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Comparative Study of Different Five level inverters Using POD Control Strategy

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Abstract: **Multilevel converters are increasingly being considered for high power applications because of their ability to operate at higher output voltages while producing lower levels of harmonic components in the switched output voltages. This paper proposed a simulation model of four different typologies of single phase five-level inverter. The study investigated four topologies of multilevel inverter namely Flying Capacitor Multilevel Inverter (FCMLI), Diode Clamped Multilevel Inverter (DCMLI), Cascaded H-bridge Multilevel inverter (CHMLI) and POD inverter. These topologies were compared in terms of Total Harmonic Distortion (THD and the number of power electronic components being utilized. The simulation result was conducted using MATLAB/SIMULINK. The findings showed that the POD PWM H-Bridge topology has the lowest total harmonic distortion (THD).**

Keywords: **Cascade, DCMLI, FCMLI, Multicarrier PWM, Multilevel, multilevel inverter, total harmonic distortion, stepped wave inverter.**

I. INTRODUCTION

Inverters are used to create single or polyphase AC voltages from a DC supply. In the class of polyphase inverters, three-phase inverters are by far the largest group. A very large number of inverters are used for adjustable speed motor drives. The typical inverter for this application is a “hard-switched” voltage source inverter producing pulse-width modulated (PWM) signals with a sinusoidal fundamental [Holtz, 1992]. Recently research has shown detrimental effects on the windings and the bearings resulting from unfiltered PWM waveforms and recommend the use of filters [Cash and Habetler, 1998; Von Jouanne et al., 1996]. A very common application for single-phase inverters are so-called “uninterruptable power supplies” (UPS) for computers and other critical loads. Here, the output waveforms range from square wave to almost ideal sinusoids.

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 multilevel inverter has been introduced since 1975 as alternative in high power and medium voltage situations. The multilevel inverter is like an inverter and it is used for industrial applications as alternative in high power and medium voltage situations. The need of multilevel converter is to give a high output power from medium voltage source. Sources like batteries, super capacitors, solar panel are medium voltage sources. The multilevel inverter consists of several switches. In the multilevel inverter the arrangement switches’ angles are very important.

Multilevel inverters are three types Diode clamped multilevel inverter, Flying capacitors multilevel inverter and Cascaded H- bridge multilevel inverter. The main concept of diode clamped multilevel 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.

In the case of Flying Capacitors Multilevel inverter a series connection of capacitor clamped switching cells are used. The capacitors transfer the limited amount of voltage to electrical devices. In this inverter switching states are like in the diode clamped inverter. Clamping diodes are not required in this type of multilevel inverters. The output is half of the input DC voltage. It is drawback of the flying capacitors multilevel inverter. It also has the switching redundancy within phase to balance the flaying capacitors. It can control both the active and reactive power flow. But due to the high frequency switching, switching losses will takes place.

The cascaded H-bride multilevel inverter is to use capacitors and switches and requires less number of components in each level. This topology consists of series of power conversion cells and power can be easily scaled. The combination of capacitors and switches pair is called an H-bridge and gives the separate input DC voltage for each H-bridge. It consists of H-bridge cells and each cell can provide the three different voltages like zero, positive DC and negative DC voltages. One of the advantages of this type of multilevel inverter is that it needs less number of components compared with diode clamped and flying capacitor inverters. The price and weight of the inverter are less than those of the two inverters. Soft-switching is possible by the some of the new switching methods. Multilevel cascade inverters are used to eliminate the bulky transformer required in case of conventional multiphase inverters, clamping diodes required in case of diode clamped inverters and flying capacitors required in case of flying capacitor inverters. But these require large number of isolated voltages to supply the each cell.

