A Low Cost Single Phase Inverter with Virtual DC Bus for Common Mode Ground Leakage Current Elimination in PV Systems

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Abstract **- This paper presents a low cost single phase inverter with virtual DC bus for common mode ground leakage current elimination in PV systems. It concentrates on the removal of common mode ground currents in the transformer less PV systems using virtual DC bus concept. In addition to this, the virtual Dc bus provides a negative voltage level for the generation of negative ac grid current. Based on this idea, an inverter topology is designed, in which the virtual DC bus is created with the switched capacitor technology. It uses two switched capacitors, five power switches and only a single filter inductor, which results in reduced cost of the device. This inverter topology is modulated with two techniques such as unipolar sinusoidal pulse width modulation (UPSPWM) and double frequency sinusoidal pulse width modulation (DFSPWM) for a DC input of 400V from the PV panels. Simulated results concluded that the proposed inverter topology provides the reduced output current ripple, low THD and high power factor.**

Key words- photovoltaic (PV) systems, virtual DC bus, common mode (CM) current, unipolar sinusoidal pulse width modulation (USPWM), double frequency sinusoidal pulse width modulation (DFSPWM).

I INTRODUCTION

In general common mode ground leakage current is caused by the stray capacitance between the PV panels and ground in the transformer less PV systems. Mainly the inverters are used to feed the power into the utility grid. The cost of PV panels is high, that's why our invention regarding PV panels should be of high efficiency, smaller size and low cost. If we considered the traditional grid-connected PV inverters, we have used either line frequency transformer or high frequency transformer.

These transformers provide galvanic isolation between the grid and PV panels. Now a days we are compensating these transformers with power electronic devices such as buck, boost converters. Replacing transformers by the power electronic devices result in the improved efficiency and the reduced size and cost.

Removal of transformer means removal of galvanic isolation, it generates the common mode (CM) ground leakage current that appear on the parasitic capacitor between the PV panels and the ground. The presence of the CM current may improve the grid current distortion, reduce the power conversion efficiency, electromagnetic compatability and rise in safety problems.

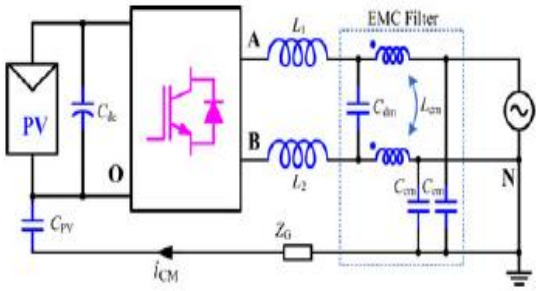

Fig.1 Path of the CM current for transformer less inverter

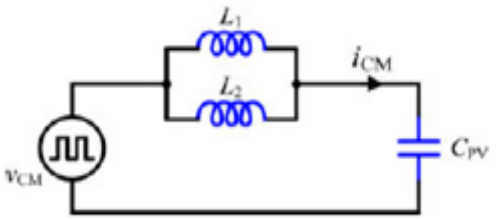

Fig.2 Equivalent circuit for common mode current path

The path of the common mode current in the transformer less grid-connected PV inverter system is shown in Fig.1. The common mode (CM) current path is

equivalent to an LC resonant circuit in series with the CM voltage shown in Fig.2. However this common mode current can be made to zero by making use of the proposed inverter topology.

II PROPOSED CIRCUIT

In this paper, a new inverter topology strategy with virtual DC bus concept is proposed for the transformer less grid-connected PV inverter. In this inverter topology, the grid neutral line is directly connected to the negative pole of the DC bus as shown in Fig.3, so that the voltage across the parasitic capacitor C_{PV} is reduced to zero. Therefore, the common mode current is eliminated completely by the structure of inverter itself. In addition to this, the virtual DC bus is defined to generate negative output voltage. A LCL filter is used to interconnect an inverter to the utility grid in order to filter the harmonics produced by inverter shown in simulation.

As shown in the above proposed inverter topology, it contains virtual DC bus by the switched capacitor technology. In this inverter topology five IGBTs are used as the switching devices and a filter inductor is used to reduce the ripple contents of output current. For the better understanding nature of virtual DC bus concept, its importance during the production of sinusoidal output is explained from Fig.4.

