International Journal of Electrical and Electronics Engineering (IJEEE)
ISSN(P): 2278-9944; ISSN(E): 2278-9952
Vol. 3, Issue 3, May 2014, 59-68

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

MODIFIED SINGLE PHASE H-BRIDGE MULTI-LEVEL INVERTER TOPOLOGY WITH SPWM TECHNIQUE FOR SOLAR-PV APPLICATION

KIRTI KASSI[1] & ARVIND MITTAL[2]

[1]M.Tech Student, Department of Energy, M.A National Institute of Technology, Bhopal, Madhya Pradesh, India

[2]Associate Professor, Department of Energy, M.A National Institute of Technology, Bhopal, Madhya Pradesh, India

ABSTRACT

This paper presents a modified topology of single-phase cascaded H-Bridge multilevel inverter for stand-alone photo-voltaic system. The main objective of the research is to propose an alternative topology for H-Bridge multilevel inverter with reduced number of power devices. Proposed topology with SPWM control technique results in reduction of total harmonic distortion (THD) and electromagnetic interference generation The analysis of five, seven and nine level are also presented here with SPWM control scheme. The THD of five-level multilevel inverter is reduced to 3.31% which is much lower than the nine level of conventional MLI.

KEYWORDS: Cascaded H-Bridge Multilevel Inverter (CHB-MLI), Multilevel Inverter (MLI), MATLAB/Simulink, SPWM, SOLAR-PV, THD

INTRODUCTION

Conventional sources are main energy supplier world-wide, but as these are on the verge of depletion and also led to many problems to environment, hence, renewable energy sources are becoming more popular as an alternative source. Therefore, with regard to the worldwide trend of renewable energy, solar power technology has become most popular and promising source of energy. The output of PV cells is dc, but as all equipment and loads require ac supply, so dc-ac inverters are to be used along with the solar PV panels.

In recent years, multilevel inverters [1] have drawn tremendous interest in the power industry. With the advancements in power semiconductor devices and converter topologies, the issue of power quality has become more and more significant. Multilevel inverters (MLI) are emerged as a solution to the problems faced by the conventional square wave and two/three level PWM inverters. With MLIs the harmonic content in voltages has reduced considerably, it has low voltage stress on power semiconductor devices, good electromagnetic compatibility reduced switching losses and improved reliability on fault tolerance [1,2]. Because of all these advantages a lot of further researches are currently going on to devise better topology and control technology which can bring about further reductions in harmonics in the output voltages and device voltage stresses. Multilevel inverters consist an array of power semiconductors switches and voltage sources (like battery, capacitor, distributed generation, etc), they require various pulse width modulation (PWM) strategies [1].

CASCADED H-BRIDGE MULTILEVEL INVERTER

Cascaded H-bridge multilevel inverter (CHB-MLI) generates nearly sinusoidal waveform, which may be obtained from several DC sources like solar cell, batteries, ultra capacitor. This system does not require transformer to provide isolation and do not require flying capacitors or clamping diodes. It comes with an advantage of smaller dv/dt stress, it requires least number of components and no high rated capacitors and diodes are required. Also the cascaded MLI is best suited for solar photo-voltaic applications.

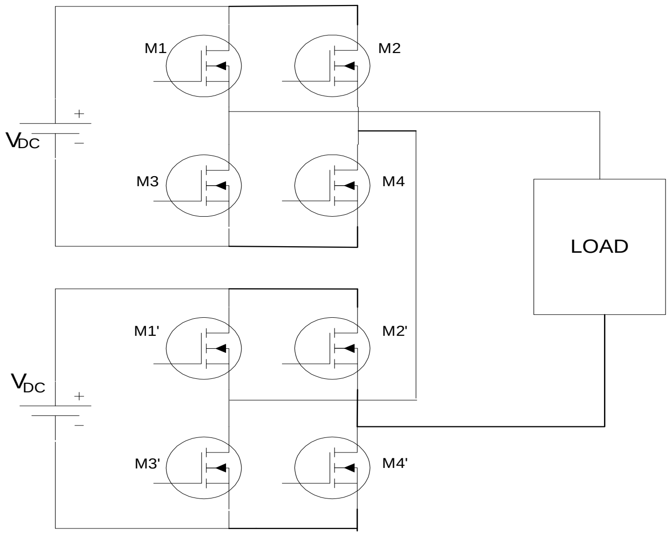


Figure 1: Single Phase Structure of Cascaded Multilevel Inverter

Each single H-bridge converter is associated with a single DC source. Modules are connected in series with each other. Through different combinations of the four switches it gives five different voltage outputs of +2V, +V, 0, -V, -2V. Output voltage of 'm' level inverter is the sum of all individual inverter outputs.

