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REVIEW ON LOW FREQUENCY PULSE WIDTH MODULATION FOR CASCADED H-BRIDGE MULTILEVEL INVERTER USING SINGLE DC- SOURCE AND ISOLATION TRANSFORMER

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ABSTRACT: Cascaded H-Bridge multilevel inverter is a promising topology for generation of high power output. This can be done by cascading number of H-bridge modules. Though it has wide application area and merits, it has greater disadvantage that it use separate DC supply. CMI with single phase transformer and single DC source is proposed for ensure high quality output power waveform. Numerical methods like N-R method is presented where switching angles are computed such that a certain lower order harmonics are eliminated. The proposed topology provides minimisation in cost in terms of THD, losses and filter size. In this report, the modulation techniques SPWM, Fundamental frequency and SHE-PWM are proposed and comparison of them with each other for ensures effectiveness.

I. INTRODUCTION

Background

Numerous industrial applications have begun to require higher power apparatus in recent years. Some medium voltage motor drives and utility applications require medium voltage and megawatt power level. For a medium voltage grid, it is troublesome to connect only one power semiconductor switch directly. As a result, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations. A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for a high power application.

Harmonics in Electrical Systems

Harmonics is one major problem in the electrical system. Harmonics is a concern because they can cause excessive heating and pulsating and reduced torque in motors and generators; increased heating and voltage stress in capacitors; and mis operation in electronics, switchgear and relaying. Generally, two types of harmonics are:

1) Voltage harmonics, and
2) Current harmonics.

Current harmonics is usually generated by harmonics contained in voltage supply and depends on the type of load such as resistive, capacitive, and inductive load. Both harmonics can be generated by either the source or the load side. Harmonics generated by load are caused by nonlinear operation of devices, including power converters, arc-furnaces, gas discharge lighting devices, etc. Load harmonics can cause the overheating of the magnetic cores of transformer and motors. On the other hand, source harmonics are mainly generated by power supply with non-sinusoidal voltage waveform. Voltage and current source harmonics imply power losses, Electromagnetic Interference (EMI) and pulsating torque in AC motor drives. Any periodic waveform can be shown to be the superposition of a fundamental and a set of harmonic components. By applying Fourier transformation, these components can be extracted. The frequency of each harmonic component is an integral multiple of its fundamental. The method used to express harmonic content commonly used is Total Harmonic Distortion (THD), which is defined in terms of the amplitudes of the harmonics,Hn, at frequency nωo, where ωois frequency of the fundamental component whose amplitude of H1 and n is integer.

The THD is mathematically given by,

$$\% \text{ THD} = \frac{\sqrt{\sum_{n=2}^{\infty} H^2(n)}}{H1}\%$$

The Concept of Multilevel Inverters

Conventional two-level inverters, seen in Figure 1.1, are mostly used today to generate an AC voltage from an DC voltage. The two-level inverter can only create two different output voltages for the load, Vdc/2 or –Vdc/2 (when the inverter is fed with Vdc). To build up an AC output voltage these two voltages are usually switched with PWM, see Figure 1.2. Though this method is effective it creates harmonic distortions in the output voltage. This may not always be a problem but for some applications there may be a need for low distortion in the output voltage.

