Power Quality Enhancement inMulti-level Inverter for PV Based Grid-Connected System Utilizing Modified MPPT

Jaspreet Kaur[1]

[1]**Researcher, Manav Rachna International Institute of Research andStudies, Faridabad**

Dr. Anita Khosla[2]

[2]**Professor, Manav Rachna International Institute of Research and Studies, Faridabad**

Abstract**—**Energy experts are designing an optimal grid to meet the rising demand for green and sustainable power. Solar electricity may be more efficiently added to the electrical grid by using Grid-Connected System (GCPS). However, power quality needs issues to be addressed. Among the latest developments in solar energy technology are multi-level inverters in order to employParticle Swarm Optimization (PSO) based MPPT direct predictive control for the output. This paper uses MATLAB Simulink to design and study the use of H-bridge multilevel inverters in grid-connected solar systems. In order to fine-tune the existing direct model predictive control strategy, this researchis adding amodified MPPT algorithm.Results validate both the voltage and current THD of 9 levels ideally followed by IEEE standards. This paper enhances the existing approach by PSO, which leads to lower levels of THD in both the current and the voltage.

Keywords- Current THD, MPPT, Multi-Level Inverter, PSO, Voltage Regulation

I. Introduction

Over the past several decades, multilevel inverters have garnered substantial interest from professionals in the power electronics industry due to their unique characteristics that set them apart from traditional counterparts. To understand these aspects better, it is essential to investigate the quality of the output waveforms, the level of electromagnetic interference, and the filtering requirements.

Due to the integration of renewable energy sources, the usage of cascaded multilevel inverters (CMLIs) has significantly increased. One notable contributing factor is the adaptability and redundancy of capacitors in CMLIs, which eliminates problematiccapacitor voltage balancing issues. Moreover, the topologies of publicly known CMLI circuits primarily focus on increasing voltage levels, resulting in improved output waveforms. In situations where multiple levels of input voltage are required, asymmetric inverters, such as cascaded multilevel inverters, can be a suitable solution.

However, utility-grade applications cannot utilize hybrid CMLIs due to their inherent voltage distribution imbalance and lack of flexibility. This limitation prevents the adoption of hybrid CMLIs in utility-grade applications. One drawback of CMLIs is the need for a separate DC power supply with discrete input and output ports. This requirement reduces the device's capabilities and adds complexity. Fortunately, several established techniques can help reduce the number of required direct current power supply units.

The findings of this study propose a novel method for installing multi (9) level inverters in single-phase grid-linked applications. This approach aims to enhance the grammatical structure of the English language while preserving the original content. Research on grid-connected photovoltaic systems (also known as GCPS) is a crucial aspect of the sustainable solar energy field. However, it is also essential to conduct research on other types of solar energy, such as standalone and community-based systems. The increase in research is driven by both the growing energy demand and advancements in power electronics converters. Nevertheless, the significant improvement in total energy efficiency primarily stems from a considerable decline in PV panel cost [1],[2]. The development of power electronics converters is inevitable due to the increasing energy demand. When establishing an effective environmental categorization system, three crucial characteristics must be taken into account: PV panel power tracking, conversion efficiency, and total harmonic distortion (THD) [3]. The combination of GCPS and the control approach significantly impacts performance. There are several alternative topologies that can be utilized to meet various power supply requirements [4]. Multilayer inverters, also known as MLI, are a type of power converter that is still undergoing development. They have the potential for further enhancement and can handle moderate to high power levels, accepting input from various voltage sources or multiple photovoltaic panels. Additionally, MLIs generate a sinusoidal output waveform resembling a staircase with low total harmonic distortion (THD). In recent years, there has been an increased utilization of inverters in various applications, including smart grids, grid-connected photovoltaic systems, induction motor drives, and conveyor belts[5]. Multilevel inverters primarily employ three different topologies: diode-clamped topology, flying capacitor topology, and cascaded H-bridge design (CHB). Among these, the CHB design is the most commonly used MLI due to its modularity, ease of management, and absence of energy storage devices [6],[7]. Over the course of the last several decades, GCPS has become more well-known due to the unique benefits offered by its topology [8],[9]. The CHB method is being utilized in the production of new semiconductor chip manufacturing processes like GCPS because of its improved efficiency. The converter's effectiveness plays a vital role in its performance, and it's important to consider that the number of semiconductor switches significantly impacts the converter's efficiency[10]. The newly developed CHB-based topology, referred to as the innovative H-Bridge MLI [11], exhibits higher efficiency compared to the CHB-based topology [12] and previously published MLI topologies [13].