II. SINGLE PHASE MULTI LEVEL INVERTER TOPOLOGIES

A. *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.. 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.

In diode clamped inverter, the diode is used as the clamping device to clamp the dc bus voltage so as to achieve steps in the output voltage. Thus, the main concept of this inverter is to use diodes to limit the power devices voltage stress. The voltage over each capacitor and each switch is V_{dc}. An n level inverter needs (n-1) voltage sources, 2(n-1) switching devices and (n-1) (n-2) diodes. By increasing the number of voltage levels the quality of the output voltage is improved and the voltage waveform becomes closer to sinusoidal waveform. 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. Applications of Diode Clamped Multilevel Inverter are Static var compensation, variable speed motor drives, High voltage system interconnections and High voltage DC and AC transmission lines

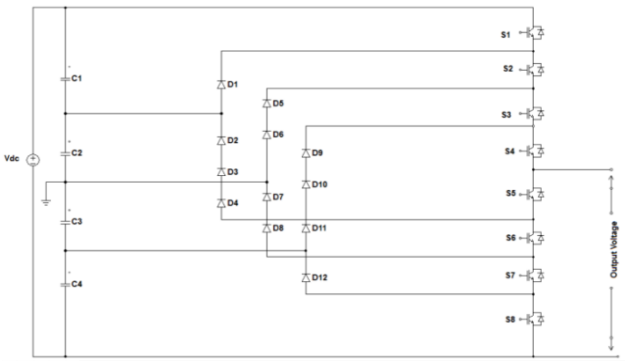

Fig.1: Diode clamped multilevel inverter

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B. *Flying Capacitor Multilevel Inverter:*

To generate *m*-level staircase output voltage, *m*-1 capacitors in the dc bus are needed. Each phase-leg has an identical structure. The size of the voltage increment between two capacitors determines the size of the voltage levels in the output waveform. The main concept of this inverter is to use capacitors. It is of series connection of capacitor clamped switching cells. The capacitors transfer the limited amount of voltage to electrical devices. In this inverter switching states are like in the diode clamped inverter. Clamping diodes are not required in this type of multilevel inverters. The output is half of the input DC voltage. It is drawback of the flying capacitors multilevel inverter. It also has the switching redundancy within phase to balance the flaying capacitors. It can control both the active and reactive power flow. But due to the high frequency switching, switching losses will takes place.

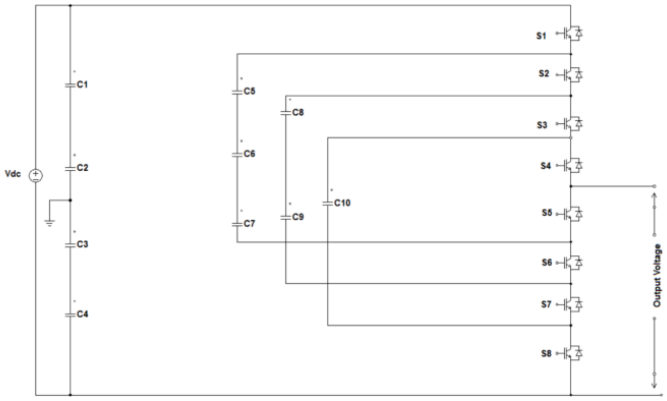

Fig.2: Flying capacitor multilevel inverter

Applications of flying capacitor multilevel inverter are induction motor control using DTC (Direct Torque Control) circuit, Static var generation, both AC-DC and DC-AC conversion applications, Converters with Harmonic distortion capability and Sinusoidal current rectifiers.

C. *Cascaded multilevel inverter:*

The cascaded H-bride multilevel inverter is to use capacitors and switches and requires less number of components in each level. This topology consists of series of power conversion cells and power can be easily scaled. The combination of capacitors and switches pair is called an H-bridge and gives the separate input DC voltage for each H-bridge. It consists of H-bridge cells and each cell can provide the three different voltages like zero, positive DC and negative DC voltages. One of the advantages of this type of multilevel inverter is that it needs less number of components compared with diode clamped and flying capacitor inverters. The price and weight of the inverter are less than those of the two inverters. Soft-switching is possible by the some of the new switching methods. Multilevel cascade inverters are used to eliminate the bulky transformer required in case of conventional multiphase inverters, clamping diodes required in case of diode clamped inverters and flying capacitors required in case of flying capacitor inverters. But these require large number of isolated voltages to supply the each cell.

