Review of Multilevel Inverters - Topologies, Control Techniques and Reduction of Leakage Current in Cascaded Multilevel Inverter

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ABSTRACT

Multilevel inverters are a source of high power, often used in medium-voltage application. Multilevel converters have received increased interest recently due to high quality output waveform and decrease the harmonic distortion in the output waveform without decreasing the inverter power output. A multilevel inverter uses a series of semiconductor power converters, 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 transformer less method and sine modulation techniques are presented to reduce the leakage current. This paper presents a review on most important topologies, control techniques of multilevel inverters and reduction of leakage current.

Keywords - Multilevel inverter, Neutral point clamped, CHB, FC, Leakage current reduction, Transformer Photovoltaic (PV) system.

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1. INTRODUCTION

There are a lots of multilevel converter topologies have been developed during the last two decades. In these researches novel converter topologies and unique modulation schemes are focused. In this review paper mainly focused on reduction of leakage current and topologies. The study is on work of frequency modulation and various control techniques such as sinusoidal pulse width modulation (SPWM), sampling technique etc. The most common multilevel converter topologies are the neutral-point-clamped converter (NPC), flying capacitor converter (FC) and Cascade H-Bridge (CHB) have been proposed from last two decades. Multilevel inverter are beneficial for both medium and high power application. From study we find that the half-bridge inverter or the full-bridge inverter with bipolar sinusoidal pulse width modulation (SPWM) is used for avoiding common mode leakage current as there is not generation of variable common mode voltage. 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. But the half-bridge inverter requires a high input voltage which is greater than, approximately, 700 V for 220-V ac applications.
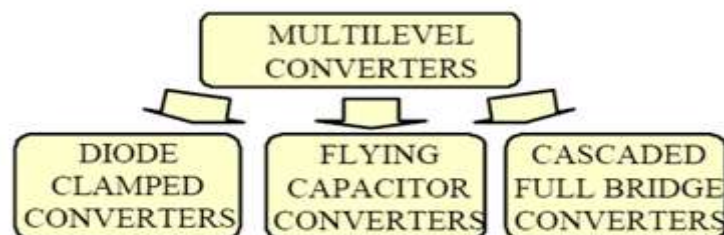
2. MULTILEVEL INVERTER-TOPOLOGIES

Fig. 1: Multilevel converter topologies

2.1 DIODE CLAMPED INVERTER

The multilevel topology is the neutral-point-clamped (NPC) PWM topology. The three-level version of this topology, shown in Figure 2.1, has several distinct advantages over the two-level topology.

There are few following advantages are:
(1) Voltages across the switches are only half of the dc-link voltage. (2)The first group of voltage harmonics is centered on twice the switching frequency.

Few drawbacks in use of multilevel inverters such as (1) This topology requires high speed clamping diodes that must be able to carry full load current and are subject to severe reverse recovery stress. (2) For topologies with more than three levels the clamping diodes are subject to increased voltage stress equal to $V_{pn}.(n-1)/n$. So connection of diodes will be required in series.
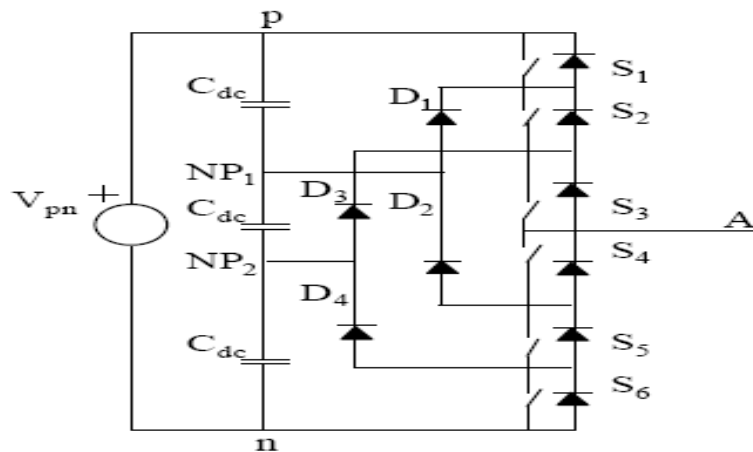

Fig 2.1: Three-level version of Diode clamped topology.

