise with increased grid-connected transformerless PV systems. One of the most important issues is how to reduce or eliminate the leakage currents through the parasitic capacitor between the PV array and the ground [3-10]. In general, the leakage current can be significantly mitigated from the viewpoint of system topology or modulation schemes. For example, the single-phase H-bridge topology with the bipolar modulation has the inherent feature of the leakage current reduction. However, it leads to the relatively more high frequency ripples due to the two-level output voltage. On the other hand, the unipolar modulation with three-level output voltage is beneficial in terms of low voltage ripples and small filter size, but the leakage current is significantly increased due to the time varying high frequency common mode voltage.

In order to solve the abovementioned problem, many interesting topologies have been reported in the past few years. The basic idea behind them is to keep the system common mode voltage constant to eliminate the leakage currents. With the basic idea, a new single-phase three-level topology for transformerless photovoltaic systems is presented in this paper. Compared with the conventional H-bridge topology, it only needs two additional asymmetrically distributed switches, and the system common-mode voltage can be kept constant with a simple modulation scheme. The theoretical analysis and test results demonstrated that the proposed topology is very promising for transformerless PV systems.

II. PROPOSED TOPOLOGY

Fig. 2.employs two extra switches on the ac side of inverter, so the leakage current path is cut off as well. Fig. 3 and Fig.4 shows the H6-type topology and the hybrid-bridge topology respectively. Comparing with a full-bridge inverter, two extra switches are employed in the dc sides of these two topologies.

In the active modes, the inductor current of the proposed H6 topology flows through two switches during one of the half-line periods and through three switches during another half-line period. As a result, for comparing with the topologies presented in [17], [19], and [20], the proposed H6 topology has achieved the minimum conduction loss, and also has featured with low leakage currents.

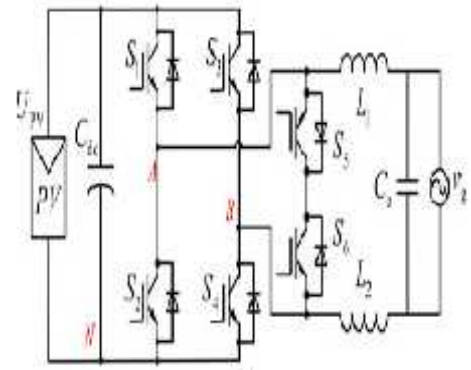


Fig.2. Transformerless full-bridge inverter -(HERIC) Topology

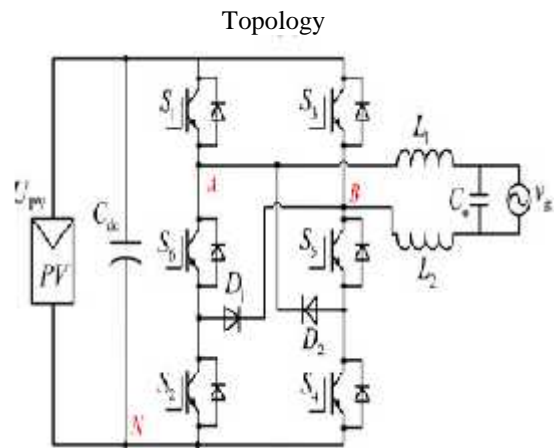


Fig.3. Transformerless full-bridge inverter- H6-Type

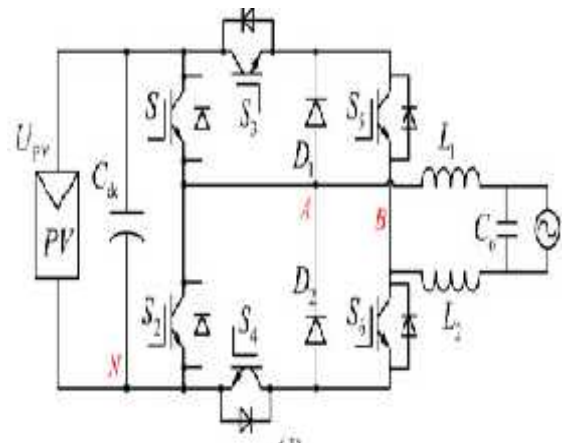


Fig.4. Transformerless full-bridge inverter- Hybrid Type

A. Modes of operations :

PV grid-tied systems usually operate with unity power factor. The waveforms of the gate drive signals for the proposed novel H6 topology are shown in Fig.5.

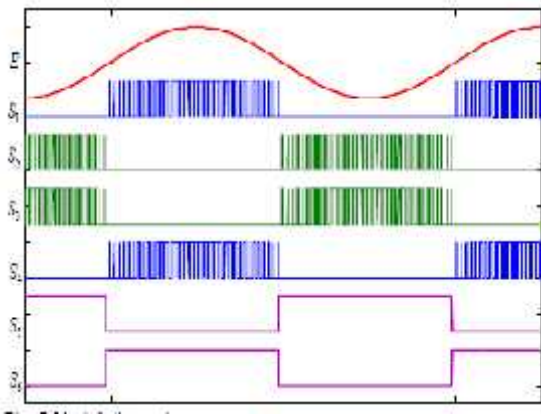


Fig.5. Modulation Scheme for gate drive signals with unity power factor.

