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Solar Powered Multilevel Inverter and Battery using MPPT Technique with Inverted Sine Modulation Control Strategy

Shara Kandula[1], Dr.G.Annapurna[2]

[1]*PG Student, Dept. of EEE, G.Narayanamma Institute of Technology and Science, Telangana, India*
[2]*Professor, Dept. of EEE, G.Narayanamma Institute of Technology and Science, Telangana, India*

Abstract - *Now a days non-renewable energy sources are diminishing and hence we are going for renewable energy resources. Solar photovoltaic system is sustainable, ecological and it can withstand rising load needs. Because solar PV modules output varies according to the weather, the system's efficiency is reduced. To extract the most power possible, the maximum power point (MPP) tracking approach must be used. In order to achieve the intended outcomes, this study suggests implementing the MPPT in charge controller's perturb and observe (P and O) algorithm utilizing a boost converter. A bidirectional/two-way DC to DC converter connected to battery which in turn can be used as electric vehicle battery. Multilevel inverter with inverted sine modulation technique integrated with PV modules is being analyzed. This paper also presents the contrast of sine PWM and inverse sine PWM control strategies for different levels. The proposed techniques offers improved proficiency and performance contrast to SPWM and also generates less harmonics, switching losses. The proposed project is carried through MATLAB/SIMULINK.*

Key Words: **PV system, Battery, Maximum/Peak Power Point Tracking, Inverted/Inverse Sine Modulation Control Strategy(ISPWM), DC-DC Converter.**

1.INTRODUCTION

These days, the global energy crisis and pollution management are the main issues. The majority of electricity is produced using non-renewable resources, and as the demand for electricity is growing daily, these sources will eventually run out of supply. One of the renewable energy sources is Photovoltaic (PV) modules that are coupled to the grid are a viable substitute for autonomous and sustainable energy source. By continuously modifying the electrical functioning point of the modules or arrays, Maximum/Peak Power Point Tracking (MPPT) is a technology used in photovoltaic modules to maximize the power production from solar energy panels. This technique ensures that the solar energy panels function at their maximum power point (MPP), where they can produce the highest possible power under varying environmental conditions. Power electronic technology, which is widely used and developing quickly, is crucial to distributed generation and the inclusion of non-exhaustible energy sources into the electrical grid. Due to a number of benefits, including better spectral performance with a lower switching frequency than traditional inverters, which in turn reduces switching losses, multilevel voltage-source converters have become one of the finest options for medium-voltage, high power applications. Because of its modular circuit construction, the CHB converter is one of the top well-liked multilevel inverter topologies. Comparing the CHB topology to other topologies, fewer DC-link capacitors are needed[1]. With their superior efficiency over traditional two-level inverters and their capacity to produce high-quality output waveforms with little harmonic distortion, Multilevel/Multistage Inverters (MLIs) are a cutting edge in power electronics technology that have drawn a lot of interest. Multiple power switches are used by MLIs to produce a stepped waveform that resembles a sine wave solution. Recently the use of renewable energy resources has been increased to save the environment and remaining fossil fuel and the requirement of storing the energy is also increased[2].

The primary tool for interacting with the battery as a storage device to improve system reliability is a bidirectional dc to dc converter. In electric vehicles also, bidirectional converter is used in between source of energy and motor for supplying power from storage device to motor. Thus, bidirectional dc to dc converters are getting more and more attention in academic research and in industrial applications[2].

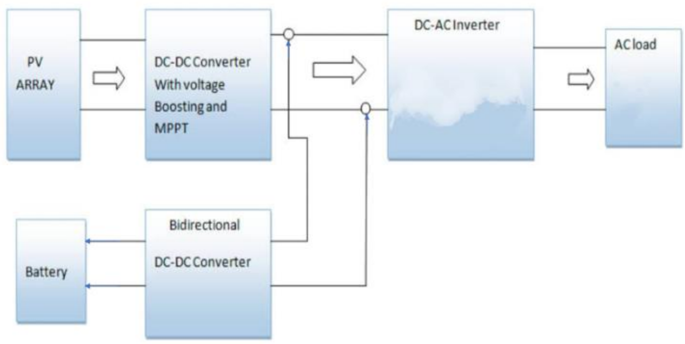
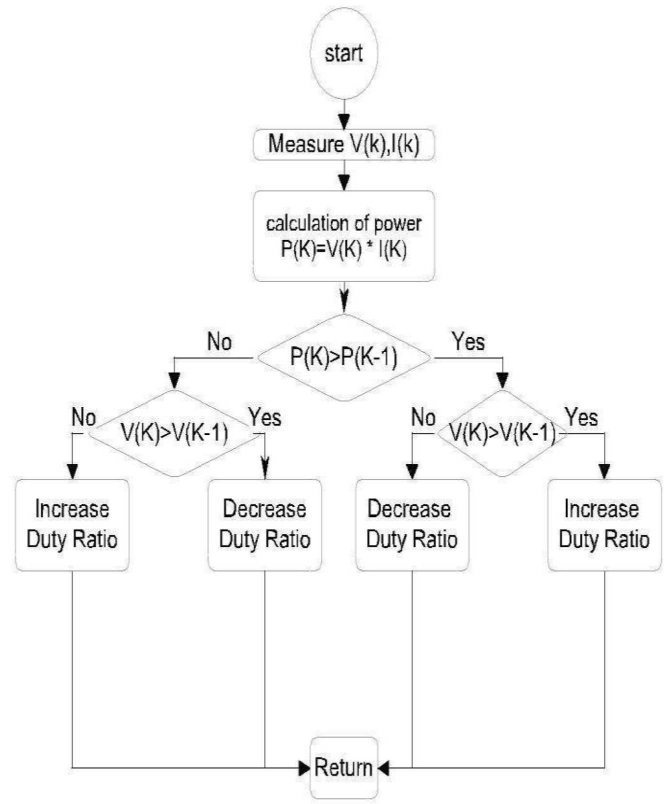