2.2 FLYING CAPACITOR MULTILEVEL INVERTER

Figure 2.2(a) (b) gives the Three and Four-level flying capacitor phase leg. This multilevel topology is supposed the good alternative to the diode-clamped topology

Few advantages of this topology are: (1) It overcome the clamping diode problems exist in the diode-clamped multilevel topologies.(2) In this topology charge in capacitors will be maintained with the help of additionally switching.
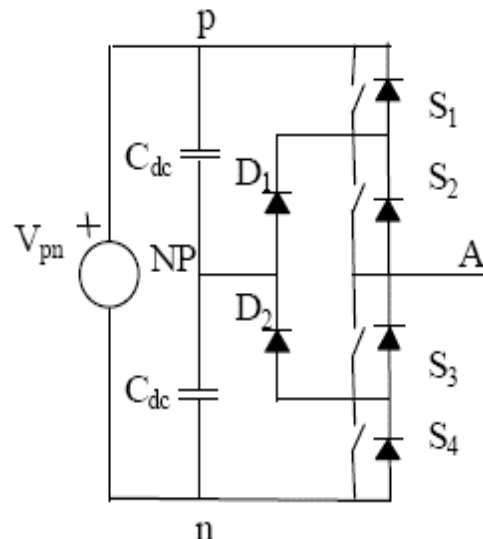

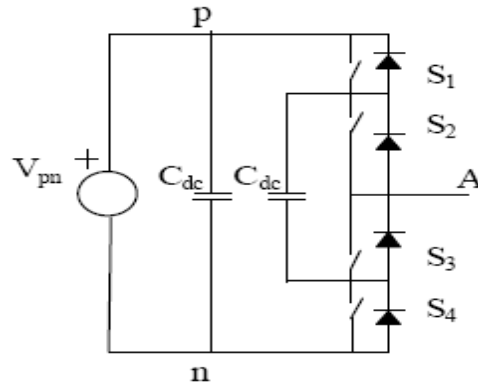**Fig. 2.2 (a) Single Phase Three -level flying capacitor inverter**

Fig. 2.2 (b) Single Phase Four -level flying capacitor inverter

2.3 HYBRID H-BRIDGE MULTILEVEL INVERTER

This inverter is shown in Figure 2.3. Each of the three separate voltage source , A1,A2,A3 connected in cascaded with other sources through a special H-bridge circuit. Every circuit have four active switching elements so that the output voltage source will be converted as required in either in positive or in negative polarity, or it may be simply zero volts depending on the switching condition of the switches in the circuit. The advantage of hybrid multilevel inverter is high number of levels with reduced number of bridges and dc sources.
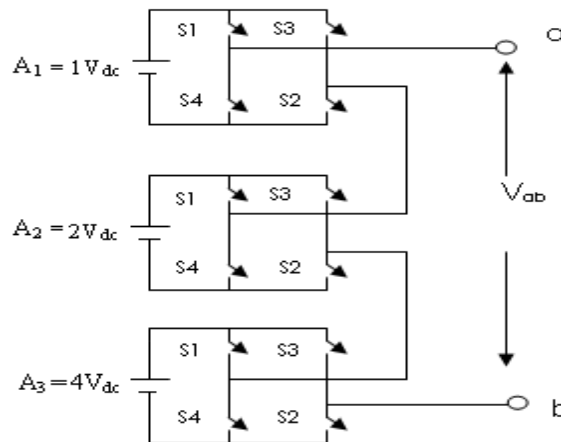

Figure 2.3: Topology of Hybrid H-Bridge Multilevel Inverter

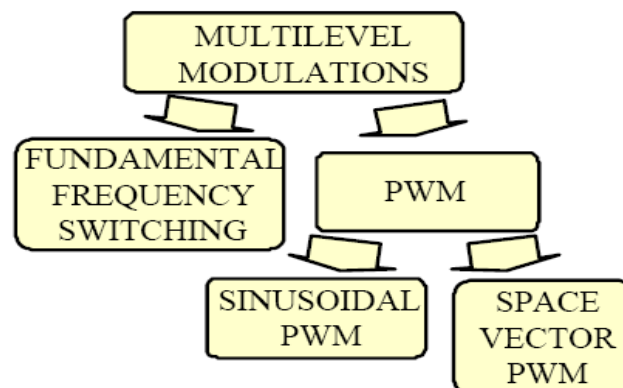## 3. MULTILEVEL INVERTERS – CONTROL TECHNIQUE

Figure 3: Multilevel modulation techniques.