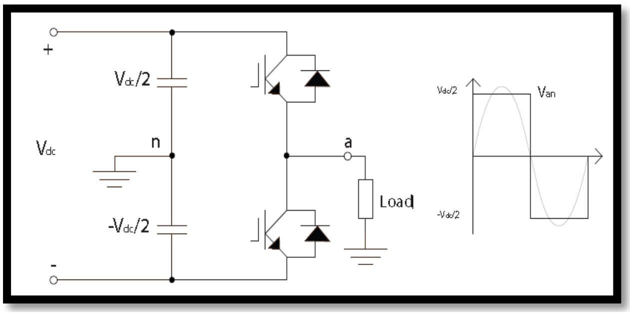

Figure-1.1: One phase leg of a two-level inverter and waveform without PWM

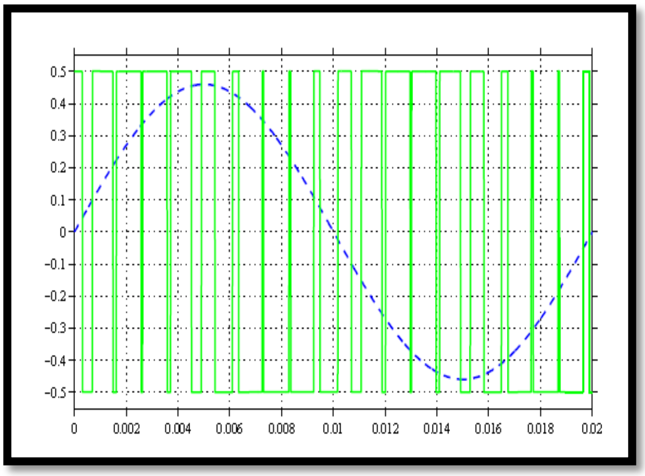

Figure 1.2: PWM voltage output, reference wave in dashed blue

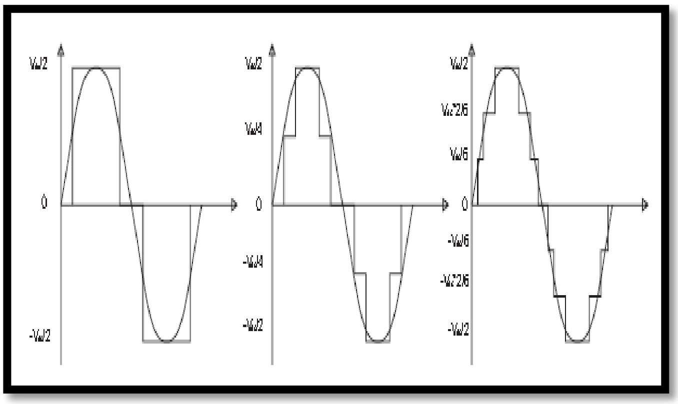

Figure1.3: A three-level, a five-level and a seven-level waveform

The concepts of Multi-Level Inverters (MLI) do not depend on just two levels of voltage to create an AC signal. Instead several voltage levels are added to each other to create a smoother stepped waveform, see Figure 1.3, with lower dv/dt and lower harmonic distortions. With more voltage levels, the waveform becomes smoother, but with many levels the design becomes more complicated, with more components and a more complicated controller for the inverter is needed.

Some of its most attractive features in general are as follows [1]:

- They can generate output voltages with extremely low distortion and lower dv/dt.
- They draw input current with very low distortion.
- They generate smaller common-mode voltage, thus reducing the stress in the motor bearings. In addition, using sophisticated modulation methods, voltages can be eliminated.
- They can operate with a lower switching frequency.

These all benefits, together with the ability to deal with high voltage levels, confer on multilevel converters a very important role in the field of high power applications. There are also different topologies of multilevel inverters that can generate a stepped voltage waveform and that are suitable for different applications. By designing multilevel circuits in different ways, topologies with different properties have been developed. The Multilevel inverter topologies are: Neutral- Point Clamped Multilevel Inverter (NPCMLI), Capacitor Clamped Multilevel Inverter (CCMLI), and Cascaded Multi-level Inverter. The most dominant multilevel inverters use one or more voltage sources, as the three-level inverter, and topologies which are presented in this report will have voltage sources, so called Voltage Source Inverters (VSI).

II. LITERATURE REVIEW

José Rodríguez et.al [1]

This paper presents the most important topologies with switching scheme like diode-clamped inverter (neutral-point clamped), capacitor-clamped (flying capacitor), and cascaded multi-cell with separate dc sources. Emerging topologies like Mixed-Level Hybrid Multilevel Cells, asymmetric hybrid cells and soft-switched multilevel inverters are also discussed.

