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Advanced Inverters for Photovoltaic Systems Utilizing Multilevel PWM

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ABSTRACT

This research aims to develop a photovoltaic-based MLI that utilizes a pulse width modulation strategy as its mode of operation. In this particular example of a multilayer inverter, two switches are employed to enable the switching of the fundamental frequency and the carrier frequency. The initial three sections of this article delve into the analysis and discussion of the influence that different levels of carrier signal exert on inverters. Assess the impact it has on the voltage, current, and harmonics distortion. Assess the effect it has. Additionally, the study examines the impact of load variations on the output of the PV-based multilayer inverter and analyzes the resulting harmonic count. Yet another comparison was made between a seven-level inverter and a nine-level hybrid inverter, focusing on the use of a multilevel PV-based inverter. The aim was to reduce harmonic distortion, increase the output voltage, and analyze the impact on losses. This was a comparison that involved a seven-level inverter. Calculations and results obtained from a customized version of the MATLAB program suggest that the entire range of harmonics can be addressed by integrating level change technology with multi-stage hybrid inverters. These calculations and results were accomplished.

Keywords: *Inverter; Pulse Width; Solar; Energy; Photovoltaic.*

1.0 Introduction

Because of people’s actions, energy consumption is currently at levels not seen in several decades. This has been going on for the better part of the last several decades. Due to the increasing load demand happening all over the world, the quality of the generated energy is steadily declining. Traditional resources, on the other hand, will suddenly become very scarce. Because conventional resources are becoming increasingly scarce and because conventional resources are contributing to an increasing number of environmental problems, such as climate change, atmospheric changes, the effects of greenhouse gas emissions, etc., most countries have decided to produce a significant amount of energy from renewable sources [1]. Traditional resources are largely to blame for these issues, and they have only multiplied in frequency. Furthermore, the demand for energy produced by renewable sources has been steadily increasing. The benefits of not being contaminated are better highlighted in this context. Solar photovoltaic panels are seen as the future’s best energy source because they produce a lot of power at a cheap cost and produce almost no carbon dioxide [2].

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The third. A growing amount of energy is wasted due to harmonic distortion, even though the inverter has a very simple structure and is connected to photovoltaic (PV) applications [4]. It was determined that power applications would gain from utilizing multiple inverters in order to tackle these concerns. The components of the traditional MLI approach are the modular multilevel converter,CHB,FC,andNPC [5]. An increase in the number of levels that can be converted and an improvement in the overall quality of the power distributed throughout distribution networks are both meant by the term “multilevel inverters” [6].

A pattern resembling a wavelength that has been skipped appears in the inverter’s output voltage, which is not sinusoidal. linked in such a way that the tuned switches supply the load with the ideal sine wave and number of levels. Put simply, this is made possible by means of the connections between the switches. [7]. An integral part of the MLI plan was the PWM strategy. Through the application of various techniques, including PD, POD, and APOD, the operation was able to establish a constant switching frequency of the MLI. Using carrier signals is a crucial part of the process for N-number of level multilevel inverters (N-1), as described in [8]-[10].

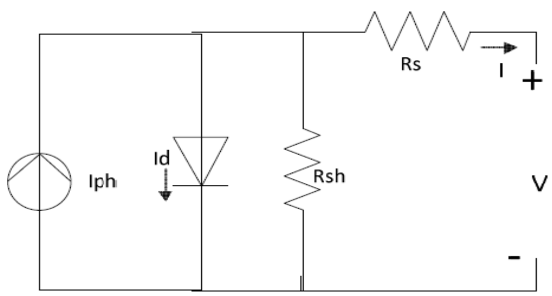
In recent discussions, the MLI has been suggested as a potential new technology for PWM switching. Inverters designed for a single phase with a total of nine levels, complete with the essential inductor and the required minimum capacity. In [11] and [12], the authors examine the various approaches taken by the MLI. However, they are not linked to any photovoltaic systems. One possible solution to the MLI problem is proposed in [13], which is a new PWM switching mechanism.

A lack of demand for single-phase nine-stage inverter capacity in the market is another issue, along with inductors [14]. Although there is just one PWM scheme in use, the nine-level CHB is connected to PV sources through LC filters [15]. The overarching goal of this study is to design a photovoltaic MLI that uses pulse width modulation as its operating mode. In order to switch the fundamental frequency and the carrier frequency, two switches are utilized in this particular example of a multilayer inverter.