3.1 PULSE WIDTH MODULATION TECHNIQUE

The commonly used PWM control techniques are:
(a) Sinusoidal pulse width modulation (sin PWM)
(b) Space vector PWM

3.1.1 SINUSOIDAL PULSE WIDTH MODULATION

In the Sinusoidal pulse width modulation scheme, as the switch is turned on and off several times during each half-cycle, the width of the pulses is varied to change the output voltage. Lower order harmonics can be eliminated or reduced by selecting the type of modulation for the pulse widths and the number of pulses per half-cycle. Higher order harmonics may increase, but these are of concern because they can be eliminated easily by filters. The SPWM aims at generating a sinusoidal inverter output voltage without low-order harmonics. This is possible if the sampling frequency is high compared to the fundamental output frequency of the inverter.

3.1.2 SAMPLING TECHNIQUE

In this method of modulation, several pulses per half-cycle are used. Instead of maintaining the width of all pulses, the width of each pulse is varied proportional to the amplitude of a sin-wave evaluated at the centre of the same pulse. By comparing a sinusoidal reference signal with a triangular carrier wave, the gating signals are generated. The frequency of reference signal determine the inverter output frequency and its peak amplitude, controls the modulation index M, and then in turn the RMS output voltage. Fig.3.1.2 shows the more common carrier technique, the conventional sinusoidal pulse width modulation (SPWM) technique, which is based on the principle of comparing a triangular carrier signal with a sinusoidal reference waveform (natural sampling).

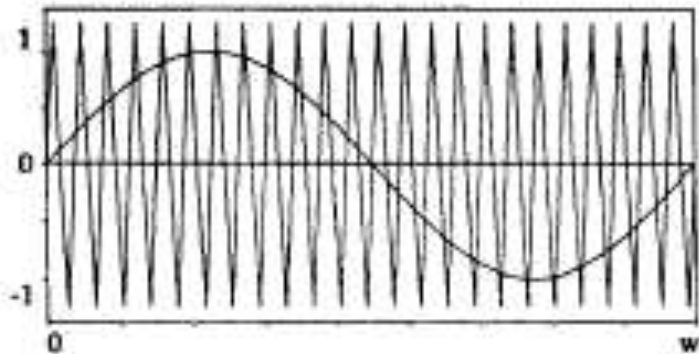The figure below gives the sinusoidal pulse width modulation.

Fig.-3.1.2 Modulating/reference and carrier waveform (M=0.8.fc=24 pu).

4. LEAKAGE CURRENT

Leakage current is the current that flows through the protective ground conductor to ground. If grounding connection is not available, it 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). Always an extraneous currents flowing in the safety ground conductor.

4.1 WHAT CAUSES LEAKAGE CURRENT

Types of leakage current: ac leakage and dc leakage. Dc leakage current generally applies to end-product equipment, not to power supplies. Ac leakage current is generated due to a parallel combination of capacitance and dc resistance between an AC voltage source and the grounded conductive parts of the equipment. In dc resistance leakage is insignificant in compared to the ac impedance of many parallel capacitances. The capacitance may be intentional e.g. spacings on printed wiring boards, insulations between semiconductors and grounded heatsinks, and the primary-to-secondary capacitance of isolating transformers within the power supply.

4.2 WHY IS IT IMPORTANT

All Electrical equipment includes a grounding system to provide protection against a shock hazard. The grounding system generally has a grounding conductor that bonds the equipment to the service ground i.e. earth. If a sudden bad failure of the insulation between the power line and contacted conductive parts, the voltage is shunted to ground. Due to this current flow fuse to blow or open a circuit breaker thus preventing a shock hazard. A possible shock hazard exists if the grounding connection is not present, either intentionally or accidentally. If there is no insulation failure and interruption of the leakage currents flowing through the ground conductor could cause a shock hazard to someone touching the ungrounded equipment and 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.

4.3 METHOD OF REDUCTION OF LEAKAGE CURRENT

4.3.1. IMPROVED TRANSFORMERLESS INVERTER

There is a galvanic connection between the grid and the PV array without an isolated transformer in PV grid power sytem, which may form a common-mode resonant circuit and induce the common -mode leakage current. The simplified equivalent model of the common-mode resonant circuit can meet the condition of eliminating common-mode leakage current. There are two additional switches S5 and S6 are symmetrically added to the conventional full-bridge inverter, and the uni-polar SPWM and double-frequency SPWM strategies with three-level output can be achieved.
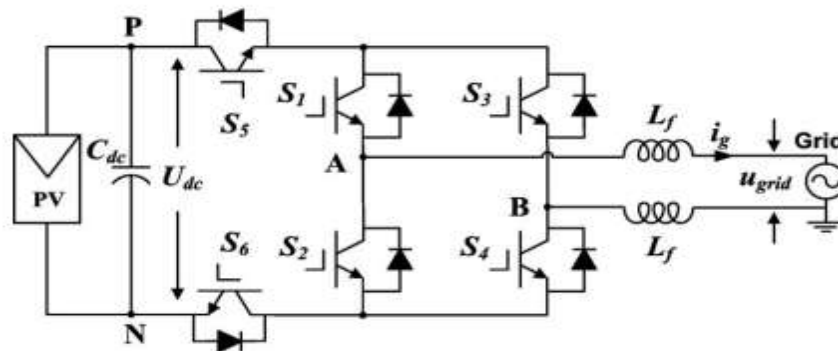

