# Analysis Design Performance of Microprocessor based Multilevel Inverter

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**Abstract:** ***Multilevel inverters have been widely applied in industries. A family of optimal pulse width modulation (PWM) methods for multilevel inverters, such as step modulation, can generate output voltage with less harmonic distortion than popular modulation strategies, such as the carrier-based sinusoidal PWM or the space vector PWM. Multilevel converters are become very popular in medium and high power applications due to their ability to meet the increasing demand of power ratings and power quality associated with reduced harmonic distortion and lower EMI. We can stress the importance of their capability of increasing the output voltage magnitude and reducing the output voltage and current harmonic content, the switching frequency and the voltage supported by each power semiconductors. By synthesizing the ac output voltage from several levels of voltages, staircase waveforms are produced, which approach the sinusoidal waveform with low harmonic distortion. Multilevel converter enables the ac voltage to be increased without a transformer. In addition, the cancellation of low frequency harmonics from the ac voltages at different levels means that the size of the ac inductances can be reduced. These new types of converters are suitable for high voltage and high power application due to their ability to synthesize waveforms with better harmonic spectrum. Amongst these topologies, the multilevel cascaded inverter was introduced in Static Var compensation and drive systems. In this paper we work on three level, five level (converter) and the harmonics analysis of different level inverters are compared .Also work have been done on PWM based inverter to reduced the harmonics further .A selective harmonics distortion elimination method is also discussed in which we can eliminate the required harmonics .This is actually the combination of conventional multilevel inverter and PWM based inverter.***

**Keywords:** Multilevel inverter, Multi level converter, Pulse width modulation (PWM), Total Harmonic Distortion (THD)

## 1. Introduction

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 [1] [2]. For a medium voltage grid, it is troublesome to connect only one power semiconductor switch directly. As a result, a multilevel power inverters structure has been introduced as an alternative in high power and medium voltage situations. Multilevel inverters not only achieve high power ratings, but also enable the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel inverters system for high power appliances [3].

The concept of multilevel inverters has been introduced since 1975. The term multilevel began with the three-level converter. Subsequently, several multilevel inverters topologies have been developed. However, the elementary concept of multilevel inverters 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 [4]. 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.

Multilevel inverters have several advantages over conventional two-level inverters that use high switching frequency pulse width modulation (PWM). The attractive features of multilevel inverters can be briefly summarized as follows [5].

- Staircase waveform quality: Multilevel converters not only can generate the output voltages with very low distortion, but also can reduce the dv/dt stresses; therefore electromagnetic compatibility (EMC) problems can be reduced [6].
- Common-mode (CM) voltage: Multilevel inverters produce smaller CM voltage; therefore, the stress in the bearings of a motor connected to a multilevel motor drive can be reduced [7].
- Input current: Multilevel converters (inverters) can draw input current with low distortion.
- Switching frequency: Multilevel inverters can operate at both fundamental switching frequency and high switching frequency PWM. It should be noted that lower switching frequency usually means lower switching loss and higher efficiency [8].

Unfortunately, multilevel inverters do have some disadvantages. One particular disadvantage is the greater number of power semiconductor switches needed. Although lower voltage rated switches can be utilized in a multilevel converter, each switch requires a related gate drive circuit. This may cause the overall system to be more expensive and complex [9] [10].

Plentiful multilevel inverters topologies have been proposed during the last two decades. Contemporary research has engaged novel inverters topologies and unique modulation schemes. Moreover, three different major multilevel converter structures have been reported in the thesis: cascaded H-bridges converter with separate dc sources.

This chapter reviews state of the art of multilevel power converter technology. Fundamental multilevel converter structures and modulation paradigms are discussed. Particular concentration is addressed in modern and more practical industrial applications of multilevel converters. A procedure for calculating the required ratings for the active switches, clamping diodes, and dc link capacitors including a design example are described. Finally, the possible future developments of multilevel converter technology are noted.