Classifications of modulation technique according to switching frequency are as:

1) Multilevel PWM,
2) SVM (space vector modulation),
3) Selective harmonic elimination,
4) Space vector control,

This paper also discussed some industrial application and technological aspects for Multilevel inverter as listed below:

- Multilevel Rectifier
- DC/DC Converters
- Large Motor Drives with Non-regenerative Front Ends
- Large Motor Drives with Regenerative Front Ends
- Applications in Power Systems

Zhong Duet.al[2]

This paper represents the cascaded multilevel inverter with single DC source.A standard cascade multilevel inverter requires n DC sources for 2n +1 levels. Without requiring transformers, the scheme proposed here allows the use of a single DC power source with the remaining n−1 DC sources being capacitors.

Switching angle for semiconductor switches are calculated using Fourier series expansion of staircase output voltage waveform of seven levels cascaded multilevel inverter. 5th and 7th harmonics are eliminated using resultant theory and polynomial theory

Ernesto Barcenaset.al [3]

Different multilevel topology, diode clamped multilevel inverter, flying capacitor and cascade multilevel inverter are discussed with its advantages and disadvantages. This paper presents a solution for the problem of multi DC source in a cascade multilevel inverter, maintaining the advantages that offer multilevel topologies.

Three main control schemes discussed for proposed topology are:

- Fundamental frequency switching,
- Space vector PWM,
- Sinusoidal PWM,

Sung Geun Songet.al[4]
This paper proposes an isolated cascaded multilevel inverter employing low-frequency three-phase transformers and a single dc input power source. In introduction General cascade H-bridge Multi-level inverter (9-level) discussed. Configuration of single-phase boost-type H-bridge multilevel inverter employing four transformers and single dc input power source are given. When the traditional cascaded H-bridge converter needs to isolate from the ac output, it requires a three-phase transformer between the inverter and the ac outputs. On the other hand, the proposed inverter has an advantage of galvanic isolation between the source and the output voltages, which comes from being combined with transformers. there is a drawback, which is the requirement of more transformers, considering that the same number of transformers needs to be used in each phase.
Y. Suresh A.K. Pandaet.al [5]
This article proposed a new version of cascaded multilevel inverter, which employed a single dc input source and low frequency three-phase transformers. Performance of the proposed MI is investigated with three switching techniques namely, fundamental frequency switching, SHE-PWM and SPWM approaches. Cascaded H-bridge multilevel inverter with single-phase and three-phase transformer are presented, which are extensively used in utility interfacing applications. Each phase terminal is delta connected to restrain the third harmonic component.

Anup Kumar Pandaet.al[6]
The primary issue that strikes about conventional CHBMLI is that, it uses separate dc source. This issue becomes the core motivation for this paper. Details of switching pattern and output voltage waveform for CMI with three-phase transformers are shown. Unipolar switching scheme is considered for generating pulses. Details of single H-bridge operation and unipolar switching criteria are given. A prototype model of the proposed converters is developed and verified in the laboratory. For the experimentation FPGA based module was utilized. FFT report shows that lower order harmonics are completely eliminated.

III. MULTILEVEL INVERTER TOPOLOGIES

There are several topologies of Multilevel inverter, which can be classified in three main topologies[3]:
[1] Clamping diodes
[2]Flying capacitors
[3]Cascade inverters

Diode clamped multilevel inverter

The operation of this multilevel inverter is based on diodes to fix the levels of the output voltage, where each voltage level corresponds to the voltage present in a capacitor of the DC bus.

