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Cascaded H-Bridge Multilevel Inverter with Solar Based on Sinusoidal Pulse Width Modulation

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***Abstract*— Cascaded H-Bridge (CHB) multilevel inverters are widely used in solar power systems due to their ability to produce high-quality voltage waveforms with reduced harmonic distortion. This paper reviews the design, operation, and advantages of a five-level CHB multilevel inverter powered by solar energy and utilizing Sinusoidal Pulse Width Modulation (SPWM). The CHB topology is known for its modular structure, scalability, and efficiency, which make it suitable for medium to high-power applications in renewable energy. SPWM is employed to achieve precise control of the inverter's output voltage, improving power quality and minimizing losses. Solar energy, being a fluctuating source, poses challenges in terms of maintaining consistent voltage levels; however, the CHB multilevel inverter can effectively address these issues through its multilevel structure and modulation techniques. The integration of SPWM with CHB provides a robust and cost-effective solution for converting solar DC output into an efficient, high-quality AC supply suitable for grid-connected and standalone applications.**

Keywords*— *Cascaded H-Bridge, Multilevel, Inverters, Three-Phase, Grid-Connected.

I. INTRODUCTION

The rapid growth of renewable energy has intensified research and development in inverter technologies that can effectively convert and optimize solar power. Solar energy, one of the most sustainable and clean sources of electricity, often relies on efficient inverters to convert the DC output from photovoltaic (PV) panels into AC power [1]. Multilevel inverters, especially the Cascaded H-Bridge (CHB) type, are increasingly popular in this context due to their capability to produce smoother waveforms, reduce total harmonic distortion (THD), and increase overall energy efficiency. Among various multilevel inverter topologies, the CHB architecture is particularly attractive because of its modular structure, which allows for easy scalability and redundancy, making it well-suited for medium to high-power applications in renewable energy systems [2].

A five-level CHB multilevel inverter offers significant advantages over traditional single-level and even three-level inverters by producing a higher number of voltage levels, which leads to a closer approximation of a sinusoidal waveform and minimizes THD. Each level in the CHB inverter is achieved through a series of H-bridge cells, each connected to its own DC source—typically solar panels in solar applications. This configuration enables greater flexibility in power conversion and results in improved power quality, making it ideal for integrating with the grid and other sensitive electronic devices [3].

One of the key techniques used to control the switching of multilevel inverters is Sinusoidal Pulse Width Modulation (SPWM). In SPWM, a sinusoidal reference waveform is compared with a high-frequency triangular carrier wave to determine the inverter's switching states [4]. This method helps control the output voltage while reducing harmonic distortion, thereby improving efficiency and enhancing power quality. For CHB multilevel inverters in solar applications, SPWM offers an effective way to manage varying input conditions due to fluctuating sunlight and optimize the inverter's performance under different load requirements. By controlling the duty cycle of each H-bridge's output, SPWM facilitates smooth voltage transitions, reduces switching losses, and ensures that the AC output closely resembles a pure sinusoidal wave, which is essential for both grid compliance and high-efficiency power conversion [5].

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II. PROPOSED MODEL

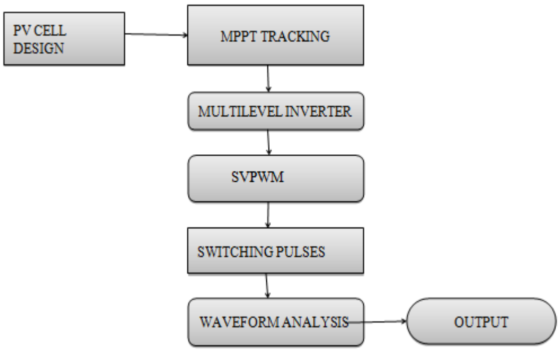

Figure 1: Flow Chart

In proposed three phase, six switch, full-bridge inverter is used to reduce the harmonic level. The SPWM very help full to making the switching pulse with better perform output. In this paper, constant switching frequency and variable switching frequency based on carrier pulse width modulation methods are presented and compared. A new modulation method called trapezoidal triangular multi carrier (TTMC) SPWM is implemented and compared with other methods. This new modulation method gives advantages in multilevel inverter to minimize the percentage of total harmonic distortion (THD) and to increase the output voltage.

