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Modeling and Optimization of Multilevel Inverter Topology for Optimized Power Quality in Green Energy Systems

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Abstract

The design and modeling of a multi-level inverter system coupled to a solar photovoltaic system with a Neutral Point Clamped connection are included in this article. The neutral clamped dot topology serves as the foundation for the multilayer inverter construction. The system's enhanced modulation of the space vector pulse width enables both quantitative and qualitative outputs and efficiency. The inverter output produces the voltage and current output, and the system is coupled to a solar photovoltaic system. This research examines the method for using the solar photovoltaic system's high power. Simulations are run using the MATLAB Simulink platform. Following the implementation of the suggested topology, encouraging and useful outcomes were obtained. Hysteresis Space Vector Modulation is used in this study to restrict the Neutral Point Clamped Multi-Level Inverter, which helps to

reduce the yield's Total Harmonic Distortion (THD) factor. The Neutral Point Clamped Multi-Level Inverter (NPC-MLI) makes sense for grid-connected photovoltaic (PV) systems without transformers. With a grid-connected system, the PV source may synchronize yield and influence the system's contribution. Additionally, the use of a split inductor helps avoid the need for a transformer, which reduces the inverter's size, spillage current, and voltage concern. MATLAB/SIMULINK was used to verify the outcomes of the suggested system reconstruction.

Keywords-DC-DC power converters, photovoltaic cells, maximum power point tracker, multilevel and single-phase inverter, Wind Energy, Solar PV, Grid Connected Energy System

Introduction

In the logical field of analysis, sustainable power sources have been becoming more and more important. In contrast to the global interest in power, PV systems might be viewed as a viable alternative [1]. Power generated by photovoltaic systems is typically sent to a grid system via a transformer, causing the system to become larger and more expensive while also becoming less efficient. Transformer-less inverters have been explored as a solution to this problem. Boundaries such as Total Harmonic Distortion (THD), reduced basic mode voltage, spillage current tragedy, and voltage stress are used to determine the geography to be used. In recent years, multilevel inverters [9] have garnered attention due to their high harmonic dismissal limit and ability to handle large voltages [2]. The diode-clamped inverter innovation used in the proposed system provides reduced dv/dt weights on exchanging, the ability to manage the receptive power stream, and increased yield effectiveness due to a more notable fall in regular mode voltages [3]. The inverter's power source is a photovoltaic system, whose energy efficiency is increased by monitoring the maximum power point. It is well known that PV displays are non-direct in nature and express maximum power at a certain operating point.

Proposed Methodology

Multilevel Convertor Technology

Diode-Clamped Topology (NPC)

According to the registry, the first inverter was the Cascade Converter in 1975. based on the registry. A multi-stage diode clamp inverter was subsequently created from the inverter. Two DC bus condensers have linked the inverter output (each of the three phases) to a common DC bus voltage that is split into three levels. For high voltage applications, using several clamping diodes results in additional costs and limitations. Additionally, certain controls are needed to balance the condenser voltage. As a result, the most practical applications for multi-level inverters are restricted to levels five or lower. For Neutral-Point-Clamped (NPC), Nabae, Takahashi, and Akagi proposed a three-tier inverter in 1981 [5]. A three-level inverter's circuit is seen in Figure 1.