Fig -1: Schematic Diagram of PV system with inverter and battery with Bidirectional DC-DC converter

In this paper, PV system is used as renewable energy source and MPPT to track maximum power for varying weather conditions. Cascaded h-bridge MLI is used as DC-AC inverter and it is supplied by PV and Battery through Bidirectional/Two-way DC-DC converter. The 3 and 5 level CHB MLI with SPWM, ISPWM are compared.

2.MAXIMUM/PEAK POWER POINT TRACKING

One of the most popular Maximum Power Point Tracking (MPPT) strategies for photovoltaic systems is the Perturb and Observe (P&O) method. This approach is well-liked since it is straightforward and simple to use. P&O method works by regularly altering (i.e., incrementing or decrementing) the voltage/current of the PV array and observing/monitoring power shift. The principle is to relocate the functioning point of PV system toward the MPP by comparing the power before and after the perturbation. Requires fewer components and computational power compared to other MPPT techniques.



Flow chart of Perturb and observe algorithm

3.CASCADED MULTILEVEL INVERTER (CHB MLI)/ CASCADED MULTISTAGE INVERTER

It is of multiple H-bridges, each connected in series on the AC side and each having isolated DC source. Every H-bridge has 4 power switches, generate three voltage levels: positive, zero, negative. For an N-level CHB inverter, if there are k H-bridges in a phase, the inverter can produce 2k+1 voltage levels (from -kVdc to +kVdc). For a 5-level inverter, the final voltage V= Vdc1 + Vdc2, where V represents the final voltage.

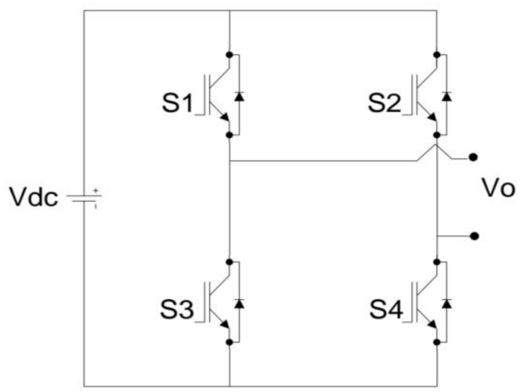


Fig -2: Single phase three-level CHB Multistage Inverter

Table -1: Switching sequence of three-level CHB Multistage inverter

Switching states	Output voltage
S1, S4	Vdc
S2, S3	-Vdc
S2, S4	0

This three-level inverter is of 4 switches and 1 DC source. The three voltage levels are +Vdc when S1 & S4, 0 when S2 and S4 or S1 and S3, -Vdc while switches S2 & S3 are activated.

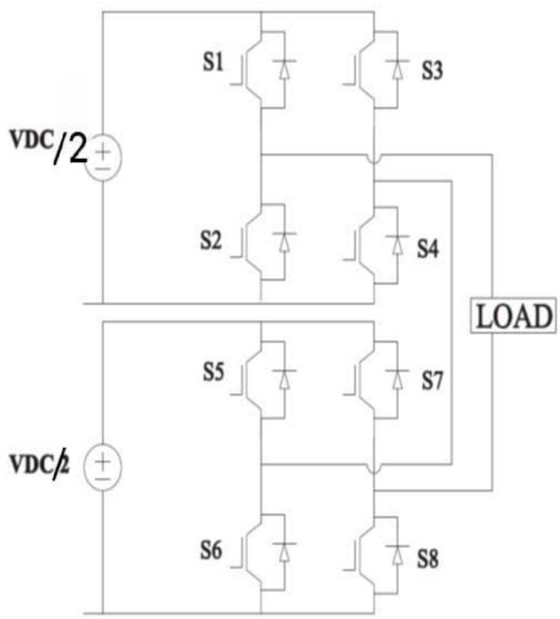


Fig -3: Five-level CHB Multistage Inverter

In a 5-level CHB Multistage Inverter two H-Bridges are in series per phase. Zero, +Vdc/2, +Vdc, -Vdc/2, and -Vdc are the five voltage levels. The +Vdc/2 level is created when switches 1, 8, and 4 are initially turned on, permitting only one DC source to conduct. Next, the activation of switches 1, 8, 4, and 5 results in the conductivity of both DC sources and the generation of +Vdc. After that, switches 2, 6, and 3 are activated. This uses a single DC supply and causes current to flow in the other direction, producing -Vdc/2. Lastly, the activation of switches 2, 6, 7, and 3 results in the conductivity of both DC sources with current flowing in the opposite direction, creating -Vdc[3].