MODIFIED CASCADED MULTI-LEVEL INVERTER

The modified MLI consists of less number of power devices when compared with conventional cascaded H-Bridge multilevel inverter. The cost of the system reduces significantly because of the reduction of devices. Hence, it looks quite attractive and an appropriate one for industrial applications.

In the proposed topology the output voltage level is defined by

$m=2N+1$, where N is the number of DC sources

The number of devices required is given by

$d=2N+2$, where N is the number of DC sources

So, for five-level inverter only six power devices are required and hence for seven and nine level, only eight and ten power devices are required respectively. For the proposed topology, its just needed to add only two more device for every rise in level. So the initial cost of the system gets reduced. The comparison of devices used in conventional cascaded H-Bridge and the modified cascaded H-Bridge MLI is tabulated in table 1

Table 1: Switches Comparison B/W Cascaded and Proposed MLI

Inverter Type	Five	Seven	Nine
CASCADED H-BRIDGE MLI	8	12	16
MODIFIED CASCADED MLI	6	8	10

The power circuit of five-level modified cascaded H-Bridge MLI is shown in figure 2

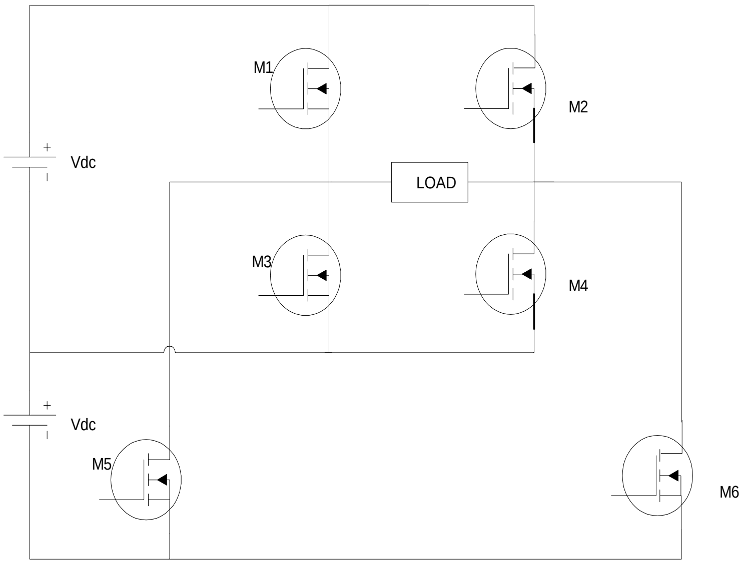


Figure 2: Modified Cascaded H-Bridge MLI Topology

Switching Conditions

In this circuit diagram M1 and M2 are conducting for 120° and M3, M4, M5 and M6 are conducting for 60°. The switching pattern of the MOSFETS and the output voltage of single phase modified five-level multilevel inverter is tabulated in table 2. For getting +12V output M1 and M4 are ON and for +24V shown in figure 3(a), output switch M1 and M6 are ON as shown in figure 3(b). Similarly for -12V output switches M2 and M3 are ON and for -24V shown in figure 3(c) output M2 and M5 switches are ON as shown in figure 3(d). In the interval of 0° to 30°, 150° to 210° and 330° to 360° the output voltage is 0V and all the switches are OFF. The expected output voltage waveform of modified MLI is shown in figure 4.