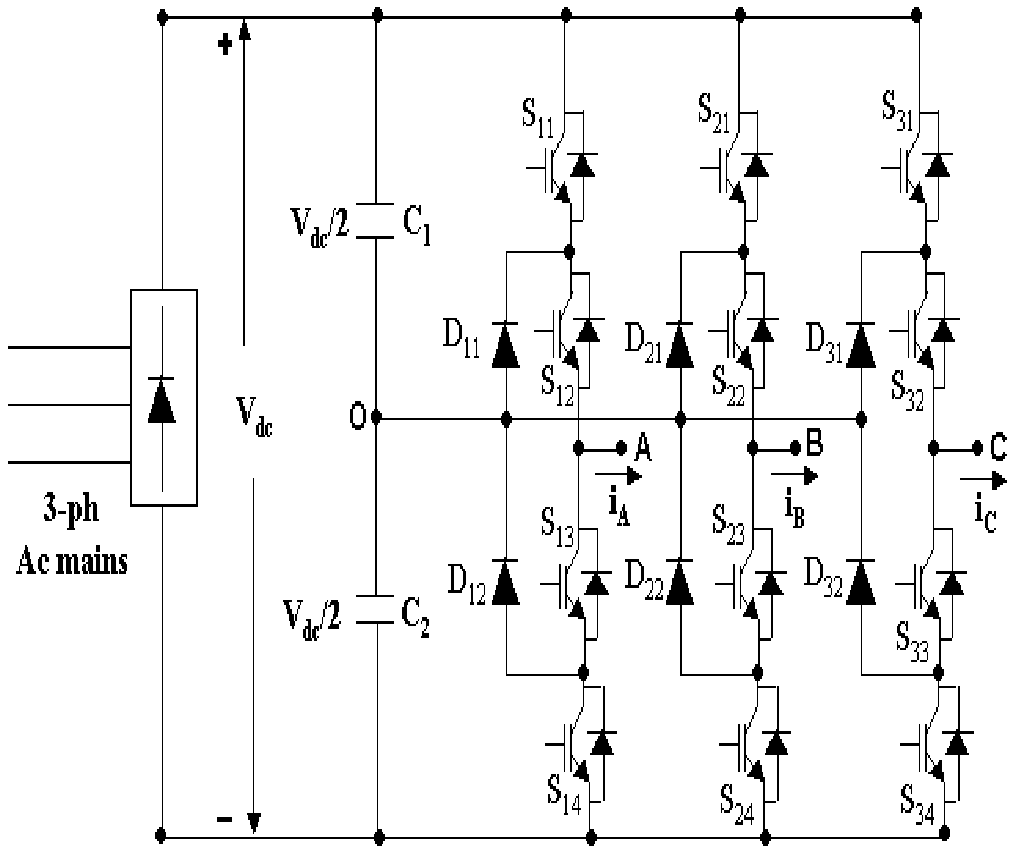

Figure 1:Neutral-Point-Clamped Three-Level Inverter

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TABLE1: Realization of the Switching Levels in a NPC Three-Level Inverter

Switching Symbols	Switching conditions				Output Voltage (v_{AO})
	S_{11}	S_{12}	S_{13}	S_{14}	
P	ON	ON	OFF	OFF	$\frac{V_{dc}}{2}$
O	OFF	ON	ON	OFF	0
N	OFF	OFF	ON	ON	$-\frac{V_{dc}}{2}$

The terminal is connected to the neutral point when devices S12 and S13 are gated. In this scenario, the clamping diode D11 and device S12 allow the phase current to flow through for the positive. The securing diode D12 and the gadget S13 flow through if the value is negative. Therefore, in this scenario, the load current is carried by DC bus condensers C1 and C2. C1 is loaded, C2 is emptied, and vice versa. The neutral point fluctuates as a result of this. It takes large DC connection condensers to reduce neutrally fluctuating points. With the circuit design described above, a total of 27 () are available since each pole voltage can adopt three states independently of the others.

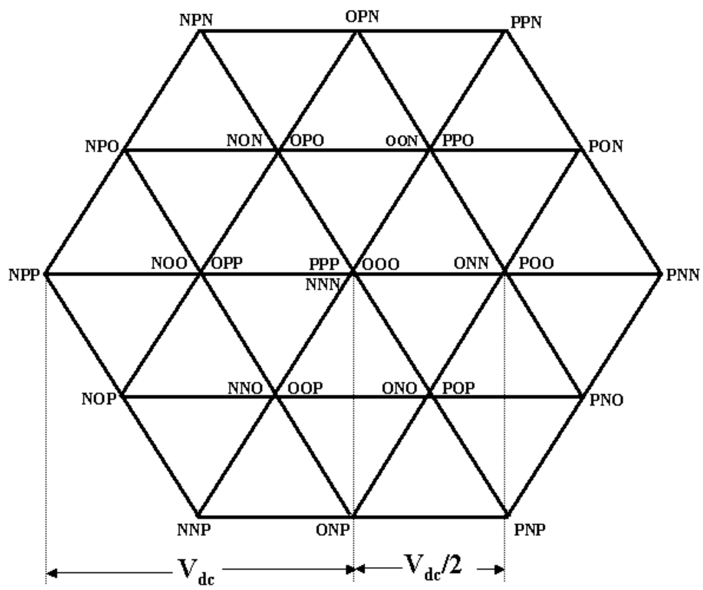

Figure 2: Space Vector Locations of the Three-Level Inverter

As a result, the output voltage switching ripple of a three-level inverter is less than that of its two-level counterpart. Several modulation strategies for controlling three-level inverters have been presented in the literature. These PWM systems rely on either spatial vectors or carriers. PWM systems attempt to limit the neutral point's volatility in addition to managing the output voltage.