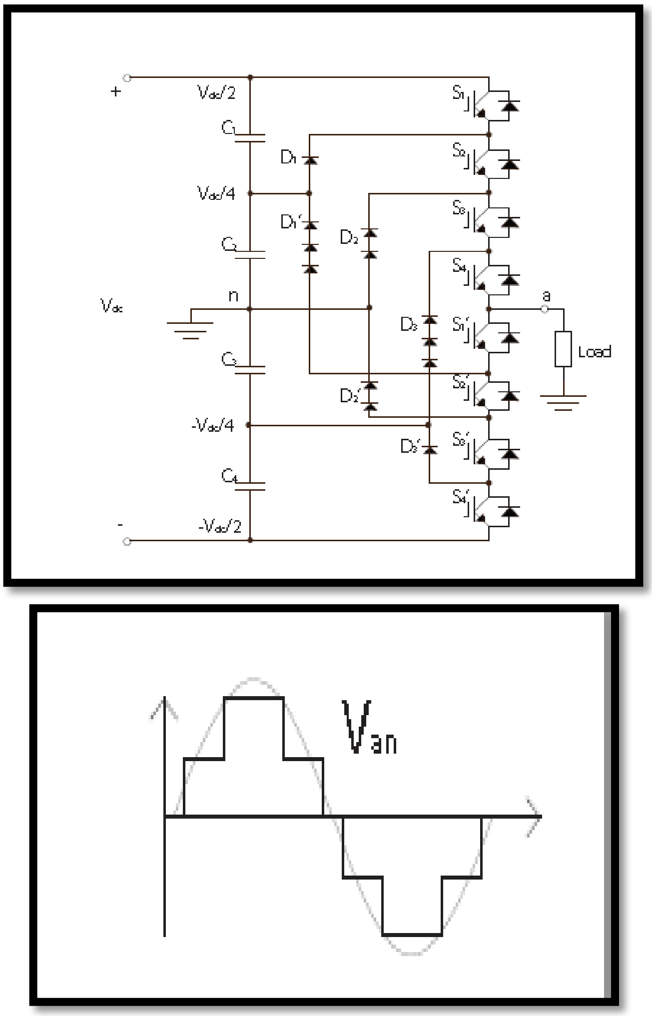

Figure 3.1:-One phase leg for diode clamped multilevel inverter

The main disadvantage of this topology consists in that the clamping diodes can support more than one level. The main switches manage the voltage of a single level.

Flying capacitor multilevel inverter

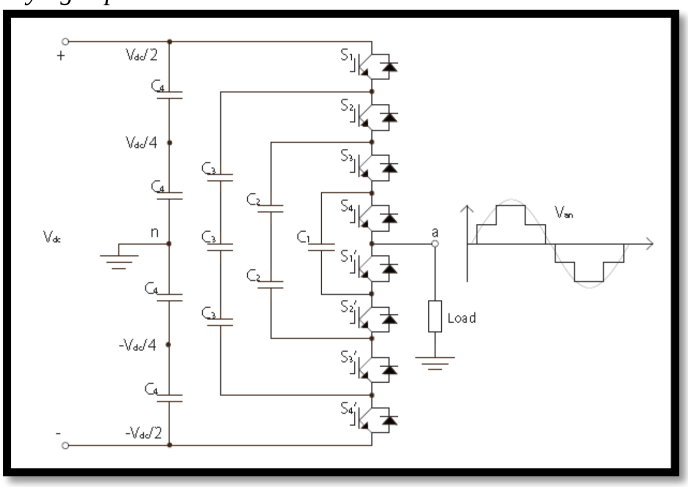

Figure 3.2:- A Capacitor Clamped Multilevel Inverter with five voltage levels

The operation of the flying capacitor multilevel inverter topology is based on the connection of capacitors. This topology uses less number of diodes and the output voltage can be expressed as the possible combinations of connection of the capacitors. The main disadvantage consists the required sequence to charge the capacitors before operating inverter. This topology can use an external system for monitoring the voltage of the capacitors and maintain them in the required level of voltage. The complexity of system is increased.

Cascade multilevel inverter

The performance of this topology is based on the connection of several full bridge series inverter which are feeding by independent DC sources. In figure the general scheme of this topology is shown.

