INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

IJARIIT

ISSN: 2454-132X
Impact factor: 6.078
(Volume 6, Issue 5)
Available online at: https://www.ijariit.com

Comparative analysis of the grid-connected solar system using neutral point clamped and cascaded H-bridge ML

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ABSTRACT

Advancement in power electronic devices has developed a class of MLI which is very efficient for the grid-connected operation of the PV system. MLIs have a higher number of output voltage levels as compared to the two/three levels in traditional inverters. The advantage of MLIs is its staircase-like output waveform, which resembles more closely to sinusoidal waveform than the traditional inverters; hence THD is very low. In the proposed work comparative analysis of 5-level neutral point clamped (NPC) and cascaded H-Bridge (CHB) MLI is designed for grid integration of the PV system. The performance analysis has been carried out under the condition of constant as well as variable irradiance for a three-phase system to obtain low THD and high efficiency.

Keywords: *Multi-level inverters (MLI), Grid Tied Solar System (GTSS), Neutral Point Coupling (NPC), Cascaded MLI (C-MLI), Pint of Common Coupling (PCC)*

1. INTRODUCTION

Owing to the inherent benefits of multi-level inverters (MLI) such as high efficiency, reduced losses and low harmonics they are becoming popular for grid tied solar system (GTSS). For utilizing solar power inverters are the most important element, since solar generates DC power and mostly appliances work on AC. Even if DC appliances are to be fed through solar the electricity characteristics has to be compatible with the appliances. Hence a converter is required. Hence while designing solar system converter control must be designed properly. In solar system two types of converters are generally employed one is Dc converter for regulating Dc output and another is AC converter for regulating AC output. Solar systems generally employed as standalone system or grid connected inverters [1]. The standalone system generally supplies the local load like, rooftop system of remotely installed system where grid can't be reached [4, 5]. The grid connected system needs a proper synchronization to interact with the grid [2, 3].the profitability of such system is worthy when the communication and power flow is two way. Figure 1 presents the conventional structure of GTSS, which means power can either be supplied or can be consumed when needed if a proper inverter control is designed. The available grid interactive PV system can be as shown in figure 1. Various architecture and control topologies have been proposed in literature on integration of wind and solar energy systems and their hybrid combinations for power quality improvement when operated in a stand-alone as well as grid connected mode [6]-[8]. In this work a 5-level cascaded h-bridge (CHB) as well as neutral point-clinched (NPC) inverter is designed in SRF to integrate the solar system with the utility grid. The performance of the GTSS-MLI has been demonstrated for harmonic elimination and comparison of both the topology in terms of efficiency and harmonic content is presented in this paper. The result shows that the proposed topology has better performance than the conventional one. It is detected that the proposed inverter has superior characteristics as compared to conventional PI controller based Voltage source inverters in terms of the required devices, control requirements, cost, reliability and efficiency. The paper is organized as; in section 2, proposed inverter topologies are discussed in brief. In section 3, proposed work is presented. Section 4 presents the simulation results followed by conclusion at last.

2. NPC AND CHB MLI TOPOLOGIES AND CONTROL

In medium and high-power range utilizations, MLI with grid technology is a very efficient alternative as the heart of interfacing systems for integration of PV systems into utility grid. In this work a 5-level NPC and CHB-MLI is designed with solar system for charging DC batteries. The NPC inverter utilizes arrangement strings of single-stage full-bridge inverters to build multilevel stage legs with independent dc sources while CHB has H shape unit with each unit having an independent DC source. The typical arrangement of NPC and CHB-MLI is presented in fig.2 and 3 respectively. The most important work in designing an MLI is to develop the switching strategy. In this work a phase shifted sinusoidal carrier wave PWM technique is used to trigger the switching devices of MLI. In this strategy of modulation, the carrier signals are shifted in phase with respect to each other which are then compared with the reference signal as shown in fig.4.

