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Multilevel Inverter Topologies or Photovoltaic Grid Connections: A Review

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***Abstract*— This paper investigates the various topologies and controlling strategies used in a multi level inverter. Multi level inverters are used to improve the waveform output of the inverter to be nearly sinusoidal so that the harmonic injection by that inverter when it is integrated with the grid is minimum. Study is being carried out of ways that can be used to implement a multi level inverter used in photo-voltaic grid integration.**

***Index Terms*— Renewable Energy Source, Multi Level Inverter, Photovoltaic Grid Integration, Harmonic Reduction**

I. INTRODUCTION

The continuous economic development of many countries and the environmental issues (gas emissions and the green house effect) observed in the last decades forced an intense research in renewable energy sources. Hydro, photovoltaic (PV) and wind energy conversion are the most explored technologies due to their considerable advantages [1]-[2] such as reliability, reasonable installation and energy production costs, low environmental impact, capability to support micro grid systems and to connect to the electric grid [3]. Among these energy sources the PV is pointed out as one of the most modular and environmentally friendly technologies. Therefore, PV systems have been frequently adopted worldwide, presenting a growth of 45% on the total PV power installed in 2009 [4] (the largest growth among the renewable energy sources).

Electrical production from photovoltaic panels (PV) gives DC voltage. So the use of inverters is a compelling solution to convert output voltage to the alternative form. The increase of the electric power in industrial applications leads to an increase in the switched current. Although the increase in voltage is often privileged, to improve the performance of the installation, however, it’s difficult to handle semiconductors who undergo deterioration of their dynamic and static performances [5] [8] [7].

However, a high level of power involves either a high voltage or high current, or even both at the same time. In addition, despite significant advances, the evolution of technological opportunities is slow at present compared to industrial application [6]. The appearance of the multilevel inverters since the beginning of the 1980s brought solutions by making Power semiconductors in series. These topologies provide the distribution of the voltage stress on different switches while improving waveforms (harmonic spectrum) of the output quantities. In the field of multilevel inverters, new topologies have emerged in recent years. They
mainly include the technique of flying capacitor multilevel inverter FCMLI, the technique of neutral point clamped multilevel inverter NPCMLI, as well as the technique of cascaded H-Bridge multilevel inverter H-bridge MLI [9][11][10].

II. INVERTERS

The Inverter is an electrical device which converts direct current (DC) to alternate current (AC). The inverter is used for emergency backup power in a home. The inverter is used in some aircraft systems to convert a portion of the aircraft DC power to AC. The AC power is used mainly for electrical devices like lights, radar, radio, motor, and other devices.

A. Multilevel Inverter

Now a day’s many industrial applications have begun to require high power. Some appliances in the industries however require medium or low power for their operation. Using a high power source for all industrial loads may prove beneficial to some motors requiring high power, while it may damage the other loads. Some medium voltage motor drives and utility applications require medium voltage. The multi level inverter has been introduced since 1975 as alternative in high power and medium voltage situations. The Multi level inverter is like an inverter and it is used for industrial applications as alternative in high power and medium voltage situations.

B. Diode Clamped Multilevel Inverter

The main concept of this inverter is to use diodes and provides the multiple voltage levels through the different phases to the capacitor banks which are in series. A diode transfers a limited amount of voltage, thereby reducing the stress on other electrical devices. The maximum output voltage is half of the input DC voltage. It is the main drawback of the diode clamped multilevel inverter. This problem can be solved by increasing the switches, diodes, capacitors. Due to the capacitor balancing issues, these are limited to the three levels. This type of inverters provides the high efficiency because the fundamental frequency used for all the switching devices and it is a simple method of the back to back power transfer systems. The circuit diagram of a diode clamped multilevel inverter is shown in figure 1 and the waveform output of five level multilevel inverter is shown in figure2

