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# Artificial Intelligent based Grid-connected PV System using Cascaded Multilevel Inverter

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**Abstract**

Based on the environmental benefits, photovoltaic (PV) power production is now widely used in many nations. Power electronics converters are critical in PV power conversion. Today, boost and buck-boost converters using MPPT algorithms are employed in PV systems, resulting in lower conversion efficiency and poor power quality. A fuzzy-based MPPT controller was developed to control the converter, and the super lift Luo converter was studied and simulated at various stages of topology to improve the PV system's conversion efficiency. A new Cascaded Multi-Level Inverter (CMLI) was proposed to achieve good power quality at PV-grid integration. The new CMLI has a small solid-state switch range and can function on asynchronous voltage sources. The planned CMLI's output standard has improved, reducing Total Harmonic Distortion (THD) and increasing PV system power efficiency. This theoretical PV model was simulated in MATLAB and its performance was assessed. It uses the suggested converter and MPPT algorithm to improve power quality and reliability by integrating the PV system into the grid. Finally, the suggested system's simulation results are reviewed and confirmed against the IEEE 519 & 1547 standards.

**Keywords:** Photovoltaic, MPPT, Fuzzy, Cascaded Multilevel Inverter, THD

## 1 INTRODUCTION

Global warming is becoming the world's most pressing issue, caused by both greenhouse gases and the usage of fossil fuels for power production and transportation. In recent years, several nations have concentrated on renewable energy sources such as solar and wind. The Indian MNRE modified the rule in January 2011 to increase the solar-specific RPOs from 0.25 percent in 2012 to 3% in 2022. The NAPCC also predicts a minimum of 15% renewable energy in the entire energy mix by 2020. Solid-state electronics has played an important part in the distribution of renewable energy and power sources, which have traditionally been employed in different network designs. Multiple checking approaches and interface components were also used. They decide to enhance the system's advantages by tweaking their equipment and control procedures. Currently, renewable and alternative energy sources are spread throughout microgrids. These technologies are preferred in a micro-grid because they maximise resource usage, enhance power efficiency, and boost source stability. Modern grid infrastructure includes multi-microgrids, interconnected AC-AC microgrids, and interconnected AC-DC microgrids. This new network design optimises clean energy and renewable resources [1]. Interconnecting 2 or more microgrids permits reserve sharing, resistance voltage, and frequency sharing, thus improving overall efficiency and durability [2]. PV and fuel systems provide clean DC outputs. Conversion of DC-DC and AC-DC converters is vital in the output voltage setup and management. Boost, Buck, Buck-Boost, and Cuk converters are presently utilised for DC-DC and MPPT converters. The primary disadvantages of traditional controllers are excessive output ripple voltage and current. Many researchers concentrated on the above-mentioned difficulty and found a solution through Super-lift Luo converter [3]. Low ripple voltage and current are benefits of the Super-lift Luo converter. So the super lift Luo converter is better for boosting voltage and MPPT controller design [4].

Design and analysis of the Fuzzy controller based MPPT algorithm for 5300W PV panel using Super - lift Luo converter are discussed in II section. Then design and analysis of 13 levels of new CMLI for the PV system are discussed in section III. Further in Section IV, the design and analysis of grid interfacing of the photovoltaic system via new CMLI and controlled by a fuzzy logic algorithm is discussed and finally, the conclusion was discussed in Section V.

## 2 FUZZY - MPPT BASED PV SYSTEM

### 2.1 The framework of Photo Voltaic System:

Renewables are natural resources used to generate non-linear electricity. The MPPT Algorithm is critical for managing and producing full power in all renewable energy systems [4]. The MPPT Algorithm matters. Recent MPPT controls include P&O, incremental conductance, voltage and current, input capacity, and certain systems-based expert algorithms. A single PV cell cannot meet the market demand for power due to its low voltage production. These are high energy series PV cells.

Fig. 1 shows the suggested system with super-lift Luo converter. In this circuit, instead of a DC electricity supply, we connect a solar array. In a solar array, PV cells are first connected in series to achieve desirable voltages, then in parallel to create greater current. This is a 5300W PV module. The Fuzzy - MPPT algorithm based on a super lift Luo

converter was created in this book for the 5300W PV system, as illustrated in Fig.2.