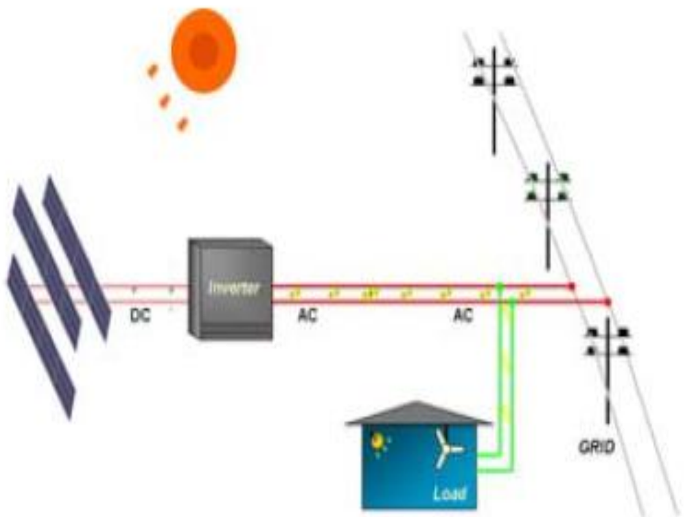


Fig. 1: Typical configuration of the Stand-alone PV-system

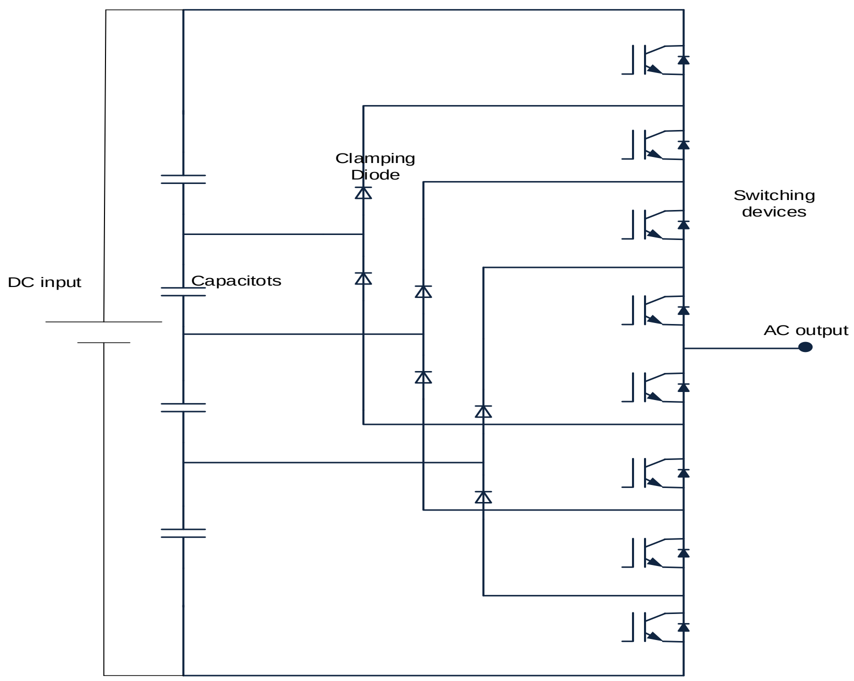


Fig. 2: schematic of single phase NPC-MLI

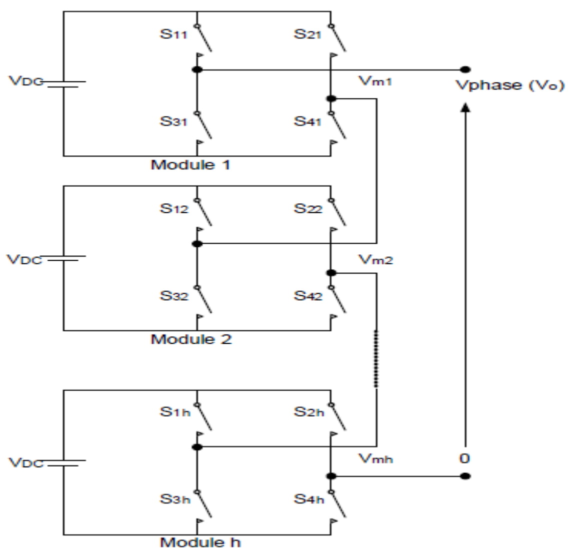


Fig. 3: Schematic of CHB-MLI.