This paper proposes a novel method by which the switching angles can be calculated in real-time in the context of step modulation for multilevel inverters. In my project, the optimization aim of the proposed algorithm is the minimization of the Voltage THD. Mathematical derivation is given to prove that the THD is minimized by the proposed algorithm. Comparison with other methods also shows that the THD gained by the proposed method is the smallest. Most importantly, the overhead of calculation is found to be so low that the calculation can be easily done in real-time without any lookup tables [12]. Experimental results are given to verify the performance of the proposed method.

## 2. Applications of Multilevel Inverter

Now here are some basic applications of multilevel inverter are given below;

### 2.1 Power quality

Application of multilevel voltage source converter (VSC) is becoming popular in power and energy systems as results of its high power density, excellent performance and high reliability. Some of the conventional and emerging applications of VSC include flexible AC transmission system (FACTS), Custom power devices and distributed energy system (e.g. Photovoltaic, Wind, Micro turbine) in transmission and distribution systems, respectively [18] [19].

### 2.2 Harmonics Distortion:

Harmonics in the power network are generally caused by the presence of non linear loads. An example of such loads is diode rectifiers and phase Controlled rectifiers. This equipment can produce significant 3rd, 5th 7th, and 11th harmonics have a number of deleterious ejects on the Power system – capacitors on the network draw excessive currents that can lead to damage, system resonance may occur which can result in over-voltages and disrupt distribution and transmission equipment, excessive losses occur in transformers, can cause commutation failure of SCR based converters, low Generalized power factor occurs, amongst others. Therefore techniques to Eliminate harmonics are important [12].

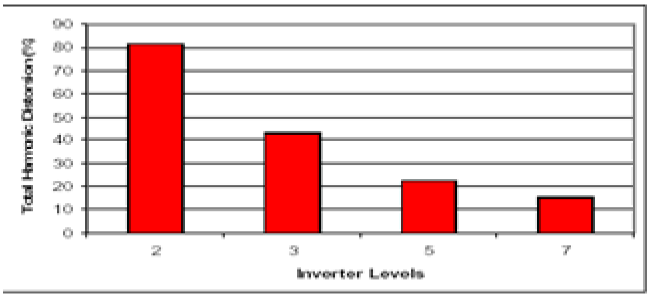


**Figure 1:** Difference in the magnitudes of the harmonics present in the unfiltered output voltage waveforms for two and five level inverters

## 3. Operation and Design of Multilevel Inverters with Modulation method

The concept of utilizing multiple small voltage levels to perform power conversion was patented by a researcher over twenty years ago.

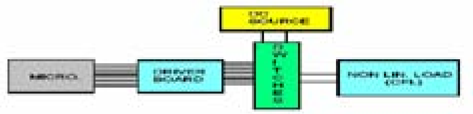

**Figure 2:** Block diagram of multilevel inverter

Advantages of this multilevel approach include good power quality, good electromagnetic compatibility (EMC), low switching losses, and high voltage capability. The circuit diagram of nine level multilevel inverter are shown in fig.3