The effects of different carrier signal strengths on inverters are examined and discussed in the article’s first three sections. Find out how it affects the distortion of harmonics, current, and voltage. Take a look to see what kind of effect it has. Secondly, the impact of the varying loads on the PV-based multilayer inverter’s output and the subsequent harmonic counting. Another study that compared harmonics in seven- and nine-level hybrid inverters used a multilevel PV-based inverter to reduce harmonic distortion, increase output voltage, and show the effect on losses. Here we see one of the seven-level inverters that were compared.

The whole harmonics range may be covered by combining the level change technology with multi-stage hybrid inverters, according to calculations and results obtained from a modified version of the MATLAB program. All of the necessary computations and outcomes were met.

Figure 1: Photovoltaic System



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2.0 Photovoltaic System

2.1 Photovoltaic system

Connecting the PV system to the circuit, the 1-O MLI integrates the solar system into the overall system [16]. The components can be used to construct a nine-level output voltage; they serve as four separate dc sources and sixteen switches.

2.2 Simulation of photovoltaic system

The block diagram presented in reference [16] offers a visual depiction of the schematic representation of a photovoltaic (PV) system in its equivalent configuration. The output current is determined by utilizing the figure displayed at the top, specifically the module photocurrent.

$$I = I_{ph} - I_d - I_{sh} \qquad (1)$$

$$I_{ph} = [I_{sc} + k_i\,(T - T_r)]\ G \qquad (2)$$

The diode current is provided as

$$I_d = I_o \left[\exp\left(\frac{qv}{nkT}\right) - 1\right] \qquad (3)$$

The reverse saturation current integrated circuit

$$I_{rs} = \frac{I_{sc}}{I_d = I_o\left[\exp\left(\frac{qv_{oc}}{nkT}\right) - 1\right]} \qquad (4)$$

$$I_o = I_{rs}\left[\frac{T}{T_r}\right]^3 \exp\left[\frac{qE_{go}}{nk}\left(\frac{1}{T} - \frac{1}{T_r}\right)\right] \qquad (5)$$

The current of the photovoltaic (PV) output is

$$I = N_p I_{ph} - N_p I_o\left[\exp\left(\frac{\frac{V}{N_s} + \frac{IR_s}{N_p}}{nV_t}\right) - 1\right] - I_{ph} \qquad (6)$$

$$V_t = \frac{kT}{q} \quad \text{and} \quad I_{sh} = \frac{V\frac{N_p}{N_s} + IR_s}{R_{sh}} \qquad (7)$$

Series resistance (Rs) and shunt resistance (Rsh) are examples of different types of resistances.

3.0 Cascaded Hybrid Multilevel Inverter (CHB-MLI) and PWM Strategy

3.1 Cascaded hybrid multilevel inverter

An inverter that is powered by photovoltaic cells and has nine different levels is referred to as a serial-connected complete bridge inverter. This particular kind of inverter accepts input from more than one source at once. These direct current sources are provided by the batteries that are a component of the photovoltaic system. The modulation of the output range from the many different dc sources was primarily the responsibility of CHB. Each hybrid was required to have one PV in addition to a clear boost converter load of MLI for the photovoltaic-based NLI, as shown in figure [17]. This was a requirement for the NLI.