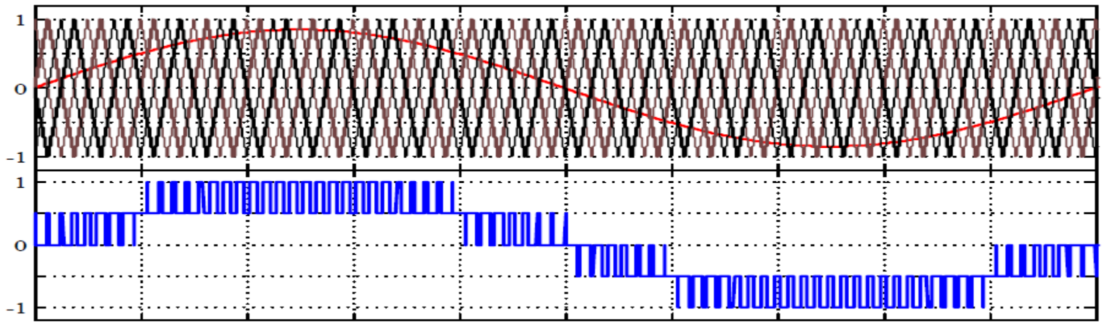


Fig. 4: sinusoidal PWM

3. PRPOSED WORK

In this work grid integration of PV panel is presented for utility grid applications. A PV system is designed, two PV-array having 40 parallel strings and 8 Series-connected modules in each array. The rated capacity of each PV panel is 100 kW. To obtain the constant DC output from Solar system a DC-DC boost converter is designed with switching frequency 5 kHz. The output voltage of the boost converter is approx. 400 V. To design a DC/AC converter a 5 level NPC and CHB MLI is designed whose pulse width modulation technique is designed using level shifted carrier modulation technique. One side of the converter is connected to the synchronized AC output of the PV system and other side to the grid. A low pass filter is connected at the output of the MLI to filter out the harmonic and to obtain the sinusoidal waveforms. The system is synchronized with the grid using PI controller and Phase Lock Loop. The design parameters are presented in Table-1. The simulation model of the single phase proposed NPC and CHB-MLI figure 5 and 6 respectively. The output voltage waveform for single phase 5-level MLI is shown in figure 7. The simulation model of proposed NPC-MLI based GTSS is shown in fig.8. The simulation model of proposed CHB-MLI based GTSS is shown in fig.8.

Table 1: Parameters selection for designing the proposed system

Parameter	Values
Switching frequency	5kHz
C_{dc}	12000µF
L1	1e mH
Inverter parameter	
Effectiv e nominal voltage of the utility (RMS) VS	415 V
Nominal utility grid frequency fS	50Hz
Switching frequency of the converters fch	5khz
inductance of filter	10 mH
Series resistance converter	0.01 ohms
Capacitances of the parallel filters	1000µF
Resistances of the converter filter	0.01 ohms
dc-bus voltage Vdc	400V

