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A NOVEL DESIGN, ANALYSIS AND SUPPRESSION OF LEAKAGE CURRENT IN TRANSFORMERLESS PHOTOVOLTAIC INVERTER

M. Kasumayan[1], Dr. R. Vimala [2], S.Ravikumar[3],
[1]Research Scholar & Professor, Bharath Niketan Polytechnic College, Aundipatti, Tamilnadu , India
[2] Associate Professor PSNA College of engineering and Technology , Dindugul, Tamilnadu, India,
[3]Research Scholar & Assistant Professor, St. Michael College of Engineering & Technology , Kalayarkovil, Tamilnadu , India,

Abstract Transformerless inverters are being widely used in grid-connected photovoltaic (PV) generation systems. Transformer elimination, in grid-connected PV systems, has many advantages. This not only reduces cost, size, and weight, but also increases the whole system efficiency. However, once the transformer is removed, there is no galvanic isolation between grid and PV array; as a consequence, leakage current appears due to parasitic capacitance to the ground, resulting in prohibitive electromagnetic interference and security issues. This research work presents a novel topology in order to reduce this ground leakage current by improving isolation between primary & secondary. The proposed system will increase the system efficiency by reducing dc component and leakage current. The main features of this proposed topology are in the first place, the negative of the PV array is connected directly to the neutral of the grid greatly reducing the ground leakage current through the parasitic capacitance; and in second place, the topology only uses two MOSFETs reducing cost of the whole system.

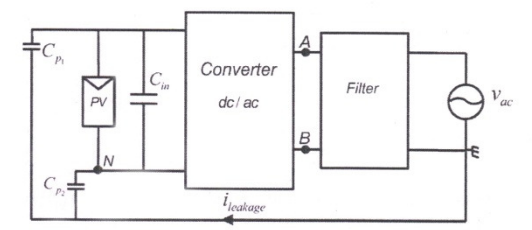
Index terms –Electrical array reconfiguration (EAR), grid connected photovoltaic (PV) systems, reconfigurable PV systems.

INTRODCUTION

PHOTOVOLTAIC (PV) Grid-connected PV systems may be also used without a transformer, which improves their efficiency and makes the whole systems lighter, smaller, and easier to install. However, a transformerless grid-connected PV system creates a common-mode (CM) resonant circuit, which includes the filter, the inverter, the grid impedance, and the PV parasitic capacitance. This CM generates a leakage current that circulates through parasitic capacitances C_{p1} and C_{p2} in PV array to the ground, as shown in The CM voltage, the modulation strateg, and the value of the parasitic capacitance greatly affect the value of leakage current.

The parasitic capacitance value depends on many factors such as :

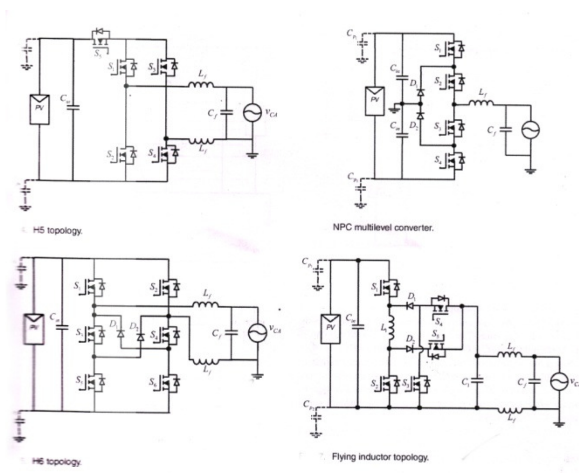
- PV panel and frame structure;
- Surface of cells;
- Distance between cells;
- Weather conditions;
- Type of electromagnetic compatibility filter;



Block diagram that illustrates the leakage current in transformer-less inverter.

II LEAKAGE CURRENT IN TRANSFORMERLESS PV TOPOLOGY

Here, a brief description of some transformerless topologies is given. At the beginning, traditional topologies are presented, then variations performed to the differential inverter are reported, and finally, converters with common connection are discussed.



A. Full- and Half- Bridge Topology

H-Bridge inverter, which consists of a full bridge, as shown in Fig. 2, is recognized due to its simplicity in design. Different pulse width modulation (PWM) switching may be used. i.e, bipolar and unipolar. Normally, unipolar PWM switching is preferred because it improves the quality and reduces the losses; however, during its operation, the leakage current is very high, which makes this not only unsafe but also unsuitable for its use in PV generation systems.