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Regarding the H-Bridge MLI, we believe that GCPSs will benefit from its integration. The use of control mechanisms contributes positively to the overall performance of GCPS. PV panels aim to maximize the energy they collect, and the subsequent current should be sent to the grid with minimal total harmonic distortion (THD)[14]. As each PV panel has its own unique DC connection, having multiple panels can provide the inverter with a source of input voltage necessary for its operation. Monitoring the maximum power point (MPP) of photovoltaic panels is necessary because different DC connections in a PV system may have varying operating voltages due to irradiance, temperature, and panel age variations [15]. Keeping the THD level as low as possible is crucial to maintain the overall quality of the grid. Similar to other fundamental systems, GCPS employs a wide range of linear control methods, such as PID, as well as compensation and modulation strategies like FBF.

A more traditional technique for control often involves longer reaction periods and substantial transient responses. Direct model predictive control (DMPC), also known as DMPC, is an innovative control method that utilizes an exact model of the plant to predict system behavior. Since, DMPC directly controls the switches without the need for a demodulator [16], it does not require one. DMPC is a suitable choice when the system exhibits nonlinear behavior, multiple control objectives, and input and state limitations must be adhered to. Additionally, DMPC demonstrates quick transient response [17]. This article discusses the dynamic motor piloting circuit (DMPC) of the new H-Bridge-based GCPS, leveraging the benefits offered by both the H-Bridge and DMPC to enhance the overall performance of GCPS. The entire system is evaluated using various topologies, comparing it to previous work conducted by DMPC addressing global crude stock profiles.In this paper, we have implemented a multilevel inverter grid connected using the PSO algorithm, resulting in improved sinusoidal output waveform resembling a staircase and minimizing the total harmonic distortion (THD) as much as possible while achieving unity.

II. Mathmatical Modelling

The novel idea is to implement PSO MPPT with direct PV method and improve the THD[18], which is described in this section. It is well knowledge that photovoltaic (PV) panels have a nonlinear relationship between the current and voltage parameters that they provide. In addition, when PV panels are partly shaded, the characteristic curve '$IpvxVpv$' may display numerous local and global maximum power points at the same time. As a consequence of this, the proposed MPPT-PSO algorithm tackles the flaws by keeping track of the global maximum power point in order to maximize the amount of power that can be extracted from the solar array[19]. Because of this, there is a possibility that the THD in the voltage and current may improve. In this part,

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we will begin by displaying the current implementation in MATLAB Simulink as seen in Figure. 1.

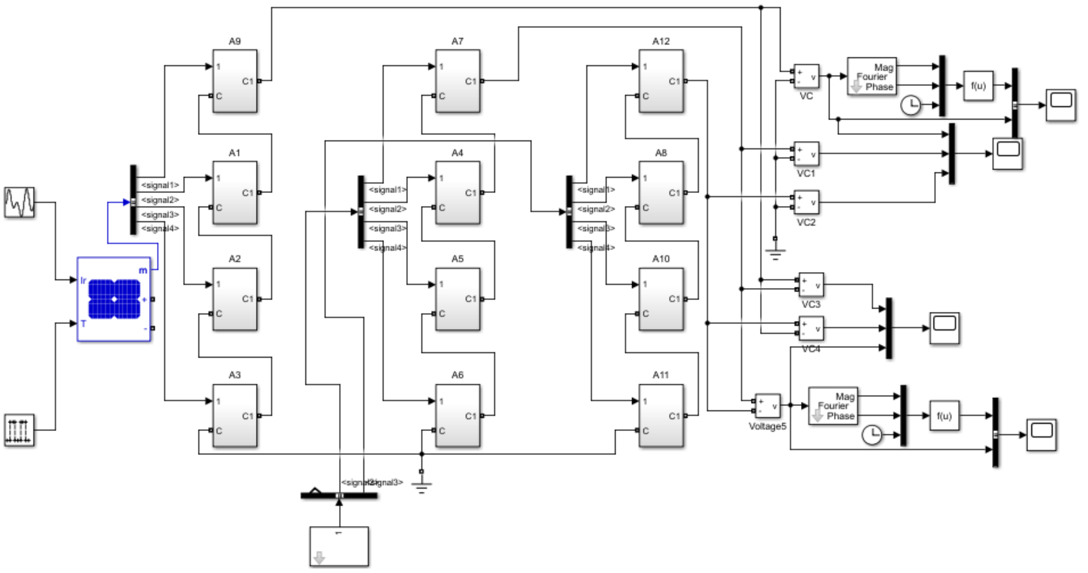

Figure1. Multi-Level Inverter with PV andGrid Connected

Figure 2 depicts the direct predictive control approach, which uses the MPPT methods in conjunction with the PID controller. Integration of PV side 1 and PV side 2 is what it entails, same as how it is described in the basic circuit.Figure 3 depicts the controller's other component, which is a joystick. It demonstrates the section of the control system that is responsible for signal generation for the H bridge transistors in the main implementation.

