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# Performance Analysis of Solar PV Based CHB and NPC Multilevel Inverters

Abhishek Ranjan<sup>1</sup>, Namrata Sant<sup>2</sup>

PG Scholar, Department of Electrical & Electronics, Bhopal Institute of Technology, Bhopal, India<sup>1</sup>

Asst. Professor, Department of Electrical & Electronics, Bhopal Institute of Technology, Bhopal, India<sup>2</sup>

**ABSTRACT:** Integrating RR with the utility system either 2-level or multi-level inverter (MLI) is employed. 2-level inverter has high THD content as compared to MLI in the AC output voltage hence MLIs are preferred. Tremendous research work is available to improve the performance of the system in a way to reduce losses, distortion and to enhance the efficiency by using different topologies of MLIs. The two most preferred topologies are neutral point clamped (NPC) and cascade H-bridge (CHB). The NPC-MLI find applications in Static VAR compensation, Variable speed motor drives, High voltage DC-AC transmission lines and applications of CHB-MLI are Motor drives, Active filters, Electric vehicle drives, DC power source utilization, Power factor compensators, Back-back frequency link systems and Interfacing with renewable energy resources. This paper NPC and CHB MLI with different levels is interfaced with the PV array and the results for 3, 5, 7, and 9 level are compared. The comparative analysis includes simulation results of a NPC and CHB fed by PV array based on Phase Disposition Pulse Width Modulation (PDPWM) technique using MATLAB-Simulink. The solar PV system used is modeled in SIMSCAPE library.

**KEYWORDS:-** Neutral point clamped, Cascade H-Bridge (CHB), Phase Disposition Pulse Width Modulation (PDPWM.), Solar Photovoltaic (PV) system, Multilevel converter, Total Harmonic distortion (THD)

## I. INTRODUCTION

The concept of MLI was developed for high power and high/medium voltage applications since they provide an effective interface with renewable energy sources. The MLI offers several features which raise its demand in present scenarios such as; possible connection of series switching devices to obtain a high voltage output without the need of snubber circuit, significantly low total harmonic distortion (THD) in output waveforms, use of IGBT as switching device at high frequency to reduce losses, reduced torque ripple in induction machine etc. MLI is preferred over traditional inverter because of numerous advantages which are summarized as follows:-

- Harmonic distortion: MLI uses tiny voltage steps for generating the desired output hence it contains less harmonic distortion.
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- Common-Mode (CM) voltage: MLI generates smaller CM voltage; hence the stress in the bearings of a motor connected to a multilevel drive can be condensed. To neutralize the CM voltage advanced modulation strategies can be employed.
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MLI topologies are reported but the most applicable are Diode Clamped or Neutral Point Clamped (DC / NPC MLI), Cascaded H-Bridge (CHB MLI) and Flying Capacitors (FC MLI)[2]. The classifications of MLIs are presented in figure 1.1. The MLIs not only generate higher voltage levels to improve the power quality but also reduce the passive filter requirements.