SIMULATION AND RESULTS

The system's enhanced modulation of the space vector pulse width enables both quantitative and qualitative outputs and efficiency. The inverter output produces the voltage and current output, and the system is coupled to a solar photovoltaic system. This research examines the method for using the solar photovoltaic system's high power. Simulations are run using the MATLAB Simulink platform. Following the implementation of the suggested topology, encouraging and useful outcomes were obtained. The exchange rate is established by comparing it to the exchange nations. As long as the source is supplied to the inverter, these heartbeats are used to activate the IGBTs in the inverters, and the shut circle continues to operate for the ensuing patterns of activity.

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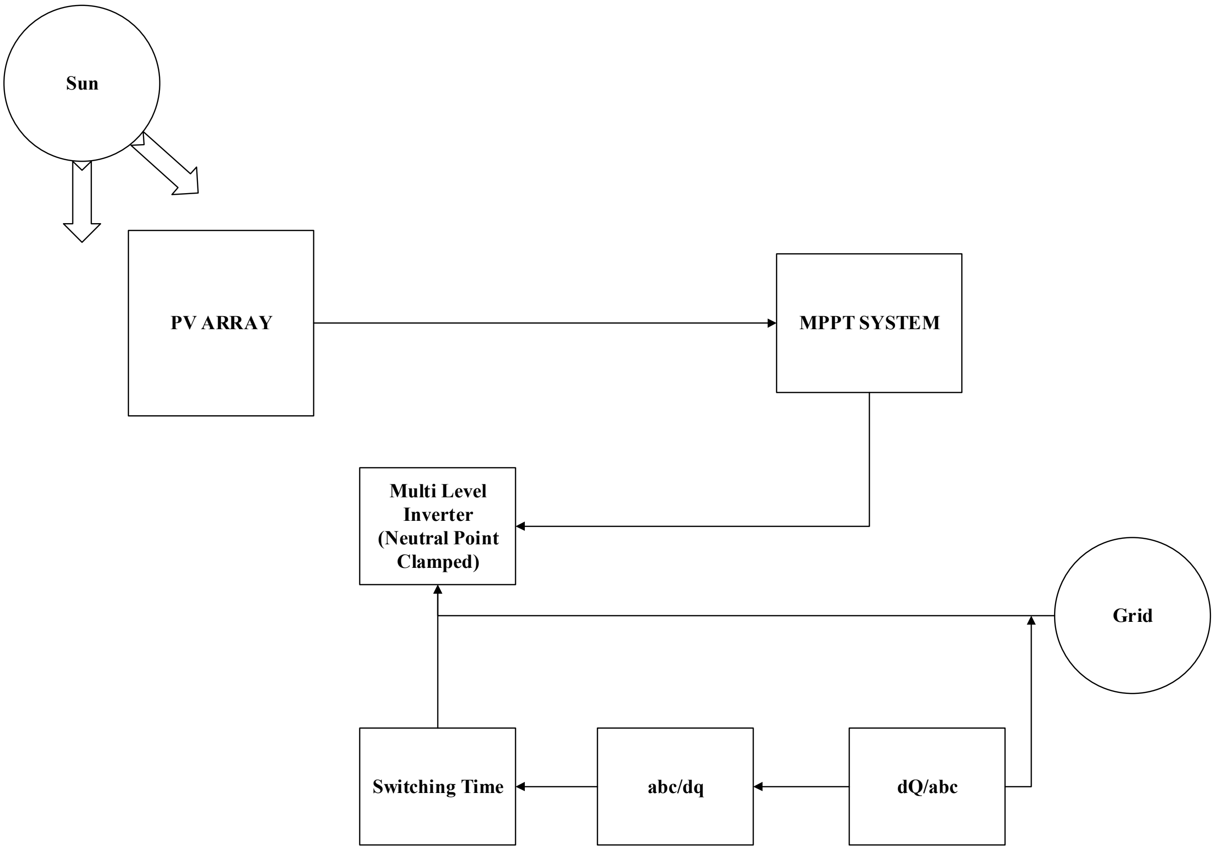