Fig 4.3.1: Improved Grid Connected Inverter

4.3.2. MULTICARRIER MODULATION TECHNIQUE

In this method single reference signal is compared with multiple carrier signals to generate PWM signal. A novel modulation technique was used 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 beneficial due to less power switch, power diodes, and less capacitor for inverters of the same number of levels over other topologies.
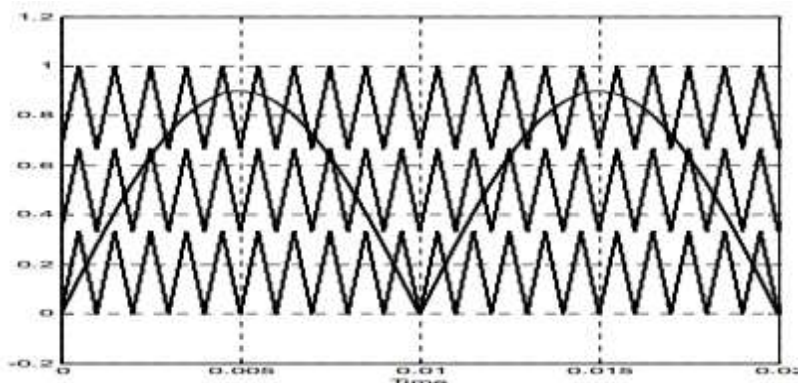

Fig 4.3.2 Multicarrier PWM technique

4.3.3. QZSI BASED CASCADED MULTILEVEL INVERTER

In This method a single-phase PV system consisted of four cascaded QZSIs. 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 saw-tooth-carrier-based PWM modulation strategy is used for each module and the carrier waveforms are phase shifted to minimize the total output harmonics.
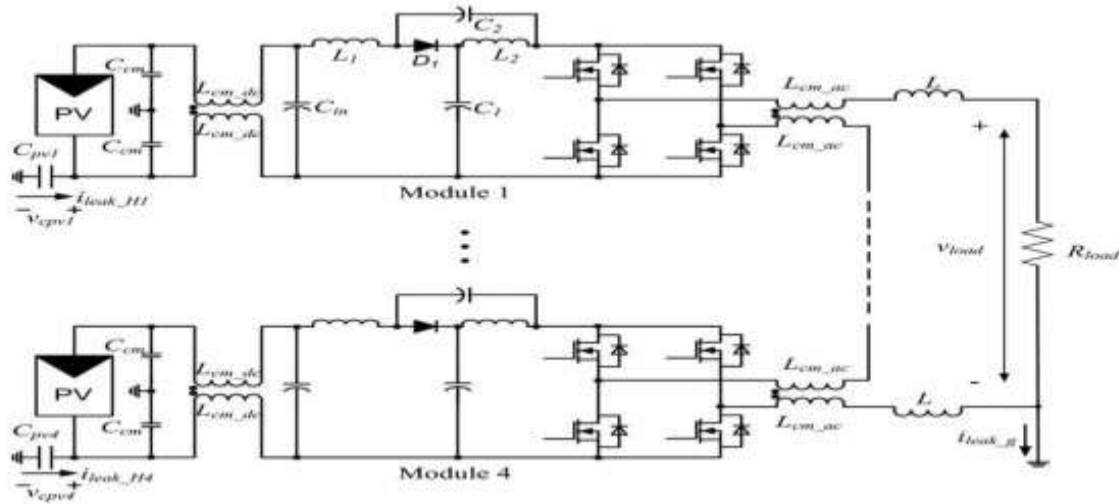

Fig 4.3.3: Cascaded qZSIs with leakage current suppression

CONCLUSION

In this paper many topologies and control techniques have been reviewed, which tells about the use of efficient techniques to control multilevel converters for reduction of leakage current. To reduce the leakage current various method are presented in which Transformerless method is commonly used for leakage current suppression methods. For reduction of leakage current in improved transformerless inverter method, grid connected inverters are used. Shifted carriers are used in multicarrier PWM technique. 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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