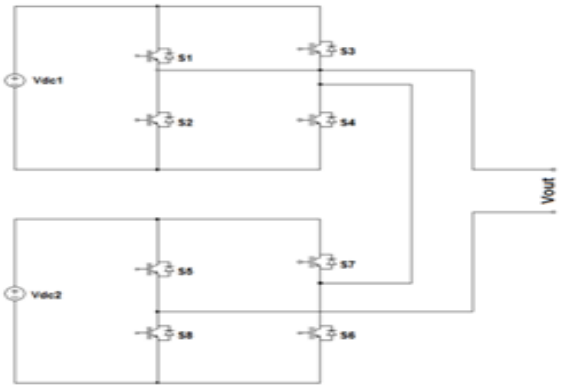

Fig.3: Cascaded multilevel inverter

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D. *Single Phase Five POD Multilevel Inverter:*

The proposed technique is based on POD technique. POD stands for phase opposition and disposition technique . The proposed technique is used for pulse generation in multilevel inverter shown in figure 3 .In figure 4 if sine wave l is greater than carrier wave, switches Tp+ is on else Tp- is on . If sine wave 2 is greater than carrier wave ,switch Tn+ is on else switch Tn- is on .If sine wave 1 is positive then switches Ta+, Tb- are on and if sine wave is negative then switches Ta-,Tb+ is on. Figure 3 illustrates the proposed multi-level inverter which is based on cascaded H bridge multi-level inverter. In the proposed multi-level inverter two dc link capacitors C_1 and $C_2$and 8 switches are used Input supply to inverter is V_{dc} and voltage across each capacitor is$V_{dc/2}$. The output of the inverter is connected to LC filter in order to eliminate the harmonics.

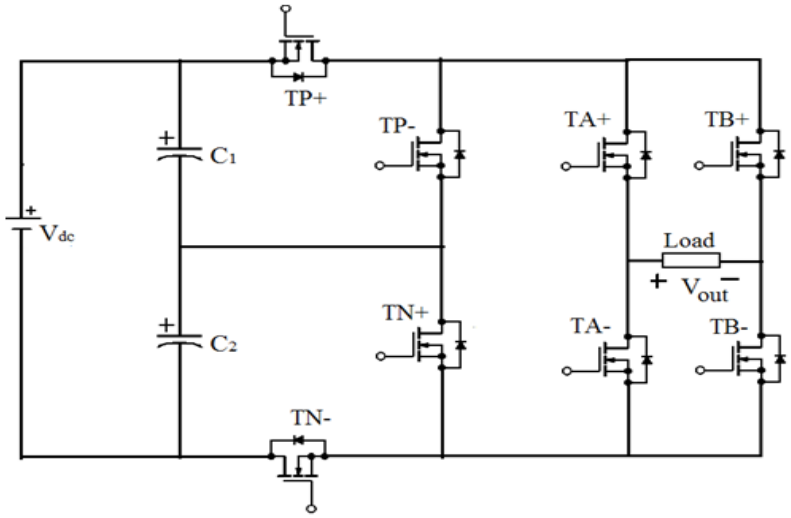

Fig.4 Single phase POD multilevel inverter

III. SIMULATION ANALYSIS AND RESULTS

The proposed 5-level inverter is tested to verify the operating principle of the proposed MLI and all conventional MLI. The LC filter is inserted between the output of the inverter and the load. Electrical specifications of the proposed inverter are summarized in Table 1.

Table 1.Simulation Parameters

Parameters	**Values**
dc link voltage	100V
output voltage	200V
dc link capacitor	2200µH
Filter inductor	350mH
Filter capacitor	3300 µH
Output frequency	50HZ

A. *Simulink Model of Single Phase Five Level POD Inverter:*

Simulation of proposed multi-level inverter is carried out in MATLAB/Simulink. Dc supply of 100 volts is given using batteries and 2 dc link capacitors are used and 8 MOSFET are used as switches and output of multi-level inverter is connected to L, C filter to eliminate harmonics. The technique used for pulse generation is POD technique .Generally in order to turn on 8 switches 8 carrier signals are needed but using proposed technique single carrier wave is used to generate switching pulses to 8 switches. Voltage measurement device is connected across each capacitor to measure the voltage across the capacitor.