Figure3: Controlled Strategy for Proposed System

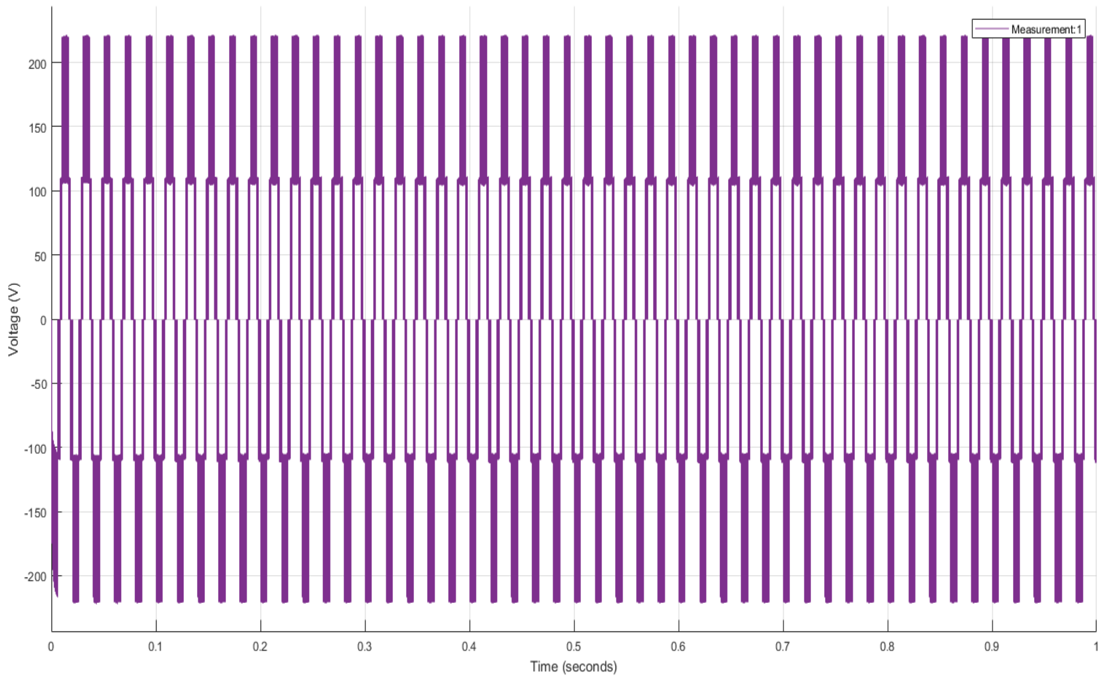

Figure4:NPC-MLI Output voltage with Grid Connected System (without Filter)

The regulated approach for the suggested system, which consists of a solar panel coupled to a three-level multi-level inverter with a neutral point clamped topology