Table 2: Switching States of Proposed MLI

Time Period	Conducting MOSFETS	V_{out}(single phase)
0-30°	-	0
30°-60°	M_1, M_4	12 V
60°-90°	M_1, M_6	24 V
90°-120°	M_1, M_6	24 V
120°-150°	M_1, M_4	12 V
150°-180°	-	0
180°-210°	-	0
210°-240°	M_2, M_3	-12 V
240°-270°	M_2, M_5	-24 V
270°-300°	M_2, M_5	-24 V
300°-330°	M_2, M_3	-12 V
330°-360°	-	0

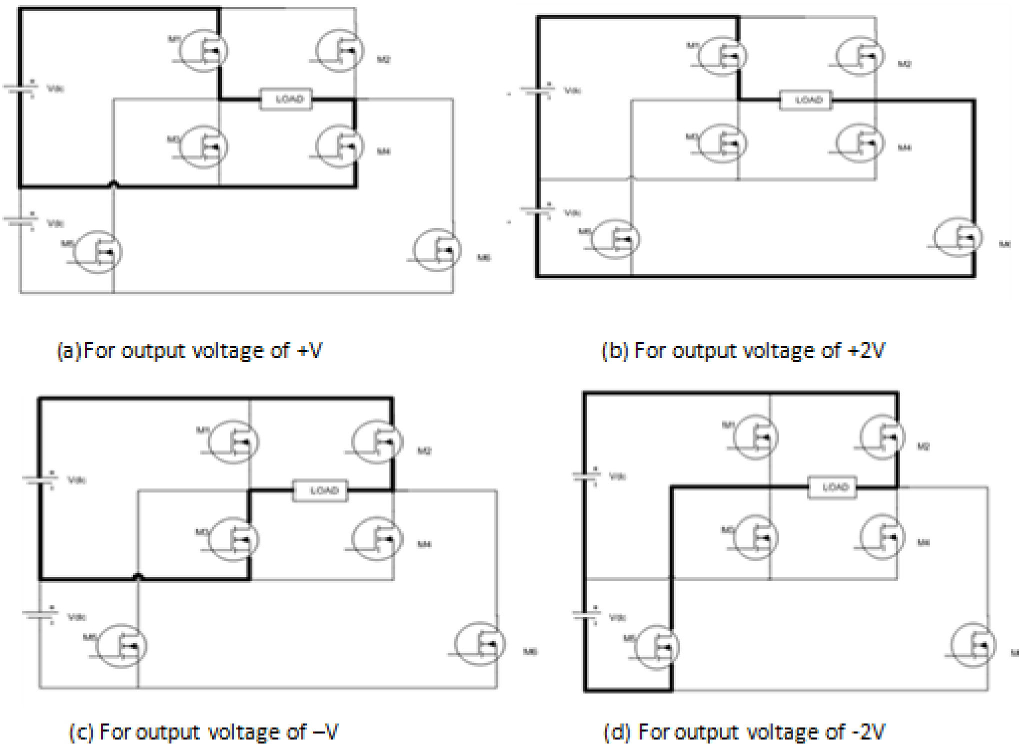


Figure 3: Working of Proposed Circuit in Various Modes

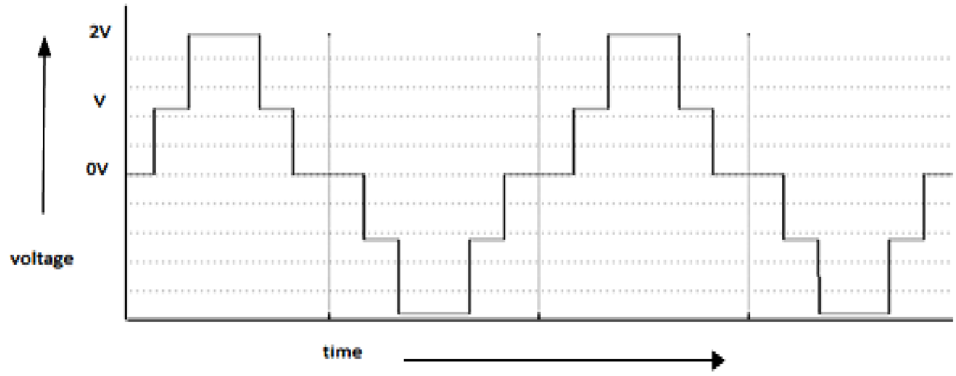


Figure 4: Output Voltage Waveform of Modified MLI

CONTROL TECHNIQUES FOR MLI

The switching losses and harmonic reduction are basically depends on the modulation scheme used to control the inverter. One of the most widely used classifications is based upon the open loop and closed loop concept. The brief controlling schemes are described by the block diagram shown in figure 5. PWM scheme is further classified into sinusoidal, vector and sigma delta schemes.