On the other hand, the 5300 W PV array may provide a gate signal for the converter switches through a fuzzy MPPT-based controller. The Fuzzy - MPPT controller [8] analyses the PV device output and creates a reliable PV output that adjusts to changing irradiance circumstances.

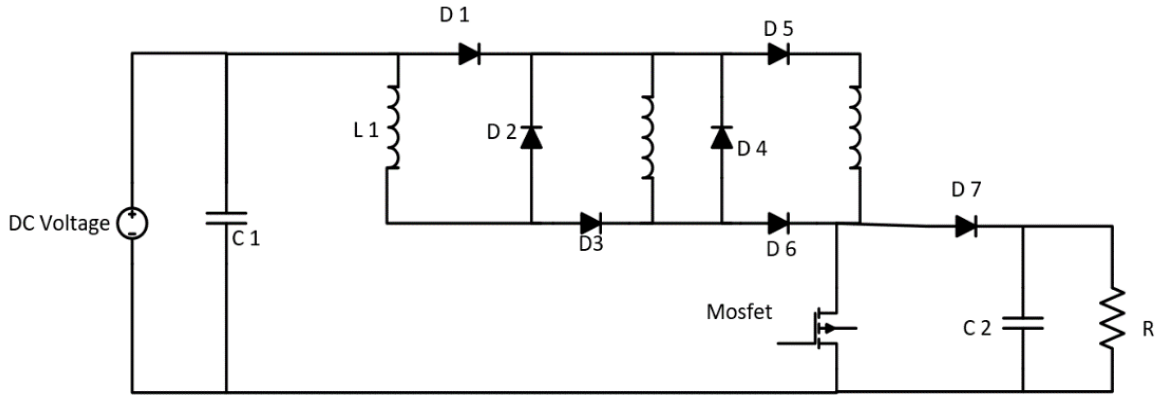


**Fig. 1**Super – lift Luo converter topology

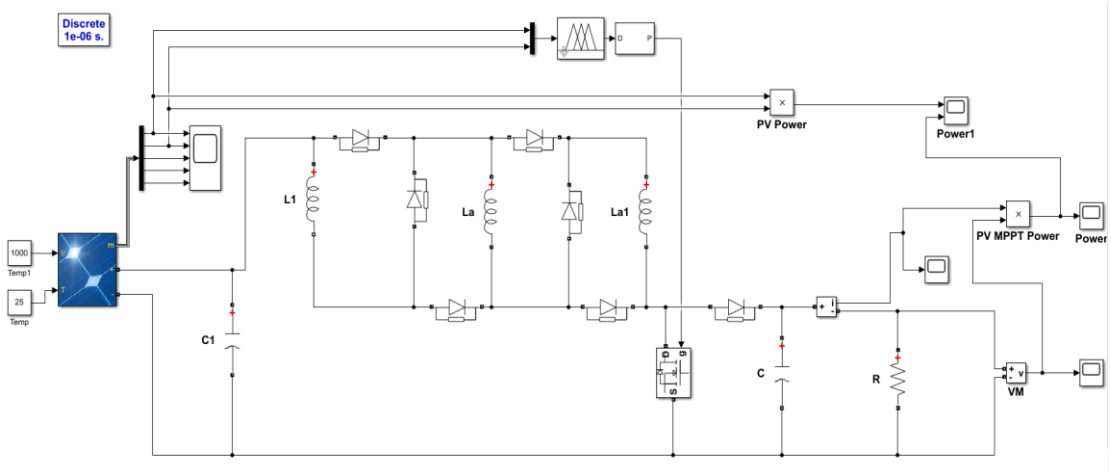


**Fig. 2.** PV connected super lift Luo converter with Fuzzy – MPPT controller

2.2 Fuzzy based MPPT controller:

There are two inputs of the Fuzzy controller which are PV voltage & current with one output, which is the duty cycle of solid-state switches in converter as seen in Fig. 3.

