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# PV to Grid Connected System with New MPPT Algorithm

***Hemant Watty[1], S. K. Verma[2]***

Student[1], Professor[2]
NRI Institute of Research and Technology, Bhopal

**ABSTRACT—**

In this article, a grid-connected photovoltaic system based on multilayer inverters (MLI) is modelled. The cascaded T-type inverter is responsible for developing the MLI topology. Connecting the PV sources in series raises the input voltage, making it challenging to connect other MLI circuits to the grid. Three-level buck-mode operation is produced by this cascaded T-type multilevel inverter (CT2MLI), which has the following benefits: a low peak inverse voltage (PIV), a low total harmonic distortion (THD), a low switching loss, and a minimal number of switches. The new umbrella MPPT technique is used to get the maximum power from a PV array. The MATLAB simulation results show that the control strategy for a CT$^2$MLI-based grid-connected PV system is efficient and effective.

***Keywords— CT$^2$MLI, FFT Analysis, Photo Voltaic (PV) System, Pulse Width Modulation (PWM), T-Type Inverter.***

## Introduction

Due to environmental concerns about global warming and CO2 emissions, the energy system is undergoing a significant shift towards the mainstream usage of green energy. In a sustainable future, distributed, small-scale smart-grid-based energy generation systems will complement the current centralised, large-grid-dependent electric power system. This objective is frequently achieved by the utilisation of renewable energy sources like solar, tidal, and wind. Since solar energy can produce a greater quantity of energy than any other fossil fuel substitute, the world is shifting towards solar solutions [1], [2].

Because solar irradiance is so widely available, researchers in various fields are interested in sun-generated power among the many renewable energy sources. PV systems use solar irradiance as an input power source. The idea of using solar energy to power electrical devices is a great one. Electricity bills are no longer a burden on our finances, nothing needs to be plugged in, and there is a limitless supply of environmentally friendly, free energy available. Of course, using solar energy in practice is a little different. Due to a variety of environmental factors, PV systems used to convert solar energy into electricity have a low conversion efficiency.

Power electronics are crucial for capturing solar energy since photovoltaic sources provide DC power, which needs to be converted into AC using an inverter. For medium-voltage and high-power applications, MLIs have drawn the most interest among various power converters. Due to its high voltage capacity, minimal harmonic distortion, and tendency to place a significantly lower voltage stress on semiconductor switches than the applied voltage to the circuit [3]. Numerous MLI topologies, including NPC-MLI, FC-MLI, MLDCL-MLI, T2MLI, and CHB-MLI, have been developed.

Among these, cascaded H-bridge inverter topology is one of the most extensively used topology as it increases the leveled AC output voltage, but requires isolated DC-link input voltage for each cell [3]-[5].

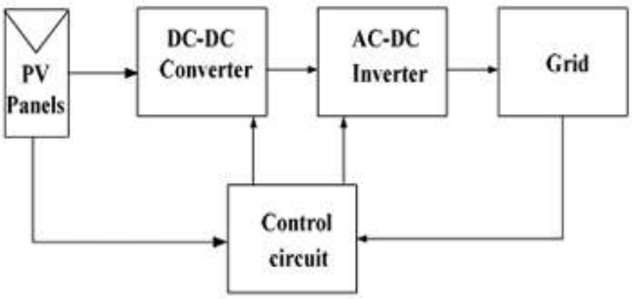



Fig.1. Block diagram of typical grid connected PV systems

The technique of varying a switch's ON and OFF duration at a fixed switching frequency is known as pulse width modulation. The literature has suggested a variety of modulation approaches for MLIs, including phase-shifted PWM, level-shifted PWM, discontinuous PWM, and others [6], [7]. LS-PWM has an uneven power distribution across each module [8]. D-PWM requires that the output waveform and switching time have a balanced relationship. Significant performance advantages of PS-PWM technology include high output waveform quality and balanced power distribution among modules. Conversely, low circuit efficiency and high frequency switching losses are some drawbacks of PS-PWM [8].

This study proposes a PV system that transmits electricity to the grid with the goal of improving the power quality of PV systems and addressing the challenge of directly connecting the increased PV output voltage of cascaded PV sources with the grid using standard topologies. The DC-DC boost converter with MPPT is the first stage of this study, and the seven-level inverter is the second. This stage uses a CT2MLI in conjunction with hybrid LS-PWM and PS-PWM to reduce the number of switches and other factors while producing a switching pulse that operates in buck-mode with a peak voltage of Vdc/2 [11]. Following this, the levelled output is linked to the grid and goes through a specially made LCL filter, producing high-quality AC output.