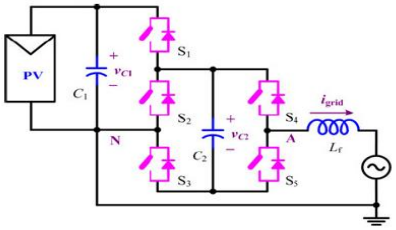

Fig.3 Proposed Inverter Topology with Vitual DC bus

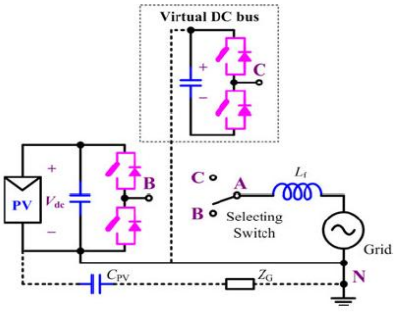

Fig.4 Virtual DC bus concept

As shown in the Fig.4, the voltage at the midpoint 'C' is either 0 or $-V_{dc}$ and at point 'B' is either 0 or $+V_{dc}$. By a smart selecting switch with points B and C together voltage at point A can be obtained with three levels $+V_{dc}$, 0 , $-V_{dc}$.

III OPERATION

The operation of single phase inverter with virtual DC bus concept for transformer less grid-connected PV system is explained in this chapter. Generally the proposed inverter topology operates in either three states or four states depending on the modulation techniques unipolar sinusoidal pulse width modulation (USPWM) and double frequency sinusoidal pulse width modulation (DFSPWM) respectively. Considering both the modulation methods, the four operating states are listed as follows.

- State 1 with voltage level $+V_{dc,}$ when S_1,S_3,S_5 are turned ON
- State 2 with voltage level 0, when S_1,S_3,S_5 are turned ON
- State 3 with voltage level $-V_{dc}$, when S_2 and S_5 are turned ON
- State 4 with voltage level 0, when S_2 and S_5 are turned ON

The proposed inverter topology rotates in first three states for unipolar sinusoidal pulse width modulation (USPWM) and in four states for double frequency sinusoidal pulse width modulation (DFSPWM). Both modulation techniques have their own advantages. The unipolar sinusoidal pulse width can assure that the virtual DC bus C_2 is charged by the real for every switching cycle, so that the current stress on S_1 and S_3 caused by the operation of switched capacitor can be reduced. On the other hand the double frequency sinusoidal pulse width modulation can provide a higher equivalent switching frequency so that the size and weight of the filter inductor can be reduced.

TABLE I
SIMULATION CONFIGURATION

Input voltage		400V	Grid voltage	400V ac
Input capacitor(C_1)		470µF	Switched capacitor(C2)	940 µF
LCL Filter	L_f	8mH	Switching Frequency	20KHZ
	C_f	0.34µF	Grid Frequency	50HZ
	L_r	0.8mH	Power Switches	IGBTs

For a case of the successful operation of the proposed inverter topology, the specifications used in the simulation are tabulated above as shown in Table.1.

IV RESULTS

In this chapter simulated results obtained are presented for the two modulation strategies such as

unipolar sinusoidal pulse width modulation (USPWM) and double frequency sinusoidal pulse width modulation (DFSPWM).