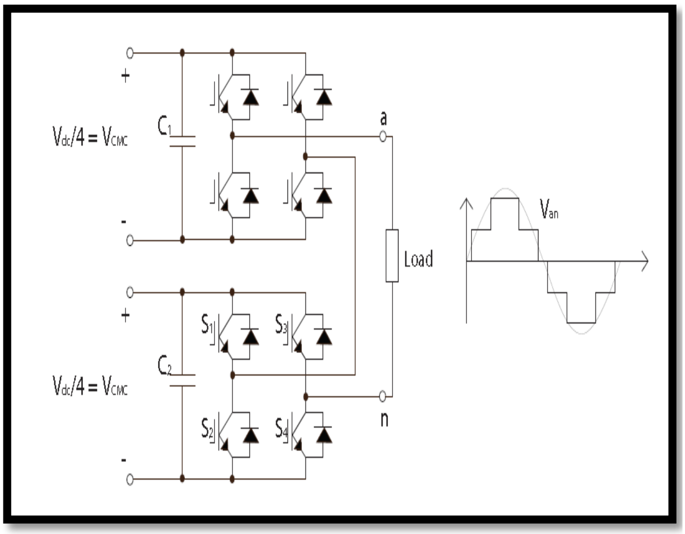

Figure 3.3: A five-level Cascaded Multilevel Inverter

The main advantage of this topology is that it does not need any additional diodes or capacitors for its implementation. It uses cascaded full bridge inverters with separate DC sources to create the stepped waveform. Each full bridge can be considered as a module. These modules can be connected in series to build up higher number of output levels. This can be extended to produce converters with as many levels as required for a particular application. In general , if n modules are connected in series ,the number of levels that can be achieved is 2n+1.This topology has high level of modularity and redundancy. It also produce high quality output voltage waveforms.

IV. MODULATION TECHNIQUES FOR MULTILEVEL INVERTER

The performance of an inverter, with any switching strategies, can be related to the harmonic contents of its output voltage. To reduce harmonics in such waveforms power electronics researchers have studied many control techniques. The modulation methods used in multilevel inverters can be classified according to switching frequency[1],as shown in figure-4.1.

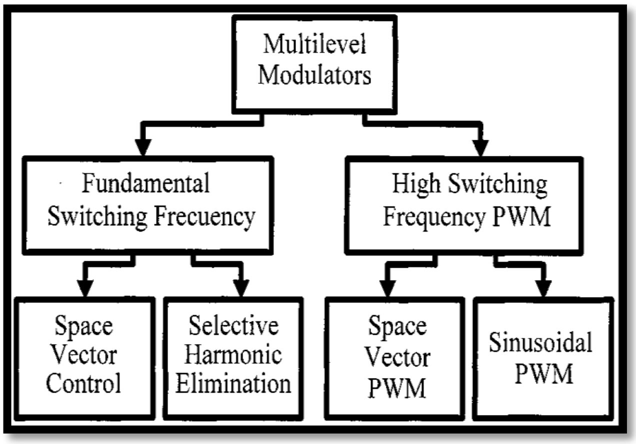

Figure-4.1 Classification of multilevel modulation methods.

Three major PWM techniques are as follows:

1) Sinusoidal Pulse Width Modulation (SPWM).
2) Selective Harmonic Elimination PWM (SHEPWM).
3) Fundamental frequency switching

Sinusoidal Pulse Width Modulation (SPWM)

PWM technique is a very efficient modulation technique as no additional components are required. By using PWM technique lower order harmonics can be either eliminated or minimized leaving higher order harmonics that can be easily filtered out by LC-filter.

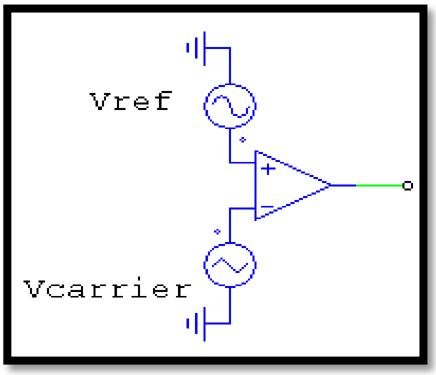

Figure-4.2Comparison between reference and carrier wave

Sinusoidal Pulse Width Modulation (SPWM) is a very popular method used in industrial application. It is the classic in carrier based method that uses the phase shifting technique to reduce the harmonics in the load voltage [1].Sinusoidal Pulse Width Modulation (SPWM) is a very simple technique and it can be implemented in both two level and multilevel inverters [9]. SPWM, two signals- a sinusoidal reference signal and a high frequency carrier signal (triangular signal) are compared to give two states (high or low).By varying Modulation Index (MI) the amplitude of the fundamental component of the inverter output voltage can be controlled. Modulation Index is defined as the ratio of the magnitude of the reference signal (Vr) to that of the magnitude of the carrier signal (Vc). Thus, by keeping Vc constant and varying Vr, the modulation index can be varied. The main advantage of SPWM is that the effective switching frequency of the load voltage is Nctimes the switching frequency of each module, as determined by its carrier signal. This property allows a reduction in the switching frequency of each module, thus reducing the switching losses[1].