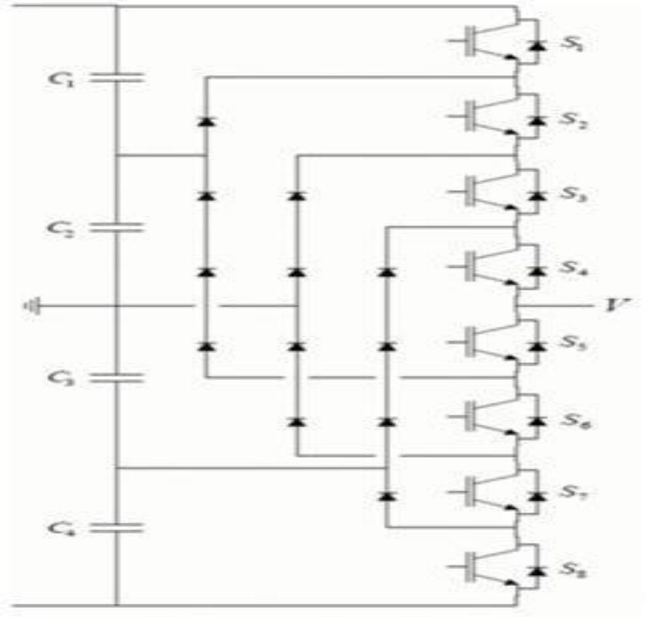

Fig 1- five Level Diode Clamped Multilevel Inverter

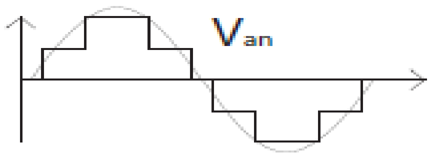

Fig 2-Waveform of a five level multilevel inverter

III. Multilevel Capacitor Clamped/Flying Capacitor Inverter, CCMLI

A topology of Capacitor Clamped (CC), or Flying Capacitor, multilevel inverter topology is shown in figure 3. Instead of using clamping diodes it uses capacitors to hold the voltages to the desired values. m-1 number of capacitors on a shared DC-bus, where m is the level number of the inverter, and 2(m-1) switch-diode valve pairs are used.

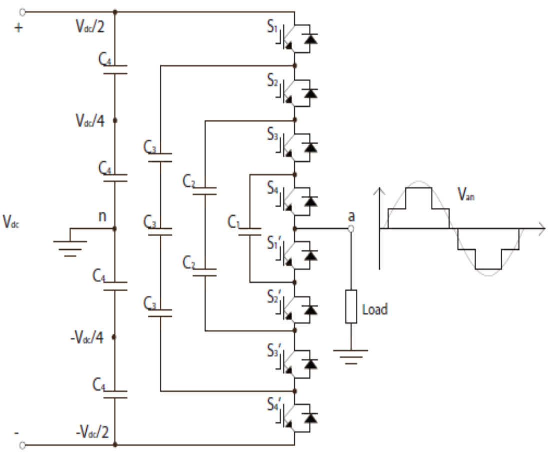

Fig -3 A Capacitor Clamped Multilevel Inverter with five voltage levels

A. *Cascaded Multicell Inverter, CMC*

A five level cascaded multicell inverter is shown in the figure. It uses cascaded full-bridge inverters with separate DC-sources, in a modular setup, to create the stepped waveform. In Figure 4 one phase-leg of a five-level Cascaded Multicell Inverter is shown. Each full-bridge can be seen as a module and it is only these modules that build up the CMCI topology. One full-bridge module is in itself a three-level CMCI, and every module added in cascade to that extends the inverter with two voltage levels.

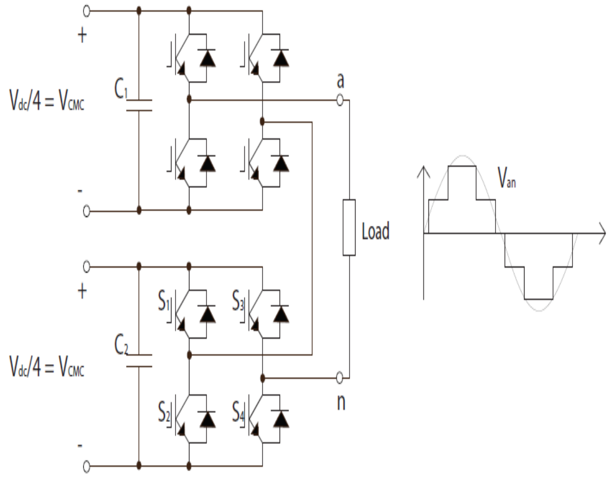

Fig-4 A five-level Cascaded Multicell Inverter

IV. Modulation Methods of Multilevel Inverter

When it comes to multilevel inverter modulation there are basically two groups of methods: modulation with fundamental switching frequency or high switching frequency PWM [16]. For both cases a stepped output waveform is achieved, but with the high switching frequency methods the steppes are modulated with some sort of PWM. Independent of switching frequency choice there are, however, also space vector methods to choose from.

