Study of Multilevel Inverters and their Control Strategies: A Review

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Abstract

In this review paper our aim is to widen the knowledge about the performance of different cascaded H-Bridge multilevel inverter fed induction motor drives through harmonic analysis. Large electric drives and utility applications require advanced power electronics converter to meet the high power demands. Multilevel power converter structure has been considered as an alternative in high power and medium voltage ranges. Multilevel converter not only achieves high power ratings but also improves the performance of total system in terms of harmonics

Keywords: *Multilevel Inverter ,THD, Harmonics*

1. INTRODUCTION:

Multilevel inverter is a power electronic load circuit which is capable of providing desired alternating voltage level using multiple lower level DC voltages as an input. Mostly a two-level inverter is used in order to generate the AC voltage from DC voltage. Multilevel inverters are becoming more popular because of their high voltage operation capability, low switching losses, high efficiency and low Electro Magnetic Interference (EMI). The term multilevel starts with the three-level inverter introduced by Nabae et al (1981). Nowadays, multilevel inverters are gaining much more in interest in power applications, due to these ability to meet the increasing demand of power rating and power quality associated with reduced harmonic distortion and lower electromagnetic interference. A multilevel inverter has several advantages over a conventional two-level inverter that uses high switching frequency pulse width modulation (PWM). As shown in figure 1, Figure 2 shows output of a multilevel inverter where by achieving number of voltage level, the output could be made close to sinusoidal.

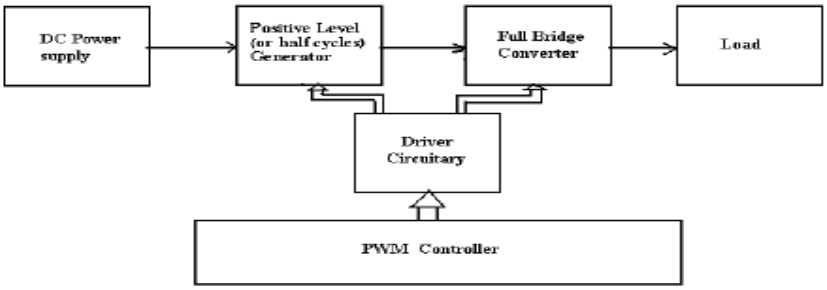

Figure 1. Basic Block Diagram

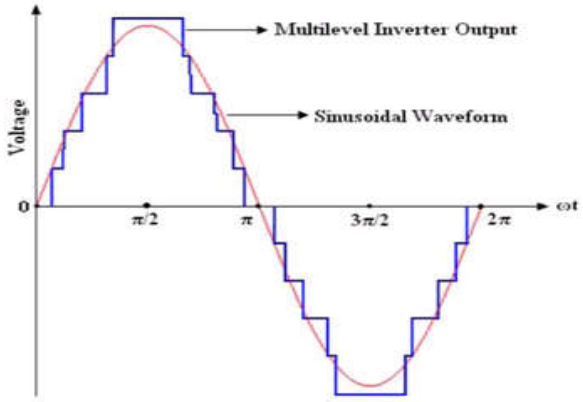

Figure 2. Staircase Sinusoidal Waveform Generated by Cascaded H-Bridge Multilevel Inverter

The important features of a multilevel inverter are as follows:
1) They can generate output voltages with extremely low distortion and lower dv/dt.
2) They draw input current with very low distortion.
3) They generate smaller common-mode (CM) voltage.
4) They can operate with a lower switching frequency.

2.Literature Review

Nasrudin Abdul Rahim, and Jeyraj Selvara [2011] has imlemented A Novel Multi-String Five-Level PWM Inverter for Photovoltaic Application in that A novel PWM control scheme with two reference signals and a carrier signal has been used to generate the PWM switching signals. The circuit topology, control algorithm, and operating principle of the proposed inverter have been analysed in detail. Experimental results indicate that the THD of the multi-string five-level inverter is much less than that of conventional multi-string three level inverter.
Rakan Khalil Antar [2018] Multilevel Inverter with Unequal and Selected DC Voltage Sources Using Modified Absolute Sinusoidal PWM Technique has implemented The main purpose of this paper is to demonstrate a single and three phase multilevel CHBVSI with the MASPWM control technique. The designed circuits use three cells of Hbridge voltage source inverter with USDCVS to produce twenty seven level output voltages compared with the conventional structure with seven levels. The THD for different levels with RL load is presented. This type of multilevel inverter with the MASPWM control technique can be applied in industrial applications where the adjustable speed drives are required