Bipolar Pulse Width Modulation

In this modulation, the gate pulses are obtained by comparing a sinusoidal modulating signal or reference signal with a high frequency carrier signal.

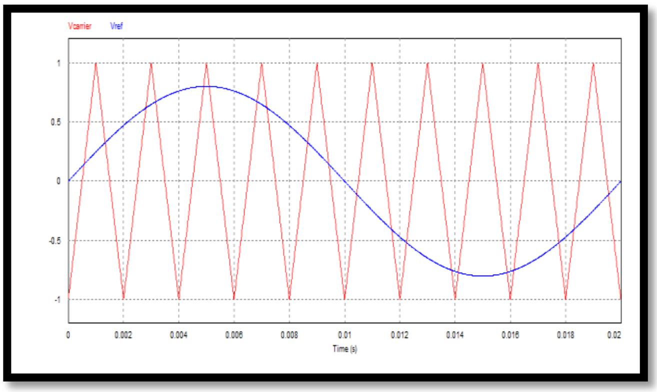

Figure-4.2:- Bipolar Pulse Width Modulation

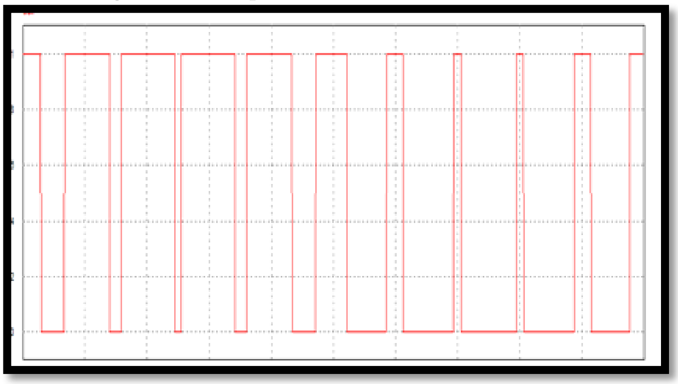

Figure-4.3:- output voltage for bipolar modulation

Unipolar Pulse Width Modulation

The unipolar modulation normally requires two sinusoidal modulating waves, which are of same magnitude and frequency but 180 degree out of phase. The inverter output voltage switches either between zero and +Vd during the positive half-cycle or between zero and –Vd during the negative half-cycle of the fundamental frequency. This modulation is also possible with two triangular carrier waves and one sinusoidal modulating signal.