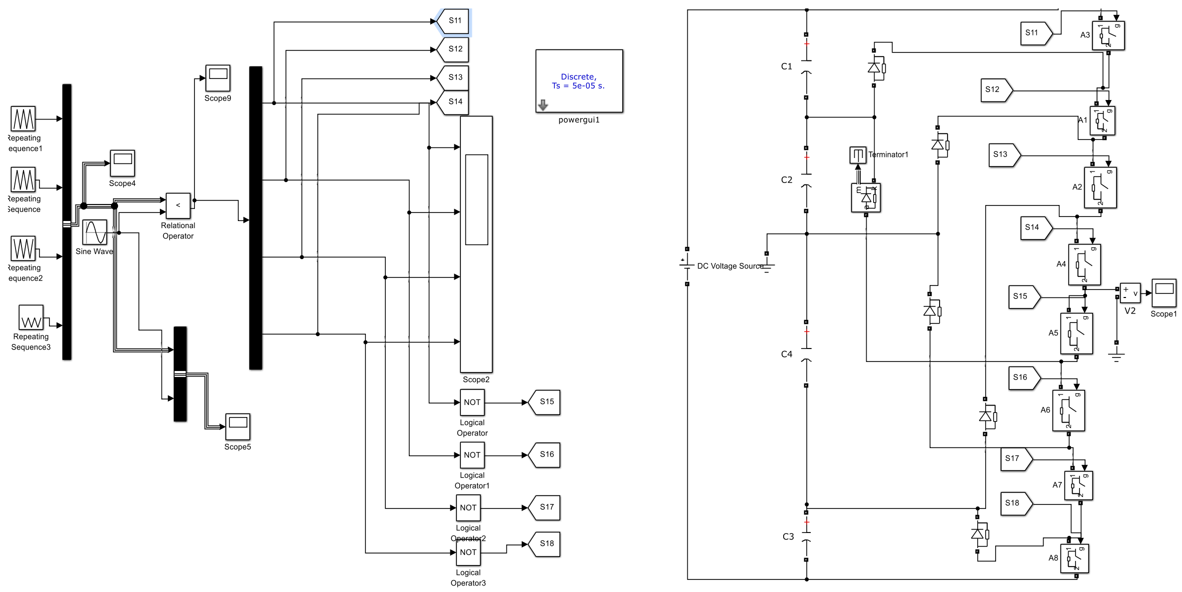


Fig. 5: Output Voltage of 5-level NPC-MLI

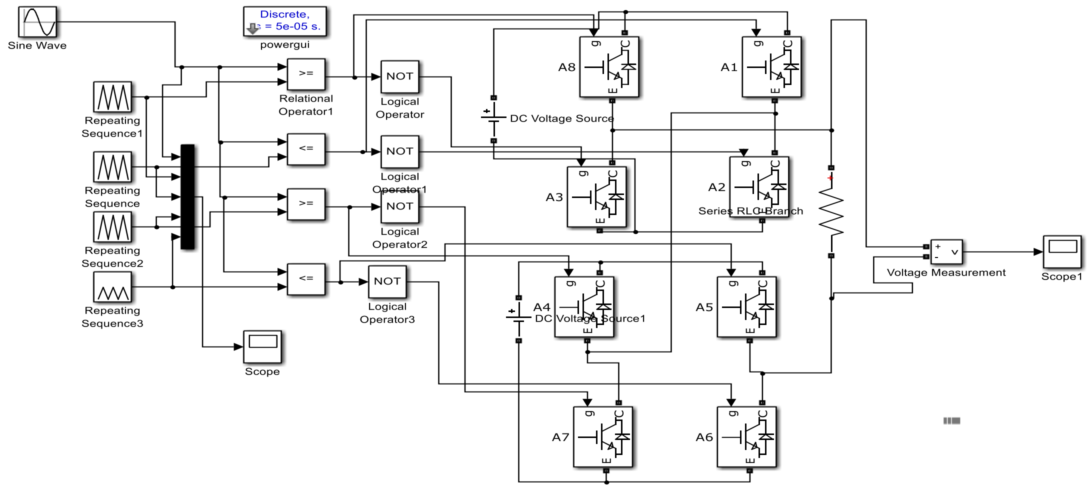


Fig. 6: Simulation model of proposed CHB-MLI

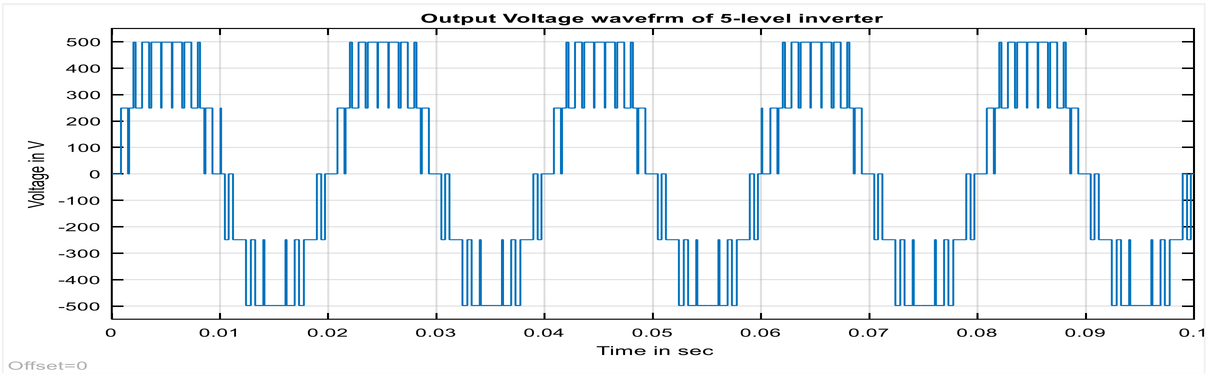


Fig. 7: Output voltage of single phase 5 level CHB-MLI

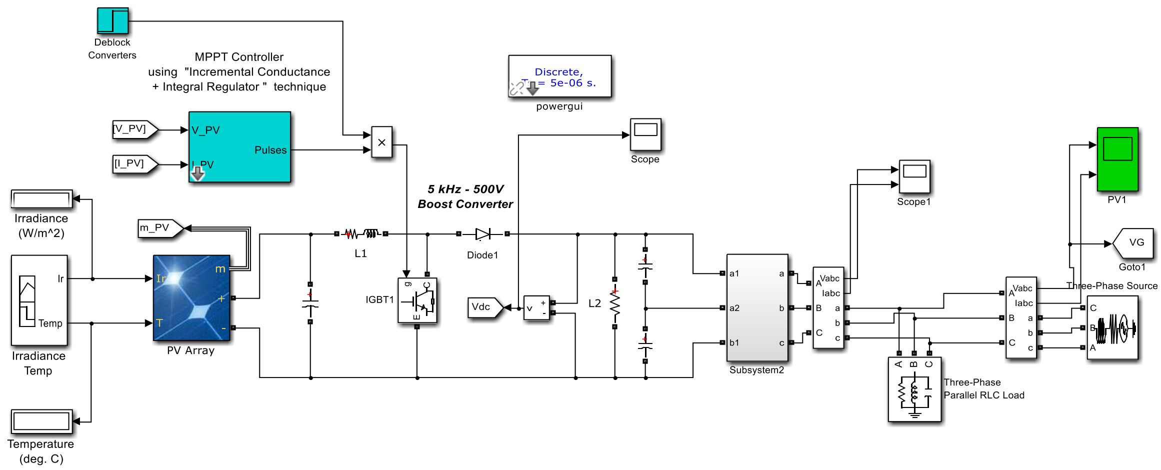


Fig. 8: The simulation model of proposed NPC-MLI based GTSS

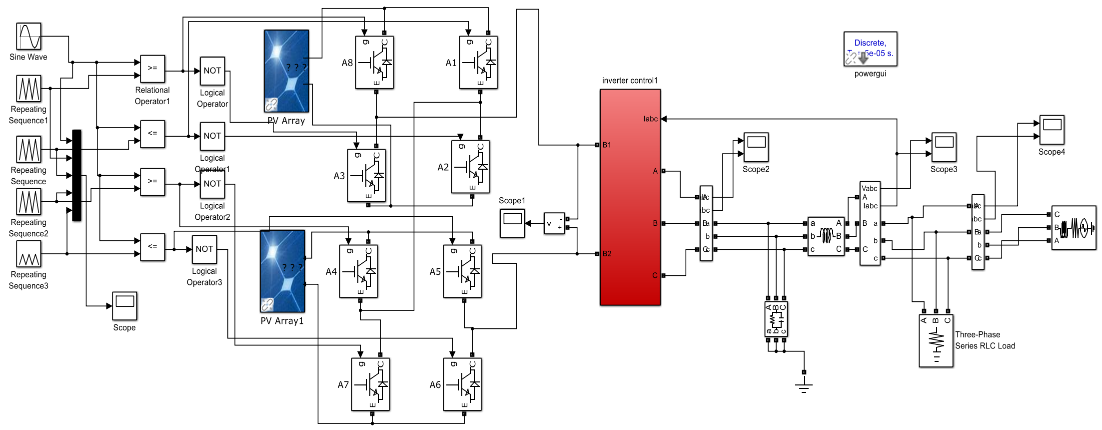


Fig. 9: The simulation model of proposed CHB-MLI based GTSS

4. RESULT ANALYSIS

The output voltage of boost converter is shown in fig.10. The output voltage and current of grid integration of PV with proposed NPC-MLI is presented in fig.11 and 12 presents the output voltage and current of grid integration of PV with proposed CHB-MLI. The THD analysis of grid voltage is presented in fig. 11 for NPC-MLI based GTSS and The THD analysis of grid voltage is presented in fig. 12 for CHB-MLI based GTSS. The comparative analysis for component requirement harmonic content in load voltage and current and efficiency of NPC and CHB based topology is presented in table 2 and 3. The comparison shows that though both the topologies are compatible for grid connected operation of solar system but CHB has some drawbacks like complex switching and more DC source. The THD for grid voltage and current in case of NPC is 0.37% and 0.8 % respectively. The THD for grid voltage and current in case of CHB is 1.6 % and 1.5 % respectively.

