# AI-Optimized Harmonic Reduction in Multi-Level Inverters Using Reversing Voltage Topology

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***Abstract*—This paper presents an improved approach to harmonic reduction in a 15-level multi-level inverter (MLI) using Reversing Voltage (RV) topology, integrated with AI-driven optimizations. The AI-enhanced model optimizes switching strategies and reduces computational complexity, improving overall efficiency. The study compares Total Harmonic Distortion (THD), active power, and reactive power, using MATLAB-SIMULINK simulations and an AI-based control model for enhanced performance. Results validate the proposed system's superiority over conventional MLIs.**

***Index Terms*—SPWM, Multi-Level Inverter (MLI), AI Optimization, THD, PIC Controller.**

## I. INTRODUCTION

Power electronics inverters are becoming increasingly popular for various modern drive applications. In recent years, inverters have become essential for several implementations, such as motor control and power systems [1]. Rising fuel costs, growing concerns about global climate change, and increasing worldwide demand for energy have led to a global effort to promote the use of renewable energy sources such as solar, wind, and biomass.

In the case of solar photovoltaic (PV) systems, energy is harnessed in DC form. This DC power is then converted into AC form and either fed into the grid or used for standalone loads. Various techniques are available for DC-to-AC conversion, and multilevel inverters (MLIs) have gained popularity in recent years. The power quality improves as the number of levels in the output waveform increases [2].

A multilevel inverter (MLI) utilizes semiconductor devices to generate a staircase waveform that closely resembles a sine wave. It is considered the best option for most power generation applications in solar PV systems. Traditional two-level inverters suffer from high switching voltage stress, lower efficiency, and poor power quality, as noted in [3,4].

There are different types of inverters, including neutral-point-clamped, flying capacitor, and cascaded H-bridge MLIs, as discussed in [5,6]. However, MLIs present challenges, such as a higher number of power switches and complexities in design. Reducing the number of switches has become a crucial factor in improving MLI performance [7]. A lower switch count simplifies design complexity and enhances the overall efficiency of MLIs [8].\

Key MLI topologies include diode-clamped inverters (neutral-point-clamped), capacitor-clamped inverters (flying capacitor), and cascaded multilevel inverters with independent DC sources. Several control and modulation techniques have been developed for these converters, such as multilevel sinusoidal pulse-width modulation (PWM), selective harmonic elimination, and space-vector modulation [9].

The proposed models generate output voltages with low total harmonic distortion (THD) and provide the required harmonic content or loss components in the output voltage. The output voltage and specific harmonics are controlled by adjusting phase angles. Simulation results validate the proposed inverter structure, demonstrating THD values and performance under different conditions [10].

One of the most critical issues in power quality is the presence of harmonic content in the electrical system. Harmonics refer to distortions in the normal electrical current waveform, primarily caused by nonlinear loads. Examples of nonlinear loads include switched-mode power supplies, variable-speed motors and drives, printers, and other electronic devices.

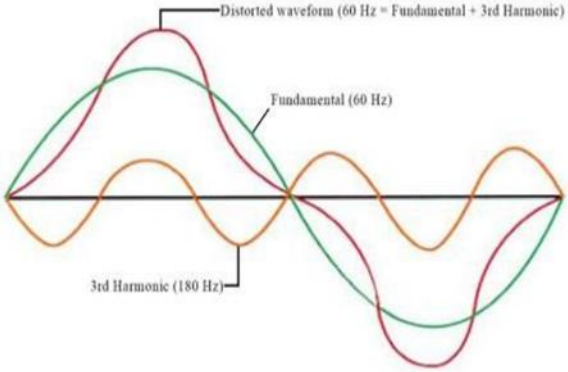



Figure 1: Harmonics in electrical waveforms

Harmonics-Related Issues

Harmonics-related issues negatively impact system efficiency. As the number of harmonic-generating loads has increased in recent years, it has become crucial to address their effects during system expansion or modifications. Harmonic currents can significantly affect the electrical distribution system and the equipment connected to it. These distortions travel back into the power source and may impact other devices sharing the same power supply.

Harmonics are generally classified into two types:

1. Voltage Harmonics
2. Current Harmonics

1. Cascaded H-Bridge Inverter

The conventional cascaded multilevel inverter is one of the most significant topologies in the family of multilevel inverters. The cascaded structure enables the use of multiple DC voltage levels to generate the desired AC voltage. These DC voltage levels are typically sourced from energy storage units such as photovoltaic cells, batteries, or similar power sources. An H-Bridge Inverter consists of four switches, a DC source, and a load (which can be either isolated or grid-connected) across the two arms of the H-Bridge. Each switch operates for 180° of the cycle, with gate input signals applied diagonally across opposite switches.