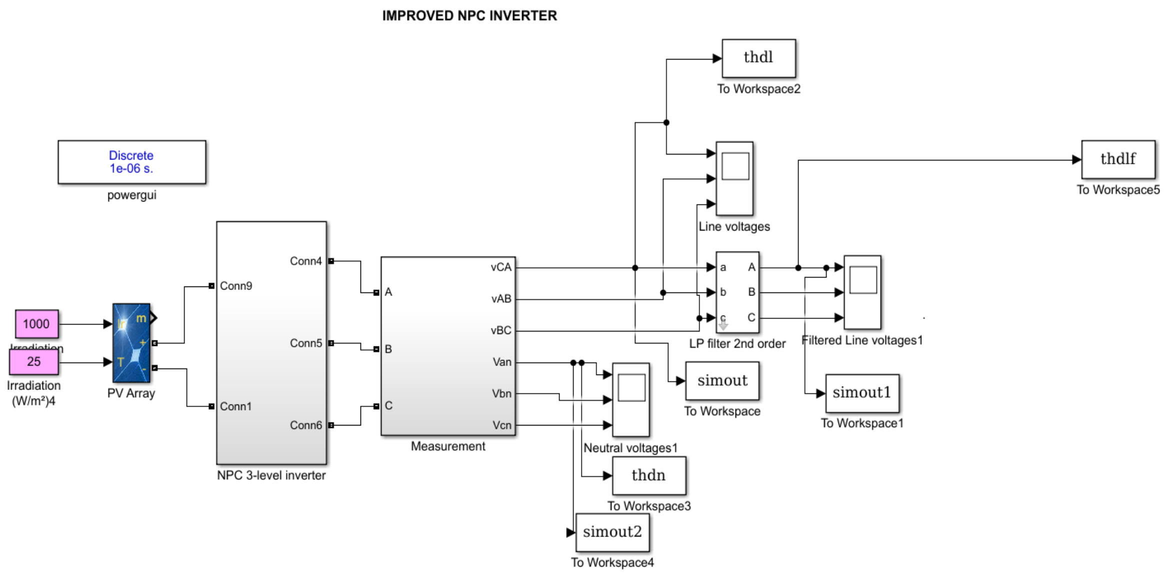

Figure5:Interconnection of the Inverter System

The output voltage of the grid-connected NPC-MLI is displayed in Figure 4. Output After the filter circuit is connected, the three-phase MLI's voltage is shown. It is clear that the filter circuit produces a clean sine wave with few harmonics.