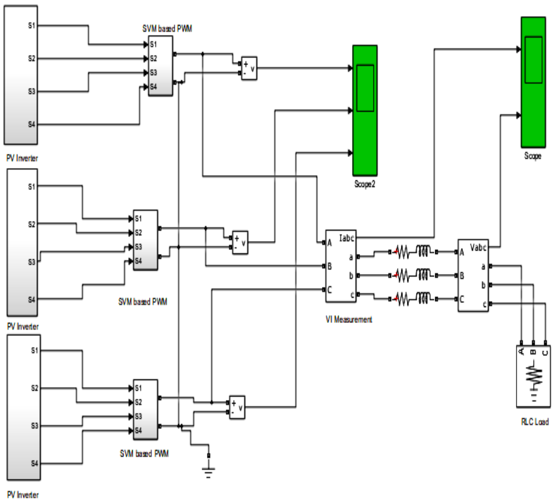

Figure 2: Proposed model

Figure 2 is showing proposed cascaded H-Bridge multilevel PV inverter. This model consists various sub models which is described in details.

Sub-Modules

- PV Cell
- Inverter
- SVM based PWM (SPWM)
- Analysis

III. SIMULATION RESULT

The implementation of the proposed model is done over MATLAB 9.4. The various electrical toolbox and blocks helps us to use the functions available in MATLAB Library for various design strategy.

Case –I

The waveform simulated value is assigned for sine wave and S1, S2, S3 and S4 carrier wave. The phase angle in rad is 0.

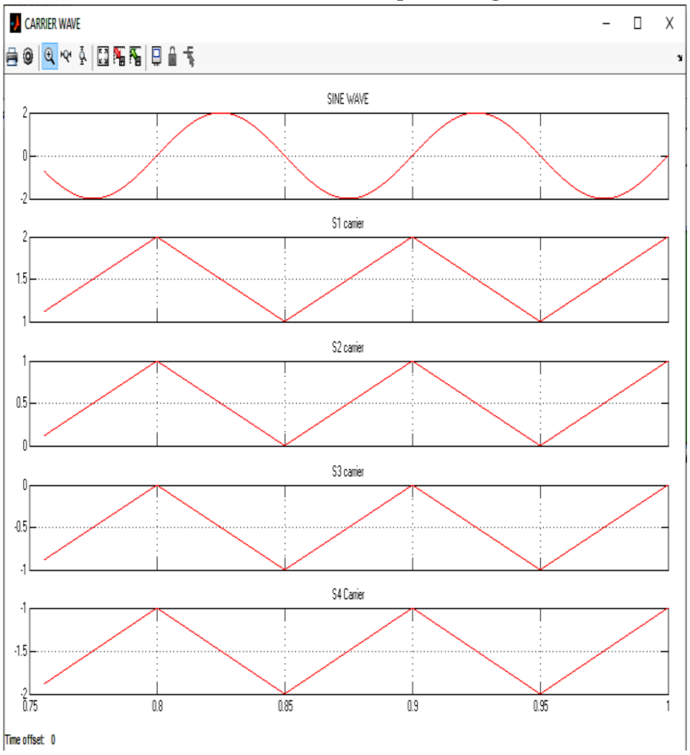

Figure 3: Sine wave and Carrier wave

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Figure 3 is showing the sine wave and all carrier wave. A theoretical sine wave is a "pure" wave in that it has no harmonics and involves zero bandwidth in the recurrence space. X hub is showing the time scale and Y pivot is showing the adequacy of wave. A switching succession framed by a few switching conditions of the converter is performed and the normal estimation of the yield voltage must correspond with the ideal reference.

