

# POD and APOD PWM FOR FLYING CAPACITOR MULTILEVEL TOPOLOGY IN SOLAR PV SYSTEM

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**Abstract:** This paper presents the study of three and five level flying capacitor multilevel inverter with Phase disposition PWM, Phase opposition disposition modulation techniques for PV system. The multicarrier PWM (MCPWM) techniques phase opposition disposition method is employed for the control strategy of three and five level flying capacitor multilevel inverter. In this paper the in-phase disposition PWM controlling strategy is used for controlling the three and five flying capacitor multilevel inverter. Simulation has been carried out using MATLAB (2017) and the output voltage waveforms are recorded. The Total Harmonic Distortion (THD) is found to be less for the multilevel inverter compared to the cascaded H-bridge multilevel inverter

**Keywords:** *PWM Inverter, Flying Capacitor, Multilevel Inverter, Phase Opposition Disposition (POD) & Alternate Phase Opposition Disposition (APOD).*

## 1. Introduction

The area of power electronics is revolutionized using by the advent of multilevel inverters and rapid growth of this new area in recent past. This technology finds use in many applications including industries. The technology of multilevel inverters is an ever-expanding technology which progresses manifold and day by day, new variants and versions of multilevel inverter technologies are spotted many times in recent literature. This paper mainly focuses on review and in-depth view of this rapid ever-growing power electronic technology. The paper first describes the penetration of the multi level inverters in the various types and scales of industries and other auxiliary applications. Later, the advanced and updated power electronic circuit topologies are presented. There happens to be numerous advantages of multilevel inverters in the field of power electronics. Improvement of percentage reduction of harmonics, reduced effect of problem of electromagnetic interference (EMI), enhanced rating of the inverter topology are preliminary advantages of multilevel inverters in addition to the increase of levels of dc and improvement in the waveform of the output voltage. Modular photovoltaic system, vehicular technology based on electricity, drives used in industries for middle level voltage applications are the primary users of the multilevel power electronic technology. The present focus of the paper lies in the design of multilevel power electronic topology for middle level and high-level industries and other related applications. The background of paper idea is clearly discussed and the objectives along proof of motivational aspects are also presented in detail.

## 2. Medium and High-Power Inverters

The design of inverter the involves various topologies of power electronic technology-based converter and associated control strategies with them. There are various aspects of the converter topology and the variation in the topology is observed based on the usage and applications of the converter. The approaches to the design aspects are varied based on the specification of the converter application and usage. The main philosophy lies in the superior quality of power delivered out from the inverter. The non-ideal output voltage waveform is filtered using various filtering appliances like capacitive elements, inductive elements [1-2].

If the multilevel converter technology involves the concept of transformer then care should be taken to implement filtering scheme on primary as well as secondary side.

Low-pass channels are connected to permit the key part of the waveform to go to the yield while constraining the entry of the consonant segments. Subsequently nature of waveform can be balanced. Note that, typical inverters dependably create low quality yield waveforms. To make the yield waveform subjective, low pass (LC channel) are frequently included the circuit. Be that as it may, at first, we attempt to make sense of the converter applications from low energy to high power and after that we abridge the prerequisites to take care of the power demand. At long last we attempt to display the issues and arrangements accessible to take care of the power demand.

The table 1 summarizes the range of power and type of power electronic equipment to be used based on various applications. The table shows that this latest power electronic based mutli inverter technology is found be promising and has

numerous applications in near future. The applications of multilevel technology range from mining, petroleum and petrochemical based, manufacturing, various transport based, vehicles that use electricity, non-conventional energy sources based as well as small and medium power based like domestic, etc. The table 1.1 refers to the wide range of inverters useful for various applications whether it can be AC or sometimes DC. The latest hot topic is to develop new variants of the multilevel power electronic technology especially for high and medium power range applications.