2. DC-AC Inverter

In systems where inverters are used, distortion can be present. The primary function of an inverter is to convert DC power into AC output. Ideally, the output voltage waveform should be purely sinusoidal. However, in real-time operation, harmonics introduce distortions, resulting in a distorted output waveform.

To mitigate this issue, advanced inverter designs are implemented to generate sinusoidal and distortion-free output waveforms, improving overall system efficiency and performance.

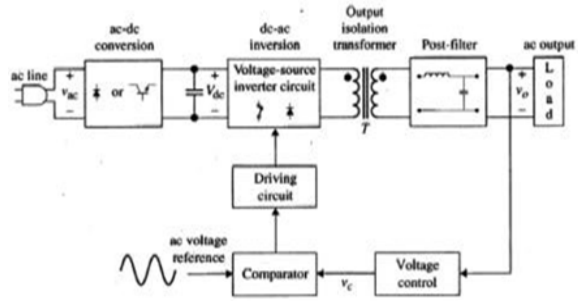



Figure2: Power Electronic Circuit with DC-AC Inverter.

Distortion can occur in any system where inverters are used. The primary purpose of an inverter is to generate an AC output from a DC source. Ideally, the output voltage waveform should be purely sinusoidal. However, in real-time operation, distortions are inevitable due to the presence of harmonics in the system, resulting in distorted output waveforms.

Therefore, inverters are designed to produce output waveforms that are as close to a perfect sinusoidal form as possible, minimizing losses and improving overall power quality.

## II. EXISTINGSYSTEM

As execution of diodes and capacitors is there in other Multi-Level Inverters (DCMLI and FCMLI), the voltage drops and the utilization of capacitors increments. Assuming switches are more the PWM Complexity increments, there by expanding the expense and the proficiency likewise the expense and the proficiency likewise diminishes. Even Cascaded MLI must be worked for 28 switches [S=2(m-1) ].

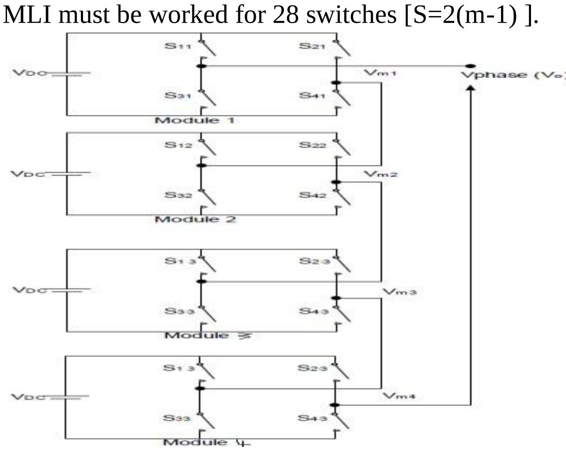



Figure3: Existing system model without RV

In this system it produces the THD level of 3.87%

## III. PROPOSEDSYSTEM

In conventional multilevel (ML) inverters, power semiconductor switches are combined to generate a high-frequency waveform with both positive and negative polarities. However, it is not always necessary to use all the switches to produce bipolar levels.

This concept has been explored in a new topology, which introduces a hybrid multilevel inverter design. This topology divides the output voltage into two sections. One section, known as the level generation part, is responsible for generating voltage levels in the positive polarity.

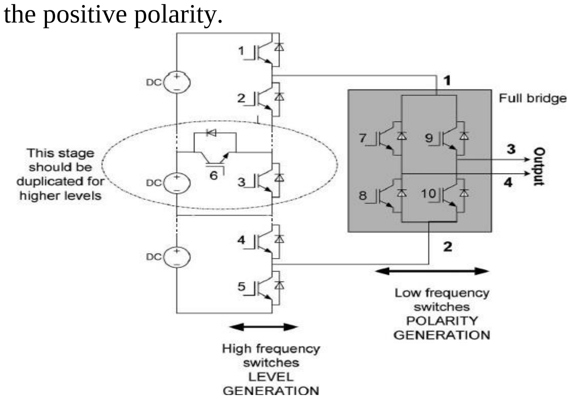



Figure 4: Proposed system model with RV

This section requires high-frequency switches to generate the desired voltage levels. The switches in this part must have high switching frequency capabilities.

The other section is called the polarity generation part, which is responsible for determining the polarity of the output voltage. This section operates at a low frequency, typically at the line frequency. The topology integrates both sections—high-frequency and low-frequency—to produce the multilevel (ML) voltage output.

To generate a complete ML output, the high-frequency section (level generation) produces the positive voltage levels. These levels are then fed into a full-bridge inverter (polarity generation), which determines the final polarity of the output voltage. This approach eliminates the need for many semiconductor switches that were previously required to generate both positive and negative polarity voltage levels. This topology is also more efficient because part of the inverter operates with switching power devices at line frequency. As a result, not all switches need to function at high frequency, leading to a simpler and more reliable control of the inverter.