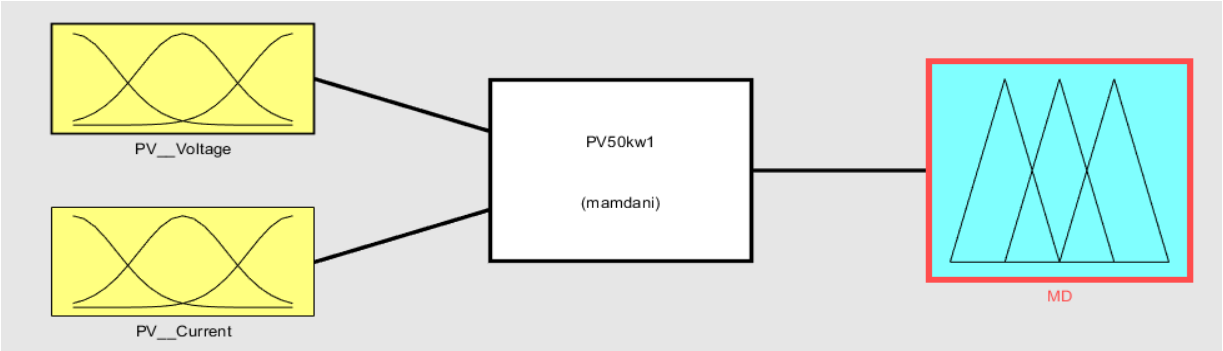


**Fig. 3.** Fuzzy controller based MPPT algorithm

The fuzzy input and output membership function has been developed by using the trapezoidal function and each membership function is classified into three ranges such as low, medium, and high**.** Based on these ranges fuzzy rules have been developed for input and output membership functions as mentioned in table 1.

In this case, the centroid process was used to transform the fuzzy value into a crisp value.[11] The fuzzy intervene rules are drawn up according to PV module input and output variables presented in Fig. 4.

**Table 1.** Fuzzy logic for the proposed system

| **PV panel Current / PV panel Voltage** | **Low** | **Medium** | **High** |
|---|---|---|---|
| **Low** | High | High | Medium |
| **Medium** | High | Medium | Medium |
| **High** | Medium | Medium | Low |

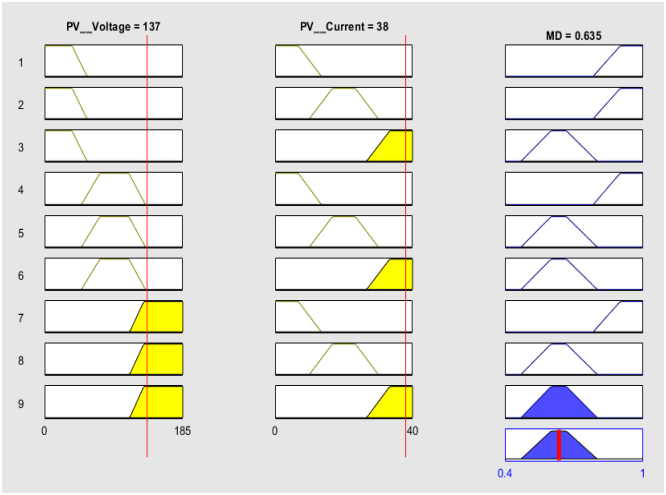


**Fig. 4.** Fuzzy Rules-based system for MPPT algorithm

2.3 PV system outputs:

*Two-stage Super lift Luo Converter.*

The PV system from the super lift Luo converter generates higher power than the PV system from the boost converter and is shown as a waveform for power comparison in the Fig. 5. Here, the super lift Luo converter-based PV system generates 5300 W of converter-side power while the booster-based PV system produces 5000 W of converter-side power. Normally boost converter is used in PV-based power systems but has less conversion efficiency.

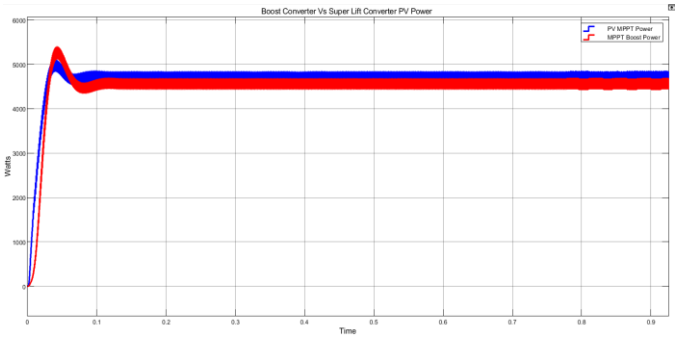


**Fig. 5.** Comparative analysis of Boost and Super lift converter for 5300W PV system

The MPPT algorithm for the PV system is designed by a fuzzy controller which generating the duty cycle for the super lift Luo converter (Two Stage) existing in the PV system. In which, PV system performances such that Power, Voltage, and Current have been analyzed under various weather conditions. Here, PV input power and PV – MPPT power has been compared and presented in Fig. 6.