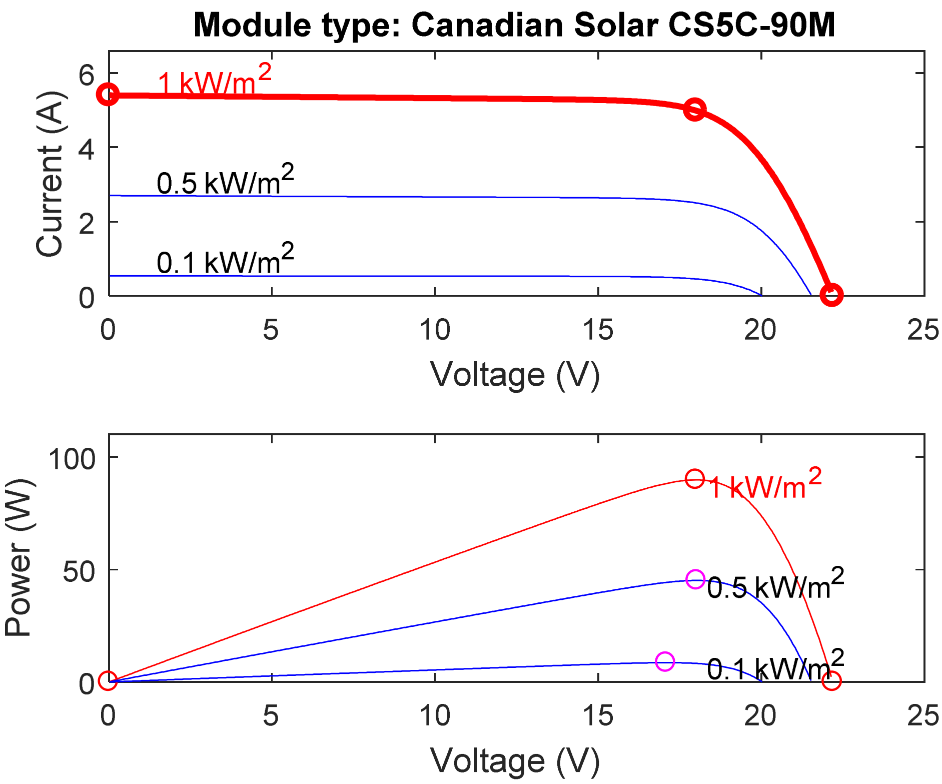

Figure 6:Characteristic plot of photovoltaic system

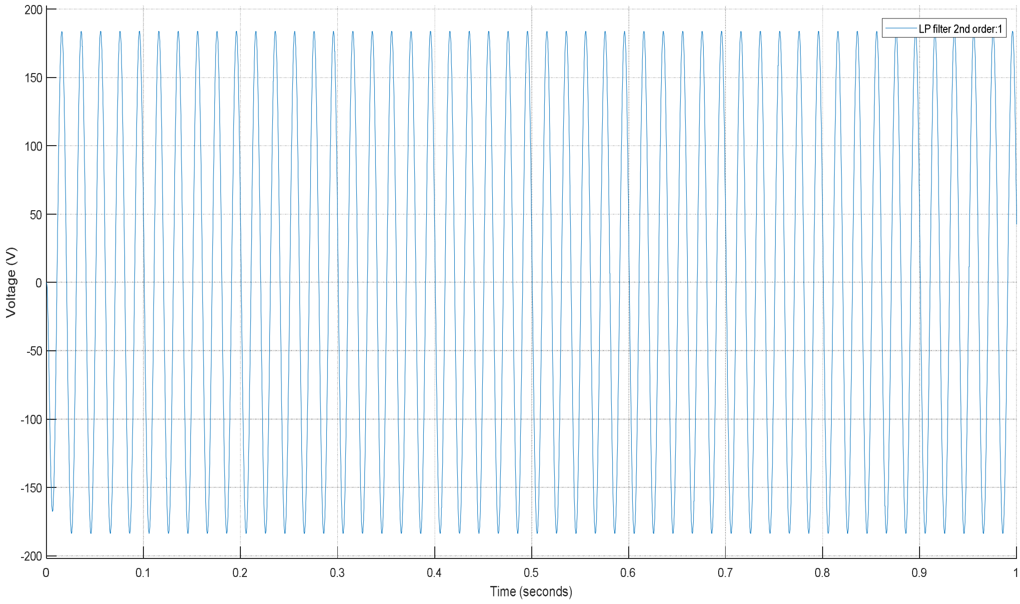

Figure 7: 3-Level NPC-MLI Output Voltage with Filter Circuit

The output voltage of the grid-connected NPC-MLI is displayed in Figure 7. Output After the filter circuit is connected, the three-phase MLI's voltage is shown. It is clear that the filter circuit produces a clean sine wave with few harmonics.

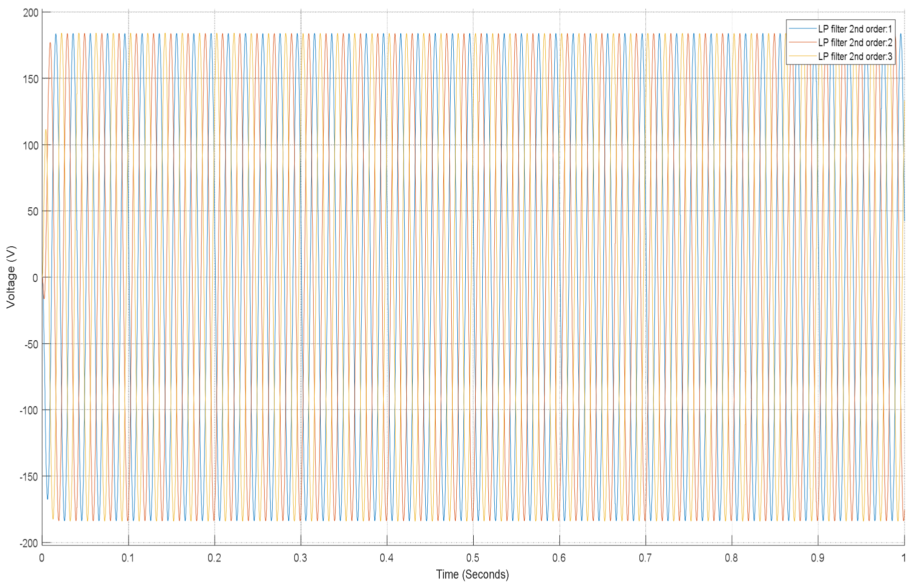

Figure8: NPC-MLI Output Voltage (3 Phase Filtered Voltage

A multi-level inverter system for high power applications of the application in renewable energy is connected. The output parameters of the inverter are logged to obtain the desired output for analysis of the proposed system. Figure 8 shows the output voltage of the NPC-MLI connected to the grid in terms of line to neutral voltage, which is further connected for all three phases in the given connection of the system.