**Table 1:** Summary of Power Inverters

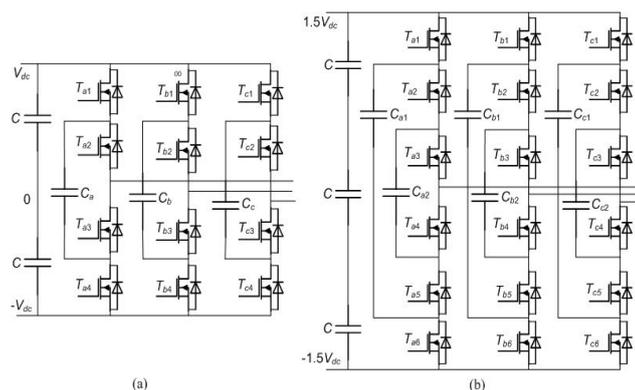
	Low Power	Medium Power	High Power
Power Range	Up to 2kw	2-500 kw	More than 500kw
Usual Converter Topologies	Ac/dc, dc/dc	Ac/dc, dc/dc, dc/ac	Ac/dc, dc/ac
Typical Power Semiconductors	MOSFET	MOSFET, IGBT	IGBT, Thyristor,
Typical Applications	Low Power devices, Home appliances	Electric Vehicles, PV systems	Power distribution, Industry

Enhancing power quality is the best prerequisite. In spite of the fact that technologists have constructed a various power inverter, yet at the same time scientists are in search for another kind of design which can deliver top notch waveform with a smaller number of parts. Enhancing power quality is the best prerequisite. By considering above perspectives, let us make a framework with respect to the requesting parts of energy inverters, specific in Medium and high-power run.

### 3. Flying Capacitor Multilevel Inverter

FC inverter utilizes extra capacitors oppositely charged to be incorporated into arrangement with dc supply, since after the disposal of the diodes it isn't conceivable to associate leg yield specifically to the coveted dc voltage. The flying capacitor (FC) topology is somehow gotten from its diode clipped ancestor by the disentanglement – disposal of the bracing diodes. The guideline of the changing is like the DCI, and will be clarified for three-level and four-level cases appeared in Fig. 1. These capacitors have a similar capacity of the cinching diodes in diode-braced converter: they keep consistent the voltage drop between the transports to which they are associated. Thus, they are called clamping capacitors, giving the name to the converter [3]. Another name that can be found in the writing is the nest cell converter [4]. Be that as it may, there is a distinction in the rule: cinching capacitors should be associated in arrangement, and must not be short circuited by turning on switches associated in parallel. The instants of switching and output voltages are given in Tab. 2, demonstrating repetition for leg yield voltage equivalent to zero which is another distinction as for DCI. These voltage-level redundancies can be utilized as additional degrees of opportunity for control or advancement purposes.

The principle disadvantage of the FCI is highly complicated control calculation and numerous voltage sensors for high number of capacitor voltages to be controlled. Another issue is capacitors flying association that requires both instatement and control, which requires the utilization of the excess states. Also, capacitors are unequally appraised, as can be noted in Fig. 1(b), where the external capacitors need to withstand full dc voltage, contrasted with DCI where all capacitors were equivalent and generally little. Nonetheless, the primary and most essential contrast with the NPC topology is that the FC has a particular structure that can be all the more effortlessly stretched out to accomplish more voltage levels, consequently here and there called multicell inverter [5]. The equipment hindrance is prerequisite for critical number of capacitors. Since the applications are at bring down transporter frequencies the high estimations of capacitors are the real weakness of the FCI [3]. Furthermore, the disadvantage of unequal switch streams basic with DCI remained. To close, the most youthful among the basic multilevel setups (proposed under twenty years back), this converter stayed in the shadow of the other two contenders.



**Fig.1:** Flying capacitor multilevel inverter (a) three-level, (b) five-level.

**Table 2:** Switching states and leg output voltages for three-level flying capacitor inverter

Ta1	Ta2	Ta3	Ta4	Output Voltage
1	1	0	0	Vdc
1	0	1	0	0
0	1	0	1	0
0	0	1	1	-Vdc
0	1	1	1	Short Circuit

#### 4. Control Technique for Multilevel Inverter

In the sinusoidal PWM strategy we are having the balanced flag and the transporter flag if the bearer flag is to be of single then it is called single bearer based pwm procedure. In the event that the bearer flag is to be of different all together then it is called multi transporter based PWM control procedure. In the transporter flag we have taken a multi bearer flag which is of Triangular fit as a fiddle. Here we have taken a 3-stage five level fell Hbridge MLI for this 5-level inverter the transporter signals are 4 all together. There are distinctive control strategies for a fell H-connect MLI. In this PWM control procedure is the best one. In this open circle and shut circle control strategies are there out of these open circle control procedures has been picked in this paper. In the open circle control systems sinusoidal, space vector, sigma delta control procedures are generally ideal. Out of these sinusoidal methods has been taken. In the Modulating signal we have unadulterated sinusoidal, third symphonious infusion and dead band signals are there out of these sinusoidal signs has been taken. Out of these bearer flag age APOD and POD control procedures has been taken. The THD investigation for the given APOD and POD control methods in both Bipolar, unipolar method of task for various adjustment indecies has been introduced in [6], [7].