In, a buck-boost converter plus a two half-bridge inverter to support split Phase is proposed this configuration has the advantage of having reduced low – frequency input current ripple, additionally to the leakage current.

B. H6 Topology

This inverter is composed of six power MOSFETS AND two diodes for the freewheeling mode, as shown in Fig While operating in a freewheeling mode for the positive semicycle, the current circulates through S_4 and diode D_1 that allows not only the disconnection between the PV array and the grid, but also avoids the high-frequency voltage inconvenience for implementing the system.

C. Multilevel Topologies

The multilevel neutral-point-clamped (NPC) inverter, as shown in Fig, is suitable for reducing the leakage current. The midpoint of the dc-Link capacitor should be connected to the neutral line of the utility grid. The output voltage may be unipolar. During operation of this system. The input voltage must be twice higher than the H-bridge inverter, a reason. Probably enough. to disregard this converter.

In a new multilevel inverter that should be useful in PV applications is proposed, providing a low harmonic distortion, but certainly increasing the number of semiconductors and complexity.

D. Flying Inductor Topology

A flying inductor converter is shown in Fig, It is also known as the Karchny inverter. This topology has the advantage of having the negative PV array connected directly to the neutral terminal of the grid. However, not only it requires more diodes that eh H-Bridge but also most of the switching states have three devices conducting at the same time, which become a serious demerit it reduces efficiency.

E. CM Topology

An unusual topology is reported in, which connects the PV negative terminal to the neutral line of the utility grid. It is easily seen that the input voltage may be similar to the traditional H-bridge inverter. However, its operation is not only complex, but also the required number of components is considerably higher that the normally used.

III. PROPOSED TOPOLOGY

The proposed topology is compared here with other schemes that connect the PV negative terminal with the neutral of the grid, where also the NPC topology was included. All these schemes certainly offer a very low leakage current. For comparative purposes, the amount of semiconductors, the passive elements and the stress of the semiconductors are considered. The proposed converter, not only has fewer semiconductors than other topologies, but also, it has fewer or almost the same amount of passive elements. The input voltage in all the converters must be higher the peak of the ac.

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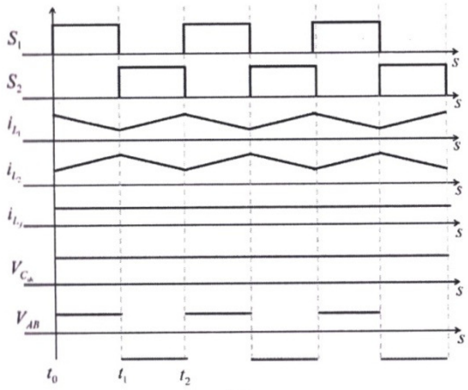
The circuit diagram for the proposed inverter is shown in fig.. The topology is composed by two power MOSFETs (S_1 and S_2) , and a single device is conduction in each switching state. The converter includes two capacitors and three inductors.

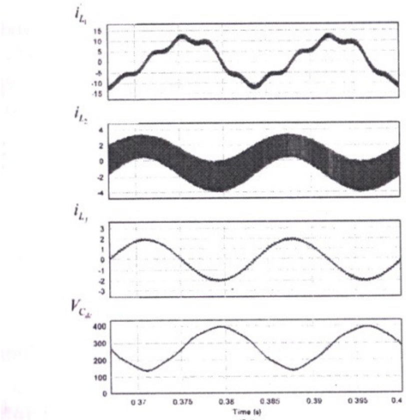
Since the negative of the PV array is connected straight to the neutral line of the grid, the ground leakage current is very low for our proposal topology, whereas the applied voltage to the parasitic capacitance is maintained almost constant.

The converter operates as follows.

1. During t_0-t_1 The positive switching state is used at this time. Where S1 is turned on and S2 is turned off . During this switching state, the input voltage is applied to the LCL output filter, which provides a positive voltage (V_{AB}). It should be noticed the polarity of the capacitor voltage (C_{dc}), where the inductor L_l is discharged into the capacitor.
2. During t_1-t_2. The negative switching state is applied at this time, where S_1 is turned off and S_2 is turned on. The capacitor voltage. i.e, C_{dc}, is applied to the output filter, which provides in this form a negative voltage to the LCL output filter (V_{AB}) At this stage, the inductor L_l is charged from the PV panel.



(a)



(b)

The proposed converter is able to provide ac current to the ac mains with an appropriate controller, since the converter may provide a positive or negative voltage depending on the switching state. Typical waveforms for the converter at low frequency. These were obtained by numerical simulation.

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