Table -2: Sequential switching of five-level CHB inverter

S1	S2	S3	S4	S5	S6	S7	S8	V_o
ON	OFF	OFF	ON	ON	OFF	OFF	ON	V_{dc}
ON	OFF	OFF	ON	OFF	ON	OFF	ON	$V_{dc}/2$
OFF	ON	OFF	ON	OFF	ON	OFF	ON	0
OFF	ON	ON	OFF	OFF	ON	OFF	ON	$-V_{dc/2}$
OFF	ON	ON	OFF	OFF	ON	ON	OFF	$-V_{dc}$

4.SINUSOIDAL PULSE WIDTH MODULATION (SPWM)

One of the most often used methods for changing a DC voltage to an AC voltage is sine pulse width modulation (SPWM). The reference is sine signal and the carrier is triangular. This technique compares sine and triangular signals, and if the sine signal's amplitude is larger than the triangular signal's, a pulse is generated for the positive half cycle; if the triangular signal's amplitude is greater than the sine signal's, a pulse is generated for the negative half cycle[4].

5.INVERTED/INVERSE SINUSOIDAL PULSE WIDTH MODULATION(ISPWM)

This approach uses sine waves as reference signals and inverted sine waves as carrier waves. When the amplitude of the sine wave is greater than that of the inverted sine wave, switching signals are produced by comparing the two sine waves[5].

When using this method instead of traditional SPWM, the Harmonic Distortions are usually reduced.

The equations for generating inverted sine waves are:

$$x.P_1=R \quad (1)$$

$$P_2*x*-1=S \quad (2)$$

Where x = sine wave

P_1 = {1 if $|x| \geq 0$

{0 if $|x| < 0$

P_2 = {1 if $|R| \leq 0$

{0 if $|R| > 0$

R = Positive half cycle of sine wave

S = Inverted sine wave

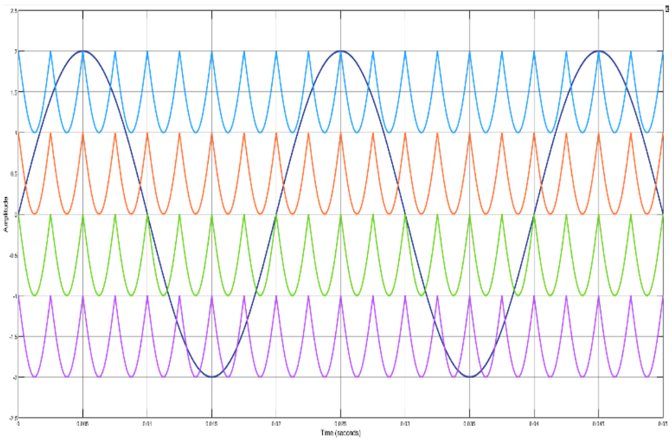


Fig -4: Inverse sine waveforms as carrier for ISPWM

6.BIDIRECTIONAL DC-DC CONVERTER (TWO-WAY DC-DC CONVERTER)

The output of the renewable energy system fluctuates owing to changes in the weather, so a bidirectional DC to DC converter is utilized as a crucial component to interface the storage devices among source and load in the renewable energy system(RES) for continuous power flow. It is commonly referred as a two-way DC-DC converter. Bidirectional dc to dc converters work in both buck and boost mode and can manage the flow of power in both the direction between two dc sources and load and hence generated excess energy can be stored in batteries[2].

- In Buck operation battery gets charged.

  S1 ON, S2 OFF

- In Boost operation battery gets discharged.

  S1 OFF, S2 ON

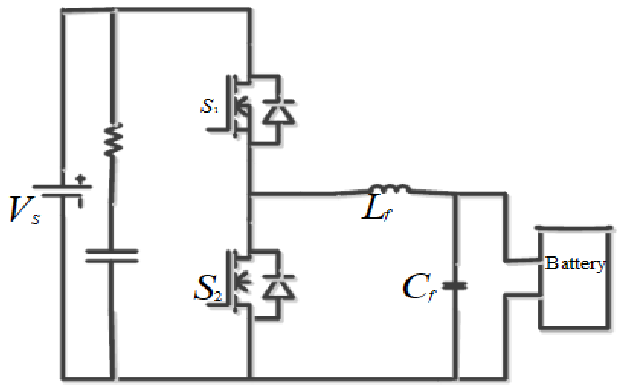


Fig -5: Bidirectional DC-DC converter

7.SIMULATION RESULTS & ANALYSIS

A) MATLAB Simulation of three-phase three-level and five-level CHB inverter using SPWM