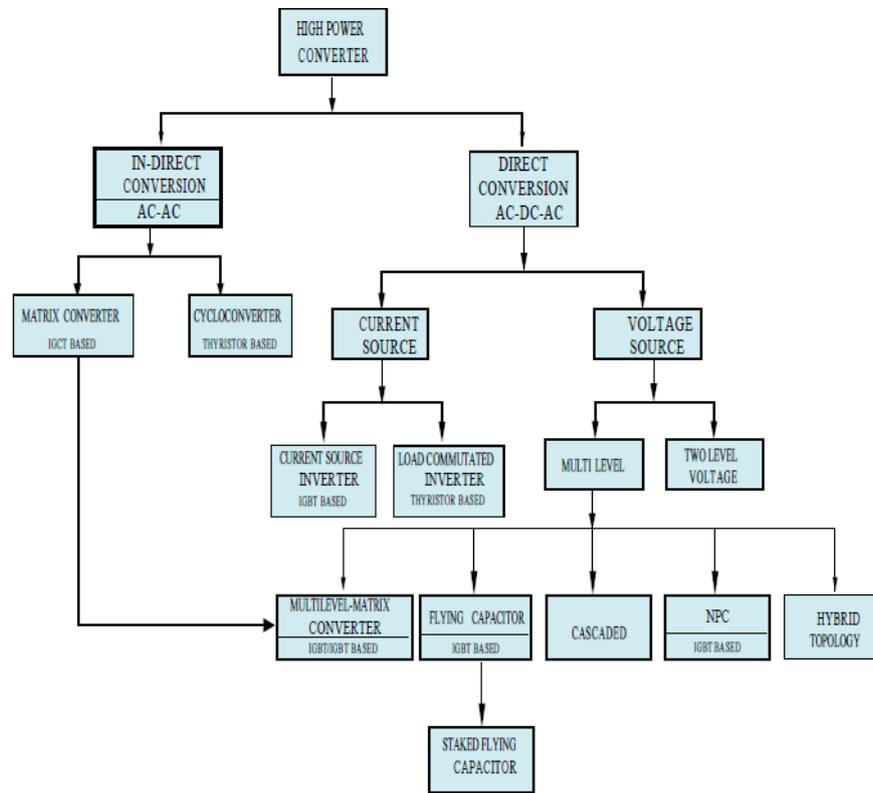


Figure 1.1 Topologies of Multilevel Inverters

**A) Neutral Point Clamped Topology (NPC-MLI)**

A NPC-MLI possesses, as the number of level increases there is a reduction in THD. All of the phases share a common dc bus that minimizes the requirements of capacitance in the converter. Hence NPC topology is convenient and practical for uses in high-voltage back- to-back inter-connection or an adjustable speed drive. The pre-charging of capacitors can be done. In case of fundamental switching frequencies efficiency is high enough.

**B) Cascade H-Bridge Topology (CHB-MLI)**

The series of CHB gives modularized packaging and layout, hence manufacturing of CHB becomes economical and quick. The output voltage levels are more than twice the number of dc sources. Separate DC sources are required for each CHB configuration. This shrinks its application range.

**C) Flying Capacitors Topology (FC-MLI)**

The advantages of the capacitor-clamped multilevel inverter are, At the time of long discharge transient capacitors allows extra energy for arge  $n$ . In the condition to balance the voltage levels of the capacitors phase redundancy is present. When  $n$  is large, THD is low The disadvantages are, Since additional capacitors are required, it adds to the cost and increase the complexity. Complex control is required to maintain the capacitors voltage balance. Technical advancement in power electronics has commenced to improve the level of inverter to cater to the need of medium voltage high power applications without transformer. There applications reduce the harmonics problem with reduced voltage stress across the switch. On the other hand, MLI feature several DC-links due to which independent voltage sources can be used.