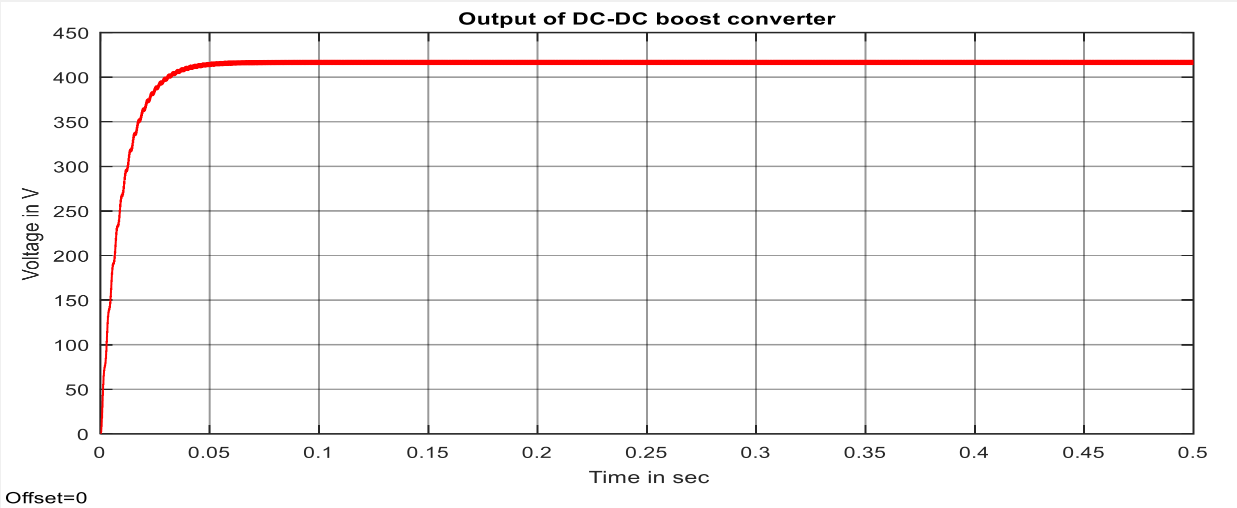


Fig. 10: Output of DC-DC boost converter

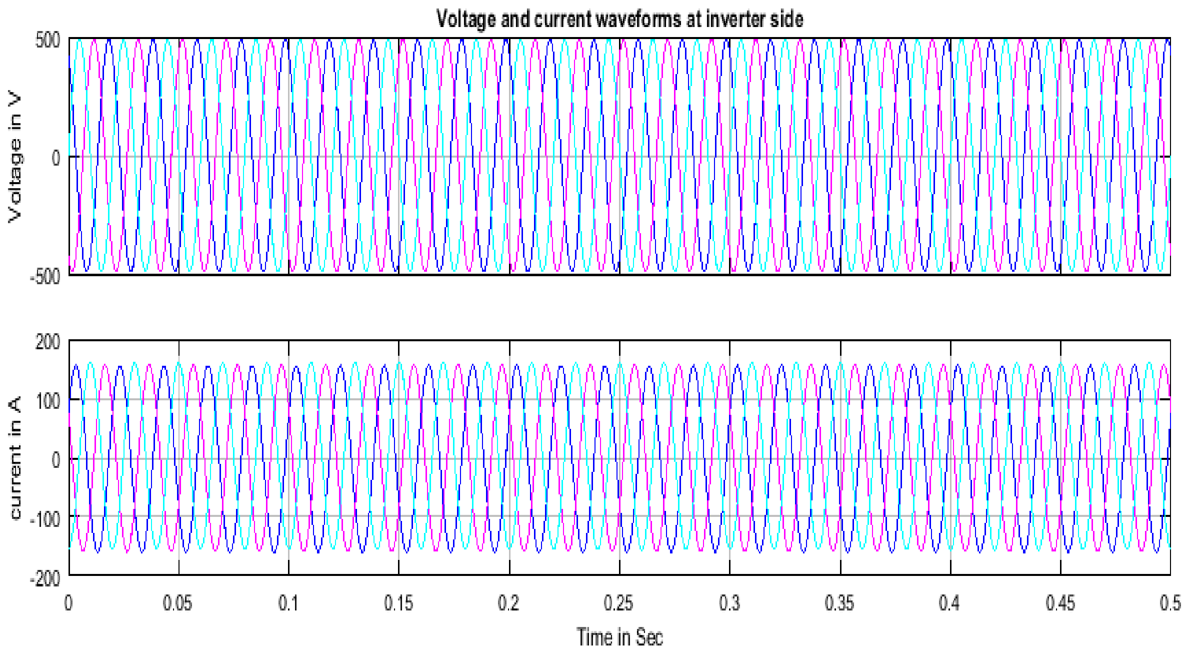
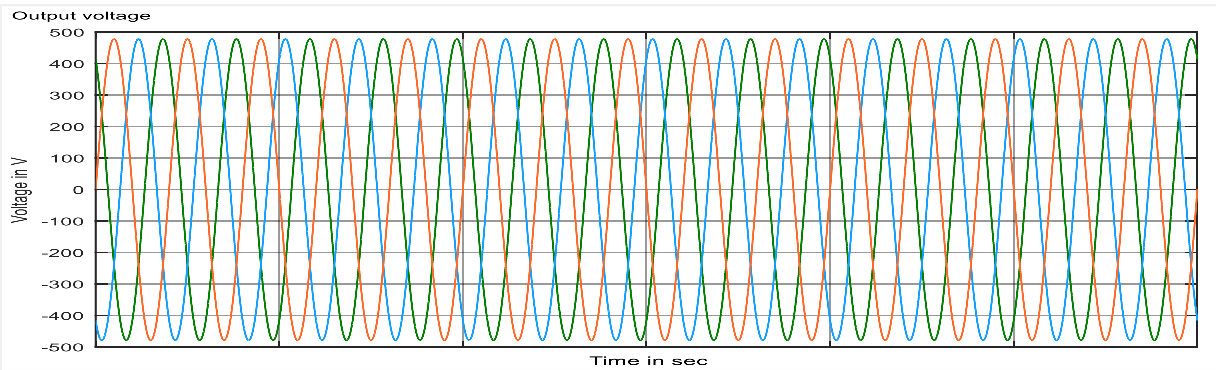