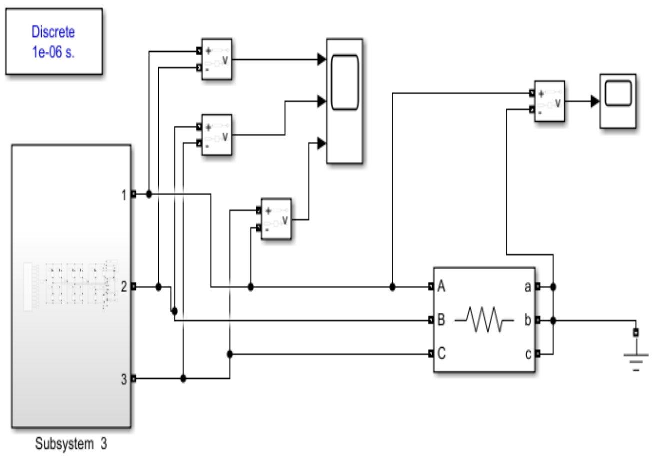


Fig -6: MATLAB Simulation of three-level Multistage Inverter with Sine PWM

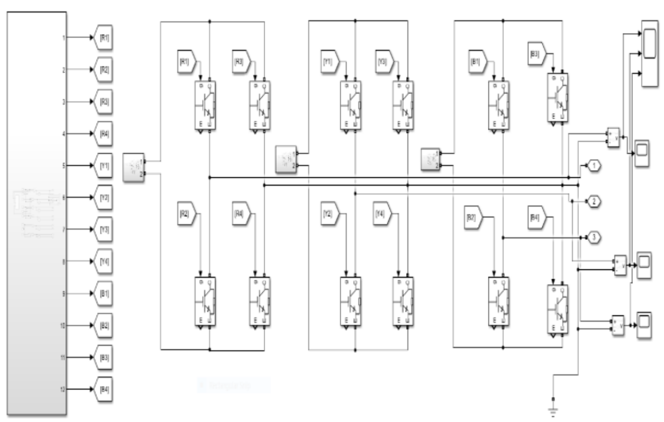


Fig -7: MATLAB Simulation of three level CHB Multistage Inverter

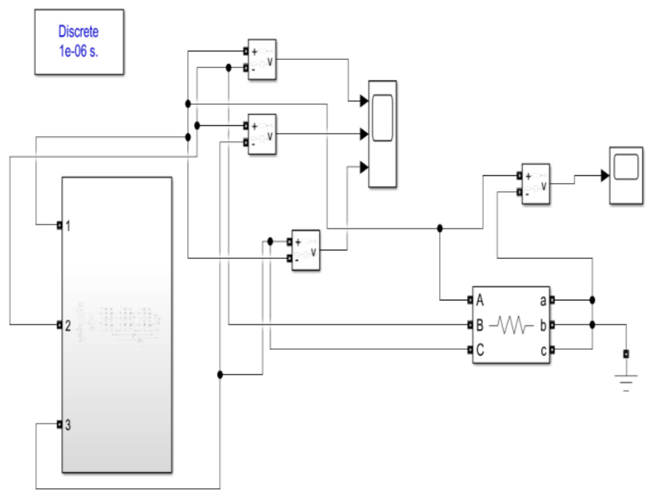


Fig -8: MATLAB Simulation of five level CHB Multistage Inverter with Sine PWM

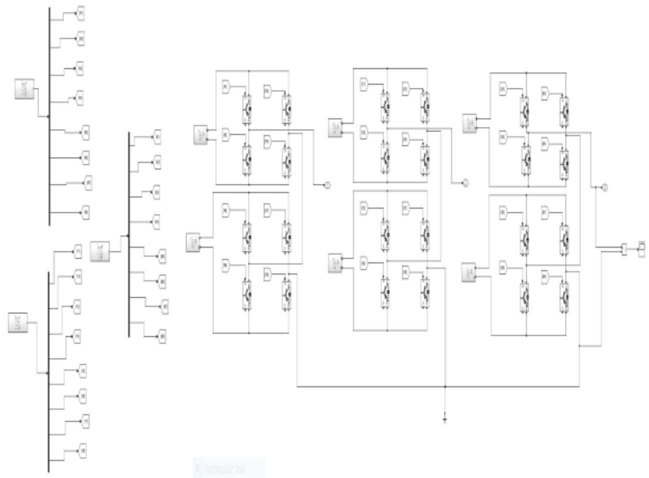


Fig -9: MATLAB Simulation of five level CHB Multistage Inverter

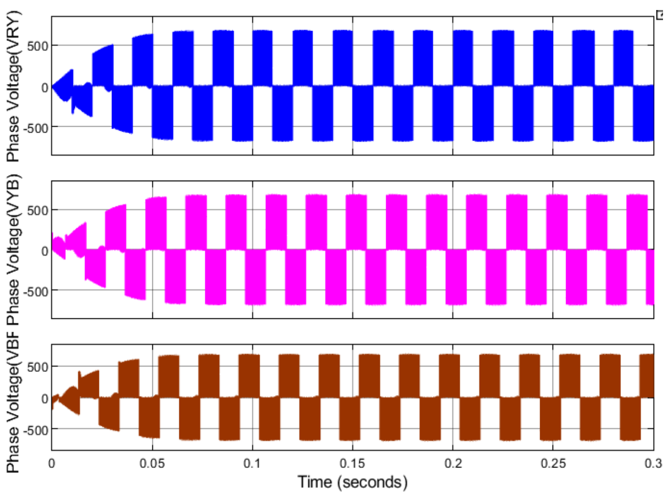


Fig -10: Phase-ground voltages of three level CHB Multistage Inverter with Sine PWM