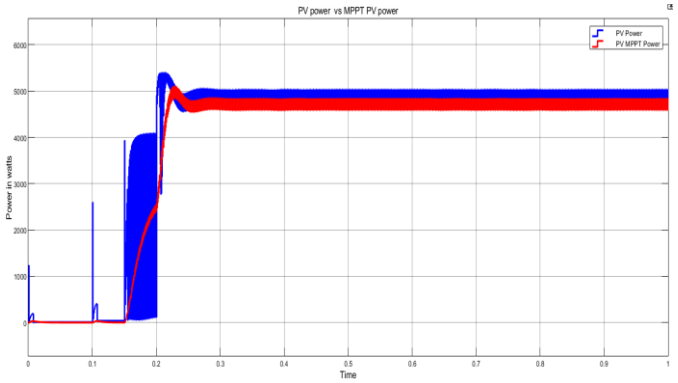


**Fig. 6.** Two-stage Super lift Luo converter Power waveform (PV and PV MPPT)

Here, the super lift Luo converter-based PV system gain was even higher than the boost converter-based PV system. The voltage and current waveforms are shown in Fig. 7. and Fig. 8. respectively, the voltage was improved even higher than the traditional converter.

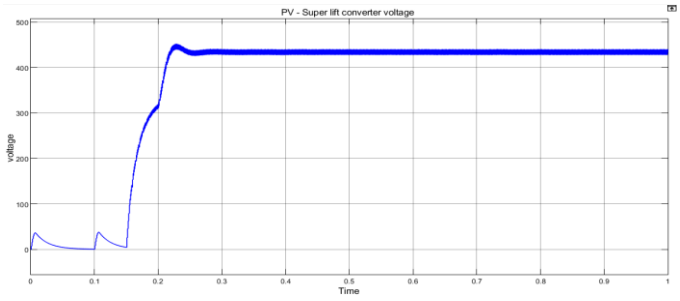


**Fig. 7.** Two-stage Super lift Luo converter voltage waveform (PV MPPT)

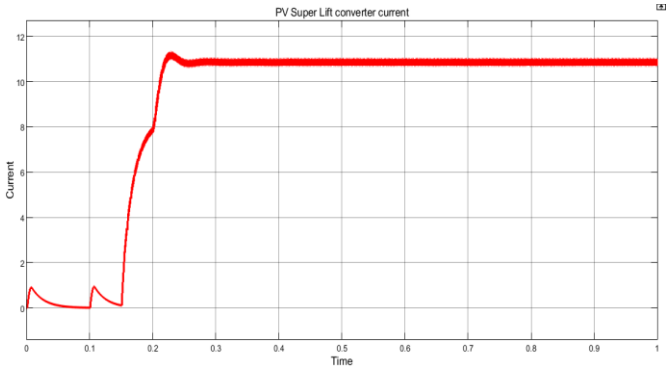


**Fig. 8.** Two-stage Super lift Luo converter current waveform (PV MPPT)

*Three-stage Super lift Luo Converter*

The 3-stage Luo converter is created, and the above analyses are performed and the performance features are analyzed under various weather conditions. Here, the voltage and current waveforms are presented in Fig. 9. and Fig. 10. respectively. The voltage level here was much higher than the two-stage Luo converter.