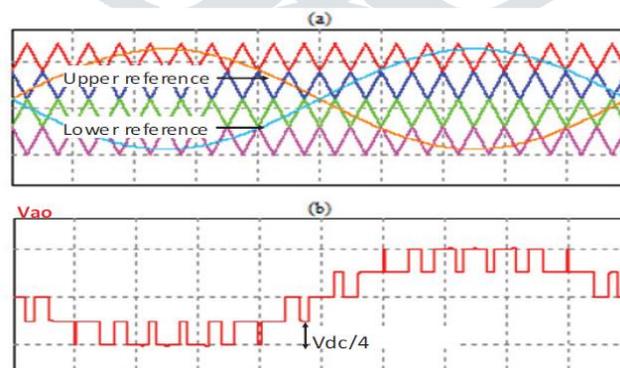
The entire document should be in Times New Roman. The font sizes to be used are specified in Table 1.

##### 4.1. Alternate Phase Opposition Disposition (APOD)

This system requires every one of the m-1 transporter waveforms, for a m-level stage waveform, to be stage arranged from each other by 180 degree then again as appeared in fig4. The symmetry of the bearers and reference voltages demeanor in (N+1) tweak methodologies ensures that are ON exchanged [8]. Here for the coveted control method there are four bearer signals have been taken. In the upper a large portion of the two signs are 180 degrees out of stage each other and a similar case will rehash for bring down half too. Thusly, as indicated by conditions (1) and (2), (N+1) tweak methodologies prompt a low inductor voltage and an insignificant MMC coursing current which is appeared in figure 2

$$V_a - \frac{V_{dc}}{2} + V_{Ta1Ta2} = 0 \quad (1)$$

$$V_a - \frac{V_{dc}}{2} - V_{Ta3Ta4} = 0 \quad (2)$$



**Fig. 2:** APODPWM, (N+1) modulation strategy; N=4 a) carriers disposition b) Simple output voltage: 5 voltage levels

##### 4.2. Phase Opposition Disposition (POD)

Here for the coveted control procedure there are four bearer signals have been taken. In the upper a large portion of the two signs they are in same stage and the lower half will be 180 degree out of stage with the upper half [6]. This strategy requires every one of the m-1 transporter waveforms, for a m-level stage waveform, to be stage arranged from each other by 180 degree as appeared in fig 3.

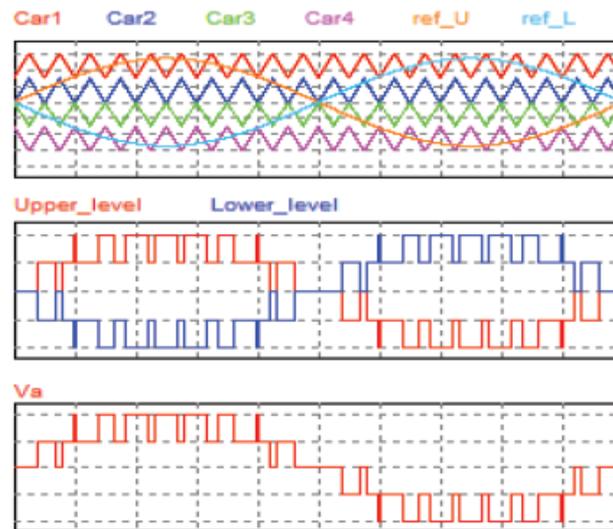


Fig. 3: PODPWM for five level MLI

### 5. Converter Control Principle

Flying capacitors are supplanted by consummate DC sources, each equivalent to  $V_{dc}/3$ . The issue of flying capacitors adjust is examined in the following passage. The control flag of every SM comes about because of the examination of its bearer and it's relating reference. As opposed to utilizing similar transporters for upper and lower sub-modules, the proposed PODPWM does out a bearer for every SM and a reference for each arm. PODPWM, introduced on fig. 4, is planned as:

- All three carriers for the upper arm are identical: initial phase angle is 0 and the magnitude is equal to  $\frac{V_{dc}}{N}$  these three carriers are vertically shifted with  $\frac{V_{dc}}{N}$  forming 3 contiguous bands varying from 0 to  $V_{dc}$ . They are compared with a sinusoidal reference  $V_{ref}$  for upper switches defined as follows:

$$V_{ref} = \frac{V_{dc}}{2} + m \frac{V_{dc}}{2} \cos(2\pi ft) \tag{3}$$

Where  $V_{dc}$  is the DC bus,  $m$  is the modulation depth and  $f$  is the reference frequency

- All three carriers for the lower arm defined with  $180^\circ$  initial phase and  $-\frac{V_{dc}}{N}$  magnitude, forming 3 contiguous bands varying from  $-V_{dc}$  to 0. The so generated carriers are compared with a sinusoidal reference  $V_{ref\_L}$  lower switches defined by:

$$V_{ref} = -\frac{V_{dc}}{2} + m \frac{V_{dc}}{2} \cos(2\pi ft) \tag{4}$$

One can note that both references and carriers are symmetrical according to the 0-voltage level. Unlike PDPWM, the symmetry property can also be found on

Each arm phase level, as shown in fig.5. Fig.6 shows that for a three-SM MMC converter, the number of switched ON SMs is continually equal to 3.

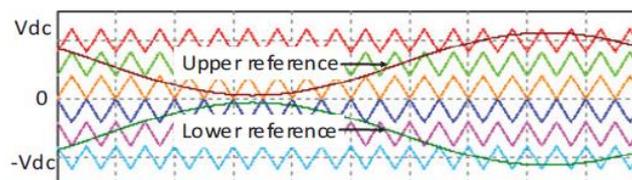
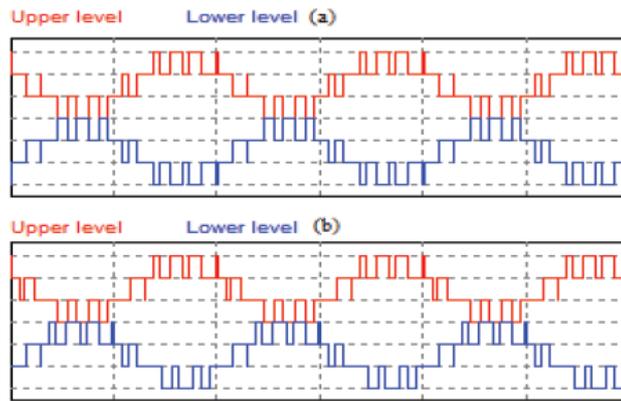
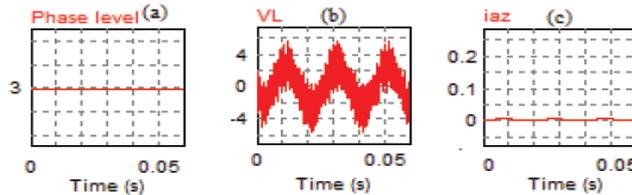


Fig. 4: Proposed PODPWM for a 3-SM MMC converter



**Fig. 5:** Upper and lower arms voltage levels a) PODPWM b) PDPWM



**Fig. 6:** 3-SM MMC converter leg characteristics a) Number of ON switched SMs b) Inductor voltage c) circulating current

**Table 3:** THD Values for APOD Control technique

Modulation Index	APOD (bipolar)	APOD (unipolar)
0.4	13.9	13.9
0.8	13.56	13.56
1	26.23	26.23
1.2	19.92	19.92

**Table 4:** THD Values for POD Control technique

Modulation Index	APOD (bipolar)	APOD (unipolar)
0.4	13.9	13.9
0.8	13.42	13.42
1	16.23	25.42
1.2	12.20	16.92

**6. Conclusion**

In this paper the recreation of 3-stage 5-level full Multi level inverter has been implemented in simulation environment by utilizing the APOD and POD control methods. The THD has been improved the situation diverse Modulation indices. From the THD investigation we can state that the THD for POD strategies less when contrasted and APOD method. For modulating indices ranging from 0 to 1, the THD is expanding and afterward after THD is diminishing for both the methods. Therefore, from the above simulation and its associated results, it is observed that POD will be the better procedure when contrasted with APOD.

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