A . SIMULATION OF THE PROPOSED INVERTER WITH USPWM

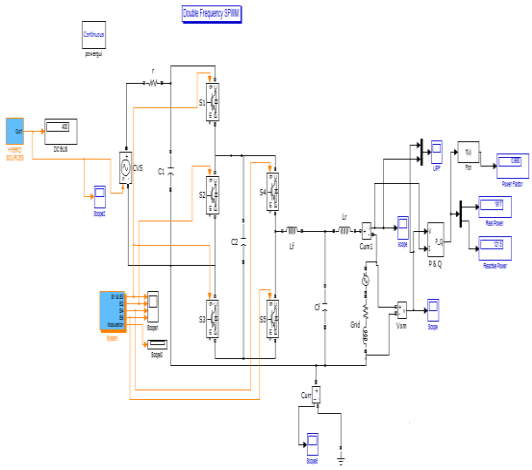

Fig.5 Simulation circuit for the proposed inverter topology with USPWM

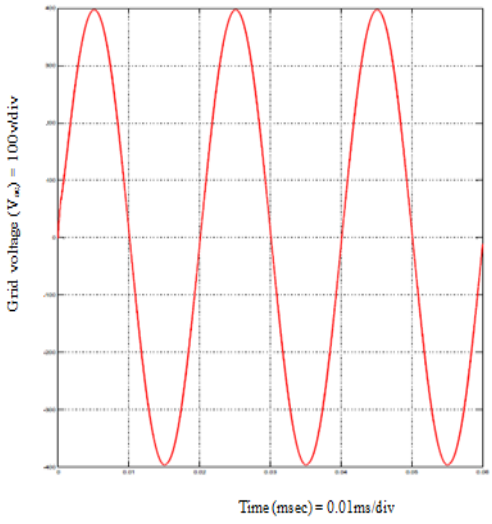

Fig.6 output AC voltage (or) grid voltage for USPWM

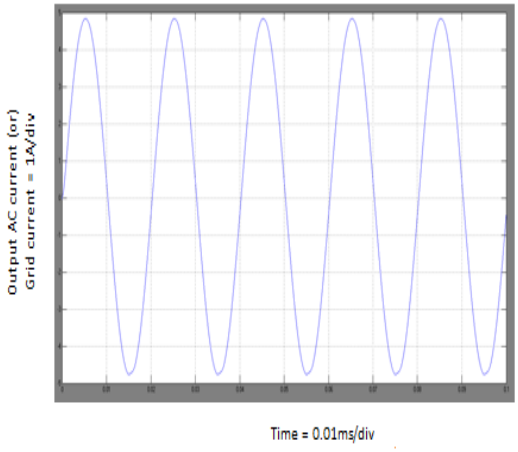

Fig.7 Grid current (or) Output AC current with USPWM

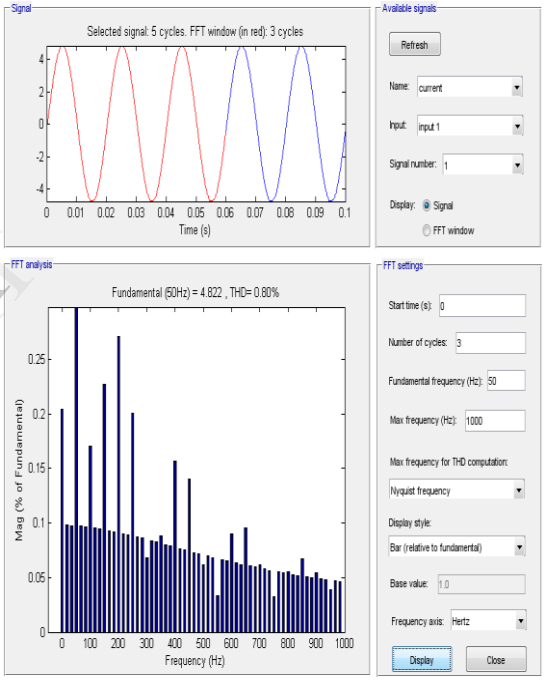

Fig.8 THD (Total harmonic distortion) for grid (or) output AC current with USPWM

These are simulated results obtained for the proposed grid connected single phase inverter with virtual Dc bus concept for transformerless grid connected PV systems. Where the magnitude of output voltage is 400V and from the results it is clear that the output power factor is 0.9857 and THD (Total harmonic Distortion) of the grid current is 0.80% as shown in Fig.8. That means the distortion in the inverter output is reduced to improve the power quality and inversion efficiency.