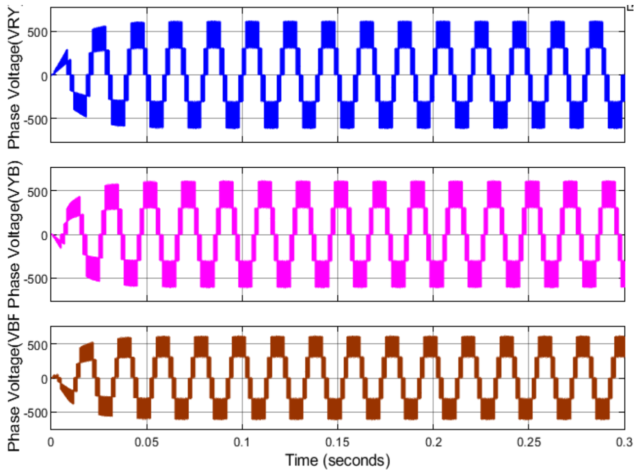


Fig -11: Phase-ground voltages of five level CHB Multistage Inverter using Sine PWM

Fig.6 and Fig.8 depicts the MATLAB Simulation circuit of three and five level CHB Multistage Inverter with Sine PWM technique and the Phase-ground Voltages are represented in Figures 10 and 11.

B) MATLAB Simulation of three-phase three and five-level CHB inverter using ISPWM

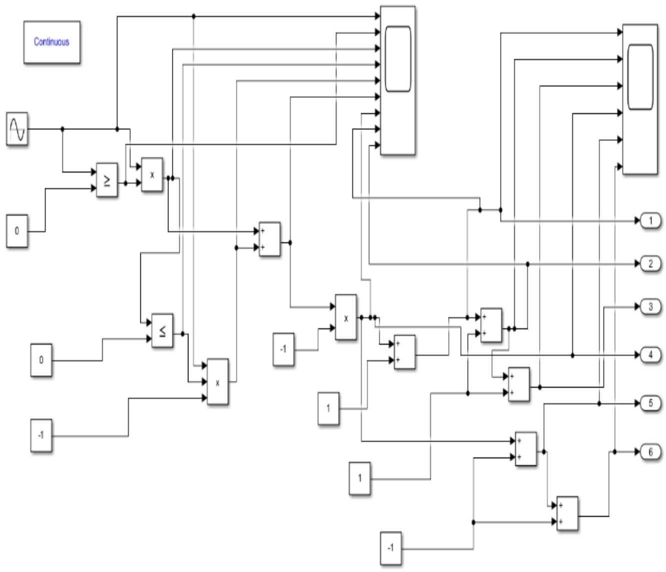


Fig -12: Simulation of Inverse Sine PWM carrier signals generation

A sub-circuit for producing flipped/inverse sinusoidal carrier signals is shown in Figure 12. Six inverted sine waves are produced by this circuit to power a seven-level inverter. But only four inverse sine pulses were utilized for a five-level inverter. Two of these inverse sine waves are contrasted to the reference sine wave's positive half cycle, while the other two are compared to the reference sine wave's negative half cycle. Fig.13. illustrates the Inverted carrier signals generated.