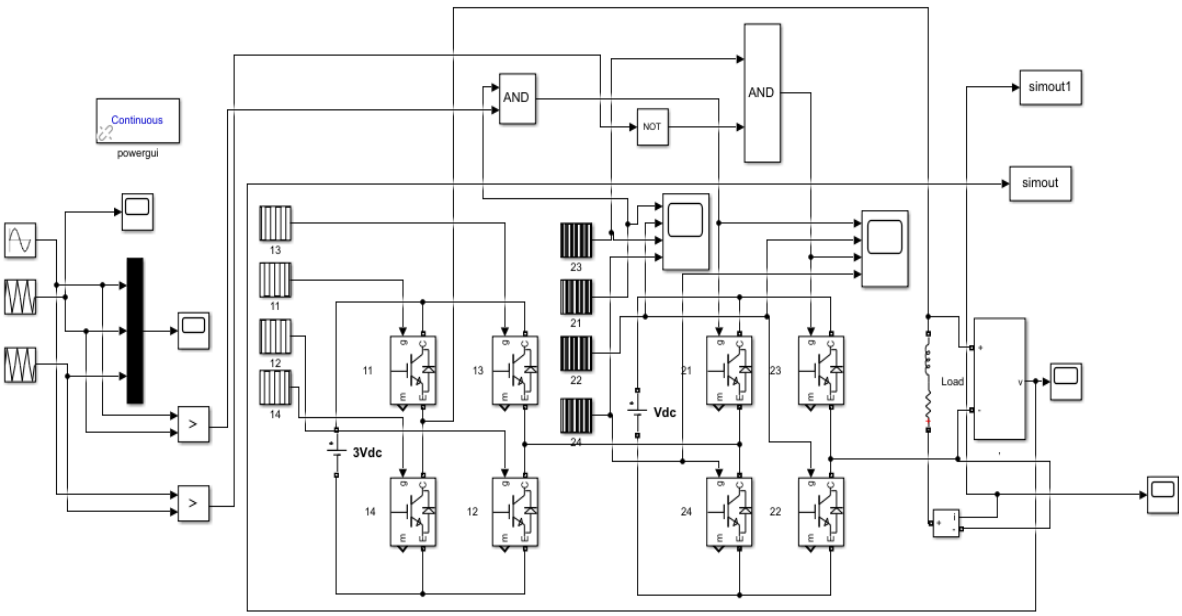

Figure2. Control System of MLI

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The algorithm for the MPPT subsystem is shown in Figure 3, which depicts the present control system method. Now, depending on the findings, the THD will be evaluated in the following steps.

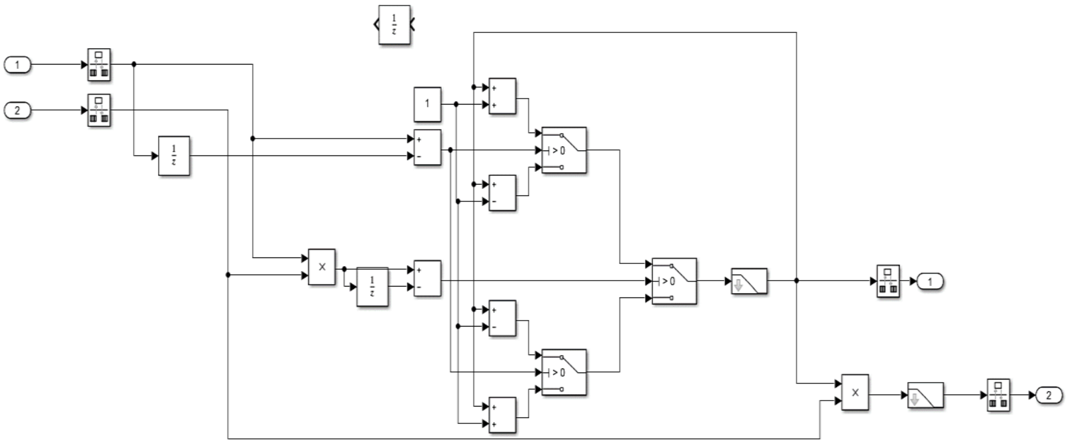

Figure3. MPPT algorithm for PV panels existing implementations

Figure. 4 depicts the MPPT block that will be used in the proposed implementation. It contains the MPPT, which will generate a reference for future implementations in accordance with the PSO MPPT.