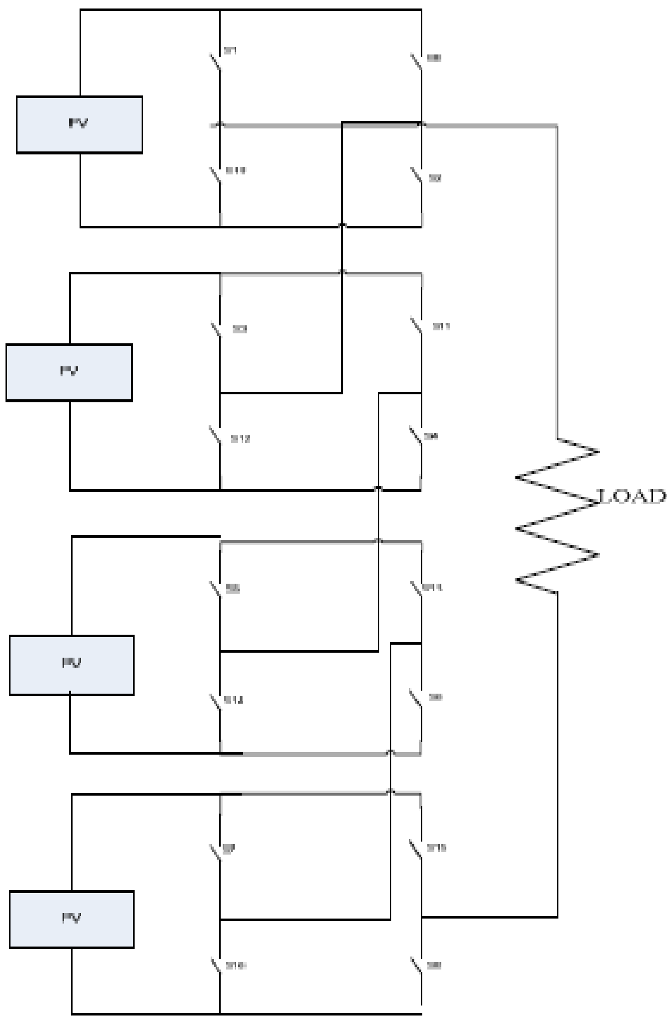
$$V_o = \sum_{4N-1}^{N} HBn = V_{HB1} + V_{HB2} + \cdots \ldots + V_{HBk}$$

In the event that there is a problem, CHB-MLI will provide a straightforward replacement of either the individual component or the whole circuit that is creating the problem. Even if the component [18] that is malfunctioning is removed from the circuit, electricity would still continue to flow through it. [Citation needed] In spite of the fact that the output voltage will gradually decrease, this will continue to be the case. Because a traditional VSI has two levels, the whole circuit will be blocked while this period is in effect because of this feature. The level of the output voltage is heavily dependent on the variable's magnitude:

$$R = 2h + 1$$

G is the level of the output voltage, and h is the number of H-bridges.

Figure 2: Layout of a Nine-level Inverter based on Photovoltaics



3.2 Part B: A nine-level hybrid inverter

The majority of the time, the nine-level hybrid MLI that has been proposed will dispose of a selection of switches that are helpful for generating the current as well as the contrasting output voltage. These switches are often removed from use. The CHB and each H-Bridge are now connected to one another through the created link. It is powered by a separate dc source that is independent. If you want to make a waveform stair flight out of a cascaded MLI, you can change the individual bridges' outputs and add them up. Putting it another way, the output of a single bridge is equivalent to the output of the cascaded MLI. This result is similar to adding up the results from each of the bridges. The final result is an output voltage with a more sinusoidal waveform, with a rise that tracks the H-bridge's steps. There are nine sections to this framework that will be used to analyse the PWM presentation.

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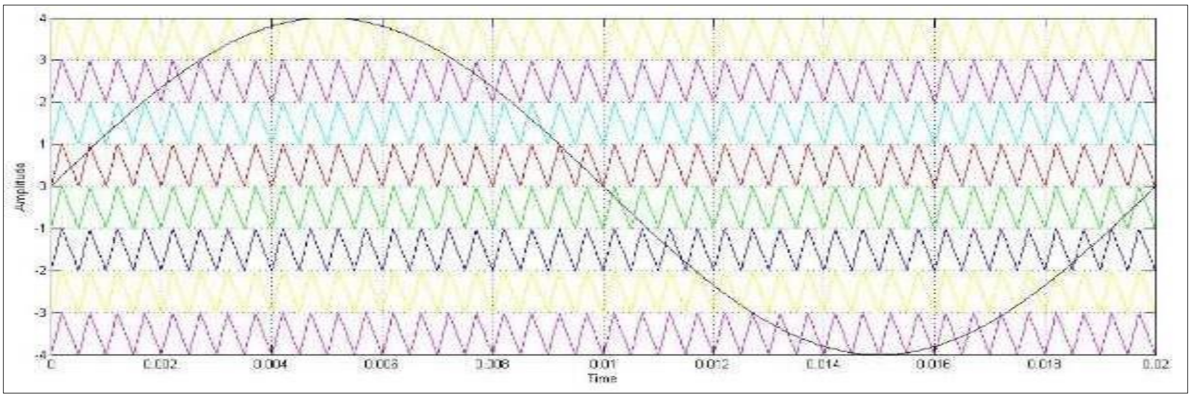
3.3 Part B: Pulse-width-based modulation