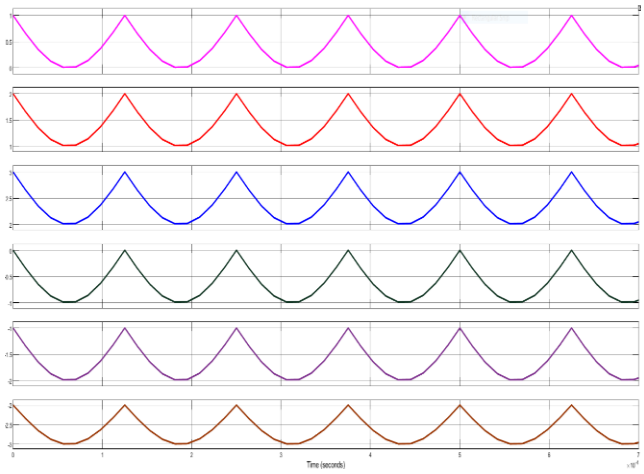


Fig -13: Inverse Sine PWM carrier signals

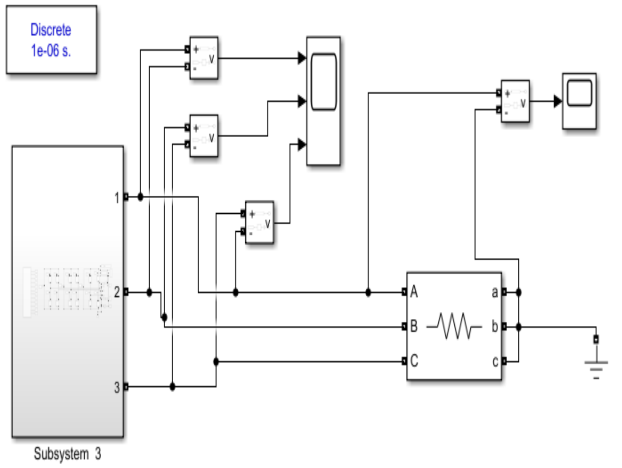


Fig -14: MATLAB simulation of three level CHB Multistage Inverter with Inverse Sine PWM

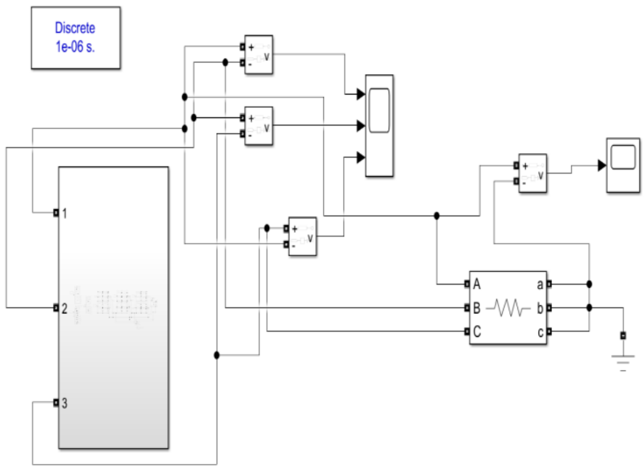


Fig -15: MATLAB simulation of five level CHB Multistage Inverter with Inverse Sine PWM

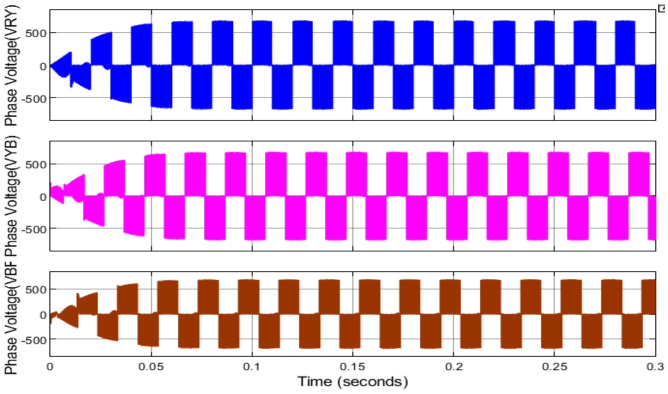


Fig -16: Phase-ground voltages of three level CHB Multistage Inverter with Inverse Sine PWM

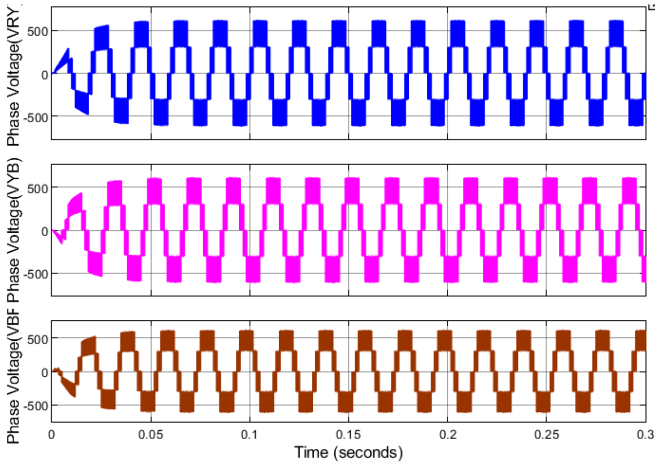


Fig -17: Phase-ground voltages of five-level CHB Multistage Inverter with Inverse Sine PWM

Fig .14 and Fig.15 depicts the MATLAB Simulation circuit of 3 and 5 level CHB Multistage Inverter with inverted Sine PWM technique and the Phase-ground Voltages are represented in Figures 16 and 17.