B .SIMULATION OF THE PROPOSED INVERTER WITH DFSPWM

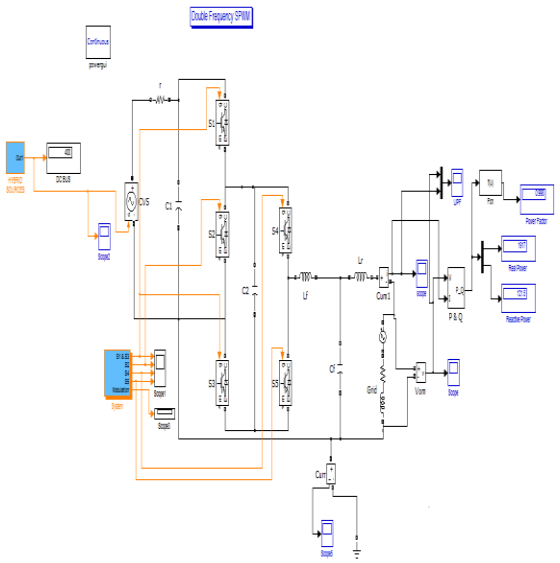

Fig. 9 Simulation circuit for the proposed inverter topology with DFSPWM

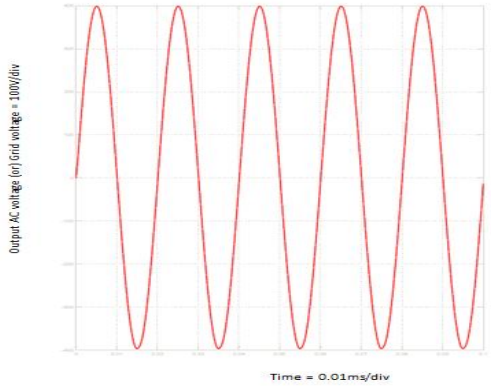

Fig.10 Output AC voltage (or) grid voltage for DFSPWM

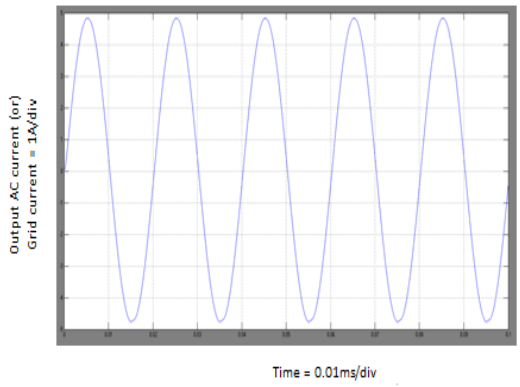

Fig.11 Grid current (or) Output AC current with DFSPWM

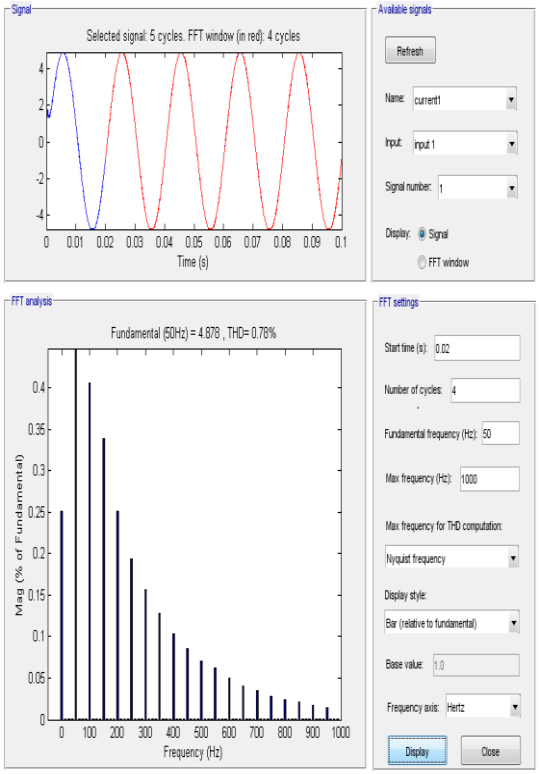

Fig.12 THD (Total harmonic distortion) for grid current (or) Output AC current with DFSPWM

With this advanced modulation technique (DFSPWM) also results are obtained effectively. In this modulation technique we analysed that output power factor is 0.998 and THD (Total Harmonic Distortion) for grid current or output AC current is 0.78% only as shown in Fig.12. Therefore, we have obtained best results for the proposed inverter topology with both the modulation techniques.

V CONCLUSION

The common mode (CM) ground leakage currents in transformerless grid-connected PV systems can be eliminated completely using the proposed inverter topology structure, having a connection between grid neutral line and negative pole of the DC bus, voltage on the stray PV capacitor is clamped to zero. Which means no additional system is needed. The proposed inverter topology provides high power factor and low THD to improve the inversion efficiency. Power electronic devices cost can be curtailed due to the reduced number of power switches and reduced size of filter inductor. With these excellent features of proposed inverter topology with virtual DC bus concept, this inverter topology will be widely adapted for the transformerless grid-connected PV systems.

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