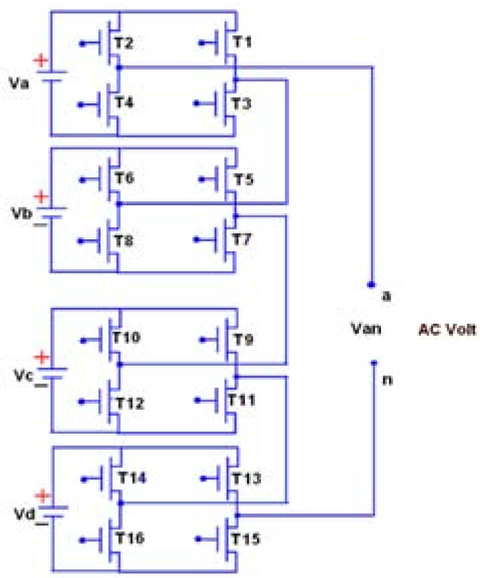


**Figure 3:** Circuit diagram of multilevel inverter

The main disadvantages of this technique are that a larger number of switching semiconductors are required for lower-voltage systems and the small voltage steps must be supplied on the dc side either by a capacitor bank or isolated voltage sources [11] [13]. The first topology introduced was the series H-bridge design this was followed by the diode clamped converter which utilized a bank of series capacitors. A later invention detailed the flying capacitor design in which the capacitors were floating rather than series-connected. Another multilevel design involves parallel connection of Inverter phases through inter-phase reactors. In this design, the semiconductors block the entire dc voltage, but share the load current. Several combinational designs have also emerged. Some are involving cascading the fundamental topologies. These designs can create higher power quality for a given number of semiconductor devices than the fundamental topologies alone due to a multiplying effect of the number of levels [14].

Recent advances in power electronics have made the multilevel concept practical. In fact, the concept is so advantageous that several major drives manufacturers have obtained recent patents on multilevel power converters and associated switching techniques Furthermore, several IEEE conferences now hold entire sessions on multilevel power conversion. It is evident that the multilevel concept will be a prominent choice for power electronic systems in future years, especially for medium-voltage operation.

This chapter describes the fundamentals of multilevel power conversion. Some background material is provided followed by the mathematical details of the power and control sections.

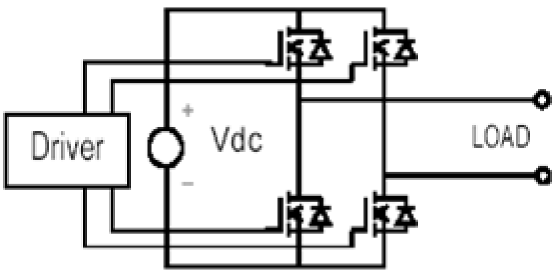


**Figure 4:** Show a drive which will be used to exemplify general multilevel concepts.

Although an inverter is used as the basis for this discussion, the multilevel converter can be used in active rectifier and flexible AC transmission systems (FACTS) applications from a system point of view, the multilevel inverter has been inserted in place of a standard inverter. Herein, Drivers are used to give gate firing voltage to SCRs or MOSFETs, dc voltage source may be battery or capacitor banks or it may be solar panel also. Number of switches (MOSFET or SCR) is used in order to meet harmonic requirements at the output terminals [15].

### 3.1 Multilevel power converter structures

As previously mentioned, three different major multilevel converter structures have been applied in industrial applications: diode clamped, flying capacitors and cascaded H-bridges converter with separate dc sources. Before continuing discussion in this topic, it should be noted that the term multilevel converter is utilized to refer to a power electronic circuit that could operate in an inverter or rectifier mode [6].

### 3.2 Modulation Methods

There may be different modulation methods for the multilevel converter, different modulation methods can be used to drive an induction motor. The following methods have been developed and tested.

a) Step Modulation
b) PWM Modulation
c) Vector Modulation

#### 3.2.1 Step Modulation

To avoid the high-switching losses, the step modulation method can be used. The functionality is simple, one phase of the converter works like a quantize of the ideal sine-wave reference voltage. If the current quality has to be improved, a larger number of steps per phase have to be taken. Three different methods were developed to commutate the single-phase multilevel converter with the step modulation: the first method consist of a normal series turn on and turn off from one cell after the other [7] [8].

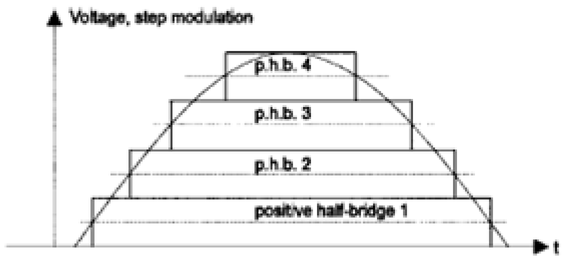


**Figure 5:** Represent the modulation for a half period

#### 3.2.2 Pulse width Modulation (PWM)

In PWM modulation the width of the pulse is changes according to the amplitude of the sine wave [12].