## II. PROPOSED METHODOLOGY

The main objective of this thesis is to use the full available potential of the RES i.e. Solar Energy to generate electricity for giving power to the low power single phase industrial loads or domestic loads. The main objectives of this work can be summarized as below:

I). To design and simulate the mathematical model of the PV array which is able to produce the voltage of 21.6 V and 5 Amp current.

II). To design and simulate a single phase NPC-MLI with sinusoidal pulse width modulation (SPWM) scheme of switching to convert the dc output voltage of Solar PV into the single phase ac voltage consisting multiple levels to feed the single-phase industrial loads.

III). To design and simulate a single CHB-MLI with sinusoidal pulse width modulation (SPWM) scheme of switching to convert the dc output voltage of PV into the single phase ac voltage consisting multiple levels to feed the single-phase industrial loads.

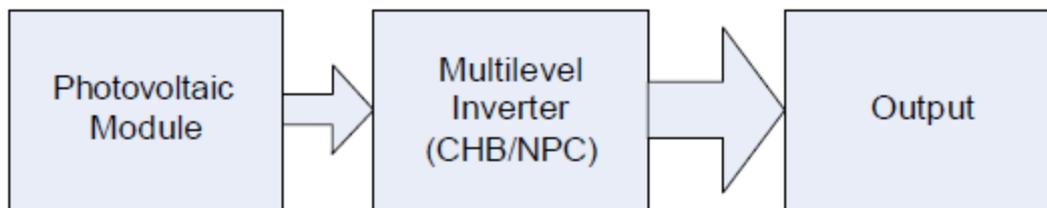


Figure 1.2 Block Diagram of the Proposed Methodology

## III. MATLAB/SIMULATION AND RESULTS

The NPC and CHB MLI in MATLAB/Simulation for different levels for both the topologies and the simulation results are displayed. Their FFT analysis shows the THD for each level. The model makes use of single phase power conversion and PWM control strategy. Several techniques can be seen in literature for the reduction of the voltage harmonic contents. PWM strategies used in a conventional converter can be redesigned for MLIs. The comparison of THD is used to indicate the quantity of harmonic contents in the output waveforms of different MLI topologies.