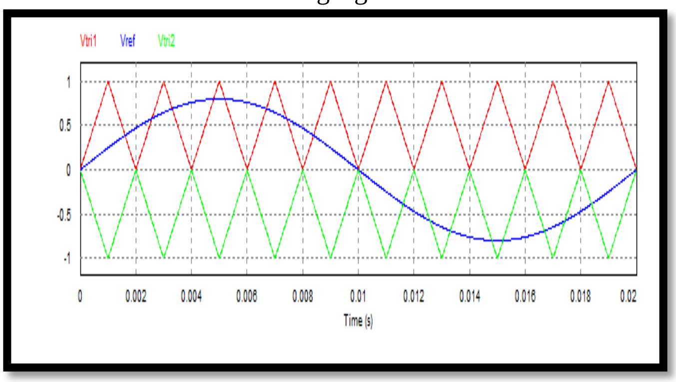

Figure-4.4:- Unipolar Pulse Width Modulation

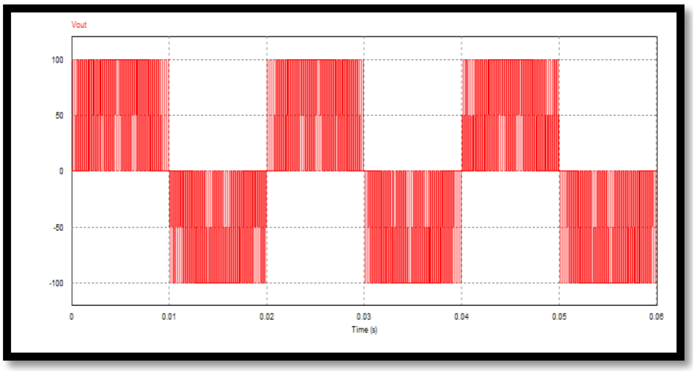

Figure-4.5:- Output Voltage Waveform For Unipolar Modulation

Selective Harmonic Elimination Pulse Width Modulation (SHE-PWM)

The elimination of low-order harmonics is an important issue in many applications. When high switching efficiency is outmost importance, it is desirable to keep the switching frequency much lower. Selective harmonic elimination (SHE) techniques were introduced and some other SHEPWM techniques were presented in [5] - [7].

Concept of SHEPWM

The SHE PWM technique is applicable to both a half-bridge and a full-bridge inverter [5].The output voltage of half bridge and full bridge can be synthesized by using SHE PWM technique. In this chapter, a three-level SHE-PWM generated by a full-bridge inverter is considered.

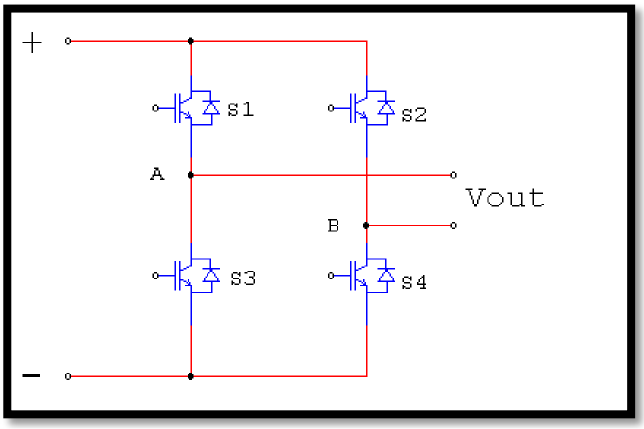

Figure-4.6:- A full-bridge voltage source inverter

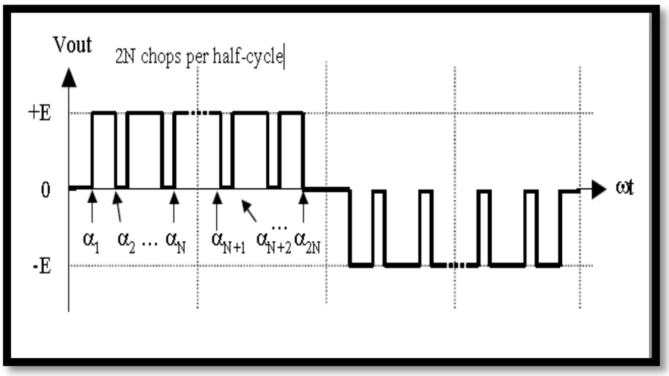

Figure-4.7:- Generalized three-phase SHE PWM waveform

A full-bridge or H-bridge voltage source inverter, which comprises four switches and one dc source, is shown in Fig. 4.6. Three states of an output voltage waveform can be obtained such as positive, negative, and zero. Fig 4.7 shows a generalized three-level SHE PWM waveform. The output waveform is chopped N times per quarter and therefore the switch is switched N times per cycle to generate such a waveform.

V. CONCLUSION

Cascaded H-bridge multilevel inverter has tremendous advantage in terms of harmonic contents, simple structure and low switching losses. From the comparison of SPWM, Fundamental Frequency approach and Selective harmonic elimination PWM methods it can be seen by simulation and THD analysis, as the voltage level is increased it lower the harmonic distortion from the output of the Cascaded H-bridge Multilevel inverter.

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