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Review of Reduction of Leakage Current in Cascaded Multilevel Inverter

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ABSTRACT

Multilevel inverters are a source of high power, often used in industrial applications and can use either sine or modified sine waves. A multilevel inverter uses a series of semiconductor power converters (usually two to three) thus generating higher voltage. Reverse leakage current in a semiconductor device is the current from that semiconductor device when the device is reverse biased. In earlier method transformer is used for generating multilevel output and grid synchronization. Transformer increases the leakage current. Now transformerless method and sine modulation techniques are presented to reduce the leakage current.

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I. INTRODUCTION

A primary goal of these systems is to increase the energy injected to the grid by keeping track of the maximum power point (MPP) of the panel, by reducing the switching frequency, and by providing high reliability. In the last years, multilevel converter topologies have been also considered in PV applications. Multilevel converter topologies can generate high-quality voltage waveforms with power semiconductor switches operating at a frequency near the fundamental. The cascaded multilevel converter constitutes a promising alternative, providing a modular design that can be extended to allow a transformerless connection to the grid.

The cascaded multilevel topology has also disadvantages, as the strings of PV panels are not grounded and extra measures have to be taken in order to avoid currents due to stray capacitances between the panel and the earth. Pulse width modulated (PWM) multilevel inverters (MLIs) are gaining both popularity and applications, becoming an effective alternative to current inverter topologies. In their early stage, they were employed mainly in high-voltage high-power industrial and traction applications because they distribute the applied voltage among a number of cascaded power devices, thus overcoming their voltage limits and allowing the elimination of output transformers in medium–high voltage systems

To avoid the common-mode leakage current, the conventional solution employs the half-bridge inverter or the full-bridge inverter with bipolar sinusoidal pulse width modulation (SPWM), because no variable common-mode voltage is generated. However, the half-bridge inverter requires a high input voltage which is greater than, approximately, 700 V for 220-Vac applications.

II. MULTILEVEL INVERTER

The concept of multilevel converters has been introduced since 1975. The term multilevel began with the three-level converter . Subsequently, several multilevel converter topologies have been developed. However, the elementary concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple dc voltage sources. The commutation of the power switches aggregate these multiple dc sources in order to achieve high voltage at the output; however, the rated voltage of the power semiconductor switches depends only upon the rating of the dc voltage sources to which they are connected.

A. Cascaded H-Bridge

Multilevel cascaded inverters have been proposed for such applications as static var generation, an interface with renewable energy sources, and for battery-based applications. A prototype multilevel cascaded static VAR generator connected in parallel with the electrical system that could supply or draw reactive current from an electrical system. The inverter could be controlled to either regulate the power factor of the current drawn from the source or the bus voltage of the electrical system where the inverter was connected. Cascaded inverters are ideal for connecting renewable energy sources with an ac grid, because of the need for separate dc sources, which is the case in applications such as photovoltaic’s or fuel cells. The series of H-bridges makes for modularized layout and packaging. This will enable the manufacturing process to be done more quickly and cheaply.

B. Diode Clamped Cascaded Multilevel Inverter

The structure is more complicated than the two-level inverter, the operation is straightforward and well known. In summary, each phase node (a, b, or c) can be connected to any node in the capacitor bank (d0,d1 ,d2).Connection of the a-phase to junctions d0and d2 can be accomplished by switching transistors Ta1andTa2both off or both on respectively. These states are the same as the two-level inverter yielding a line-to-ground voltage of zero or the dc voltage. Connection to the junction d1is accomplished by gating Ta1off and Ta2on. In this representation, the labels Ta1and Ta2are used to identify the transistors as well as the transistor logic (1=on and 0=off). Since the transistors are always switched in pairs, the complement transistors are labeled Ta1 and Ta2accordingly.

C. Flying Capacitor

Another fundamental multilevel topology, the flying capacitor, involves series connection of capacitor clamped switching cells. This topology has several unique and attractive features when compared to the diode-clamped inverter. One feature is that added clamping diodes are not needed. Furthermore, the flying capacitor inverter has switching redundancy within the phase which can be used to balance the flying capacitors so that only one dc source is needed.

III. LEAKAGE CURRENT

Leakage current is the current that flows through the protective ground conductor to ground. In the absence of a grounding connection, it is the current that could flow from any conductive part or the surface of non-conductive parts to ground if a conductive path was available (such as a human body). There are always extraneous currents flowing in the safety ground conductor.

IV. WHAT CAUSES LEAKAGE CURRENT

There are two types of leakage current: ac leakage and dc leakage. Dc leakage current usually applies only to end-product equipment, not to power supplies. Ac leakage current is caused by a parallel combination of capacitance and dc resistance between a voltage source (ac line) and the grounded conductive parts of the equipment. The leakage caused by the dc resistance usually is insignificant compared to the ac impedance of various parallel capacitances. The capacitance may be intentional (such as in EMI filter capacitors) or unintentional. Some examples of unintentional capacitances are spacings on printed wiring boards, insulations between semiconductors and grounded heatsinks, and the primary-to-secondary capacitance of isolating transformers within the power supply.