The NLI generates its firing pulses using a variety of modulation techniques. In a situation with a relatively high switching frequency, the SVM and CBM algorithms perform exceptionally well. The increased complexity of the SV approach makes it harder to put into practise when there are more voltage levels. Consequently, the CBM method is practically never employed. The carriers are arranged in a CBM configuration using either level shifting methods or level shifting strategies in the CBM approach. A basic version of the level shift modulation method is implemented in the PV-based multilevel inverter in this work. This level shifting modulation technique is known by three different names: PD modulation, POD modulation, and APOD modulation.

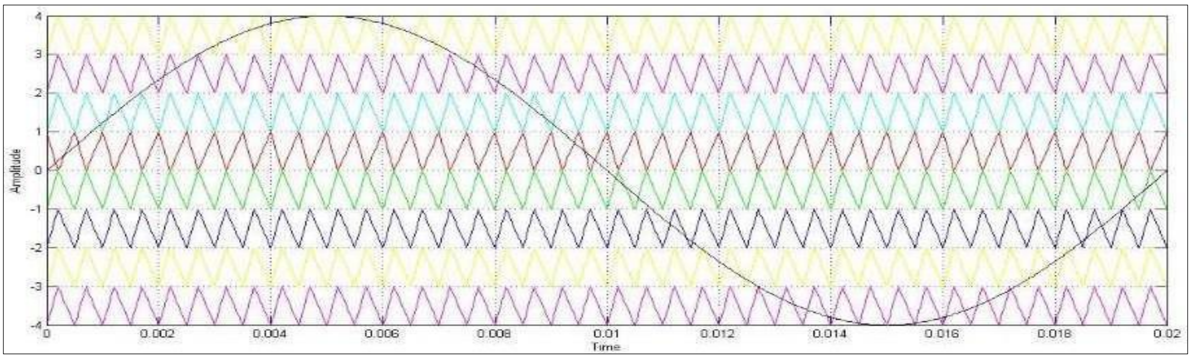
3.3.1 Phase disposition PWM

Carriers signals originating above and below the reference hub are considered at one stage of this method.



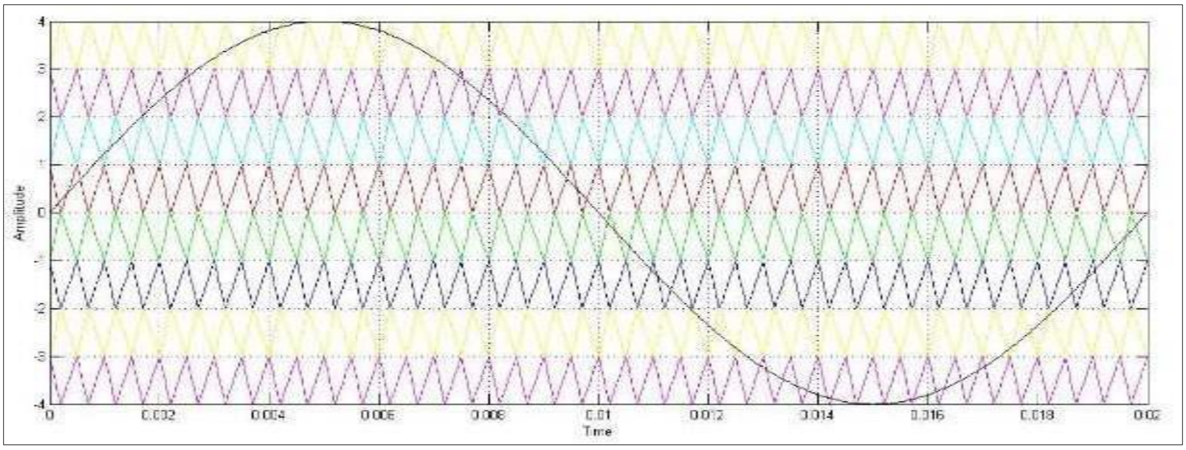
3.3.2 Phase-to-phase opposition/displacement PWM

During the execution of this specific action, the carrier's signals exhibit both amplitude and frequency. In addition to the carrier signal positioned above the reference pivot, the carrier signals positioned both above and below the pivot are also shifted by 180 degrees to align with the carrier signal above the pivot.