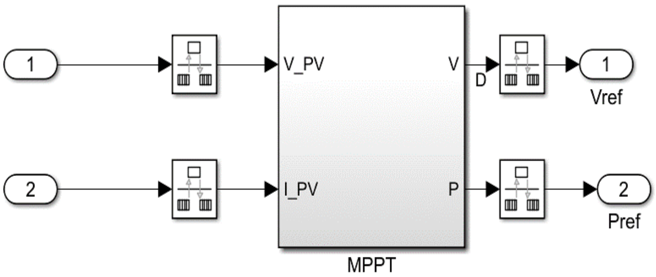

Figure 4.MPPT Block Proposed

The P&O MPPT approach is a basic algorithm that routinely raises or reduces the boost converter's duty cycle. It uses a constant step size and works with that step size throughout the process. The photovoltaic (PV) power is being watched, and as it increases, the PV current will also increase; this will result in an increase in the current reference.Figure 5 depicts the PSO MPPT subsystem for your viewing pleasure. It comes with a coding platform based on MATLAB that may be used to build the optimization functions of the PSO MPPT algorithm. This is then applied to the voltage and current of the PV modules, which results in the production of a duty cycle that is added along with a delay. This is then separated into power and voltage separations according to the saturation levels.

The current reference will be decreased if there is no sign of a decrease in the PV current. The PSO methodology is a method for global optimization that uses population-based stochastic optimization as its foundation. It is based on the behavior of social groups such as fish schools and bird flocks and how they interact with one another[20],[21]. The idea that improved performance may be achieved via interpersonal interactions or, more specifically, by modelling the behaviors of successful people is one that is brought up over and again. The algorithm is shown in Figure 6.

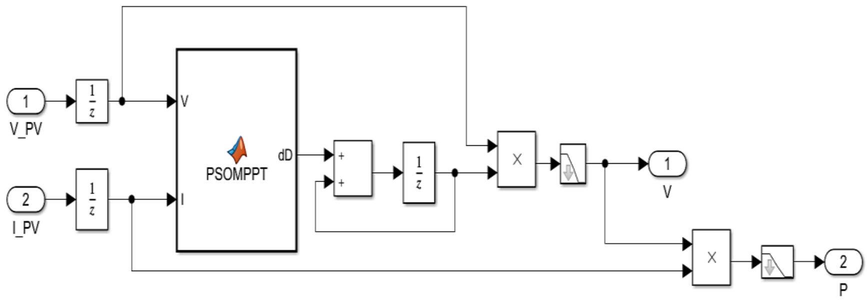

Figure 5. MPPT subsystem

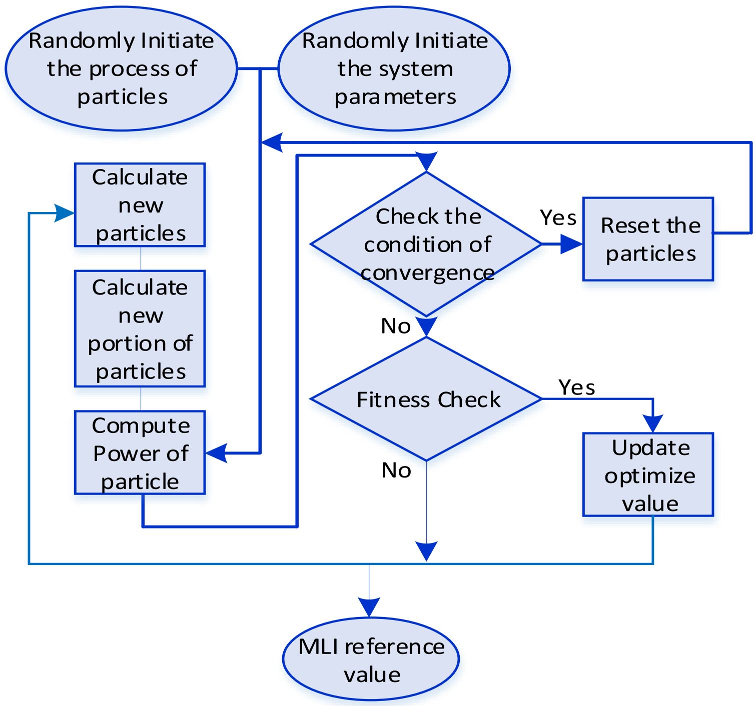

Figure 6. PSO MPPT flowchart with main Subsystem

III Results And Discussions

Figure 6 displays the Vpv1 along with its respective reference values. In a similar vein, the current of PV1 in conjunction with its reference. In a similar fashion, the voltage and current of PV2 together with its reference values are shown in relation to the

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algorithm that is already in place. It has been discovered that the optimizations are flawed at several locations across the system.