Fig. 11: Output voltage and current of proposed NPC-MLI based GTSS topology



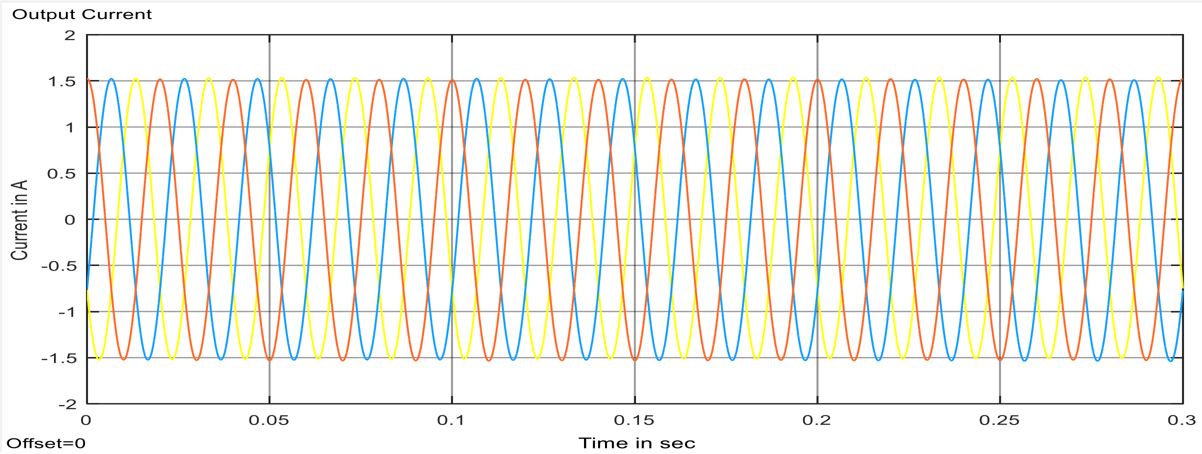


Fig. 12: Output voltage and current of proposed CHB-MLI based GTSS topology

Table 2: Comparison of component requirement for 5-level NPC/CHB MLI for grid tied PV system

Inverter level and type Parameter	Five level topology m=5	
Switching devices	NPC	CHB
Diodes	8	8
Clamping Diode	8	0
Capacitor balance	0	0
DC bus	4	2
THD%	0.8	1.6

Table 3: Comparison of THD and efficiency

THD analysis of	NPC	CHB
Efficiency	98%	95%
Load current	0.37	1.5
Inverter current	4	6
No. of PV panel	1	2

5. CONCLUSION

A robust 5 level CHB and NPC based MLI is proposed for grid connected operation of PV system. The efficacy of the proposed topology is verified by employing level shifted PWM techniques under the condition of linear and non-linear load. To increase the number of levels by this topology is easily possible to large extends which is a new direction in this field. The THD for both topology for static loading conditions is performed by connecting filter elements. The performance of the multifunctional VSC has been demonstrated for harmonic elimination. The result shows that the proposed topology has better performance than the conventional one. It is detected that the proposed inverter has superior characteristics as compared to conventional MLIs in terms of the required devices, control requirements, cost, reliability and efficiency.

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