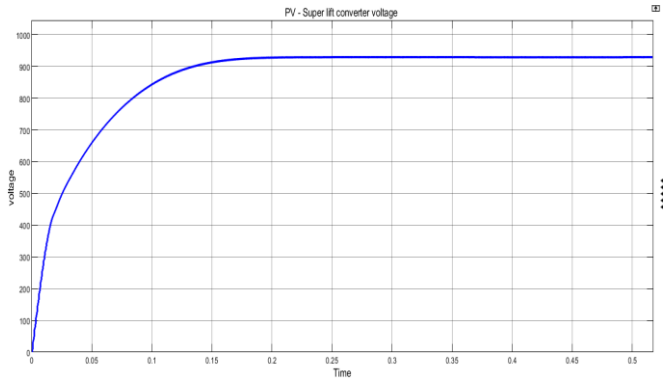


**Fig. 9.** Three-stage Super lift Luo converter voltage waveform (PV MPPT)

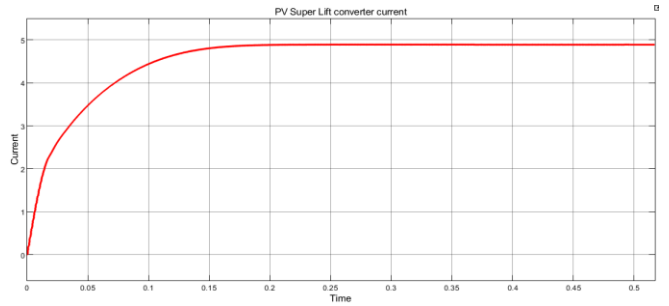


**Fig. 10.** Three-stage Super lift Luo converter current waveform (PV MPPT)

Three-stage super lift Luo PV input power and PV – MPPT power has been compared and presented in Fig. 11. Based on the analysis, the three-stage super lift Luo converter voltage conversion gain and reliability have been higher than the two-stage converter and traditional converter.

It is more suitable for the PV MPPT system where three-stage Super Luo converters are installed and used for the grid-connected system under typical irradiation.

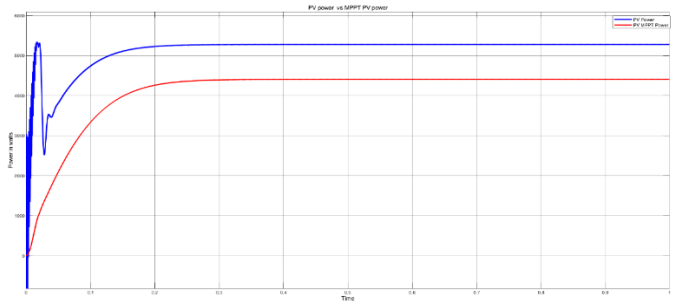

**Fig. 11.** Three-stage Super lift Luo converter power waveform (PV and PV MPPT)

## 3 Proposed Cascaded Multilevel Inverter

The CMLI is best suited for the green energy grid integration in order to increase the system energy efficiency and reliability [5][6][7]. In order to lower the THD level for the current and voltage waveform, the proposed CMLI was built with a minimal number of solid-state switches.

Six PV sources for grid integration to produce 32 kW of power where each PV source has a single solid-state switch and CMLI configuration has six solid-state switches as shown in Fig. 12**.** [11].

The modular staircase technique is used to produce the pulses for the proposed CMLI [8]. This new topology of CMLI is built and simulated in the MATLAB tool and shown in Fig.13. The voltage source controller is used to interface with the grid.