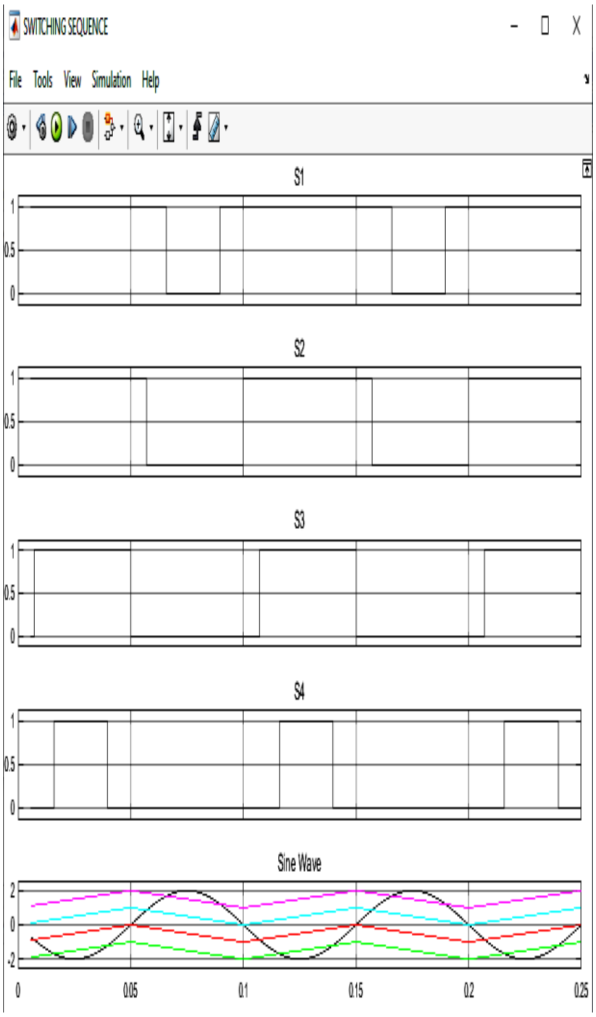

Figure 4: Switching Sequence

A switching grouping shaped by a few switching conditions of the converter is performed and the normal estimation of the yield voltage must concur with the ideal reference.

Case –II

The waveform simulated value is assigned for sine wave and S1, S2, S3 and S4 carrier wave. The phase angle in rad is 2*pi/3 or 120' phase shift.

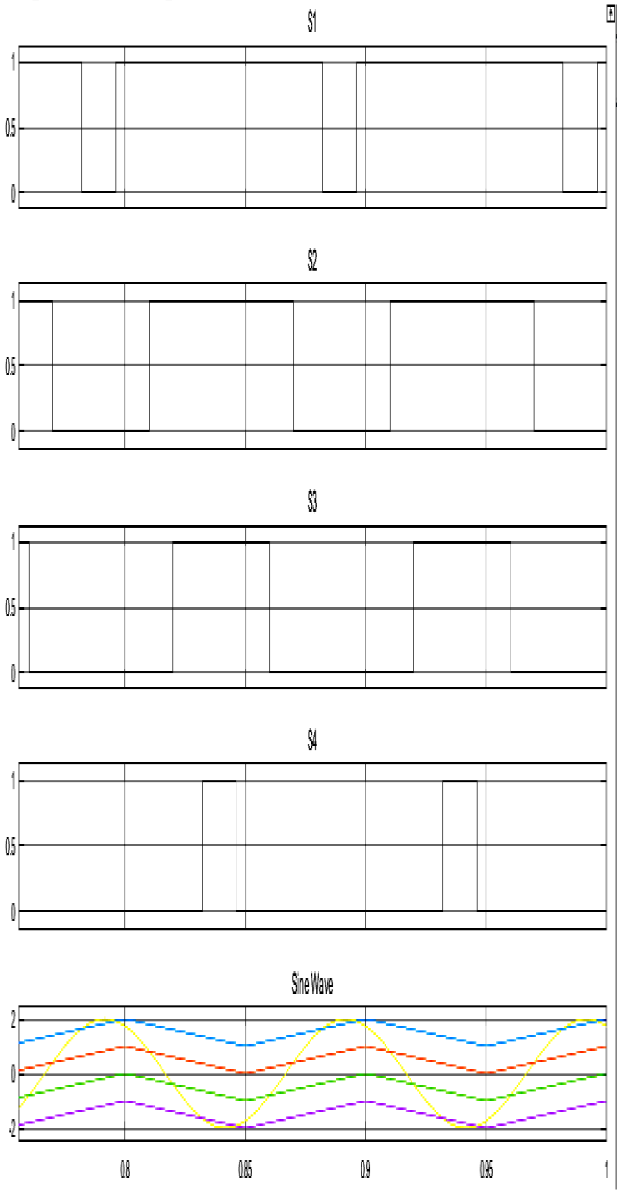

Figure 5: Switching Sequence shifted 120'

Figure 5 is showing the switching sequence of S1, S2, S3 and S4. A switching sequence formed by several switching states of the converter is performed and the average value of the output voltage must coincide with the desired reference.