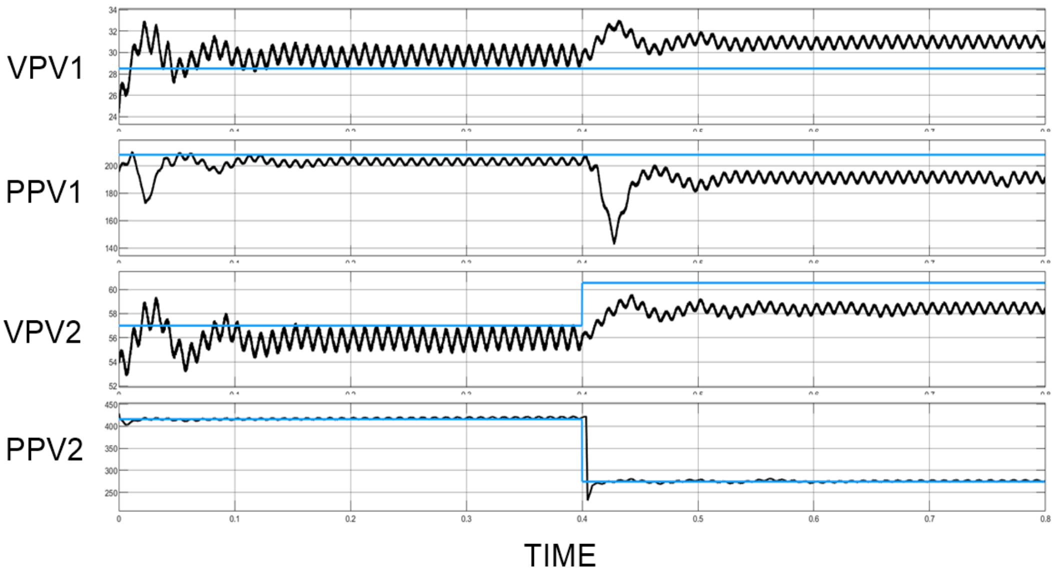

Figure 7.Voltage and power of solar PV arrays (PV1 and PV2)

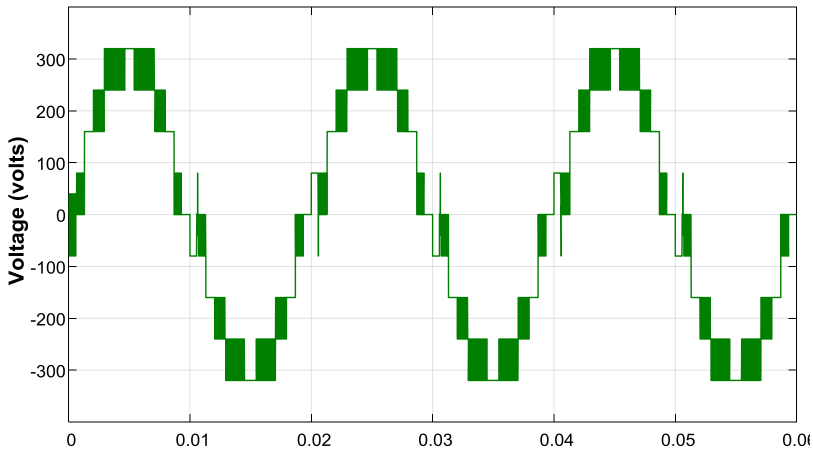

Figure 8. Voltage Multilevel Output

Figure 8 depicts the voltage output of the multilayer inverter, which may exhibit a substantial number of distortions, as can be seen in Figure 11.

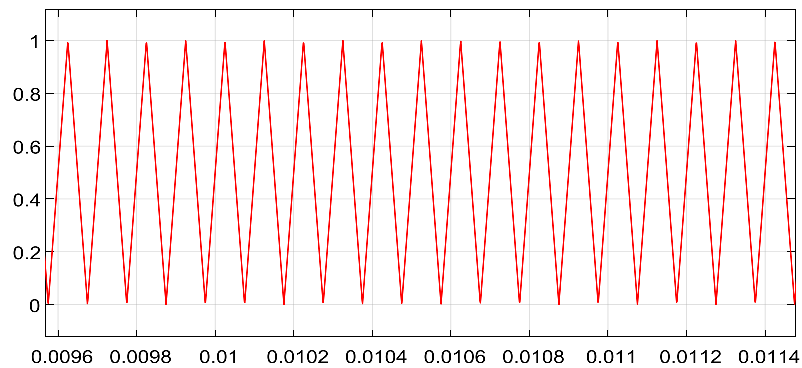

Figure 9. Grid Voltage of proposed MLI

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The grid voltage and current utilized for the FFT approach are shown in Figure 10 and Figure 11. Figure 10 displays the THD result for the voltage variable for certain instances. It is seen that the output is more smoothened in the results obtained and the results for THD are better as shown below.