The work is arranged as follows: part II presents circuit topology with T-type inverter operation. Part III, includes hybrid modulation technique as LS-PWM and PS-PWM. In section IV, the results of a PV to grid connected $CT^2MLI$ based system are shown using MATLAB/Simulink. Finally, in part V, there are some closing observations.

## CIRCUIT TOPOLGY

*NOVEL UMBRELLA OPTIMIZATION MPPT ALGORITHM:*

This algorithm is intended to identify GMPP in multiple LMPP under PSCs more quickly than the P&O algorithm. Figure displays the maximum values of estimated power Pcal) in the form of a raindrop pattern. Calculated power is the result of multiplying calculated voltage (Vcal) by calculated current (Ical) at a specific time interval. The panel's configuration determines the computed voltage and current (Voc and Isc). Between zero and Voc and Isc, respectively, are the values of Vcal and Ical. Conversely, real power, or P, is determined by multiplying the panel's actual voltage (V) and current (I) at the same intervals as Pcal. The system then keeps track of the locations where, for the greatest value of Pcal, the difference (Pcal Pr) is the smallest. The program separates the local and global peaks and distinguishes between any potential peaks that may be found.

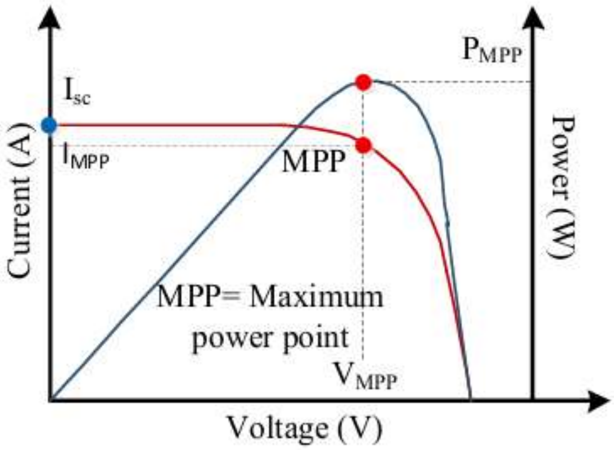



Fig.2 I-V and P-V characteristics of a PV cell

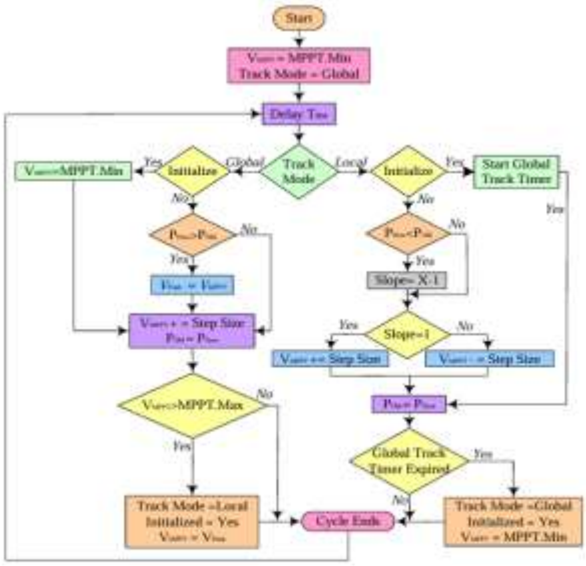



Fig.3 Flowchart of UOT based MPPT

*Design of Stage One DC-DC Boost Converter with MPPT*

The MPPT algorithm is used to collect maximum power from PV sources. The MPP on a current-voltage (I-V) curve is the point where the solar PV device produces the most Output. The power drawn from the PV array is measured at regular intervals by the P&O approach [10]. For grid-connected PV applications, a DC-to-DC boost converter is employed to maintain a steady output voltage. The boost converter converts a variable PV voltage to a more stable DC voltage by reducing the ripples. It employs feedback voltage to maintain a steady output voltage.