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Case –III

The waveform simulated value is assigned for sine wave and S1, S2, S3 and S4 carrier wave. The phase angle in rad is -2*pi/3 or -120' phase shift.

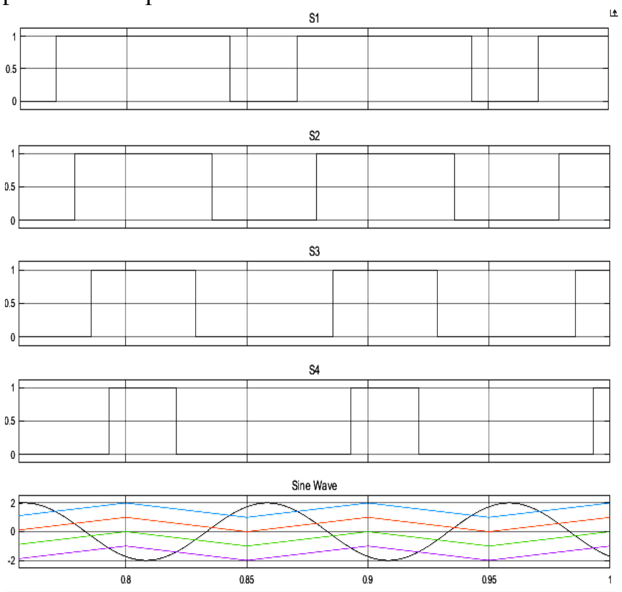

Figure 6: Switching Sequence shifted -120'

Figure 6 is showing the switching sequence of S1, S2, S3 and S4. A switching sequence formed by several switching states of the converter is performed and the average value of the output voltage must coincide with the desired reference.

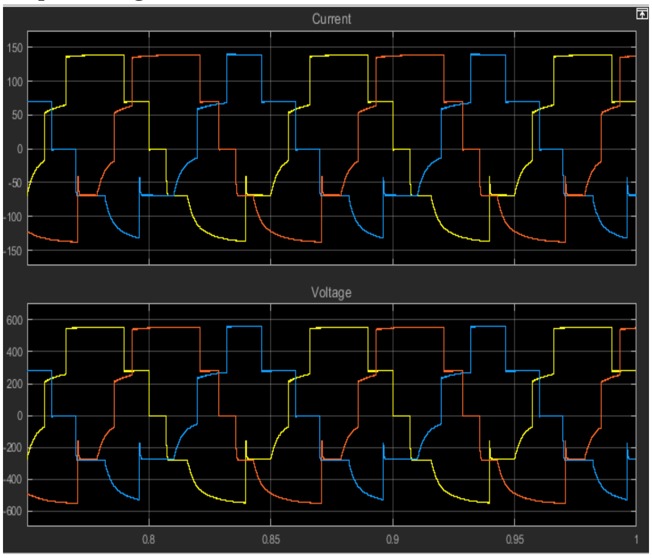

Figure 7: Inverter Output

Figure 7 is showing the multilevel inverter output current and voltage. The output voltage is 550 Voltage and current is 140 A.

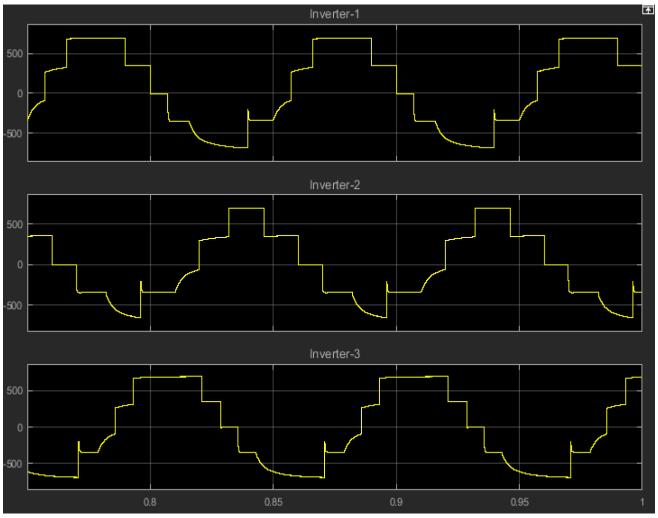

Figure 8: Inverter Voltage

Figure 8 is showing the multilevel inverter cases output voltage. All three cases have approx 550Voltage at different angle.