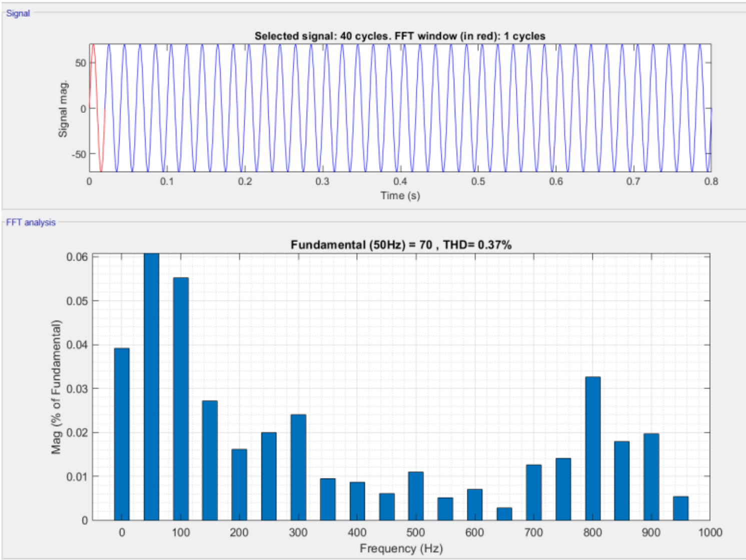

Figure 10.Voltage THD of MLI

The outcome of the THD calculation shown above reveals that the voltage THD is now less than one percent.

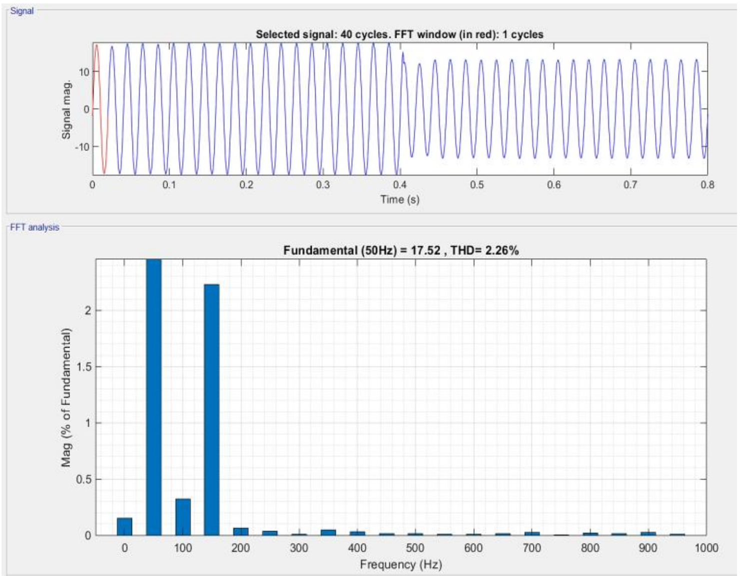

Figure 11Current THD of MLI

Figure 12 displays the voltages and currents that resulted from after applying PSO MPPT optimizations. These results largely correspond to the reference voltages presented in the next figure.

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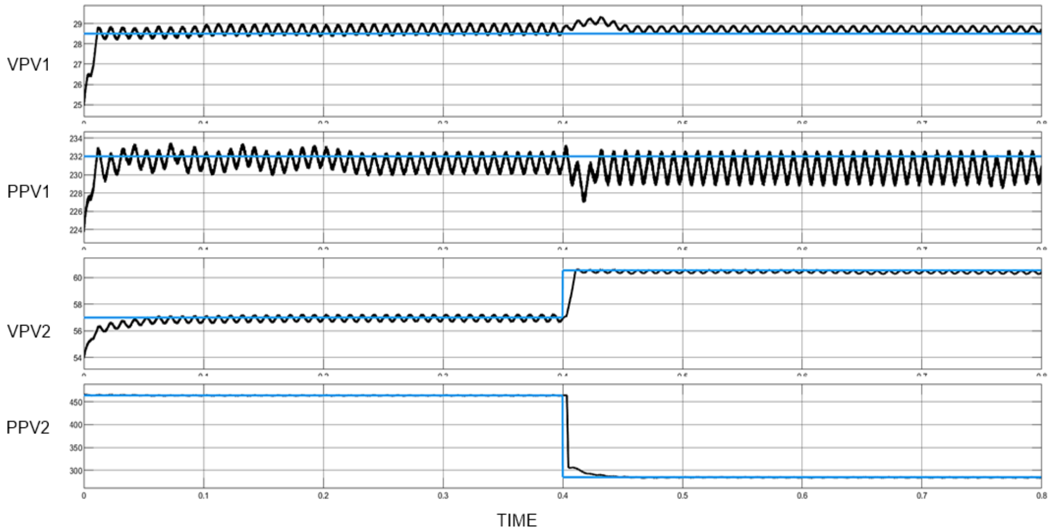