3.3.3 Alternate phase opposition disposition PWM

While this procedure is being carried out, neither the loudness nor the frequency of the transmitter will change. Both of the options now being considered are going through a phase, and 1800 is exerting pressure on the other options.



4.0 Results and Discussions

Each available method's basic output voltage and total harmonic distortion (THD) as a percentage are shown in the graph on the right. We see the effects of various PWM strategies on the fundamental voltage and total harmonic distortion. Complete elimination of harmonic distortion was achieved with each of the PWM methods.

Table 1: Distribution of Voltsge and Current

PWM Strategy	voltage	% of THD (Voltage)	Current	% of THD (Current)
PD	878.6	19.36	0.08786	19.32
POD	878.5	19.49	0.08785	19.47
APOD	880.3	19.23	0.08803	19.41

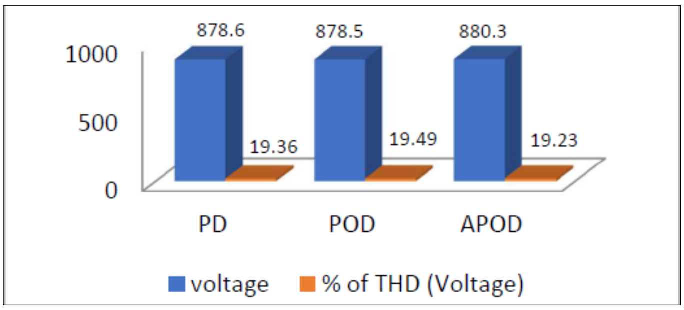


Table 2: The Figure Displays the Total Harmonic Distortion Percentage at Different Loads

	% of THD (Voltage) at various load			
PWM Strategy	100 KΩ	10 kΩ	1 kΩ	100 Ω
PD	19.33	19.36	19.55	22.21
POD	19.46	19.49	19.67	21.31
APOD	19.2	19.23	19.43	20.98

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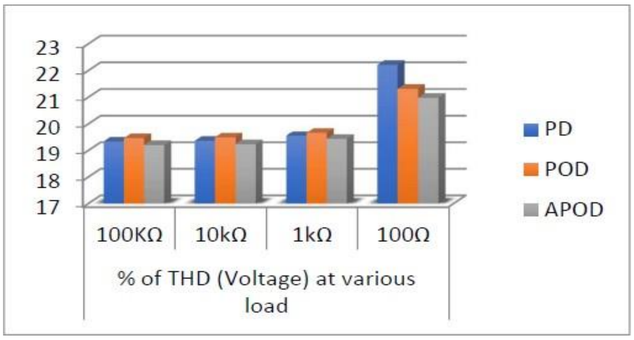
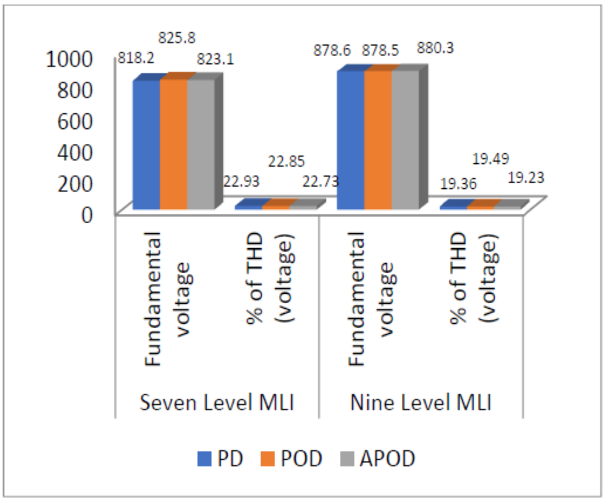


The load comparisons are shown in the graph above for your consideration. The THD count shows that when the load increases, the total harmonic distortion decreases as compared to its level when the load is modest. This is due to the fact that one of the several PWM algorithms is used to calculate the THD count.