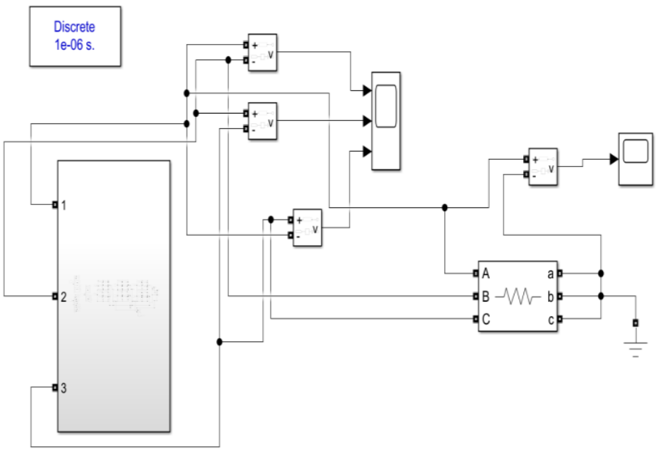


Fig -18: Simulation of five level CHB Multistage Inverter using Inverse Sine PWM with Bidirectional DC-DC converter

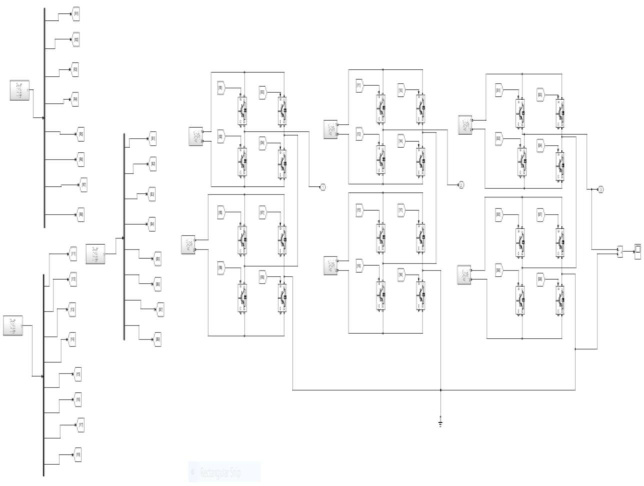


Fig -19: Simulation of five-level CHB Multistage inverter

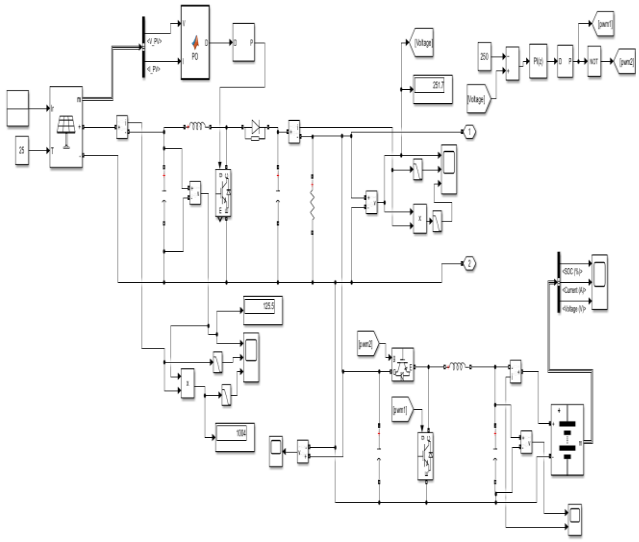


Fig -20: Simulation of Solar panel connected to battery through two-way DC-DC converter