### A) NEUTRAL POINT CLAMPED MULTILEVEL CONVERTER

NPC topology the total voltage or input voltage  $V_{dc}$  divides across the capacitor in two parts across C1 and C2 i.e.  $+V_p$ ,  $-V_p$  and the third level is the zero level position, in this way the three levels are created (36 cells of 0.6 V each connected in series), similarly the simulated response for five level, seven level and nine levels are obtained.

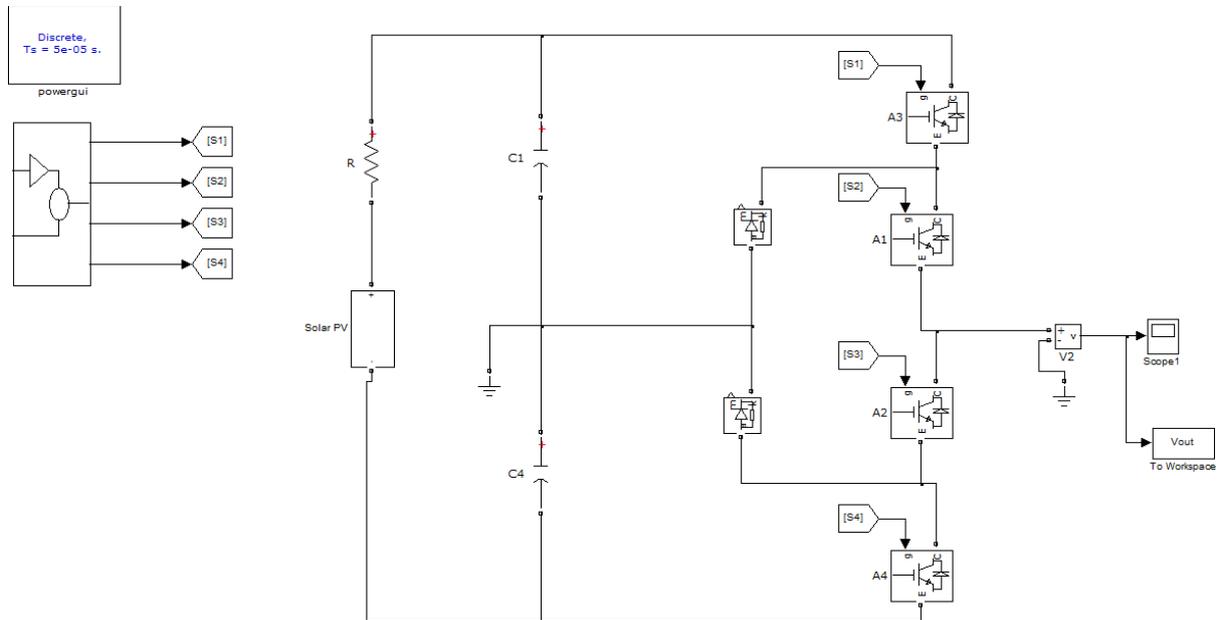


Figure 1.3 Solar-PV system interfaced with 3-level NPC-MLI

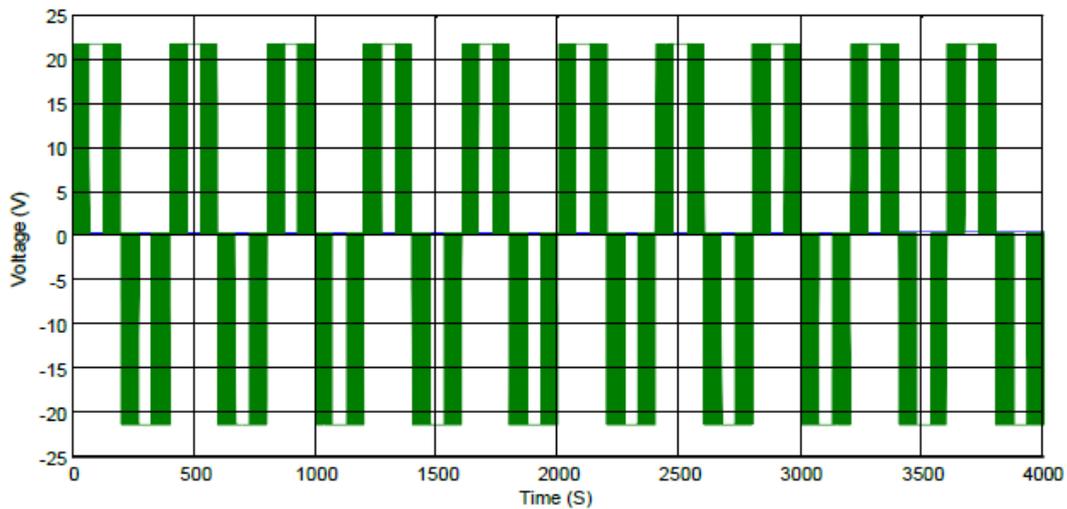


Figure 1.4 Waveform of output-voltage wrt of solar-PV system interfaced 3-level NPC-MLI.

