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# Analysis of Five Level Diode Clamped Multilevel Inverter Using Discontinuous TPWM Technique

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**ABSTRACT**:This paper presents a five level diode clamped multilevel inverter topology which can be used for low-medium power industrial applications. The topology of five levels diode clamp multilevel inverter is tested using MATLAB. Circuit operation is presented, simulated & Total Harmonic Distortion is analysed. A pulse to the inverter is provided using discontinuous PWM technique.

**KEYWORDS:** Discontinuous PWM Technique, Diode Clamped Multilevel Inverter, Total Harmonic Distortion.

## I.INTRODUCTION

Multilevel Inverters have gained much attention in the field of the medium voltage and high power applications because of their many advantages, such as their low voltage stress on power switches, low harmonic and EMI output. At present, there are three basic multilevel inverter topologies: diode-clamped multilevel inverter (DCMI), flying capacitor multilevel inverter (FCMI) and multi-module cascaded inverter (MMCI). The diode clamped multilevel inverter was also called the neutral point clamped (NPC) inverter. When it was first used in a three-level inverter in which the mid voltage level was defined as the neutral point because the NPC inverter effectively doubles the device voltage levels without requiring precise voltage matching.Among Various Modulation Technique such as PWM, SPWM, SVPWM, MPWM. SPWM Technique is more prominent over other due to following merits. It proportionally varies the width of each pulse to the amplitude of a sine wave evaluated at the center of the same pulse It is suitable for MATLAB/SIMULINK implementation.

## II.DIODE CLAMPED MULTI-LEVEL INVERTER

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. The concept of multilevel converters has been introduced by NABE- EL Since 1975 .The various advantages of multi-level inverter are, 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 (cm) voltage, thus reducing the stress in the motor bearings, they can operate with a lower switching frequency. The diode clamped multilevel inverter was also called the neutral point clamped (NPC) inverter. When it was first used in a three-level inverter in which the mid voltage level was defined as the neutral point because the NPC inverter effectively doubles the device voltage levels without requiring precise voltage matching.

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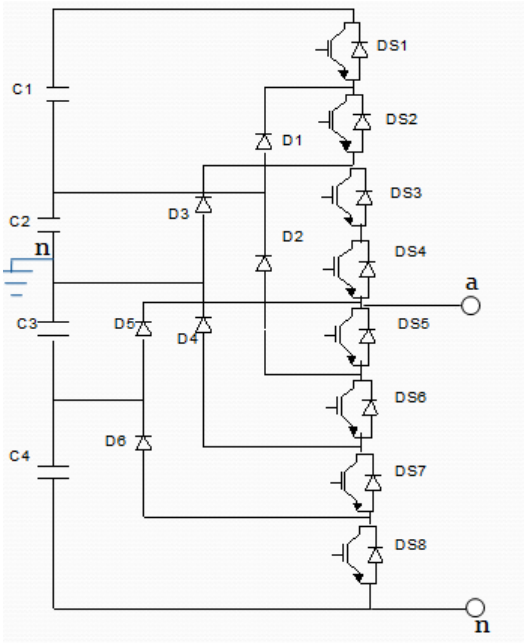


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Fig.1. Diode Clamped Five level Inverter

Number of DC bus capacitor in a multi level inverter is decided by (n-1), Number of switches in Multilevel inverter is decided by2*(n-1), Voltage source is decided by Vdc/ (n-1) & clamping diode is given by (n-1)*(n-2). Where 'n' is number of level of an inverter. For a five level inverter shown in "fig.1".

| Switching states | Output voltages | DS1 | DS2 | DS3 | DS4 | DS5 | DS6 | DS7 | DS8 |
|---|---|---|---|---|---|---|---|---|---|
| +1 | Vdc/2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| +2 | Vdc/4 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| -2 | -Vdc/4 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| -1 | -Vdc/2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |

Table 1. Switching States Diode Clamped five Level Inverter

In this circuit, the DC bus voltage is split up in to three levels as shown. Five-level diode-clamped converter in which the DC bus consist of four capacitor C1,C2,C3,C4 for DC bus voltage Vdc, the voltage across each capacitor is Vdc/4 & each device voltage stress will be limited to one capacitor voltage levels Vdc/4 through clamping diodes, For voltage levels Van= Vdc/2 turn on all upper switches S1-S4, For voltage level Van= Vdc/4, turn on three upper switches S2-S4 and lower switch S5,For voltage level Van=0, turn on two upper switches S3 and S4 and two lower switches S5 and S6, For voltage levels Van= -Vdc/4, turn on one upper switch S4 and three lower switches S5-S7, For voltage levels Van= -Vdc/2, turn on all lower switches S5-S8 NPC inverter which has been extensively used today in industrial drives, traction as well as FACT's system Based on concept of using diodes to limit power devices voltage stress Output phase voltage can assume any voltage level by selecting any of the nodes

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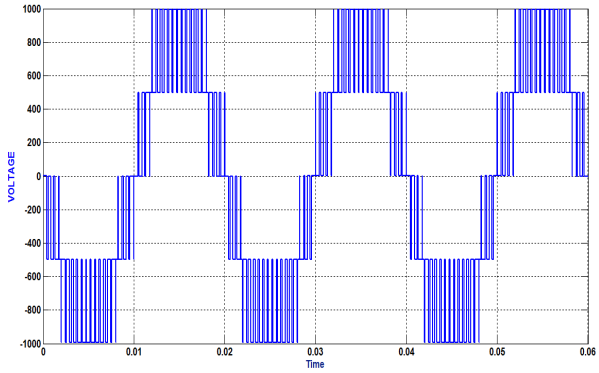


Fig.2. Output voltage of Diode Clamped Five level Inverter

DCMI is considered as a type of multiplexer that attaches the output to one of the available nodes Although main diodes have same voltage rating as main power devices, much lower current rating is allowable For three-phase DCMI, the capacitors need to filter only the high-order harmonics of the clamping diodes currents, low-order components intrinsically cancel each other Each power device block only a capacitor voltage Clamping diodes block reverse voltage.

## III.TRAPEZOIDAL PULSE WIDTH MODULATION (TPWM)

TPWM applies a pulse train of fixed amplitude and frequency only the width is varied in proportion to an input voltage in TPWM technique the power semiconductor switches are turned on and turn off several times during half cycles and output voltage is controlled by changing the width pulsen= number of carriers (n-1), modulation index=AM/n'AC where n'= (n-1)/2, where n= number of levels frequency of reference wave is 50 Hz and frequency of carrier is 2KHzwe made comparing of reference wave and carrier wave its result is pure TPWM for switching of switches for 3 level no. carriers requires two and for 5 level no. of carrier requires 4 upper two and lowers two. By using this technique we are giving the switching pulse to switches.The multicarrier TPWM techniques are based on a single modulating or reference signal, which in most cases is sinusoidal. This reference waveform is compared and sampled through a number of triangular waveforms and for this reason the TPWM techniques considered.

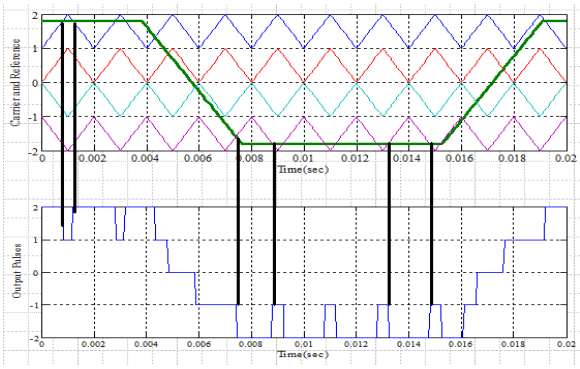


Fig.3. Trapezoidal Pulse Width Modulation.(TPWM)

Frequency of reference wave is 50 Hz and frequency of carrier is 2 KHz, on comparing reference wave and carrier wave its result is pure TPWM for switching of switches for 3 level number of Carriers required is two and for five level number of carriers required is four, upper two and lower two. By using this technique we are giving the switching pulse to switches as shown in "Fig.3".

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A. Total Harmonic Distortion (THD)

The pulse width modulated power inverters have been increasingly using to convert DC power to AC power in small wind plants. When these inverters are used for power conversion, the integrated output voltage waveform is inevitably distorted. Although increasing the switching frequency is one choice to achieve the smoother output voltage, it adds extra harmonics to the output. There are various techniques such as analogue filtering, harmonic elimination etc. To reduce the number of harmonics usually affecting the system performance. In this study, a simple but efficient modulation approach based on the optimization of the shape of the triangular voltage waveform is proposed. The results have shown that the total harmonic distortion of the optimized voltage waveform decreases gradually and thus helps improve on the power quality during the conversion.