V. WHY IS IT IMPORTANT

Electrical equipment commonly includes a grounding system to provide protection against a shock hazard if there is an insulation failure. The grounding system usually consists of a grounding conductor that bonds the equipment to the service ground (earth). If there is a catastrophic failure of the insulation between the hot (power) line and touchable conductive parts, the voltage is shunted to ground. The resulting current flow will cause a fuse to blow or open a circuit breaker; preventing a shock hazard. Obviously, a possible shock hazard exists if the grounding connection is interrupted, either intentionally or accidentally. The shock hazard may be greater than supposed because of the leakage currents. Even if there is no insulation failure, interruption of the leakage currents flowing through the ground conductor could pose a shock hazard to someone touching the ungrounded equipment and ground (or other grounded equipment) at the same time. This possibility is of much more concern in medical applications, where a patient may be the recipient of the shock.

VI. LEAKAGE CURRENT REDUCTION METHODS

A. Improved Transformerless Inverter

Without an isolated transformer in the PV grid-connected power systems, there is a galvanic connection between the grid and the PV array, which may form a common-mode

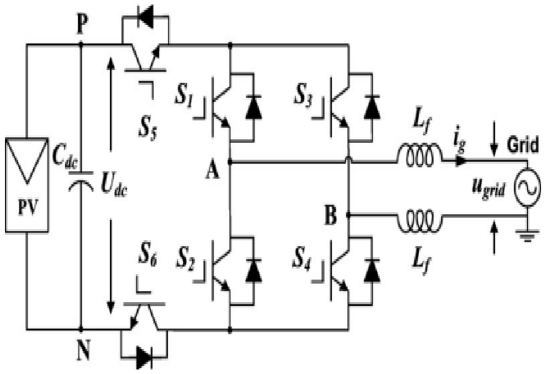

Fig 1 Improved grid connected inverter

resonant circuit and induce the common-mode leakage current. The simplified equivalent model of the common-mode resonant circuit has been derived. It which can meet the condition of eliminating common-mode leakage current. In this topology, two additional switches *S*5 and *S*6 are symmetrically added to the conventional full-bridge inverter, and the unipolar SPWM and double-frequency SPWM strategies with three-level output can be achieved.

B. Multicarrier Modulation Technique

In this method single reference signal is compared with multiple carrier signals to generate PWM signal. A novel modulation technique was proposed to generate PWM signals. Multiple carrier signals were compared with single sine reference signal, the carrier signals had the same frequency and amplitude. The carrier signals were each compared with the reference signal to generate the switching pattern. The modified H-bridge topology is significantly advantageous over other topologies, i.e., less power switch, power diodes, and less capacitor for inverters of the same number of levels.

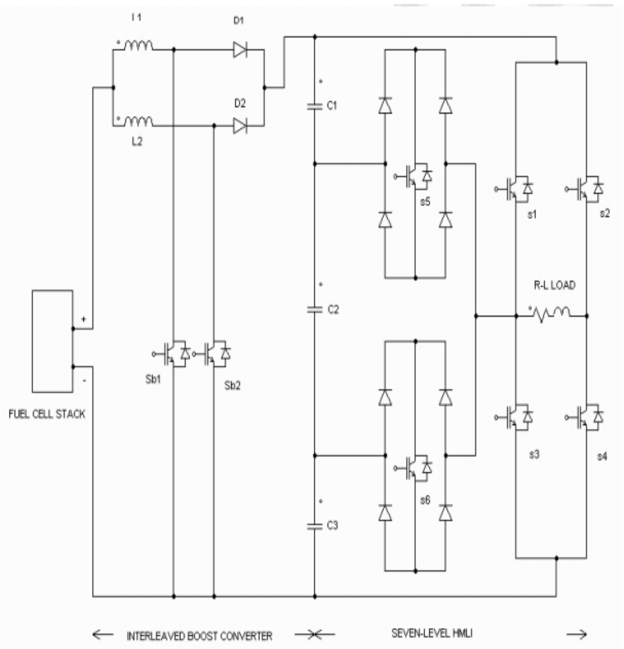

Fig 2 Hybrid cascaded multilevel inverter

C. qZSI based Cascaded Multilevel Inverter

This method is applied in a single-phase PV system consisted of four cascaded qZSIs. The system was first presented in [18] and the leakage current issue has not been dealt with in that paper. The system diagram is provided in where each qZSI module is rated at 250 W with 25–50 V input voltage range. In order to decrease the size of the quasi-Z-source network and output line filter, the device switching frequency is chosen to be 100 kHz. The sawtooth-carrier-based PWM modulation strategy is used for each module and the carrier waveforms are phase shifted to minimize the total output harmonics.