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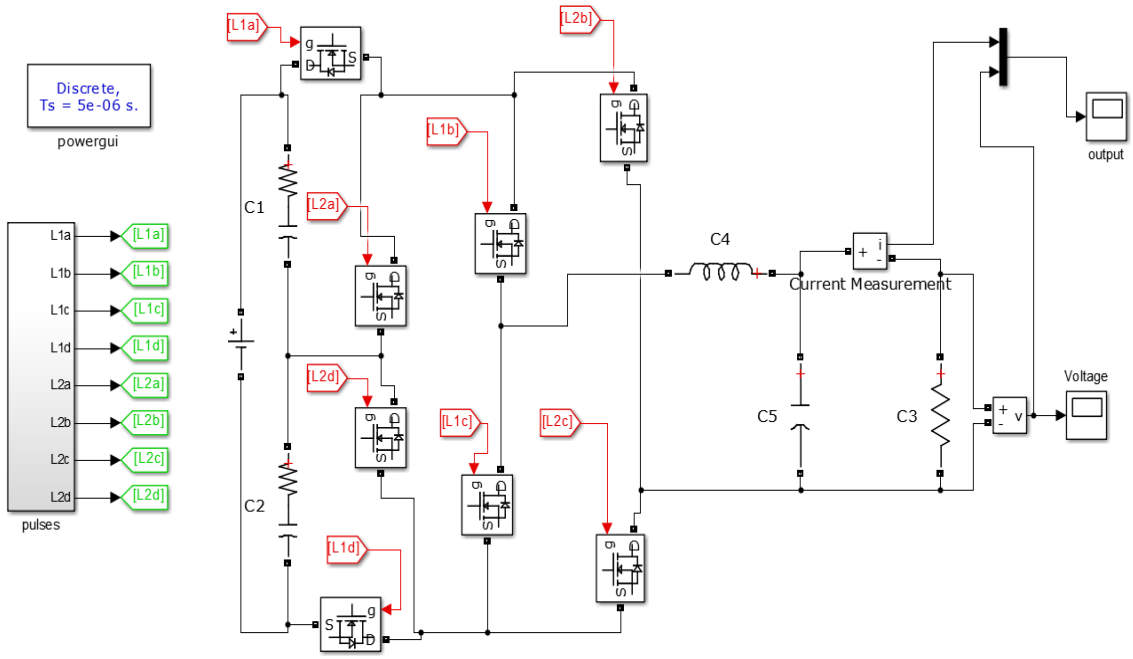

Fig.5 Simulink model of POD PWM Inverter

B. *Simulink Model for switch pulse generation:*

For the simulation of five-level inverter, single carrier wave and two sine waves are generated. Reference voltage for first sine wave is set as l.7 volts and reference voltage for second sine wave is set as 0.8 volts. Both sine waves are operating at frequency50 Hz. Time period for one carrier wave is set as 800 ms. DC supply of 100 volts is provided as input. Voltage is divided equally across two capacitors. Voltage across each capacitor is 50 volts. Voltage across each capacitor is measured using voltage measurement device .The output of Multilevel Inverter is connected to LC filter in order to eliminate harmonics and pure sine wave is obtained .Load Voltage are measured using voltage measurement device and Load current is measured using current measurement device. This type of MLI is mainly used for grid connected applications.