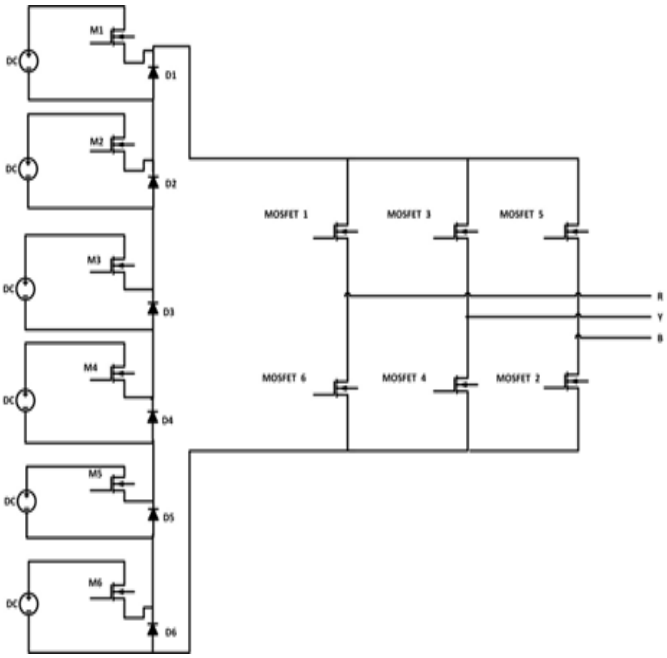


**Fig. 12.** New CMLI topology for Grid integration PV system

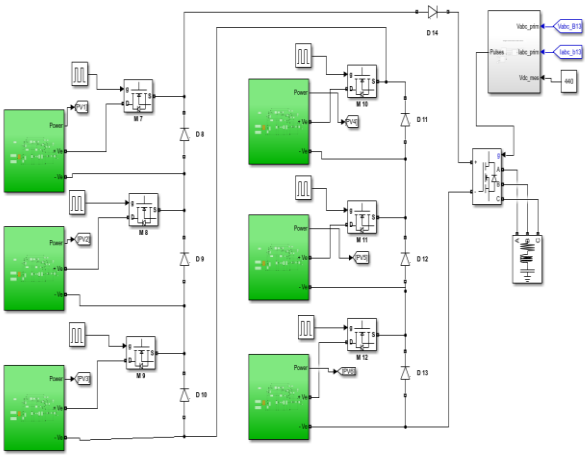

**Fig. 13.** MATLAB Simulink Model for Proposed system

Simulation has been performed and the proposed method had produced pure sinusoidal output at the CMLI terminal. The 3-phase output voltage of the device is 440V and is shown in Fig.14.This inverter design increases the performance of the device By lowering the level of THD for both current and voltage waveforms.

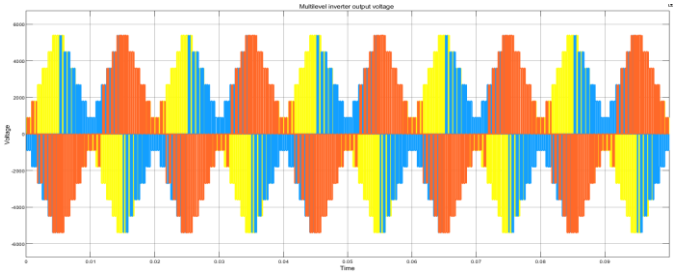

**Fig. 14.** Proposed system inverter output voltage – 440 V (13 levels)

## 4 Multilevel Inverter based Grid Integration of PV System

### 4.1 Integration of the grid:

The grid-interfaced proposed PV system configuration is seen in Fig. 15 and the grid integration model of the PV system using the multi-level inverter proposed to be operated by an artificial intelligent controller as seen in Fig.16. With the aid of the new cascade multi-level inverter, six PV sources are installed in the grid.

The inverter provides the pure grid output, while grid parameters will be taken to generate PWM for the proposed MLI as a reference for the voltage source converter (VSC). Six PV sources are used in the proposed simulation model, and each has a power supply capacity of 5,300 W [12]. The overall PV power is 32 kW interfaced to grid through new CMLI as shown in Fig. 15. In order to boost energy efficiency, and lower the THD voltage value and current waveform, the new multi-level inverter has been connected to the microgrid system via an LC filter [11].