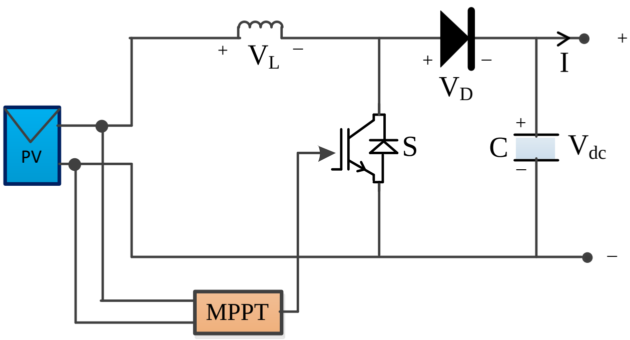



Fig. 4 DC-DC boost converter with MPPT

*Design of Stage Two T-Type Inverter*

A T-type inverter (T2I), which is appropriate for connecting to a PV array and sending power to the grid, is employed in this project. This architecture consists of a four quadrant operating bipolar and bidirectional switch (S1 and S4) and two unipolar and bidirectional switches (S2 and S3) [11]. Additionally, it has two capacitors, one of which is a dc-bus capacitor that is linked following the DC-to-DC boost converter with MPPT first stage. S1 and S4 are rated for half of the DC-link voltage, whereas S2 and S3 are rated for the full DC-link voltage Vdc. In Figure 5, the three-level T2I topology is displayed.

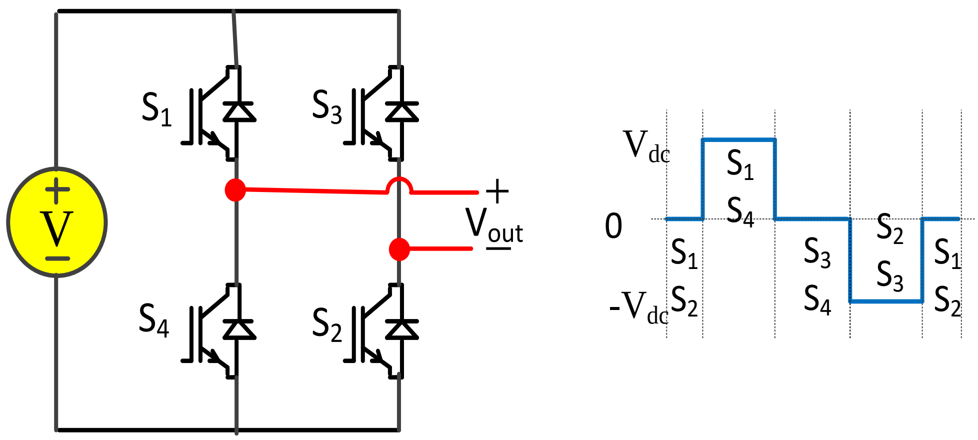



Fig. 5 H- Bridge Inverter topology

This inverter gives three output voltage levels as $+V_{dc}/2$, 0, and $-V_{dc}/2$. Different switching states are shown in Fig. 4-6. By connecting three modules in cascade can create seven-level voltage as leveled output of the inverter. This cascaded system provides a seven-leveled voltage as $+1.5V_{dc}$, $+1V_{dc,}$ $+0.5V_{dc,}$ 0, $-0.5V_{dc,}$ $-1V_{dc,}$ $-1.5V_{dc}$. Table-1 shows the different switching states of inverter. During the positive and negative state only one device is conducting, that increase the efficiency of converter.

Table-1 Switching states of H-Bridge converter

| **Voltage level** | **$S_1$** | **$S_2$** | **$S_3$** | **$S_4$** |
|---|---|---|---|---|
| $+V_{dc}$ | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 |
| 0 | 1 | 1 | 0 | 0 |
| $-V_{dc}$ | 0 | 0 | 1 | 1 |

The main objective of an inverter is to produce AC output power from the DC input power. The inverter has power devices and associated controllers.

Figure 5 shows the circuit topology of a single phase, two-level power inverter and its AC output. The output is produced by controlling the four switches for the single-phase inverter. Switches $S_1$ and $S_4$ are turned ON to obtain $+V_{dc}$, whereas $-V_{dc}$ can be obtained by turning ON switches $S_2$ and $S_3$. When ($S_1$ and $S_2$) or ($S_3$ and $S_4$) are ON, the output voltage is 0. The frequency of the resulting output voltage can be controlled by controlling the duration of the ON time of the switches.