Figure 12. VPV1,VPV2 voltage and PPV1, PPV2 Power reference for Proposed MLI

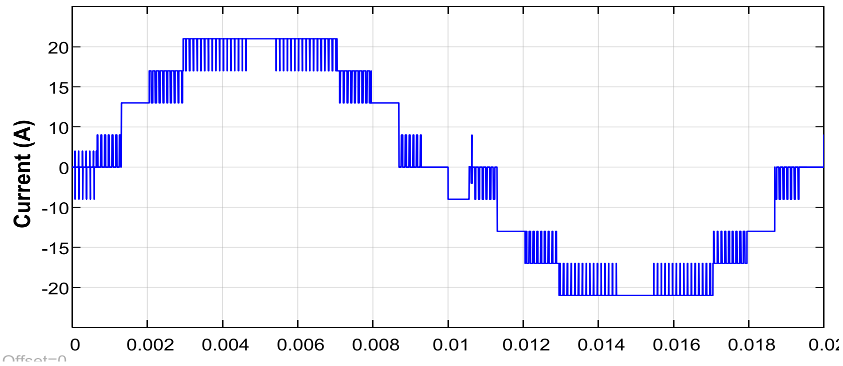

Figure13.Current waveform of multilevel inverter output

The multilevel inverter output is shown in Figure. 16 with lesser fluctuations on the different levels. The multilevel output shows that levels

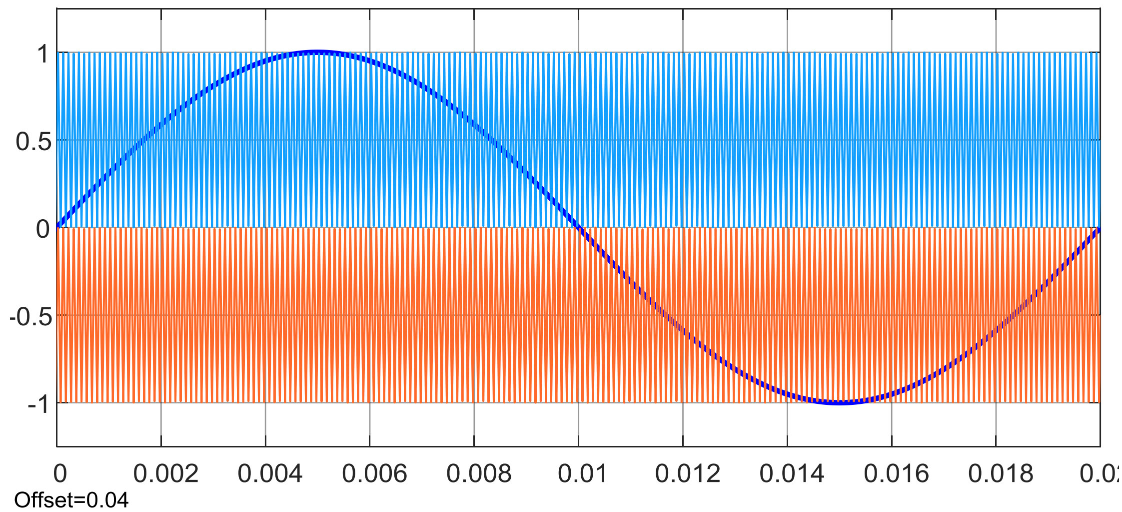

Figure 14. Voltage and Current for Grid with Proposed MPPT PSO

In Figure 14., the voltage and current outputs of grid with proposed MPPT with PSO is shown. Further in Figure 15, the voltage THD is showing the current THD.