Solar Irradiance of PV1

In this subsection, after keeping the starting input conditions of the PV modules at 1000W/m^2 irradiance and 25'C temperature, the temperature of PV1 is changed to 35'C.

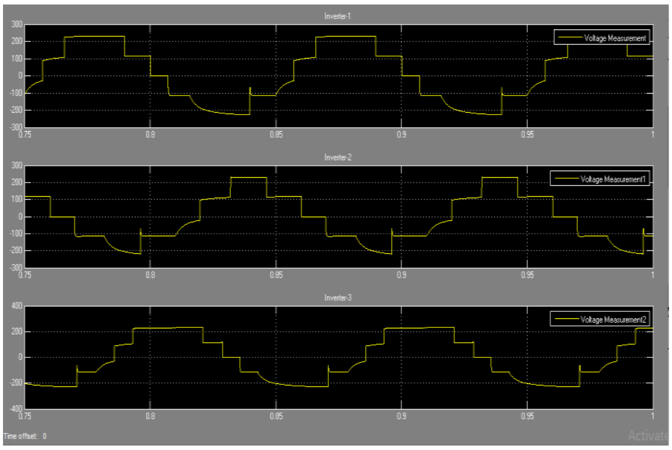

Figure 9: Inverter performance when PV1 and T 35'C

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In this condition conditions consider the solar irradiance of the module PV1 is changed from 1000 to 600W/m^2.

Step Change in Temperature of PV 2A

The temperature of PV2A is changed from 25'C to 35'C in this subsection.

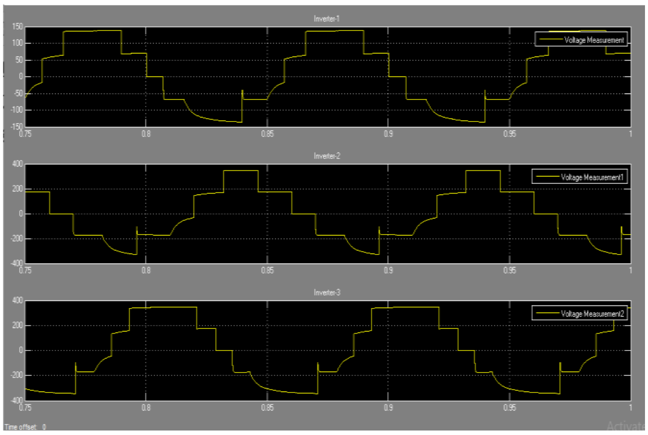

Figure 10: Inverter performance when PV2A and T 35'C

Table 1: Simulation parameters

Sr No.	Parameters	Proposed Work
1	PV irradiance	1000 W/m^2
2	Switch	3 MOSFET and 12 IGBT
3	Inverter output voltage	550 V
4	Inverter output current	140 A
5	Inverter voltage 0 angle	550V
6	Inverter voltage +120 angle	550V
7	Inverter voltage -120 angle	550V
8	Controller	PWM

Table 1 presents simulation parameters like PV irradiance value, Inverter voltage and current and controller.

Table 2: Result Comparison

Sr No.	Parameters	Previous Work	Proposed Work
1	Methodology	Grid Connected Photovoltaic Systems	SPWM
2	Switch per level	6	5
3	Switch type	MOSFET and IGBT	MOSFET and IGBT
4	Power (W)	600	770
5	Overall Efficiency (%)	94.26	98
6	MPPT Efficiency (%)	99.03	99.5
7	Inverter Efficiency (%)	96.33	98

The MPPT efficiency, inverter efficiency, and overall efficiency are deepened as simulation parameters. The proposed model gives MPPT efficiency is 99.5% while existing model gives 99.03% efficiency.

IV. CONCLUSION

This paper presents a modular cascaded H-Bridge multilevel photovoltaic (PV) inverter for single-or three-phase grid-associated applications. The simulated outcomes shows that the MPPT productivity, inverter effectiveness, and in general proficiency which are developed as reproduction boundaries. The proposed model gives MPPT productivity is 99.5% while existing model gives 99.03% effectiveness. The inverter productivity is 98% while existing have 96.33 and in general proficiency achieved by proposed model is 98% while existing is 94.26%. Therefore, proposed model reenactment result execution is superior to past model in wording proficiency and no of switches.

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