In the proposed H6 inverter topologies, there are four operation modes in each period of the utility grid. The four modes of operations are explained below

Mode 1 : Mode1 is the active mode in the positive half period of the utility grid voltage, as shown in Fig. 6. S1, S4 , and S5 are turned ON, and the other switches are turned OFF. The inductor current is flowing through S1, S4 , and S5 . $v_{AN} = UPV$, $v_{BN} = 0$; thus, $v_{AB} = UPV$, and the CM voltage $v_{CM} = (v_{AN} + v_{BN})/2 = 0.5UPV$.

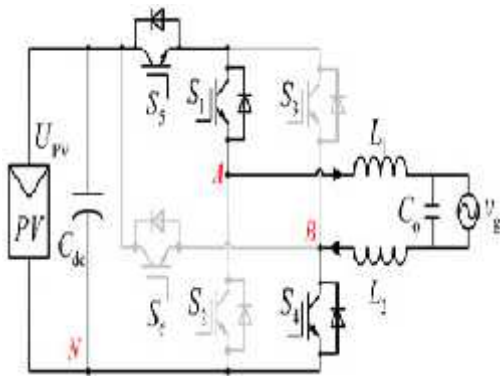


Fig.6. Equivalent circuits of operation mode- Active mode in the positive half period (Mode1)

Mode 2 : Mode 2 is the freewheeling mode in the positive half period of the utility grid voltage, as shown in Fig.7. S1 is turned ON; the other switches are turned OFF. The inductor current is flowing through S1 and the anti paralleled diode of S3 . $v_{AN} = v_{BN} = 0.5UPV$; thus, $v_{AB} = 0$, and the CM voltage $v_{CM} = (v_{AN} + v_{BN})/2 = 0.5UPV$.

Mode.3: Mode 3 is the active mode in the negative half period of the utility grid voltage, as shown in Fig.8. S2, S3, and S6 are turned ON; the other switches are turned OFF. The inductor current is flowing through S2 and S6 . Although S3 is turned ON, there is no current flowing through it, and the switch S3 has no conduction loss in this mode. Nevertheless, in the H5 topology, the inductor current flows through S2, S3 , and S5 . Therefore, the conduction loss of proposed topology is less than that of

H5 topology. In this mode, $v_{AN} = 0$, $v_{BN} = UPV$; thus, $v_{AB} = -UPV$, and the CM voltage $v_{CM} = (v_{AN} + v_{BN})/2 = 0.5UPV$.

Mode.4: Mode 4 is the freewheeling mode in the negative half period of the utility grid voltage, as shown in Fig.9. S3 is turned ON, and the other switches are turned OFF. The inductor current is flowing through S3 and the anti paralleled diode of S1 . $v_{AN} = v_{BN} = 0.5UPV$; thus, $v_{AB} = 0$, and the CM voltage $v_{CM} = (v_{AN} + v_{BN})/2 = 0.5UPV$.

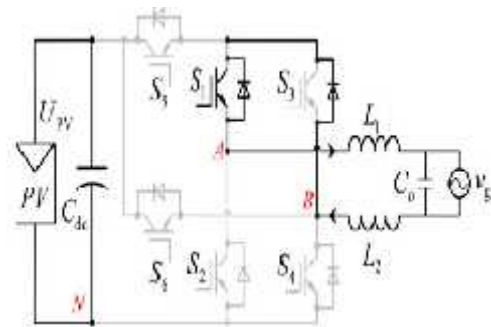


Fig.7. Equivalent circuits of operation mode- Freewheeling mode in the positive half period (Mode 2)

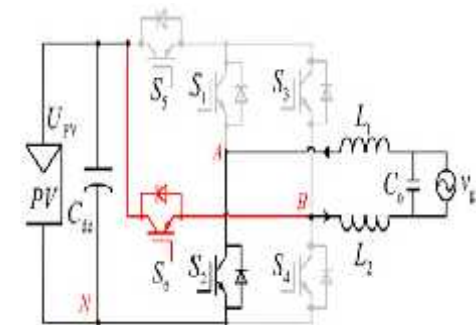


Fig.8. Equivalent circuits of operation mode- Active mode in the negative half period. (Mode 3)

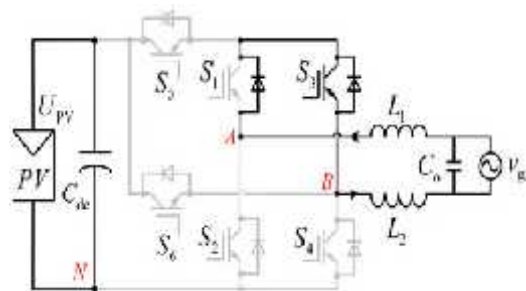


Fig.9. Equivalent circuits of operation mode- Freewheeling mode in the negative half period (Mode 4)

From the four modes of operations, i.e., from Fig.6 to Fig.9 , V_{AN} represents the voltage between terminal (A) and terminal (N) and V_{BN} represents the voltage between terminal (B) and terminal (N). V_{AN} is the DM voltage of the topology, $V_{AB} = V_{AN} - V_{BN}$. The CM voltage $V_{CN} = 0.5(V_{AN} + V_{BN})$.