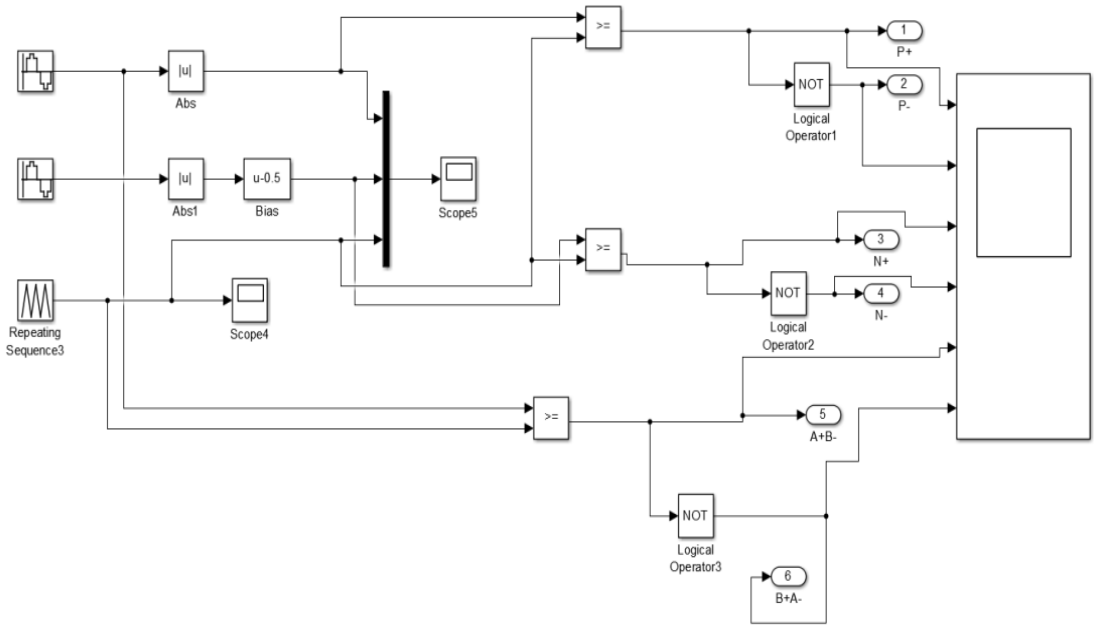

Fig.6 Simulink diagram for pulse generation

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C. *Switching Pulses:*

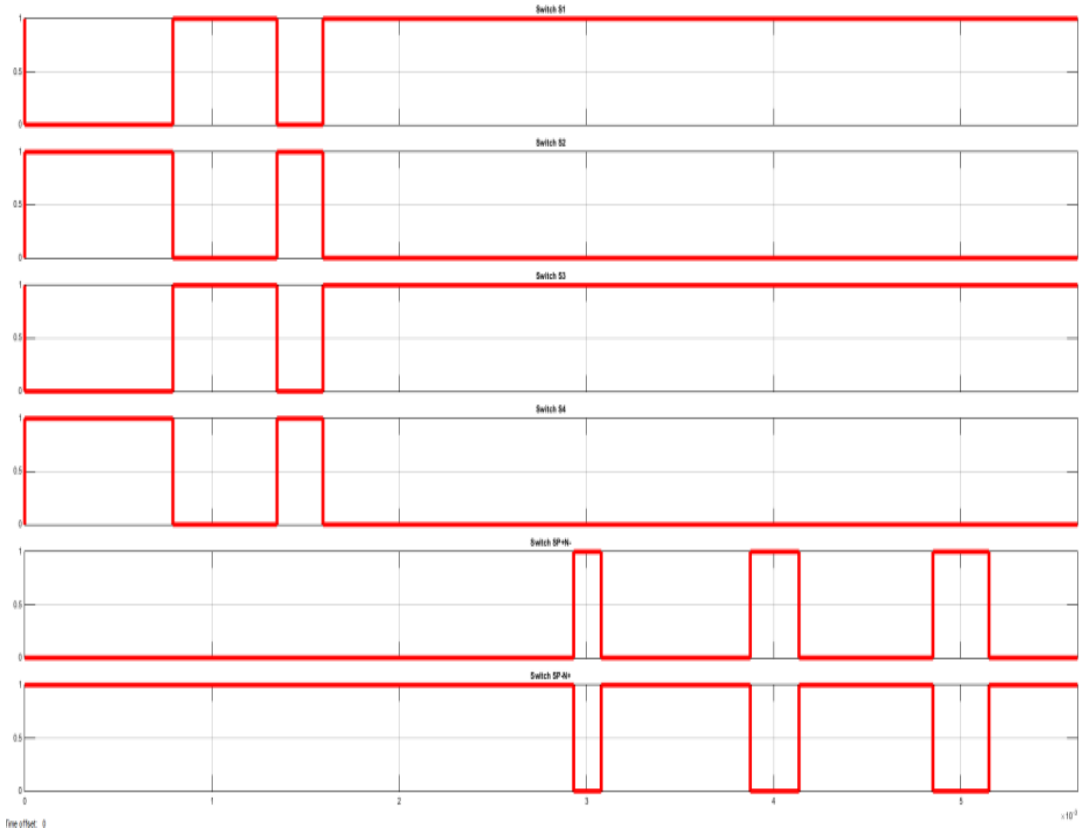

Fig.7 Switching pulses

D. *Output Voltage and Output Current of Five Level POD Inverter:*

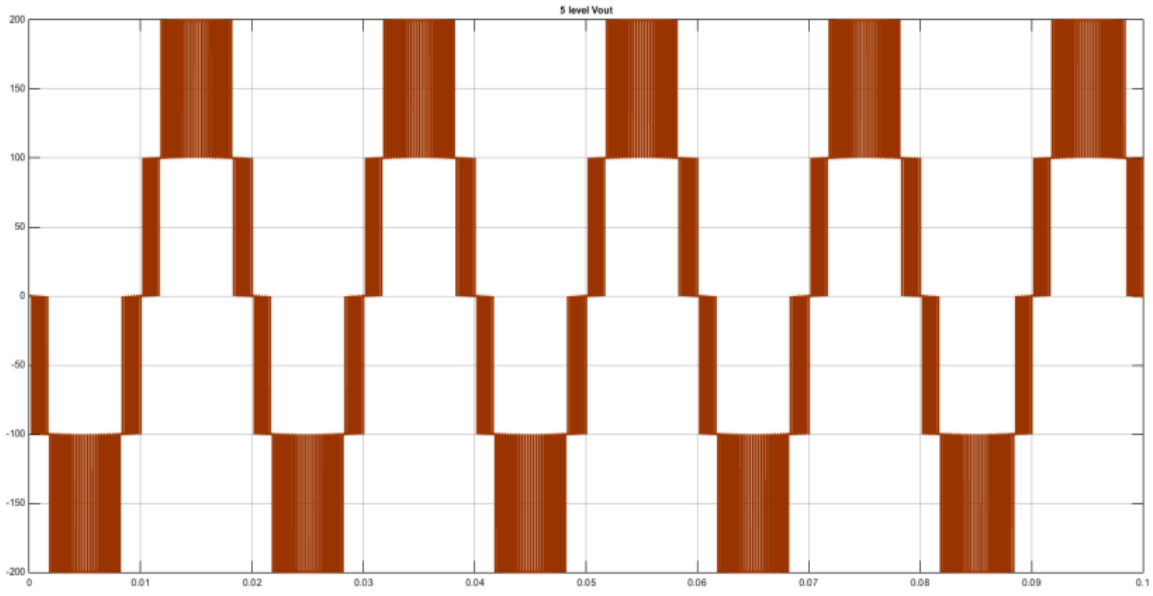

Fig.8 Five Level Output Voltage

The above figure shows the five level output voltage of the proposed inverter without using filter circuit. An input voltage of 200V dc given and a maximum voltage of 200V dc is obtained by proper switching. The circuit are tested using R load. So the current are in phase with the voltage.

E. ***Comparison of different five level Inverters:***

Table 2.1 Comparative Study of different five level inverters

SL.NO	ITEM	DIODE CLAMPED	FLYING CAPACITOR	CASCADED H BRIDGE	POD INVERTER
1	MOSFET	2(N-1)	2(N-1)	2(N-1)	2(N-1)
2	Clamping Diodes Per Phase	(N-1)(N-2)	0	0	0
3	DC Link Capacitors	N-1	N-1	N-1/2	N-1/2
4	Voltage Unbalancing	Average	High	Small	Very Small
5	Application	Motor Drive System, STATCOM	Motor Drive System, STATCOM	Motor Drive System, PV ,Fuel cells, battery system	STATCOM, STATCOM, Variable Speed Drives

F. ***THD analysis of different five level inverter:***

Table 2.2 Comparative Study of different five level inverters

SL.NO	Inverter Type	%THD
1	Diode Clamped	30.5
2	Flying Capacitor	34.6
3	Cascaded H Bridge	31.3
4	POD Inverter	26.08

IV. CONCLUSION

In this paper, a new schemes adopting the phase opposition disposition variable switching frequency single carrier pulse width modulation concepts are considered. Single phase Five level high frequency multi-level inverter employing different multi carrier single reference modulation schemes has been investigated and their FFT analysis has been performed. Multilevel inverter with individual dc sources has been proposed for use in large electric drives. Simulation and experimental results have shown that with a control strategy operates the switches at the fundamental frequency; these converters have high output voltage, less THD and high efficiency. In the proposed method semiconductor devices are reduced. The proposed method will reduce the cost, and also used only 8 switches, harmonic reduction and the heat losses .It is concluded that PODPWM technique provides output with relatively low harmonic distortion.

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