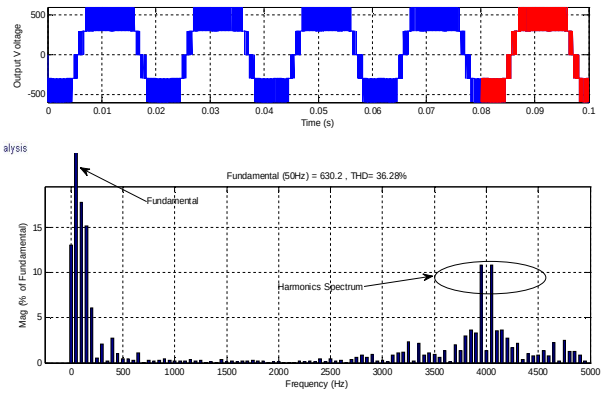


Fig.4. Total Harmonic Distortion of Five level DCMI.

The total harmonic distortion, or THD, of a signal is a measurement of the harmonic distortion present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. THD is used to characterize the linearity of audio systems and the power quality of electric power systems In power systems, lower THD means reduction in peak currents, heating, emissions, and core loss in motors TOTAL harmonic distortion (THD) is an important figure of merit used to quantify the level of harmonics in voltage or current waveforms. The distortion of a waveform relative to a pure sine wave can be measured either by using a THD analyzer to analyse the output wave into its constituent harmonics and noting the amplitude of each relative to the fundamental; or by cancelling out the fundamental with a notch filter and measuring the remaining signal, which will be total aggregate harmonic distortion plus noise.

## IV.CAPACITOR CLAMPED MULTILEVEL INVERTER

A new multilevel converter topology the so-called flying capacitor (FC) multilevel VSC was introduced. It uses a trapezoidal PWM strategy to control the individual switches and is capable of generating multilevel voltage waveforms with reduced power loss within the converter lower total harmonic distortion and increased bandwidth whencompared with conventional two-level system. Therefore this converter topology called be an ideal candidate for high power application Main switches=2(n-1) =8, DC bus capacitor = (n-1) = 4Balancing capacitor= (n-1) (n-2)/2=6

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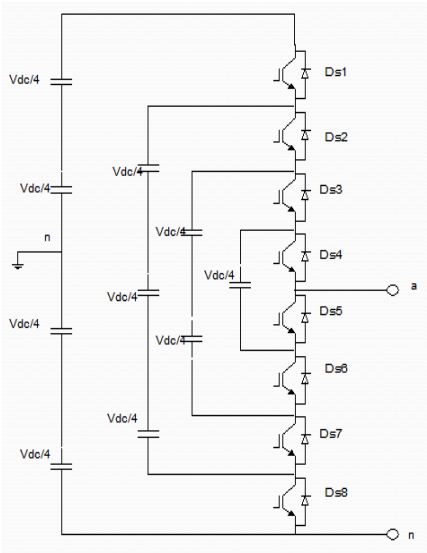


Fig.5. Capacitor Clamped Multilevel Inverter.

In this circuit, the DC bus voltage is split up in to three levels as shown. Five-level diode-clamped converter in which the DC bus consist of four capacitor C1,C2,C3,C4 for DC bus voltage Vdc, the voltage across each capacitor is Vdc/4 & each device voltage stress will be limited to one capacitor voltage levels Vdc/4 through clamping capacitor, For voltage levels Van= Vdc/2 turn on all upper switches S1-S4, For voltage level Van= Vdc/4, turn on three upper switches S1-S3 and lower switch S5,For voltage level Van=0, turn on two upper switches S1 and S2 and two lower switches S5 and S6, For voltage levels Van= -Vdc/4, turn on one upper switch S1 and three lower switches S5-S7, For voltage levels Van= -Vdc/2, turn on all lower switches S5-S8. The output voltage waveform of five level capacitor clamp multilevel inverter and its switching state is shown in table.2.& fig 7.

| Switching states | Output voltages | DS1 | DS2 | DS3 | DS4 | DS5 | DS6 | DS7 | DS8 |
|---|---|---|---|---|---|---|---|---|---|
| +1 | Vdc/2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| +2 | Vdc/4 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| -2 | -Vdc/4 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| -1 | -Vdc/2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |

Table.2. Switching State of CCMI

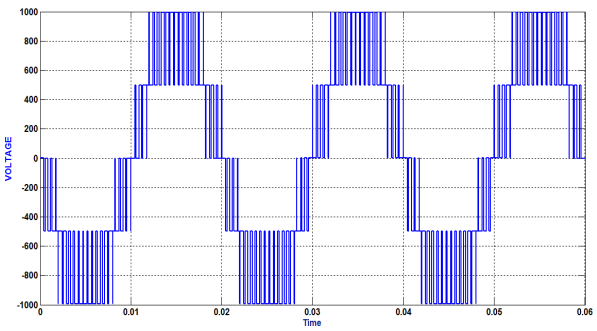


Fig.7. Output voltage of Five level CCMI

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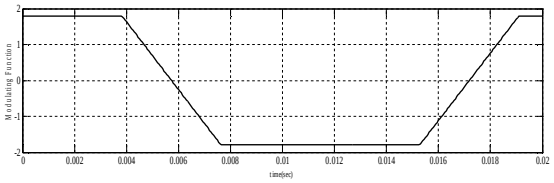
The given diagram shows the total harmonics distortion of Five level CCMI and the output voltage of Five level CCMI consist of more harmonics distortion which will affect on the efficiency of inverter, where as harmonic distortion in diode clamped multilevel inverter is very less. Hence DCMI is more preferred for medium voltage level industries rather than CCMI.

TMF:

$$F1(\alpha) = \begin{cases} 0.5 & \text{if} -60^0 \leq \alpha < 60^0 \\ 1.5 - \frac{\alpha}{60^0} & \text{if } 60^0 \leq \alpha < 120^0 \\ -0.5 & \text{if } 120^0 \leq \alpha < 240^0 \\ \frac{\alpha}{60^0} - 4.5 & \text{if } 240^0 \leq \alpha < 300^0 \end{cases}$$



(c)Trapezoidal modulating function

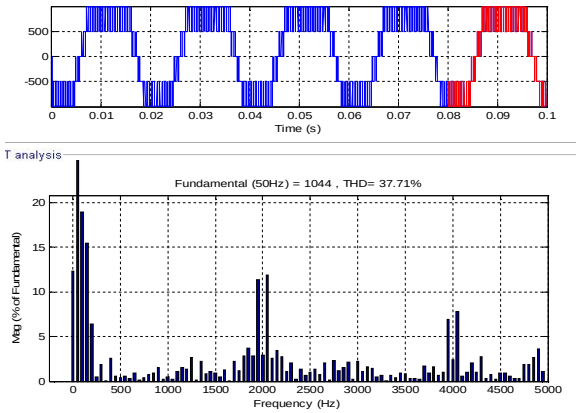



Fig.8. Total Harmonic Distortion of Five Level CCMI

Hence diode clamped inverter effectively doubled the device voltage at higher level, because of clamping diode, DCML (Diode clamped multilevel inverter) consisting of IGBT switches with lower switching frequency, they can generate output voltage with extremely low distortion and lower dv/dt, they draw input current with very low distortion, they generate smaller common-mode (cm) voltage, thus reducing on the stress on the switching devices. They are used in the aspects of harmonics content reduction in megawatt level industries

## V. RESULT

The simulation of diode clamed multilevel inverter with RLC load where R=10Ω, L=2mH, C=1μF, shows that it contains very low total harmonics distortion; hence the efficiency of such inverter is very high. When the analysis of diode clamped multilevel inverter with Capacitor clamped multilevel inverter was carried out we found that CCMI has more total harmonics distortion The total harmonic distortion of both DCMI and CCMI in numeric value is given in table below.

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| Inverter with RLC load | THD percentage |
|---|---|
| Capacitor clamp Inverter | 37.41% |
| Diode clamp Inverter | 36.28% |

Table 2.Total Harmonics distortion Analysis

From above table we conclude that diode clamp inverter is more suitable as compared to capacitor clamped multilevel inverter as its THD is less as compared to capacitor clamped multilevel inverter and hence it is more efficient and beneficial for mega watt level industries application, due to clamping diode in diode clamp inverter it doubles the output voltage as compared to normal inverter. When we apply low pass filter to the output of diode clamp inverter we get to know that we can reduce the present harmonic condition to very low level, hence diode clamp multilevel inverter is more beneficial.

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