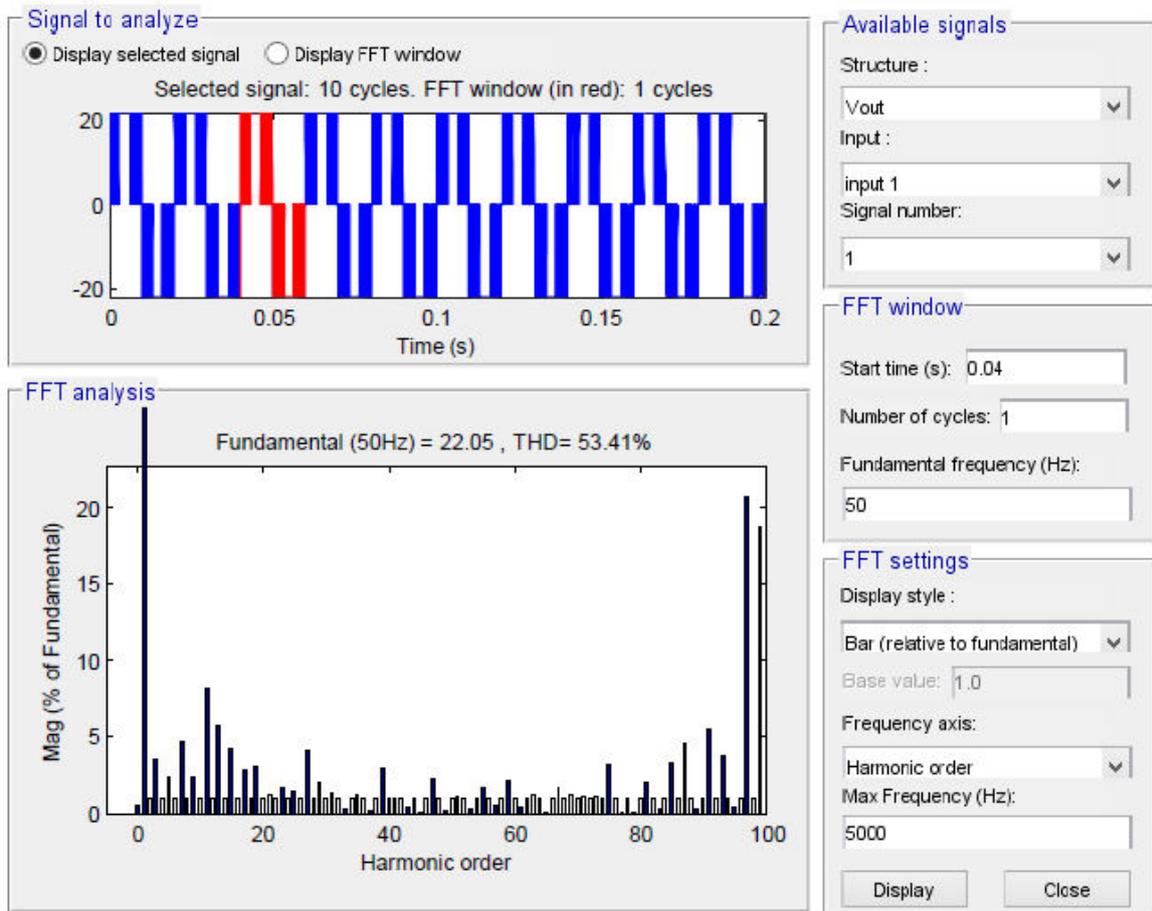


Figure 1.5 FFT analysis of 3-level NPC-MLI interfaced with PV system

The total harmonics distortion using 3-level NPC-MLI interfaced with PV system is 53.41%. Similarly for 5-level MLI operation, voltage is divided in four part across C1 C2 C3 and C4 i.e.  $+V_{pv}/4$ ,  $+V_{pv}/2$ ,  $-V_{pv}/4$ , and  $-V_{pv}/2$  and the fifth level is defined as zero potential. The THD using 5-level NPC-MLI interfaced with PV system is 25.69%. The 7-level operation of switches decides the output voltage( $V_{pv}$ ) that is the seven level converter voltage is divided in six part across C1, C2, C3 and C4, C5, C6 i.e.  $+V_{pv}/6$ ,  $+V_{pv}/4$ ,  $+V_{pv}/2$ ,  $-V_{pv}/2$ ,  $-V_{pv}/4$ ,  $-V_{pv}/6$  and the Seventh level is defined as zero potential. The THD using 5-level NPC-MLI interfaced with PV system is 25.69%. The 7-level MLI operation of switches decides the output voltage( $V_{pv}$ ) that is the seven level converter voltage is divided in six part The THD using 7-level NPC-MLI interfaced with PV system is 15.09%. The THD using 9-level NPC-MLI interfaced with PV system is 11.56%.

## B) CASCADE H-BRIDGE MULTILEVEL CONVERTER

Solar Photovoltaic system interfaced with 3- level NPC-MLI of 21.6V is displayed. in NPC topology the total voltage or input voltage  $V_{dc}$  divides across the capacitor in two parts across C1 and C2 i.e.  $+V_{pv}/2$ ,  $-V_{pv}/2$  and the third level is the zero level position, in this way the three levels are created (36 cell of 0.6 V each connected in series), similarly the simulated response for five level, seven level and nine levels are obtained.