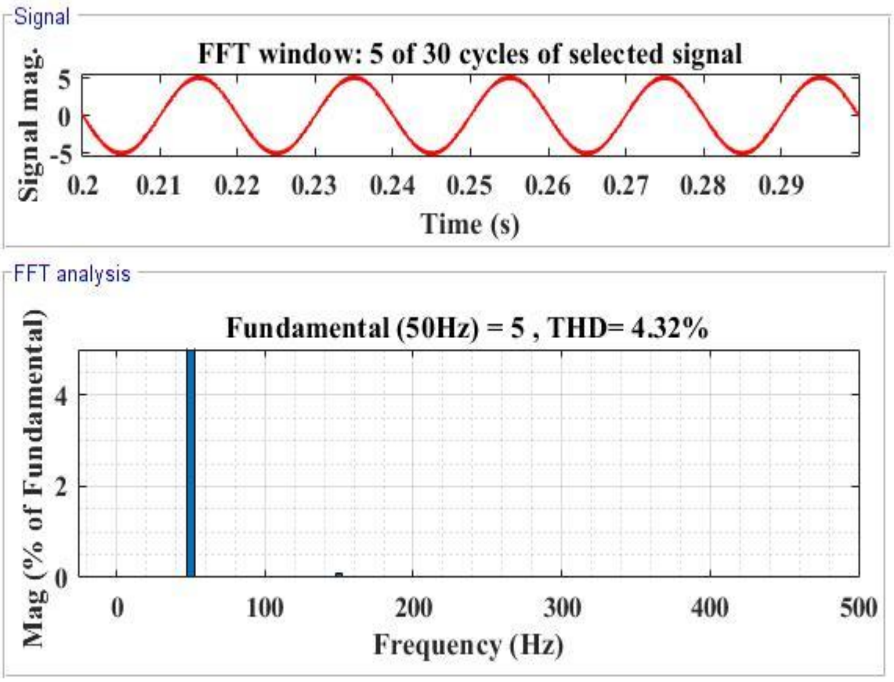

Figure 15, Voltage THD Proposed MLI

The voltage-voltage THD is exhibited here in Figure 15, which is less than 5% as per IEEE std[22]. For the next cycle THD has increased to 1 percent, which may be attributed to the usage of PSO MPPT as the source of the rise.

IV.COMPARIVE POWER QUALITY RESULTS

The total harmonic distortion (THD) of the voltage and current of the output grid-connected PV multilevel inverter is shown in Figures 18 and 4.18, respectively, for the approach that has been taken here and for the way that has been recommended. The outcomes of the tabular form are shown in Table 1.

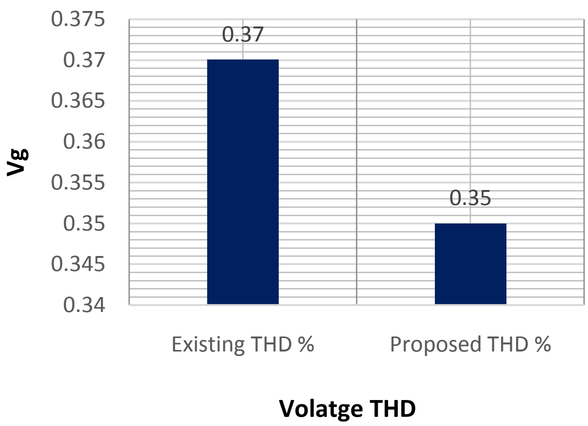

Figure 16. Voltage THD Comparison

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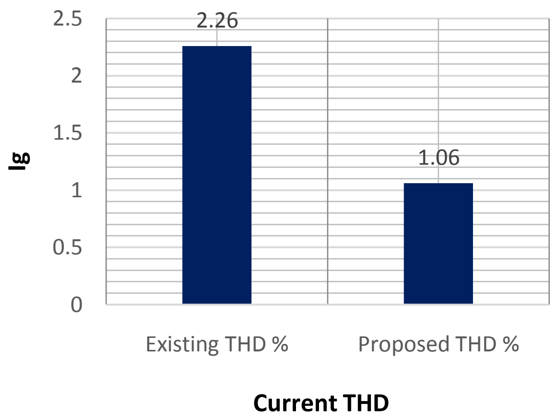

Figure 17. Current THD Comparison

According to the findings of the comparison for the THD, the suggested THD is improved in the same manner as the PSO-based MPPT is. The results are presented in tabular format in Table 1.

Table 1. Comparison of THD for Proposed Results

Parameters	Existing THD %	Proposed THD %
Vg	0.37	0.35
Ig	2.26	1.06

V. CONCLUSIONS AND FUTURE SCOPE

This paper presented a 9 level MLI control technique for determining the maximum power point of a photovoltaic (PV) system by using an MPPT approach. This method makes use of an algorithm that is based on PSO, and it is described in detail in this article. A non-linear relationship exists between the current and voltage that solar photovoltaic panels need in order to function properly. Solar photovoltaic (PV) energy is becoming more prevalent in the electrical grid as a result of advancements in technology, decreases in the cost of power electronic equipment, a variety of different government incentive systems, and the fact that solar power has a positive impact on the environment. A photovoltaic (PV) system might benefit greatly from the use of an updated H bridge inverter. A comparison is conducted between the novel MPPT-PSO algorithm and the well-established MPPT approach that is currently in use, using both actual and simulated data as the basis for the comparison. The findings are modelled with the help of a piece of software called MATLAB/Simulink. Therefore, the PWM control is optimized with the assistance of the PSO method. According to the findings, the grid's voltage as well as its current output THD have both seen positive changes in

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recent times. In future work we can implement 17 MLI with hybrid deep learning control system.

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