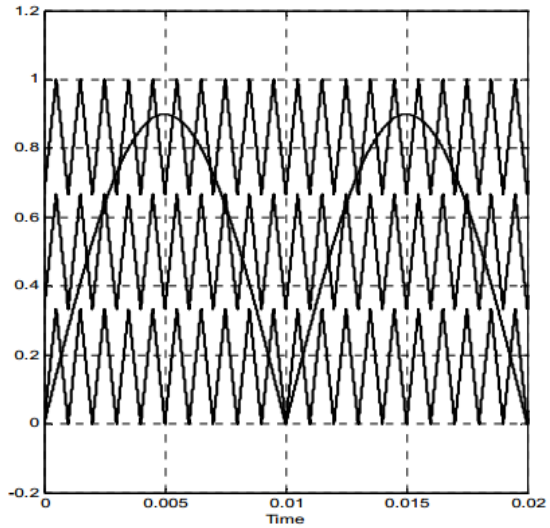

Fig 3 Multicarrier PWM technique

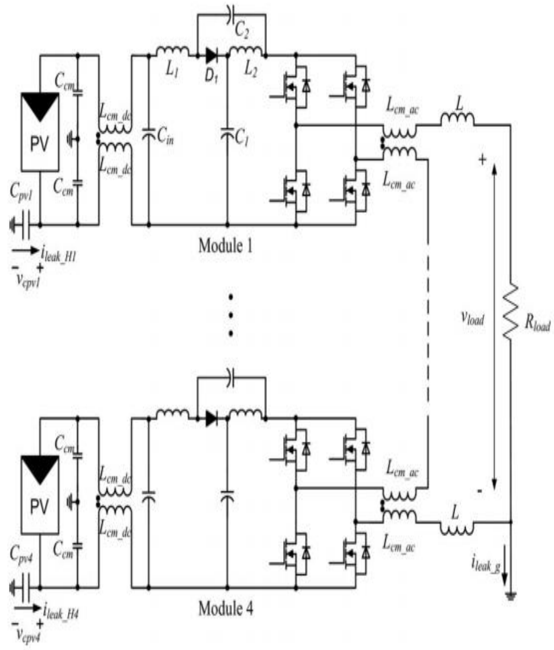

Fig 4 Cascaded qZSIs with leakage current suppression

VII. MODULATION TECHNIQUE

The proposed technique is the modified version of the phase opposite disposition (POD) pulse width modulation technique, where the number of carriers required is half of that required in POD PWM and therefore computational burden is reduced. In this modulation method, the carrier signals used are in-phase with each other. The phase of all the carriers is shifted by 180° after each half-cycle.

There is no voltage transition in zero CMV. The CMV may take the values depending upon the inverter switch states selected since the voltage-source inverter cannot provide pure sinusoidal voltages and has discrete output voltage levels synthesized from the output voltage of the PV.

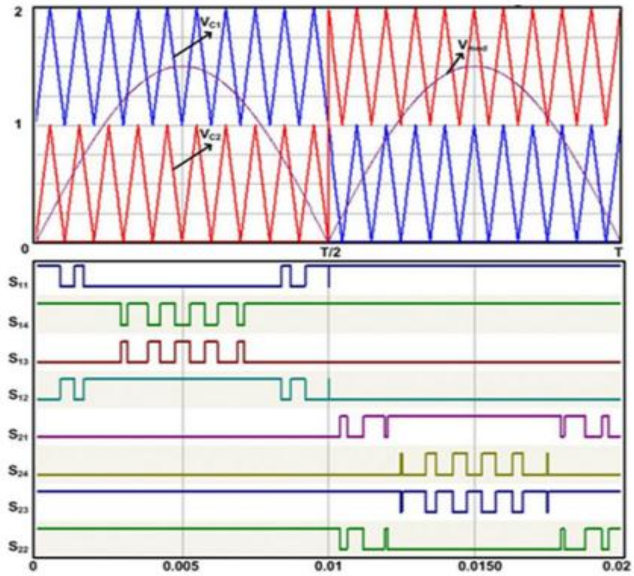

Fig 4 Switching pattern for proposed technique

VIII. CONCLUSION

To reduce the leakage current various method are presented. Transformerless method is widely used for leakage current suppression methods. In improved transformerless inverter method, grid connected inverters are used. In multicarrier pwm technique shifted carriers are used. In quasi z-source inverter parasitic capacitors and inductors are used. Suppression filters are used to reduce the output harmonics. The qZSI is advanced and recent technique and this is the best technique for leakage current suppression.

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