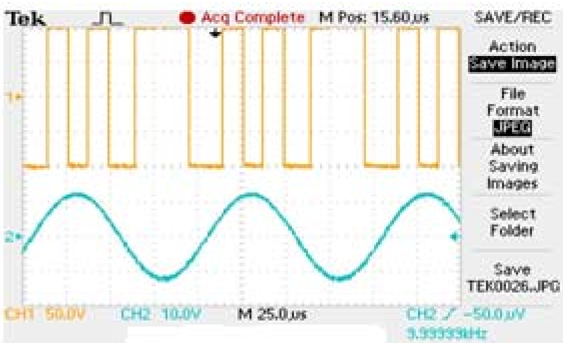


**Figure 6:** Generation the square waves of different pulse width (duty cycle) and after filtration sine wave may achieve

### 3.3.3 Vector Modulation

The upper two methods can also be used for single-phase multilevel converters. For the three-phase version, vector modulation can be used, allowing timing advantages for vector current control. With high-speed processors like DSP, the coordinate transformation can be made for fast sampling times (200 s) [20].

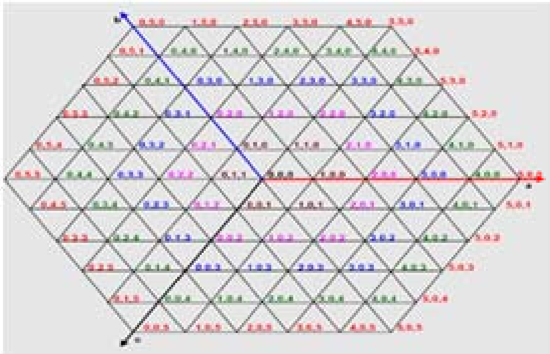

**Figure 7:** Output voltage vector position

The basis for this modulation method can be taken Out of Fig. 5 where all the possible output voltages are represented on the complex vector plane for the multilevel converter.

## 4. Switching algorithm for the multilevel inverters

### 4.1 Flying Capacitor Multilevel Inverter structure

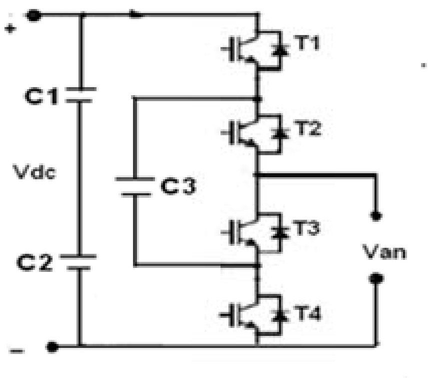


**Figure 8:** Flying-capacitor based multilevel inverter

One advantage of the flying-capacitor-based inverter is that it has redundancies for inner voltage levels; in other words, two or more valid switch combinations can synthesize an output voltage. Unlike the diode-clamped inverter, the flying-capacitor inverter does not the diode-clamped inverter has only line-line redundancies These redundancies allow a choice of charging/discharging specific capacitors and can be incorporated in the control system for balancing the voltages across the various require all of the switches that are on (conducting) be in a consecutive series. Moreover, the flying-capacitor inverter has phase redundancies [15].

### 4.2 Cascaded H-bridges

Cascade multilevel inverter consists of a series of H-bridge (single-phase full-bridge) inverter units. The general function of this multilevel inverter is to synthesize a desired voltage from several separate dc sources (SDCSs), which may be obtained from batteries, fuel cells, or ultra capacitors in a HEV [17].