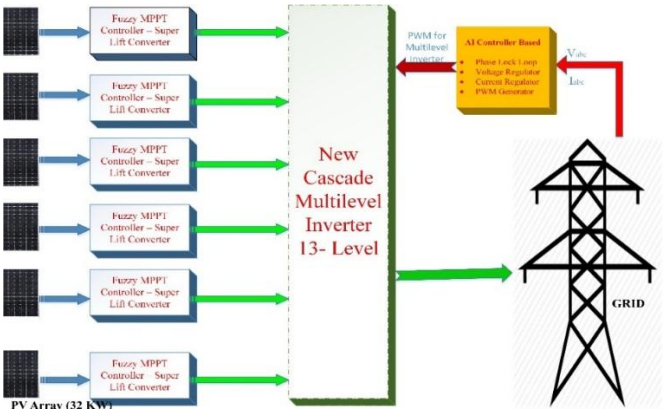


**Fig. 15.** The layout of the proposed system

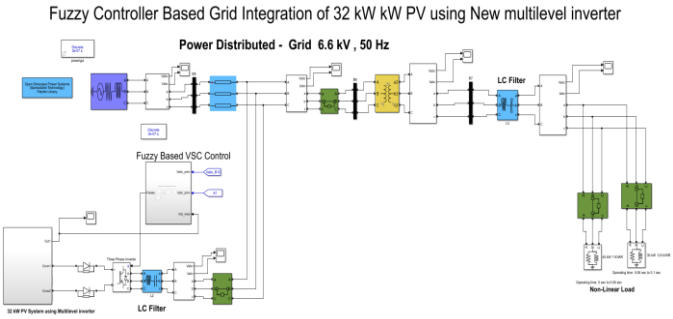


**Fig. 16.** MATLAB Simulink model for proposed AI-based PV system

### 4.2 Results and Discussion:

The AI-based proposed configuration has been simulated and the total inverter (multilevel) power generating capacity is 32 kW. The suggested CMLI is aligned with the power grid and is seen in Fig. 18. with its current and voltage waveform.

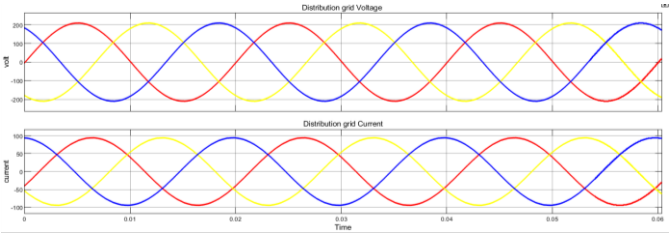


**Fig. 17.** Voltage and Current waveform of the proposed system at the grid side

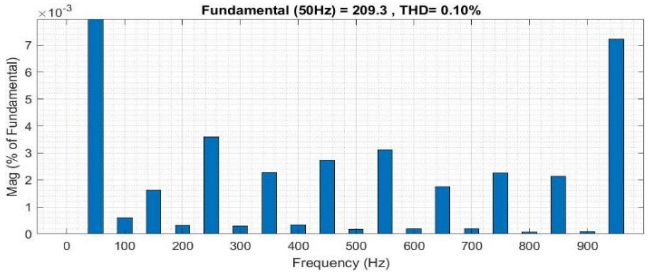


**Fig. 18.** THD for Voltage waveform

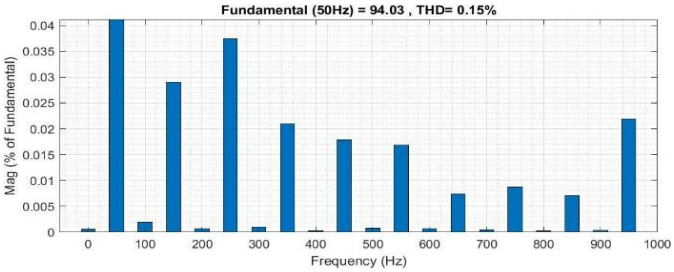


**Fig. 19.** THD for current waveform

THD is a calculation that indicates how much distortion there is voltage or current is induced by the harmonics in the signal and also, it's a significant feature of the power grid. The proposed CMLI having a smaller number of switches and having 13 level output. If the number of levels at output side increases THD getting reduced. In addition, LC filter is used in between the grid and CMLI terminal which is reduce further THD present in the voltage and current waveforms. At which less THD is accomplished at the new CMLI terminal which is evidence of the good power system's quality. The proposed CMLI increased the quality of the PV power system connecting to the power grid by evaluating and addressing its current and voltage THD levels in which the THD voltage level is 0.10 percent and the current THD level is 0.15 percent as seen in Fig. 19. and Fig. 20 respectively. To show the efficacy of the method, the THD above was calculated in compliance with standard IEEE 519&1547.

## 5 CONCLUSION

The super lift Luo three-stage converter was created in MATLAB Simulink and its output was examined under various operational circumstances. The fuzzy logic controller was built to analyse the performance of the solar system and the super lift Luo converter under various weather situations. The planned PV-new CMLI grid integration was simulated in MATLAB. The number of switches used in the system will rise as the amount of new CMLI increases, increasing the harmonic content of the PV system. The fuzzy logic controller was created to enable multi-level inverter grid integration and its output was simulated using IEEE 519 and 1547 to illustrate suggested system quality. Finally, the suggested multilayer inverter and controller system is highly recommended for both grid and autonomous industrial applications for hybrid clean energy sources.

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