A. *PWM for two-level inverters*

Ordinary PWM modulation for two-level inverters is accomplished through comparison between a reference wave and a triangular carrier wave. The reference wave have the frequency and amplitude wanted for the output voltage signal and the triangular carrier wave has the amplitude of half the DC input voltage, in an simple ordinary case, and its frequency is dependent on application but must be higher than the reference wave frequency. In electric power application the carrier wave frequency is often in the range of kHz. The reference wave frequency decides how often the switches in the inverter changes state, every time the triangular carrier wave crosses the reference wave the switches turn on or off. A plot of the ordinary two-level PWM reference, carrier wave and output voltage can be seen in Figure 5. If the carrier wave crosses the reference so it becomes higher than the reference the top switch turns off and bottom switch turns on in the two level inverter so that $V_{dc}/2$ becomes the output. When the carrier wave crosses the reference again, now getting lower than the reference, the switches change state and the output becomes $-V_{dc}/2$. When the reference is positive the output voltage signal will be $V_{dc}/2$ for the majority of the time resulting in a positive output AC signal following the reference. An straight forward example is if the reference wave is constant at zero voltage, the carrier wave would then cross it upwards and downwards with the same time between every crossing, making $V_{dc}/2$ and $-V_{dc}/2$ being the output for equal time, each cycle. This leads to that the average output voltage over one carrier wave period becomes zero.

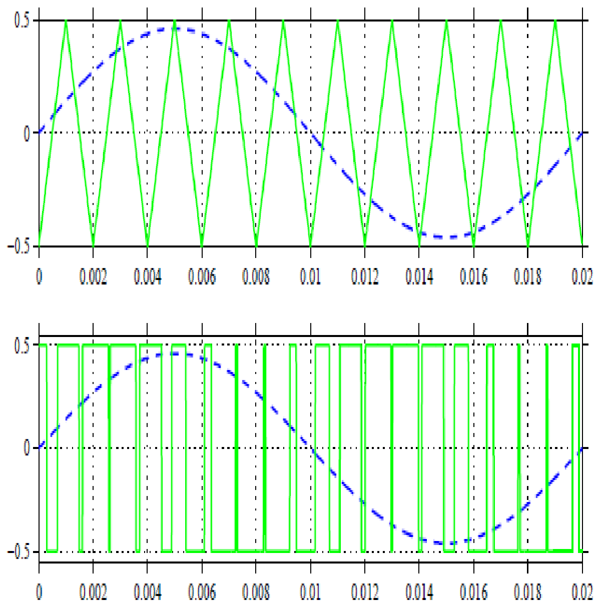

Fig 5- **PWM reference (dashed) and triangular carrier (solid) wave in upper plot and output voltage (solid) eave in lower plot**

B. PWM for multilevel inverters

Multilevel PWM methods uses high switching frequency carrier waves in comparison to the reference waves to generate a sinusoidal output wave, much like in the two-level PWM case. To reduce harmonic distortions in the output signal phase-shifting techniques are used [16]. There are several methods that change disposition of or shift multiple triangular carrier waves. The number of carrier waves used is dependent to the number of switches to be controlled in the inverter.

V. Selective Harmonic Elimination

Selective Harmonic Elimination (SHE) is a low switching frequency strategy that uses calculated switching angles to eliminate certain harmonics in the output voltage. With the help of Fourier series analysis the amplitude of any odd harmonic in the output signal can be calculated. Usually the switching angles are chosen so that the fundamental is set to the wanted output amplitude and the other harmonics to zero see Figure 3.7. The switching angles must however be lower than $\pi/2$ degrees and for a number of switching angles a harmonic components can be affected, where a-1 number of harmonics can be eliminated[16] (one angle to set the fundamental). If angles were to be larger than $\pi/2$ a correct output signal would not be achievable. For an inverter with m levels a = $\frac{m-1}{2}$. Higher harmonics can be filtered out with additional filters added between the inverter and the load if needed. For a five-level inverter a = 2, so there are two switching angles available and a - 1 = 1 angles can be used for harmonic component elimination.

VI. Conclusion

It is concluded that by using a multilevel inverter we can reduce the harmonic ijection by inverters to the grid in photovoltaic grid integration. Multilevel inverter topologies and its modulation and control techniques are studied and in future emphasis will be laid to model a multilevel inverter and do the optimal controlling so as to do the photovoltaic grid integration with minimal injection of harmonics.

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