## IV. AI-ENHANCED REVERSING VOLTAGE TOPOLOGY

The proposed approach integrates AI-driven control algorithms with the Reversing Voltage topology for an optimized multi-level inverter design. AI-based predictive models adjust switching patterns dynamically, minimizing losses and improving waveform quality.

### 4.1 AI-Based Control Mechanism

- Neural Network Optimization: AI predicts optimal switching sequences based on historical and real-time data.
- Reinforcement Learning for PWM Tuning: Dynamic modulation index tuning reduces THD effectively.
- Fuzzy Logic Control: Adjusts voltage levels in real-time for enhanced power quality.

## V. COMPARISON

The Total Harmonic Distortion (THD) in the output voltage obtained using the second design is 0.39%, whereas for the Cascaded H-Bridge inverter, the minimum THD found for a 5-level inverter is 14.99%. This demonstrates that if the number of switches in the first design (Cascaded H-Bridge) is 18 or fewer, the THD will be higher, leading to poorer power quality compared to the second design.

In the first design, a 15-level output is achieved without using the Reversing Voltage (RV) topology, while in the second design, a 15-level output is obtained with RV topology.

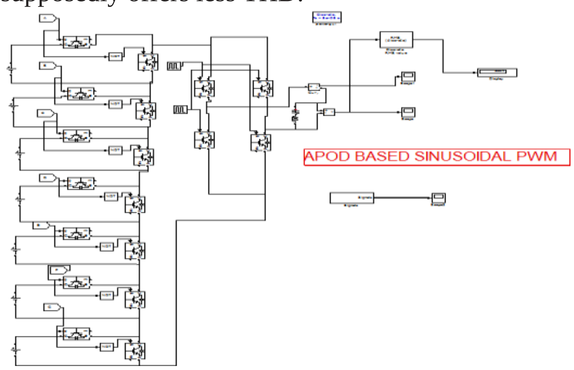
This study presents a comparative analysis of both designs without integrating RV. By implementing proper techniques in both approaches, the THD in the output load voltage can generally be reduced to below 5%. In the first design, for a 15-level inverter, the THD in the output voltage is 3.6% without RV, whereas in the second design, the THD is 0.37% with RV.

However, the first design is significantly more expensive than the second design due to the larger number of switches required. Artificial Intelligence

(AI)-based optimization techniques can be applied to further reduce the number of switches, improve power quality, and enhance the overall efficiency of the inverter system. AI-driven algorithms, such as machine learning and evolutionary optimization, can help in achieving an optimal balance between performance, cost, and efficiency in multilevel inverter designs.

## VI. OUTPUT WAVEFORMS

For the instance of single unit and upto cascaded association of 15 units, the subsequent plan supposedly offers less THD.




The variation of THD with no. of stages is shown in Figure 5.

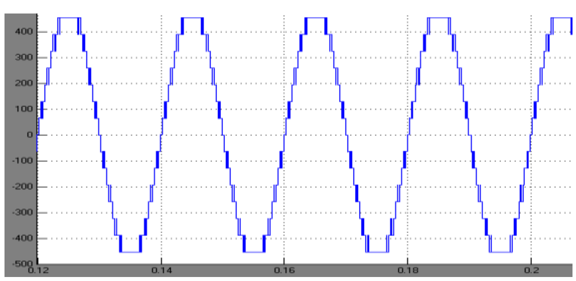


Fig .6 Output from the APOD based pulse width modulation technique with 15 level of waveform without the RV

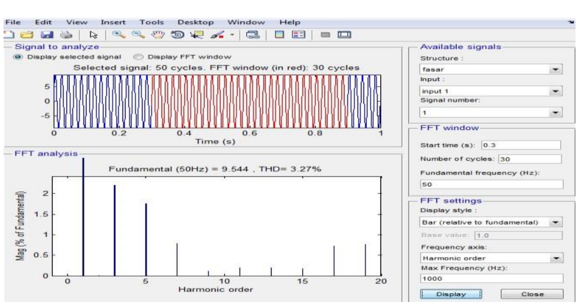



Fig.7 THD for first model without the RV

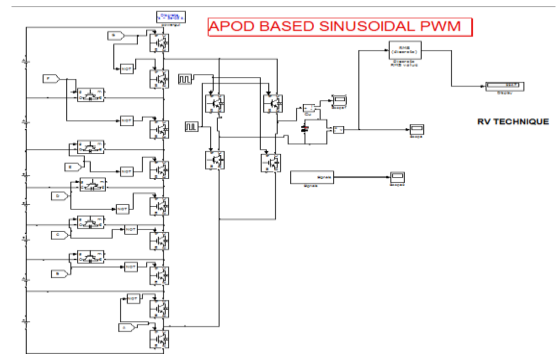



Figure.8 proposed model with APOD pulse width modulation technique with RV system