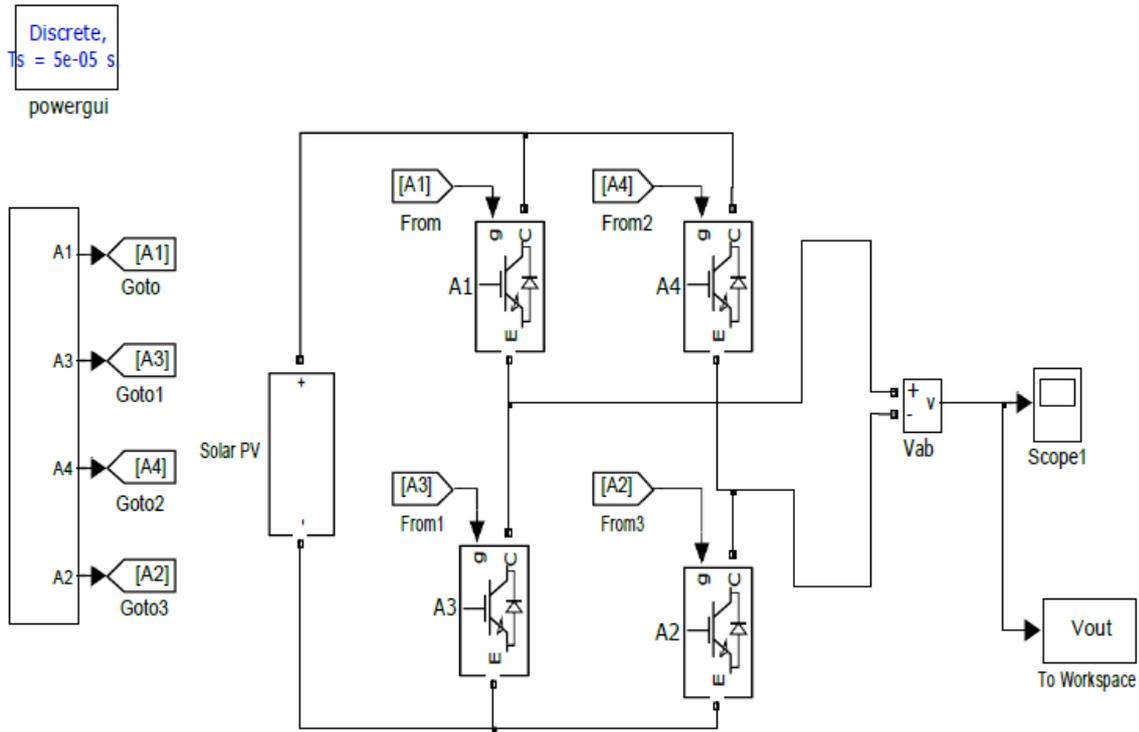


Figure 1.6 3-level CHB-MLI interfaced with PV system

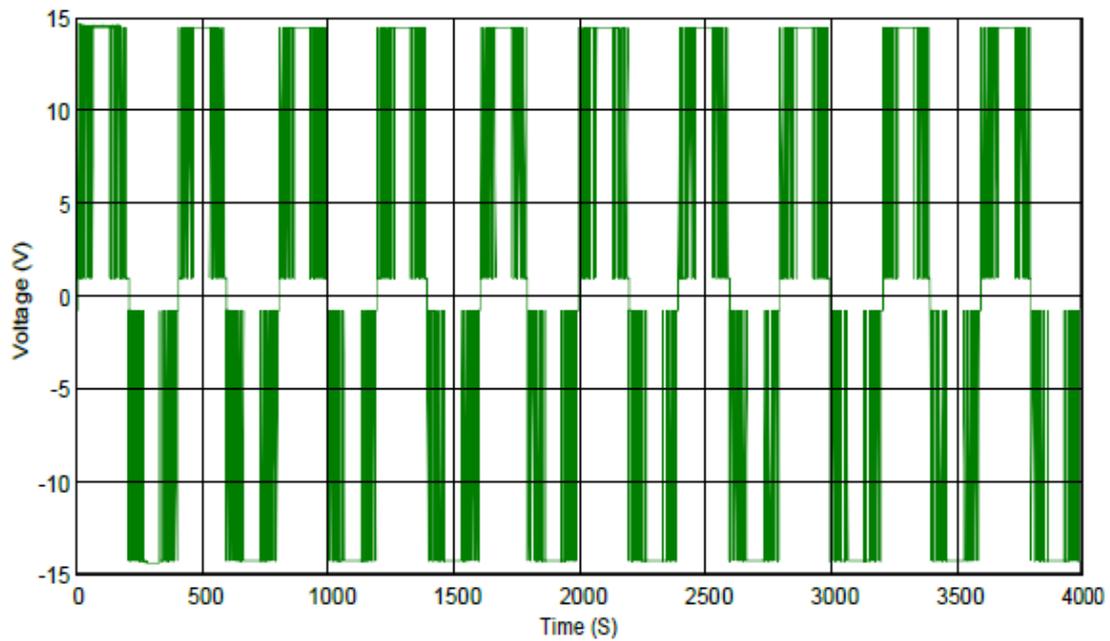


Figure 1.7. Output voltage waveform wrt of 3-level CHB-MLI interfaced with PV system