Table 3: Correlation of the Seven-Level and Nine-Level MLI Is demonstrated

PWM Strategy	Seven Level MLI		Nine Level MLI	
	Fundamental voltage	% of THD (voltage)	Fundamental voltage	% of THD (voltage)
PD	818.12	22.92	878.61	19.35
POD	825.8	22.85	878.5	19.49
APOD	823.1	22.73	880.3	19.23



The graph that is a part of this article shows the outcomes of comparing MLI levels seven and nine. For all nine level inverters, the graph reveals that as total harmonic distortion decreases, the fundamental output voltage rises. The graph also makes it very evident that this is occurring even though total harmonic distortion has gone down.

For an examination of the output voltage of PD, POD, APOD, and MLI CHB PV dependent inverters, refer to Figures 3 to 5. This comprehensive data offers valuable information regarding the voltage and voltage level of the Total Harmonic Distortion (THD) across different operations. Due to its lower THD voltage quantity and higher voltages compared to other processes, the two approaches exhibit a stronger correlation than other systems. The user's text is empty. Consequently, voltages are increased in both directions. It is evident that the reason for this is that the total harmonic distortion (THD) voltage is directly correlated to the square of the signal.

Figure 3: THD Voltage Analysis for Phase Disposition

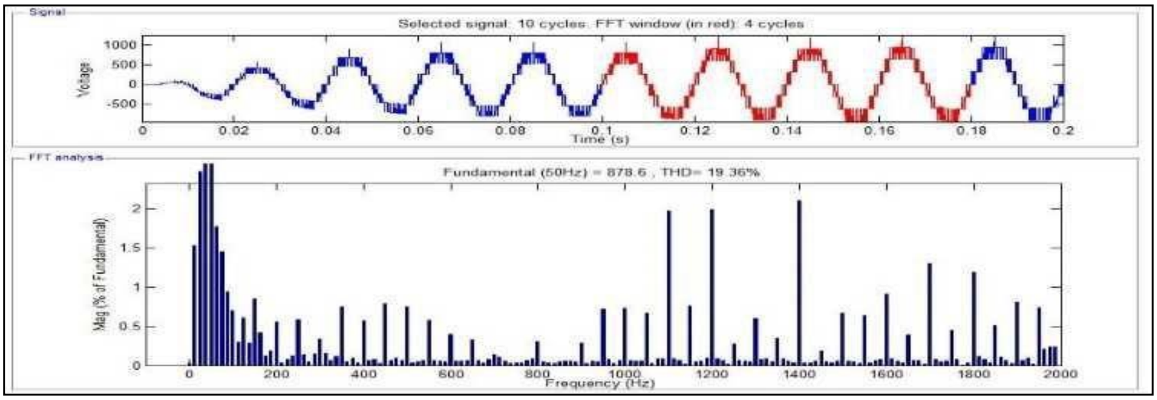


Figure 4: Analysis of THD of Voltage for Phase Opposition Disposition

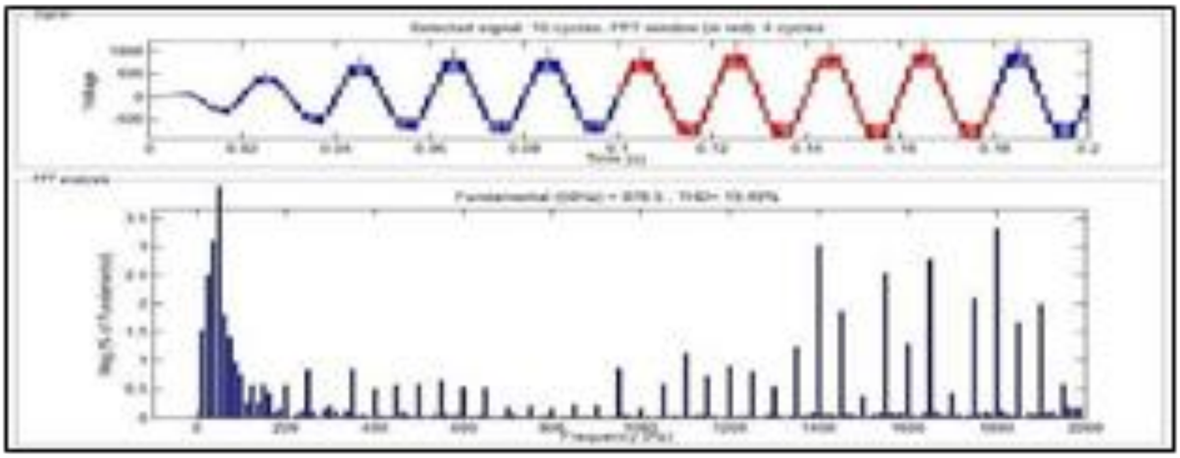
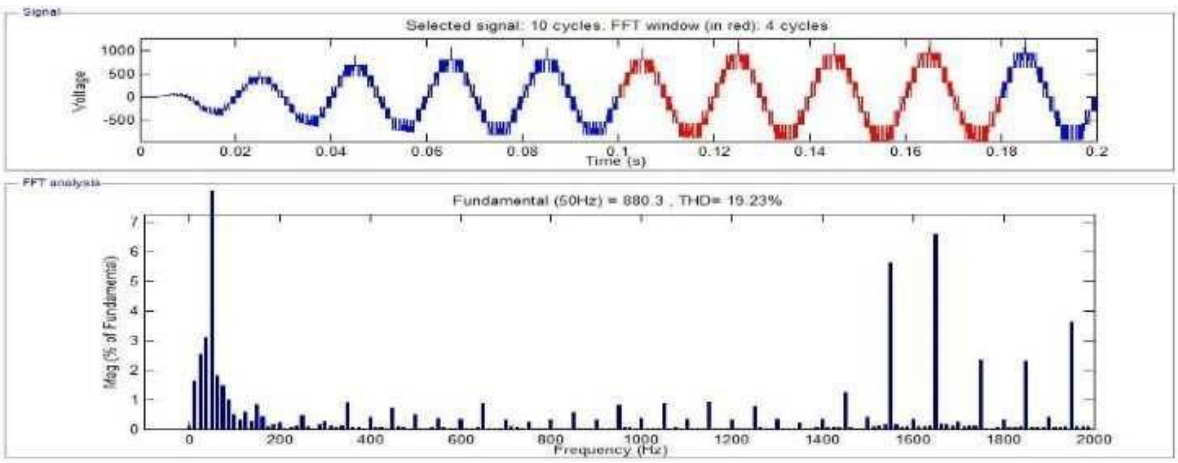


Figure 5: Analysis of THD of Voltage for Alternate Phase Opposition Disposition



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5.0 Conclusion