## MODULATION TECHNIQUE

To provide a low and fixed switching frequency for high power and industrial applications, PWM should be used to provide sufficient switching pulses. Some switching techniques, such as hysteresis, have a variable switching frequency, resulting in annoying auditory disturbances. To modulate the measured reference signal, carriers are transferred vertically.

A hybrid level-shifted and phase-shifted high frequency PWM technique is used in this study to generate switching pulses. All carrier signals are responsible for producing gate-pulses for associated voltage levels and switching states. As shown in Fig. 7, "(m-1)" carrier signals are used for "m" level output voltage, including zero level output, with a phase shift of "(n-1)×3600/N," where "n" denotes the corresponding nth leg and "N" is the total number of legs used to create the cascade. When compared to alternative topologies, the suggested method guarantees a low and constant switching frequency for the converter, which lowers switching losses and improves performance.

## RESULTS

This work proposed as a PV to grid connected system, processed in two stages where, stage one is the DC-DC boost converter with MPPT and second stage is the seven-level inverter. For this stage, three modules of T-type inverter are connected in cascade. This cascade connection of $T^2I$ generates seven-level output voltage as $+1.5V_{dc,}$ $+1V_{dc,}$ $+0.5V_{dc,}$ 0, $-0.5V_{dc,}$ $-1V_{dc,}$ $-1.5V_{dc}$. After this stage leveled output passes through designed LCL filter and AC output connected to grid.

This study uses a specific PV module with 1 parallel and 6 series connected strings to replicate a 2kW power rating. According to the PV module, the maximum PV output voltage is 250V, with a peak-to-peak ripple of 50V approx. This high voltage ripple can cause to damage the system, degrade its efficiency, and increase system losses. To reduce this much higher ripple voltage DC-to-DC boost converter is employed. DC-DC boost converter's output voltage is ripple-free and as high as 300V shown in Fig. 8.

The output of the DC-to-DC boost converter is regulated by perturb and observe method of MPPT. This converter worked as a first stage of proposed system and work on a 5kHz switching frequency. PV system generates power in a form of DC so here, required an inverter which converts this DC power into the leveled AC power. It is a second stage of the proposed method; this stage converts DC voltage into the leveled AC voltage using cascaded $T^2I$ topology.

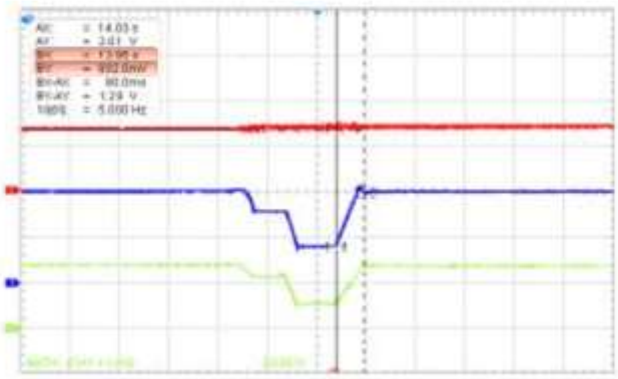


Fig.6 Voltage, current and power transient response using UOT MPPT

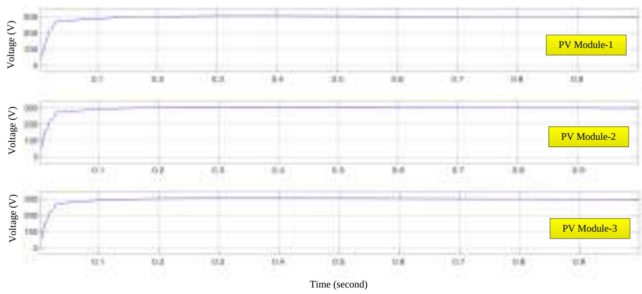
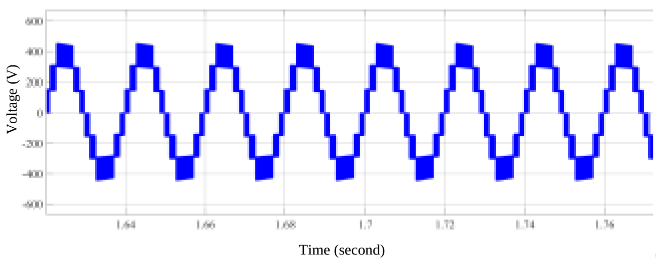