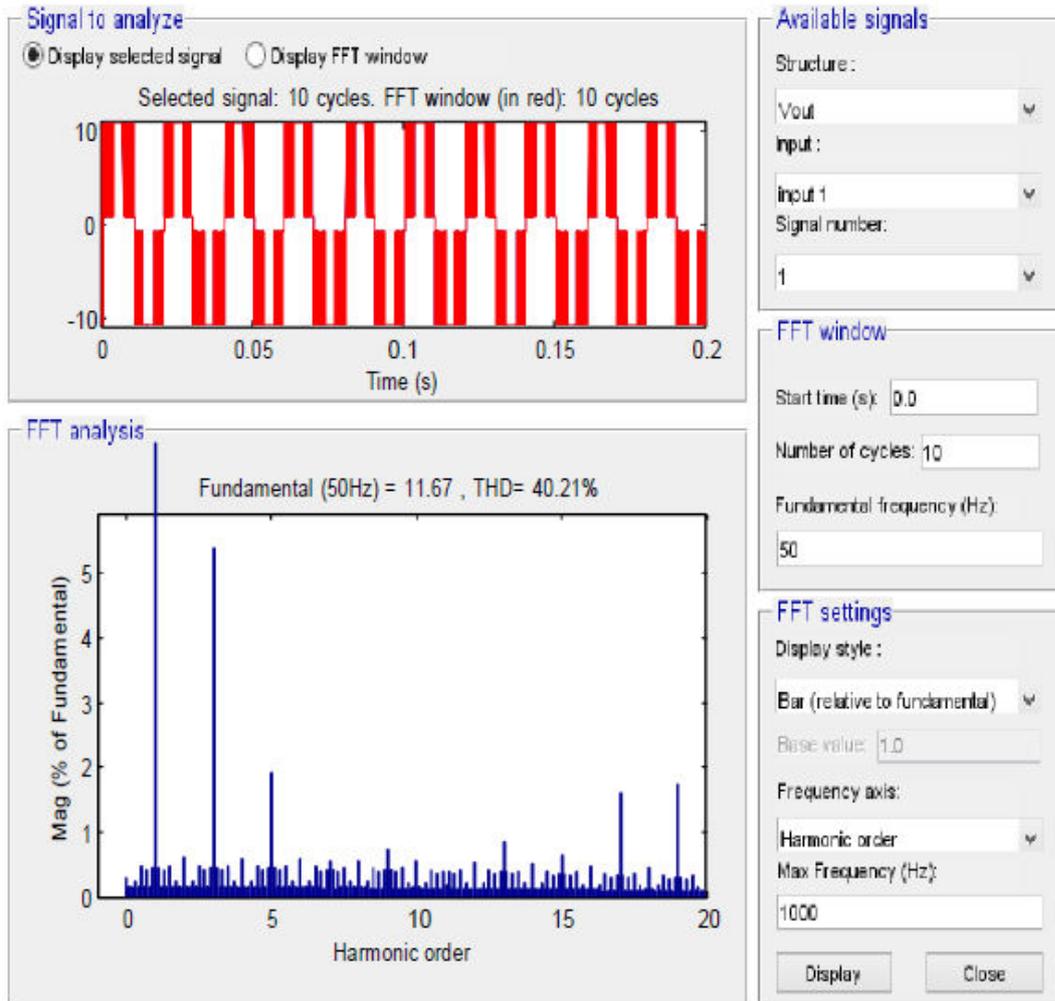


Figure 1.8 FFT Analysis of 3-level CHB-MLI interfaced with PV system

The THD using 5-level CHB-MLI interfaced with PV system is 19.66%. Considering seven level inverter three solar panels of 21.6 V each can produce seven level. The THD using 7- level CHB-MLI interfaced with PV system is 12.64%. Considering 9-level inverter four solar panels of 21.6 V each can produce 9-level i.e. +86.4V +64.8 V,+43.2V, +21.6V, 0, - 21.6 V and -43.2V,-64.8V ,-86.4V. The THD using 9-level CHB-MLI interfaced with PV system is 9.78%

#### IV. RESULTS AND DISCUSSION

some basic characteristics of NPC and CHB topologies of MLI fed solar- PV system for three, five, seven and nine level of 36 cells having total voltage of 21.6V. From the table it can be seen that number of diodes required in each configuration is same but clamping diode and DC-bus requirement of NPC is more as comparison to CHB. Also THD% of CHB is less than NPC. The only disadvantages that a CHB-MLI posse is that it require separate DC sources for each CHB configuration. This limits its application.