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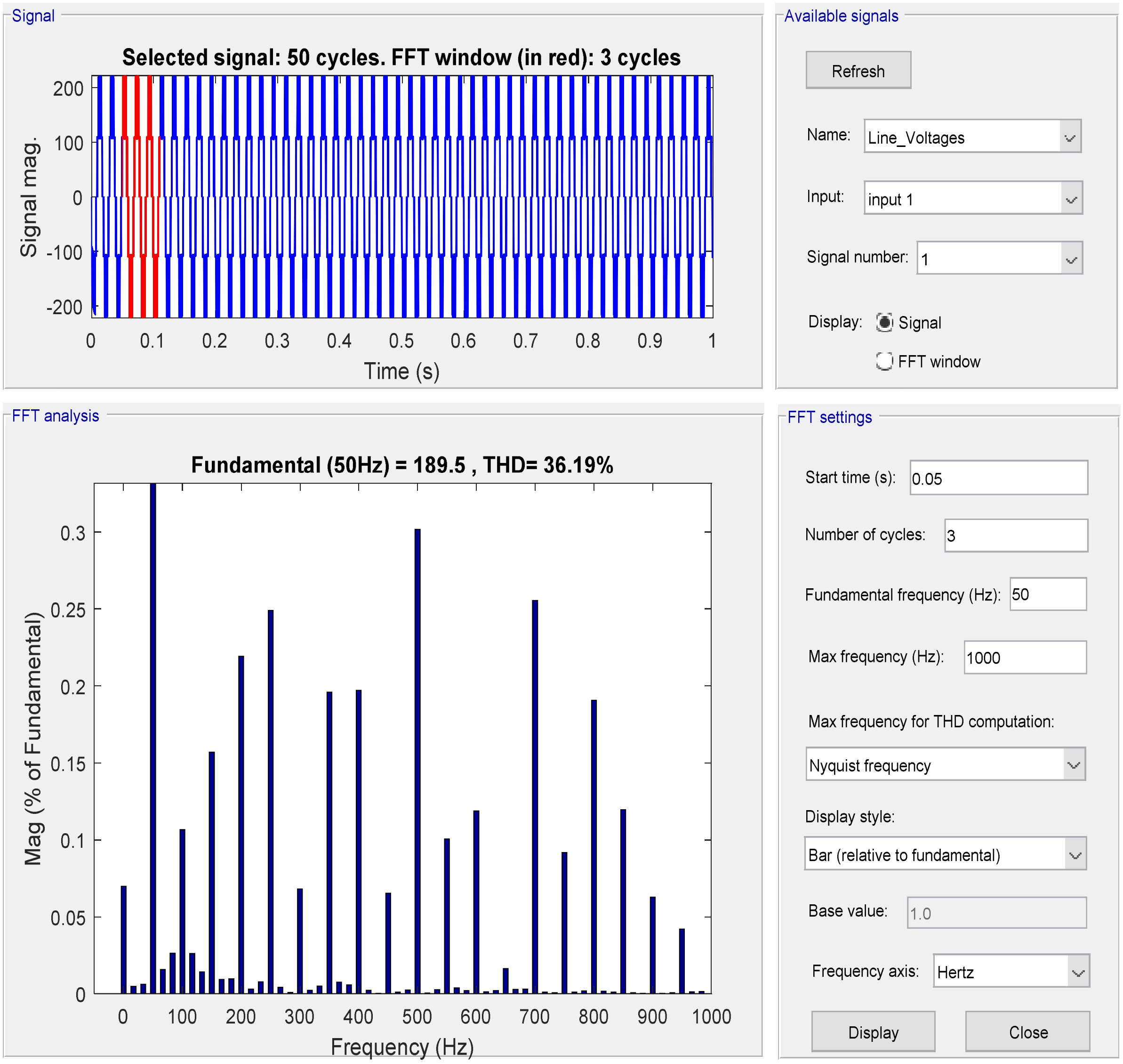

Figure 9: THD for Output Voltage of NPC-MLI

The output voltage of the grid-connected NPC-MLI is displayed in Figure 9 in terms of total harmonic distortion, which is determined using FFT analysis.