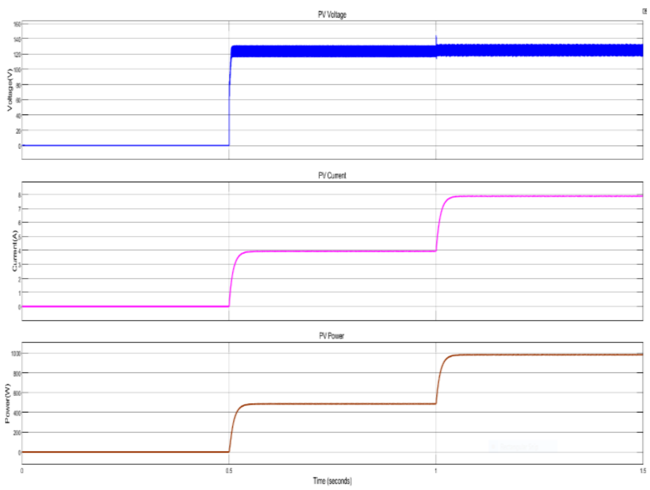


Fig -21: Output wave shapes of PV voltage, current, power

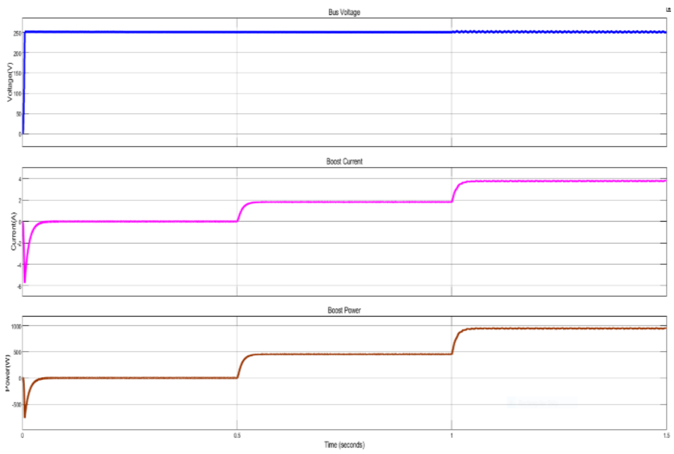


Fig -22: Output wave shapes of bus voltage, boost current and power

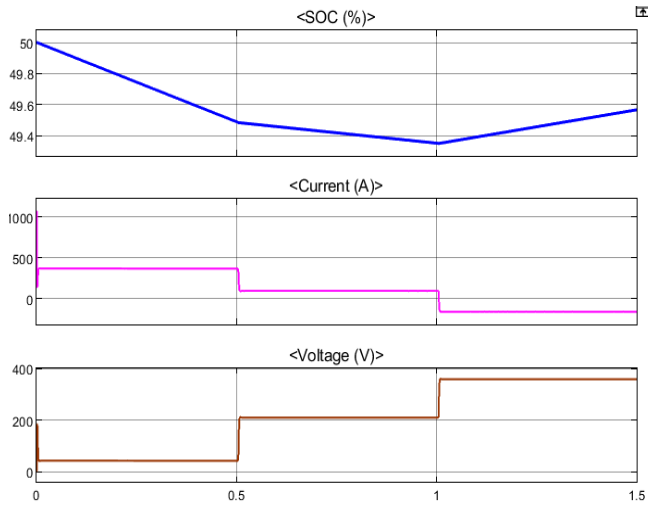


Fig -23: Battery State of Charge, Current and Voltage

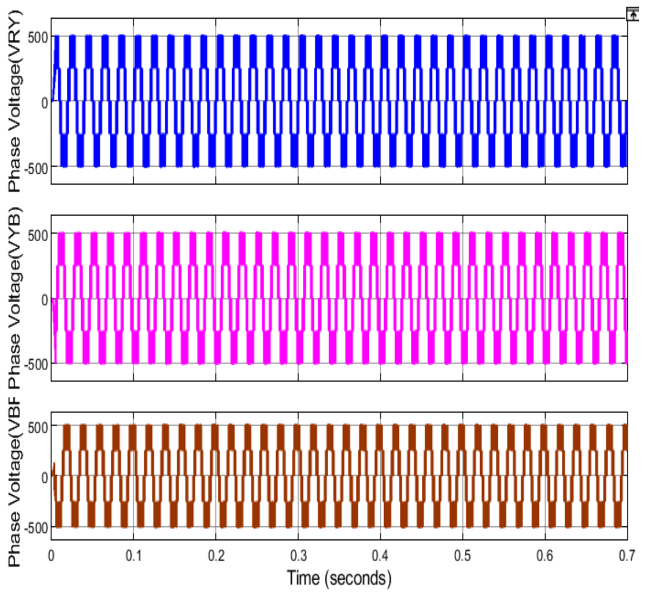


Fig -24: Phase voltages of inverter

Fig.18 shows the simulation circuit of 5 level CHB MLI using inverse sine PWM with Bidirectional DC-DC converter & Fig.19 is the simulation of fivelevel CHB MLI.

Fig.20 represents the sub circuit i.e., Simulation of solar panel connected to battery through two- way DC-DC converter. Initially the irradiance of solar panel is taken as zero and it is changed to 500W/m² at 0.5sec, 1000W/m² at 1sec and the output waveforms of PV and Boost Voltage, Current and Power are illustrated in Figures 21 and 22.

From the output waveforms we can observe that PV is tracking maximum power for different irradiances. The output waveform of PV current, power and boost current, power are increasing by increasing the irradiance. The bus voltage 250V is constant.

Fig.23 illustrates the Battery State of Charge (SOC%), current, voltage. We can observe that when solar is unable to supply, battery is getting discharged. But, by increasing the irradiance and if the solar is supplying the power more than the requirement of load then the battery is getting charged. Fig.24 illustrates the Phase voltages of inverter which is getting constant supply for the load.

C)ANALYSIS OF THD

THD contrast for three-phase H-bridge inverter with Inverse Sine PWM and SPWM is illustrated in Table-3. It is observed that THD is less for five-level cascaded H-bridge multilevel inverter compared to three-level and as number of levels increases, THD will reduce and output waveform will be near to sinusoidal waveform[5]. ISPWM results in less THD when compared to SPWM in the output voltage.

Table -3: THD Contrast for Three-Phase Three-level and Five-level inverter with Inverse Sine PWM and Sine PWM Techniques

	ISPWM	SPWM
Five-level	25.36%	39.64%
Three-level	29.53%	47.2%

8.CONCLUSION

The simulation is done through MATLAB/SIMULINK software. Under varying weather conditions solar is able to track highest power using MPPT technique. The THD for Sine, Inverse Sine PWM are contrast for three phase three-level and five-level cascaded H-bridge inverter through FFT analysis. Contrast to SPWM, the harmonics obtained are less for Inverse Sine PWM. The THD for the five level is less contrast to three level and as the number of levels increases THD reduces. It is concluded that Inverse sine PWM control method offers improved proficiency and performance contrast to Sine PWM technique. Battery is discharging when solar power is not sufficient for the load, and charging when the supply for load from solar is more than required.

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