Table1. Comparative analysis NPC and CHB topology of MLI fed by solar-PV supply

Inverter level and type Parameter	Five level topology m=3		Five level topology m=5		Nine level topology m=7		Five level topology m=9	
	NPC	CHB	NPC	CHB	NPC	CHB	NPC	CHB
Switching devices								
Diodes	4	4	8	8	12	12	16	16
Clamping Diode	4	0	8	0	12	0	16	0
Capacitor balance	0	0	0	0	0	0	0	0
DC bus	2	1	4	2	6	3	8	4
THD%	<b>53.41</b>	<b>40.21</b>	<b>25.69</b>	<b>19.66</b>	<b>15.09</b>	<b>12.64</b>	<b>11.56</b>	<b>9.78</b>

Graphical representation showing percentage THD for three, five, seven and nine level converter for NPC and CHB topology of multilevel converter fed by solar PV supply.

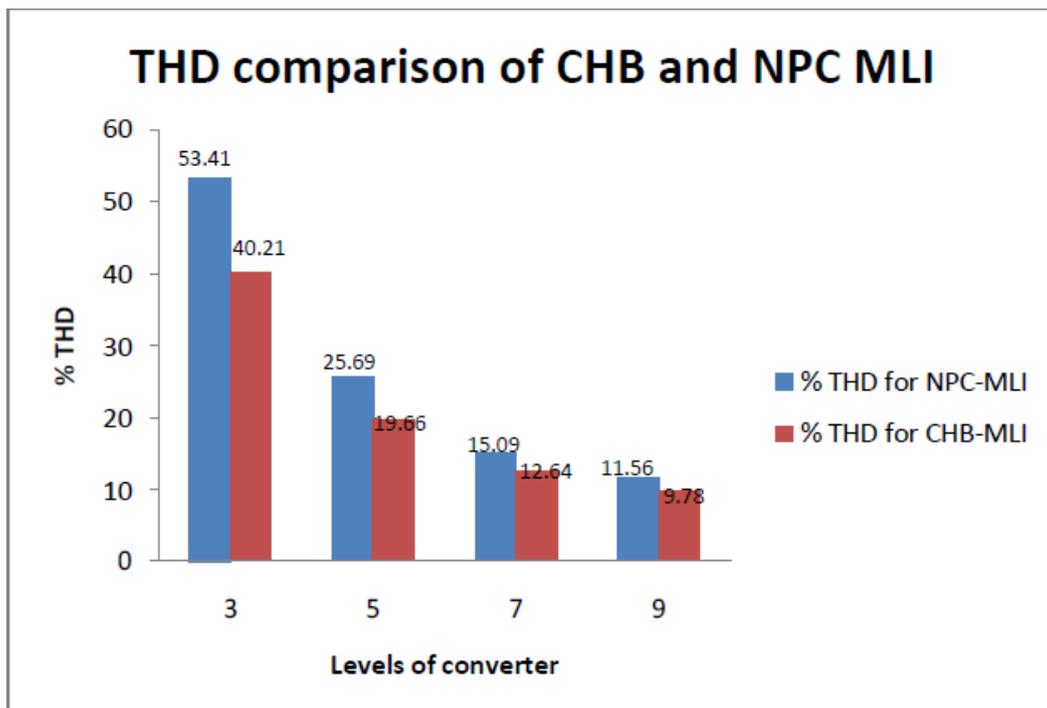


Figure 1.8 Graph showing percentage THD for three, five, seven and nine level converter



#### IV. CONCLUSION

The MATLAB simulation model of grid connected cascade H-bridge and Neutral point clamped MLI up to nine levels is designed in this paper. With the increase in the voltage levels through NPC-MLI and CHB-MLI it reduces THD. Increasing the number of levels by these topologies is easily possible to large extends which is a new direction in this field. From the results it is clear that the THD of the CHB-MLI is very low as compared to the NPC-MLI for the respective levels also NPC-MLI has the high cost of implementation. Hence choices among the two depend upon the application where they are employed. A multilevel technique for converters ensures a reduction of output harmonics as a result of sinusoidal output voltages so ends up in reduce grid filters, system cost and complexity reduction. This study was to analysis the MLI for different levels using NPC and CHB for grid integrated operation of PV system and to analyze their THD. CHB is better in terms of switches count, more cost competent and low THD than NPC. The development in power electronic technology has made the practical implementation of MLI possible. The applications of multilevel power converters and associated switching techniques are becoming popular. Moreover, many IEEE conferences currently hold entire sessions on multilevel power conversion.

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