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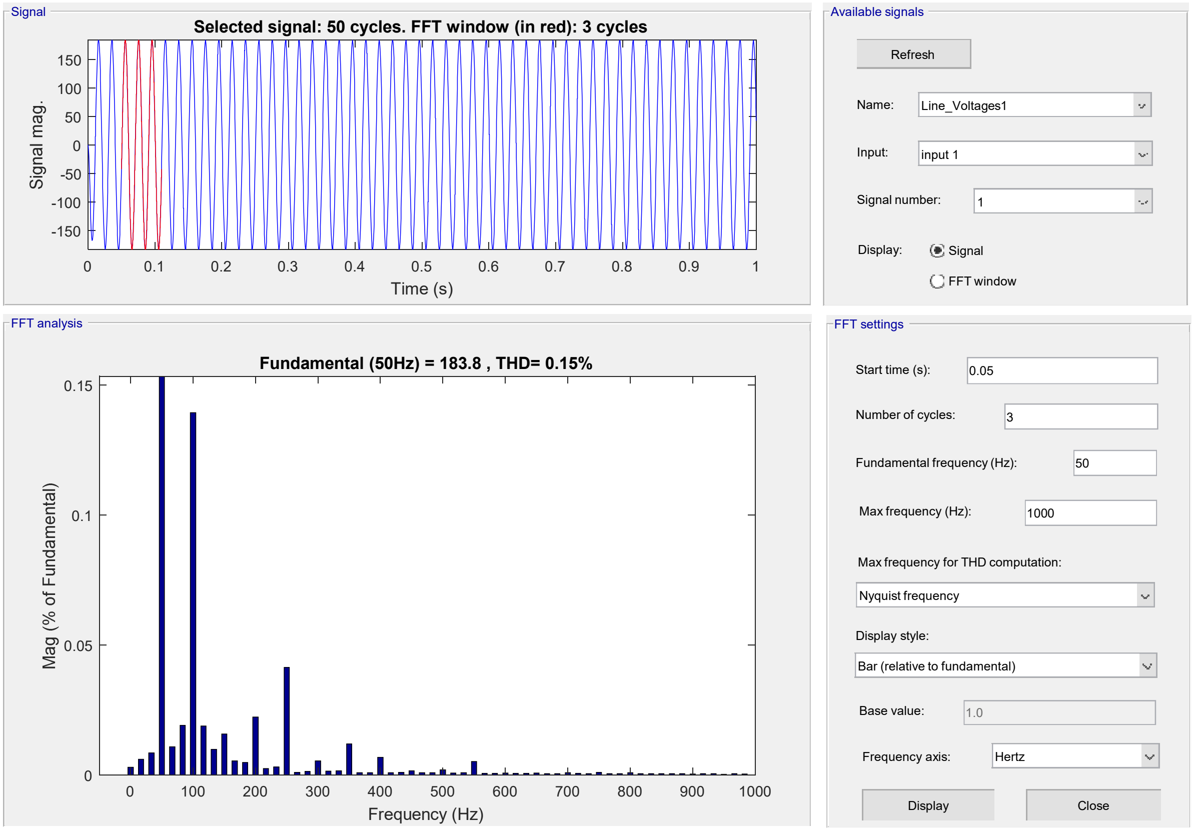

Figure 10: THD for Filtered output Voltage of NPC-MLI

The total harmonic distortion factor, which was calculated for yield voltage and current for the NPC-MLI, was 0.15 percent in the case of voltage at an important recurrence of 50 Hz.

Table 2: Harmonic Distortion (THD) Comparison

Parameter	**Voltage (%)**	**Current (%)**
THD Before Filter	5.8	6.1
THD After Filter	0.15	0.18

Conclusion

In conclusion, this research underscores the significant advantages of employing a three-level neutral point clamped (NPC) multi-level inverter (MLI) in conjunction with a solar photovoltaic (PV) system for enhanced power quality and efficiency. The system's strategic modulation and well-designed filtering approach effectively mitigate total harmonic distortion (THD), as demonstrated by the reduction from 5.8% to 0.15% in voltage and from 6.1% to 0.18% in current, showcasing the filter's efficacy in producing clean sinusoidal waveforms. The high efficiency of 95.5% achieved by the inverter highlights its capability to convert solar power into usable energy with minimal losses, which is crucial for sustainable and high-yield solar energy applications. Additionally, the study's results, as shown in tables and figures, confirm that the proposed system can adapt to variations in environmental conditions such as radiation and temperature, maintaining stable output and robust performance.

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