3. TOPOLOGY OF MULTILEVEL INVERTERS:

Multilevel inverters have an arrangement of power switching devices and capacitor voltage sources as shown in figure 3. Multilevel inverters are benificial for high-voltage applications because of their ability to synthesize output voltage waveforms with improve harmonic spectrum and attain higher voltages with a limited maximum

device rating. There are three main types of multilevel inverters: diode-clamped (neutral-clamped), capacitor-clamped (flying capacitors), and cascaded Hbridge inverter.

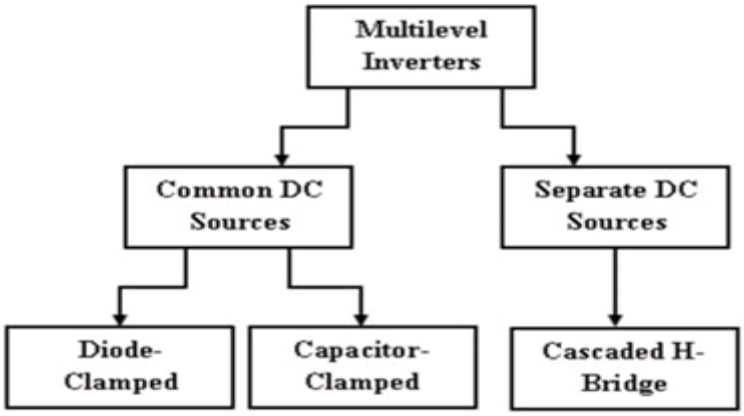

Figure 3. Multilevel Inverter Topologies

3.1. CLASSIFICATION OF MULTILEVEL INVERTERS:

The multilevel inverter is classified into following types of topologies such as,

A. Diode clamped multilevel inverter
B. Cascaded multilevel inverter
C. Flying Capacitor multilevel inverter.

A. Diode clamped multilevel inverter

One of the most commonly used topologies of the multilevel inverters is referred as Diode Clamped Multilevel Inverters (DCMLI). In this topology a single dc bus is used that is subdivided into a quantity of level of voltages by a string of capacitors connected in strings . These inverters use diodes to reduce the voltage stress of power devices. The quantity of capacitors considered in single phase is relative to the number of levels of phase voltages. With the increase in quantity of levels of this inverter, the quantity of switches as well as the quantity of capacitors also increases. In general, on the link bus of dc, the n-level inverter includes (n-1) number of capacitors which in turn produces n voltage levels at the output. Here, the devices those are connected in series are called power devices where the smaller capacitors are obtained from dc link and those are connected to switches by clamp diodes. The connections occurred in the clamp diodes are required to block the flow of current. Such inverter is well known for executing the technique of eliminating the content of stepping harmonics which is proportional to the equipments having control switching which as a result provide perfect pulse by the increase in efficiency at high loading conditions.

Advantages:

(i) With the increase in quantity of levels, the content of harmonics could be decreased which may results in avoiding the least requirement of filters.
(ii) The flow of reactive power is controlled.
(iii) The efficiency of inverter increases as all devices are switched at the fundamental frequency.
(iv) This method basically used for controlling purpose and is quiet simple.

Disadvantages:

(i) With the increase in number of diodes the need of clamping diodes will be increased.
(ii) The flow of reactive power of the single inverter cannot be controlled because of the presence of capacitances in an inequality mode.
(iii) The current ratings are different for different switches.
(iv) The reverse voltages are blocked by the diodes having high voltage rating.

B**. Cascaded multilevel inverter**

In this type of inverter, the two or more individual full bridge inverters are connected in series. This gives rise to synthesized levels of voltage at the output which are obtained from a quantity of dc voltage sources configured individually. This in return depends upon the switching patterns of the power devices of each H-bridge. The interest for cascade inverter has been increased due to the rise in demand of medium voltage high power inverters. This inverter uses the strings of single phase full bridge inverters which are connected in series helps in constructing the phase legs of multilevel with separate dc sources. A waveform having stair case structure is obtained through H-bridge which is sinusoidal even without the presence of filters. A voltage imbalance is caused occur due to charge imbalance which is generated by the uneven charging and discharging of multiple sources of dc at different levels of voltage. Several benefits are extracted from the cascade inverters as they are structured as modular shape; the rate of strength decreases with few content of THD due to immoderate form of the levels of voltage with low dV/dt. Here the final output voltage can be obtained by the summation of all the voltages of H-bridge combination and it is similar with respect to neutral point, therefore the quantity of levels of voltage becomes unusual.