Researchers are currently studying a specific type of nine-level inverter to gather data for their investigation on methods to eliminate harmonics. The MLI aims to enhance the output voltage waveform while reducing the total harmonic distortion (THD). As the voltage level increases, the output of the CHB MLI becomes more sinusoidal and exhibits a smoother waveform. This essay examines nine distinct inverters. APOD was designed to achieve the maximum output voltage, minimize harmonic distortion, and minimize losses compared to the other two PWM techniques employed in the MLI.

Nevertheless, a thorough comparison and contrast of all three approaches was conducted. As the load reaches 100, the total harmonic distortion (THD) for the resistive-inductive (RL) load caused by the cascaded H-bridge multilevel inverter (CHB MLI) decreases. That is in opposition to the higher total harmonic distortion (THD) observed at lower loads. Increasing the load to 100 percent reduces the total harmonic distortion (THD), but it also results in an increase in the generated voltage. The third section of this article presents a comparison of the outcomes obtained from seven and nine level inverters.

The nine level inverters surpass the seven level inverters in terms of both output voltage and harmonic distortion. The utilization of nine-level inverters improves PWM's overall performance by reducing harmonic distortion and increasing output voltage. The benefits can be directly attributed to the method's nine different level inverters. MATLAB A study conducted using Simulink yielded favorable results in support of the advocated strategy. Despite the uncontrolled information flow, the growing power density of PV applications makes this approach a feasible choice.

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