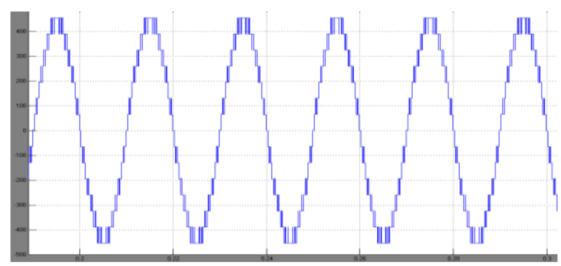


Fig.9 Output wave for 18 switch MLI inverter output voltage with 15 level of waveform

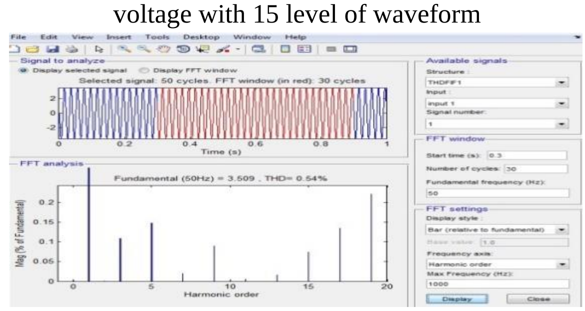
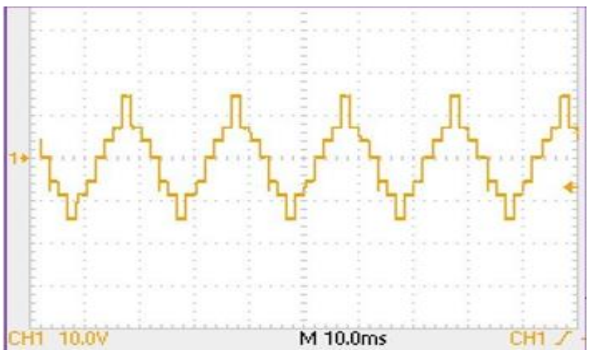



Fig.10 Assuming that the stages are expanded past 5, the THD will be better for second plan with RV.

- 15-level (18-switch) asymmetrical Level Inverter- 3.27%
- 15-level(18-switch) asymmetrical Level Inverter (RV TECHNIQUE)- 0.54%

By simulation, the calculation is done and it is proved: By operating more levels, THD can be decreased which forms the ultimate principle of multi-level inverters.

Figure11: Hardware kit model for proposed system




Fig,12 Output waveform 5Level MLI

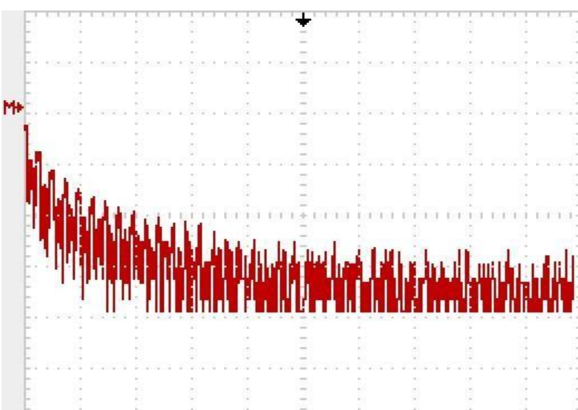


Fig.13 THD of Hardware Hardware7level Multilevel inverter THD= 3.72%

## VII. CONCLUSION

In this paper, Total Harmonic Distortion (THD) in load voltage, Active Power, and Reactive Power are analyzed for both designs using SIMULINK/MATLAB software. The performance of both designs is compared under the same DC input voltage and RL load, with and without applying Reversing Voltage (RV) topology.

In both cases, THD in load voltage can generally be reduced to below 5% by implementing a filter. However, the second design shows better THD performance and lower cost compared to the first design.

This implies that if solar panels with the same power rating and identical characteristics are used in both designs, the power quality will be higher, and the overall cost will be lower for the second design. Additionally, Active Power and Reactive Power are found to be higher in the Cascaded H-Bridge Inverter compared to the new multilevel inverter topology.

To further optimize performance, Artificial Intelligence (AI)-based techniques can be applied. AI-driven machine learning algorithms can help enhance switching control strategies, minimize THD, and improve efficiency while reducing the number of required components. AI-based optimization can also enable real-time adaptive control, making the inverter system more reliable and cost-effective.

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