Advantages:

(i) Very less quantity of components is required which helps in achieving the same quantity of levels of voltage.
(ii) The optimized circuit layout and packaging are made possible because single level has the same structure with no extra clamping diodes.

(iii) The technique of soft switching is applied here which helps to decrease switching losses and stresses of devices.
(iv) With the absence of filter circuit, the output waveform of total harmonic distortion (THD) is considered to be very low.

Disadvantages:

The H-bridges are obtained using separate dc sources, which convert real power thereby limiting its applications.

C. Flying capacitors multilevel inverter

The clamping capacitors are replaced by the diodes present in diode clamped topology which are used to clamp the voltages; such a well known fundamental topology of multilevel inverter can be described as Flying Capacitors Multilevel Inverter (FCMLI) This involves switching cells which are connected in series of clamped capacitor that results in either increase or decrease of voltages. As the clamping diodes are not present therefore the capacitors are used to store the voltages. The capacitors which are present in dc side are considered as a ladder shape. The voltage goes on varying from one capacitor to another. The size of the steps of voltage in the output waveform can be obtained by the increase in voltage between two consecutive legs of capacitor. By using the flying capacitors, the redundancy is made available in the states of switching. This as a result could be used to regulate the voltages of capacitor and the required level of voltage is obtained at the output.

Advantages:

(i) The voltage levels can be balanced by the redundancy of the flexible switch.
(ii) During power outages, capabilities could be provided by a huge quantity of storage capacitors.
(iii) The flow of both real and reactive power could be controlled.

Disadvantages:

(i) With the increase in quantity of voltage levels, the storage capacitors are increased which result in the increase in cost.
(ii) The control technique of inverter is much more complicated.
(iii) For real power transmission, the switching frequency and losses are increased.

4.CONTROL TECHNIQUES FOR MULTILEVEL INVERTER

A. Modulation
B. PWM for multilevel inverters
C. Phase shifted carrier PWM
D. Phase Distortion PWM
E. Sinusoidal PWM.
F. Space vector PWM.

A. Modulation:

Basically, there are two groups of methods for the modulation of multilevel inverter. They are as follows Modulation based on the fundamental switching frequency and high switching frequency. For both the cases mentioned the output pulse of stepped structure is achieved, but in case of the modulation of high switching frequency, the steppes obtained are modulated with some varieties of PWM signals [2]

B. PWM for multilevel inverters

This method uses a comparison of a frequency of high switching carrier waves and the reference waves which generate an output pulse of sinusoidal in shape. The harmonic distortion in the output signal could be reduced by the phase shifting techniques. The quantity of carrier waves is reliant to the controlling of quantity of switches in the inverter.

C. Phase Shifted Carrier PWM

This is a strategy having a type of modulation named as multicarrier modulation where all the waves are present and they are shifted in phase from one another The carrier waves having magnitudes are modulated by the level of actual voltage in the suitable section.

D. Phase Distortion PWM

This modulation produces carrier waves which are triangular in shape and with n quantity of voltage levels, there exists (n-1) quantity of waves. The frequency of these waves remains same and is configured on top of each other so as to combine the duration from highest output voltage to lowest output voltage. The amplitude of these waves should be modulated in phase of the magnitude of current and voltage for

one individual level of voltage, the level of the obtained voltage is developed by a single carrier wave . The accurate output voltage is not achievable because those waves are not modulated in this approach and the levels of voltage sources deviates from their theoretical value.

5.CONCLUSION:

This research paper describes different types of multilevel inverters which could be use in different types of application. Such as various types of inductive loads. Multilevel inveters are having various advantages over conventional inverters such as, lowering the harmonics, minimizing the bulgy components flexibility etc. Also with proper control strategy such inverter could be mode more efficient by improving power factor. Further a proper analysis could be done by implementing there topologies with appropriate control strategy to a load.

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