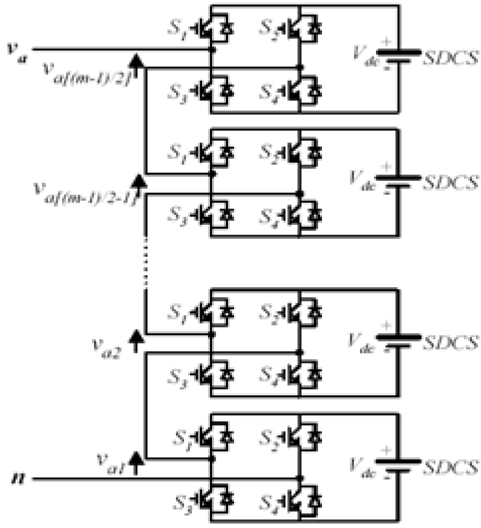


**Figure 9:** Single phase structure of a cascaded h-bridge inverter.

$$V(\omega t)=\frac{4V_{dc}}{\pi}\sum_{n}\left[\cos(n\theta_1)+\cos(n\theta_2)+\ldots+\cos(n\theta_s)\right]\frac{\sin(n\omega t)}{n}, \quad \text{where } n=1,3,5,7,\ldots$$

A single-phase structure of an m-level cascaded inverter is illustrated in Figure 6. Each separate dc source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs, $+V_{dc}$, 0, and $-V_{dc}$ by connecting the dc source to the ac output by different combinations of the four switches, $S_1$, $S_2$, $S_3$, and $S_4$. To obtain $+V_{dc}$, switches $S_1$ and $S_4$ are turned on, whereas $-V_{dc}$ can be obtained by turning on switches $S_2$ and $S_3$. By turning on $S_1$ and $S_2$ or $S_3$ and $S_4$, the output voltage is 0. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The number of output phase voltage levels m in a cascade inverter is defined by $m = 2_{s+1}$, where s is the number of separate dc sources. An example phase voltage waveform for an 11-level cascaded H-bridge inverter with 5 SDCSs and 5 full bridges is shown in Figure 7. The phase voltage van = $v_{a1} + v_{a2} + v_{a3} + v_{a4} + v_{a5}$ [11].