The full-bridge inverters only need half of the input voltage value demanded by the half-bridge topology, and the filter inductors $L1$ and $L2$ are usually with the same value. Hence, is given by

$$V_{CN} = \frac{V_{AN} + V_{BN}}{2}$$

Fig.10. shows the modulation strategy of the proposed modes of operation for gate pulses of converters .

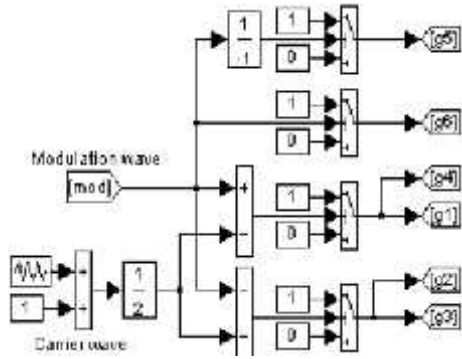


Fig.10. Modulation strategy of the proposed topology

III. MATLAB BASED SIMULATION OF PROPOSED TOPOLOGY

MATLAB based simulation diagram of proposed system is shown in Fig.11.

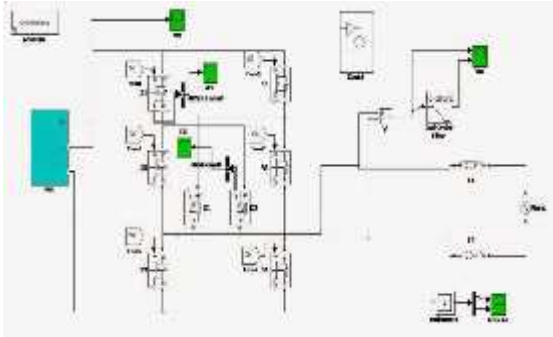


Fig.11. MATLAB based simulation diagram of proposed system.

Fig.12 shows the Voltage stress on $S5$ and $S6$ of Drain–source voltages in H6 topology. Fig.13 shows the DM characteristic of H6 topology.

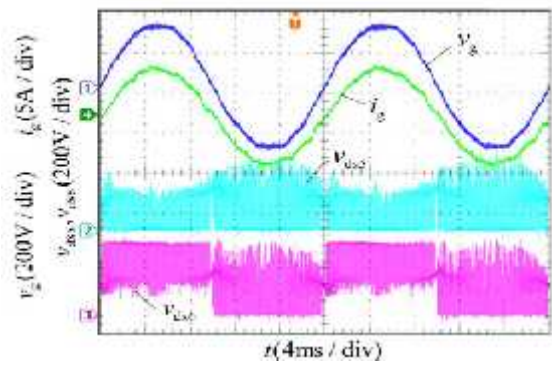


Fig.12. Voltage stress on $S5$ and $S6$ of Drain–source voltages

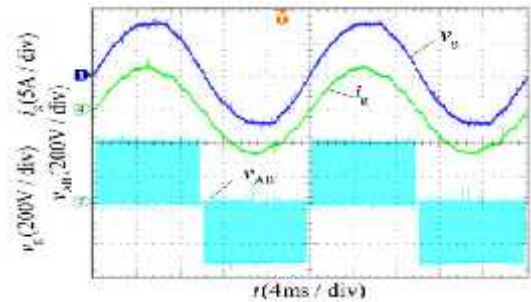


Fig.13. DM characteristic of H6 topology.

TABLE I. SIMULATION SPECIFICATIONS

Parameter	Rating
Input Voltage	380-700 V
Output Power	1kW
Grid Voltage	230V
Grid Frequency	50 Hz
Input Capacitance	940 μ F
Filter inductances	3mH
Filter capacitance	0.1 μ F

IV. CONCLUSION

Transformerless inverter topologies are being used to overcome the deficiencies of inverters with transformers. This paper proposes a novel 3-phase inverter with H6-type configuration as a part of a wide input range, high efficiency, and long lifetime PV non-isolated module. Experimental results verify the validity of the novel circuit and show high efficiency. Furthermore, the switching voltages of all commutating switches are half of the input dc voltage and the switching losses are reduced greatly. Finally , theoretical analysis and performance evaluation results indicate that the proposed topology can effectively reduce the leakage current to an acceptable level.

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