Fig. 7 Output voltage of DC-DC boost converter




(b)

Fig. 8 Cascaded seven-level output voltage waveform

A three-level inverter is operated by applying a PWM switching pulse using the suggested hybrid LS-PWM and PS-PWM technique. As seen in Fig. 9(b), the cascading of these three modules produces a seven-level voltage at the system's output. In Figures 10 and 11, grid parameters are displayed. There is some ripple since the inverter current was measured prior to the LCL filter. In Figure 11, grid voltage and grid current are shown on the same axis, demonstrating that both are in phase and provide the grid with active power. This suggested system replicates an inverter operating at a switching frequency of 10kHz with a power rating of 2kW.

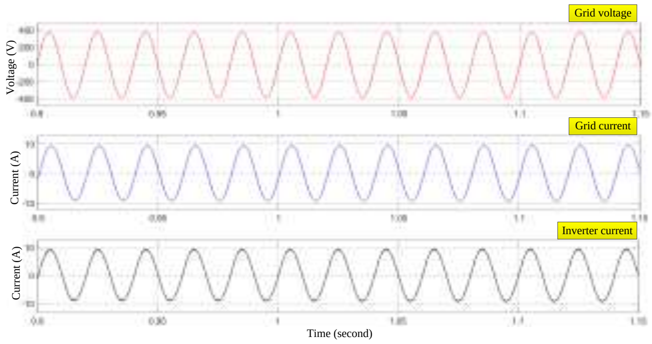



Fig.9 Grid voltage, grid current, inverter current

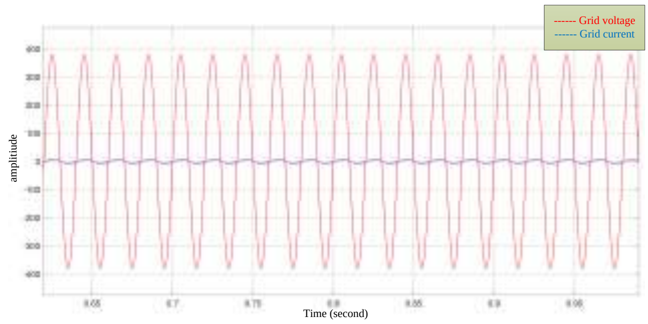



Fig. 10 Grid voltage and grid current are in phase

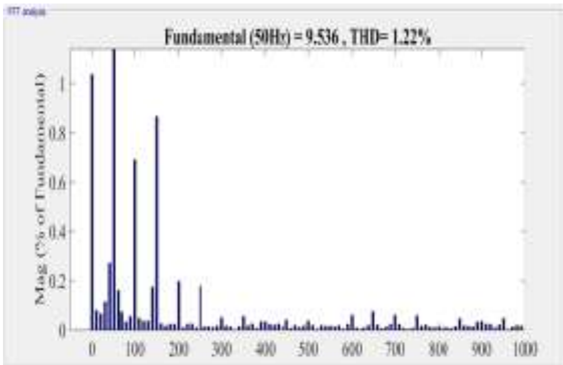



Fig. 11 FFT analysis of grid current

For verification of reduced harmonics, FFT analysis is done by using MATLAB platform. FFT analysis of grid current shown in Fig. 12. The FFT analysis of grid current shows maximum power component present at the 50Hz frequency also second maximum component present at the 150Hz frequency but its only 0.9%. So, 99.1% component present at the grid frequency so it's justified, that it reduces the harmonics.

## CONCLUSION

A power electronic converter, created by cascading T-type inverters, is necessary for connecting renewable energy sources to the grid. An inverter that transforms DC electricity into levelled AC is necessary since PV systems produce power in this form. In this study, the control approach for the cascaded T-type inverter using PV arrays as independent DC sources is established. Cascaded T-type inverters that use hybrid PWM, which combines the LS-PWM and PS-PWM strategies, make switching states for cascaded multilevel systems simpler. The simulation results demonstrate that it is possible to balance the capacitor voltages by employing this enhanced selection mechanism as the modulation technique.

Additionally, the harmonic distortion is lessened by the levelled output voltage. The T-type inverter is thoroughly examined in relation to THD. The results clearly show that the T-type inverter topology with maximum continuous boost control produces a high-quality output voltage waveform with high dependability and low THD.

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