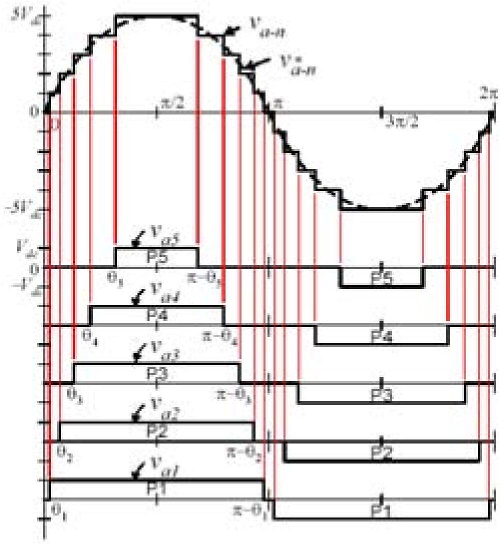


**Figure 10:** Single-phase structure of a cascaded H-bridge inverter

## 5. Experimental work and Results

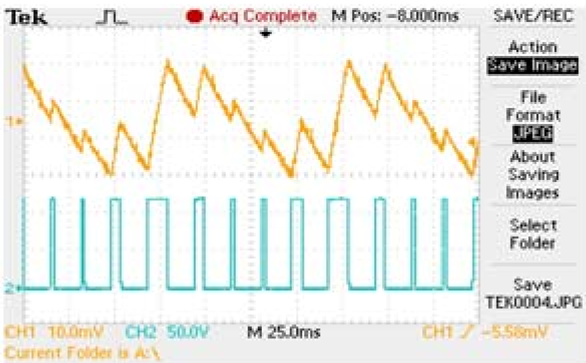


**Figure 11:** PWM wave and corresponding output with filter


**Figure 12:** Harmonics with Filter

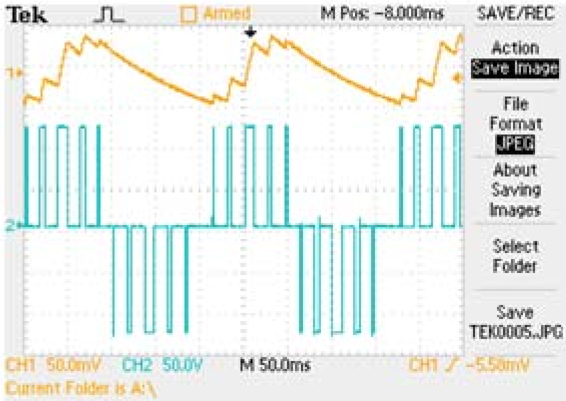


**Figure 13:** Wave form without filter

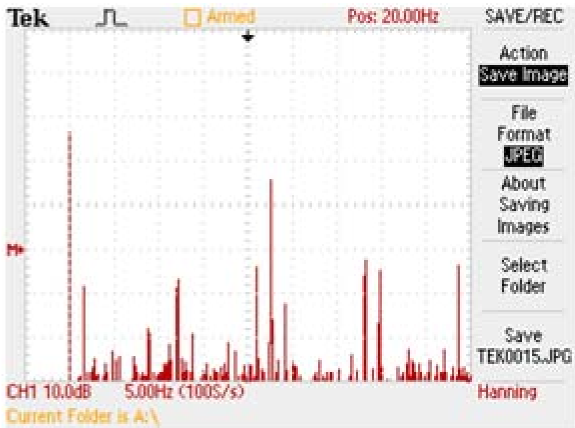


**Figure 14:** Harmonics without filter

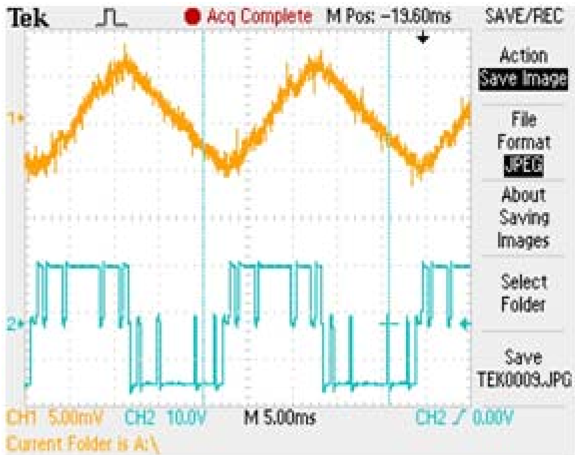


**Figure 15:** Wave form with filter


**Figure 16:** Harmonics without filter

## 6. Conclusions and further work

All these inverters are now widely used in industrial applications. The topology of the series-connected switching devices generates a three-level phase output and a five-level line-to-line output voltage. Thus, there is fewer harmonic and less voltage stresses applied across the load compared with the conventional two-level inverters. A full solution to the problem of eliminating the fifth and seventh harmonics in a seven level multilevel inverter has been given. The arithmetic methods include the carrier-based PWM schemes that induce some zero sequence voltage to control neutral-point voltage, and Space Vector Modulation based PWM schemes that make use of the redundant vectors to control the neutral-point current and then suppress the neutral-point voltage variations. All methods can work well under some conditions, but there still are some limitations in the performance and applications. In addition, various techniques to mitigate the common mode voltages were successfully applied in the converter PWM modulations. It was shown that the algorithm could be easily implemented in the high level assembly language programming.

In future we implementing a new microprocessor based program for high modulation indexes, the space vectors that can generate two-level outputs instead of three-level outputs are chosen to drive switching devices in the system. This can make the outputs skip the zero output states or go through transient zero states.

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