The SPWM is one of the most widely used modulation scheme among all present schemes. In SPWM a sinusoidal reference voltage waveform is compared with triangular carrier waveform to generate gate pulses for switching of power devices of inverter. Power dissipation is the most important factor in high power applications and hence the SPWM control method is proposed to minimize the switching losses. Further the scheme is divided into three more parts i.e phase disposition PWM, phase opposition disposition PWM and alternate phase opposition disposition PWM [11].

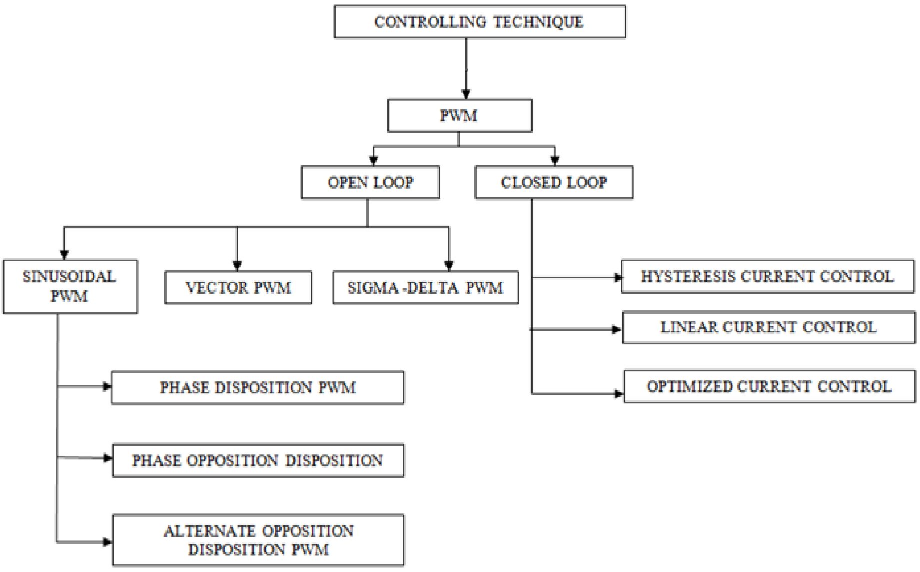


Figure 5: Control Schemes of MLI

SIMULATION RESULTS

The simulation of the modified single phase five-level CHB-MLI is done in MATLAB and the simulink model is shown in figure 6. The output voltage waveform is shown in figure 7 and it is observed that the THD is 31.92%.

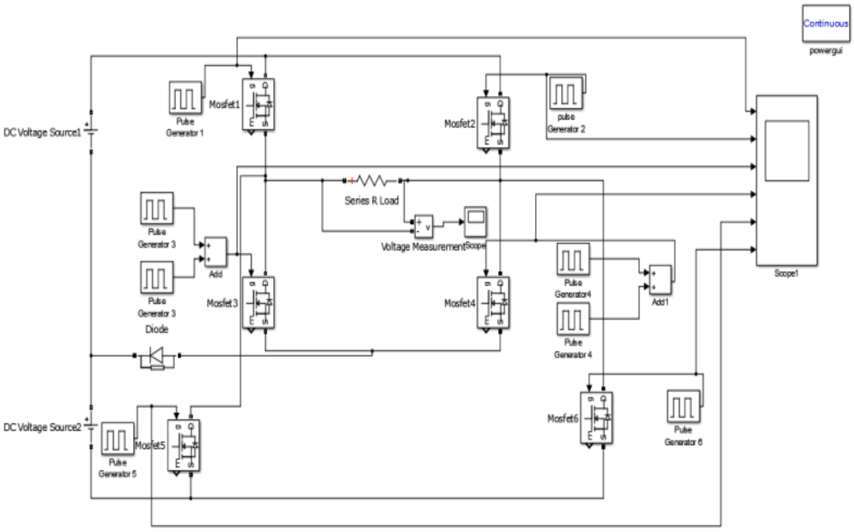


Figure 6: MATLAB Model of Modified Single Phase Five-Level CHB-MLI

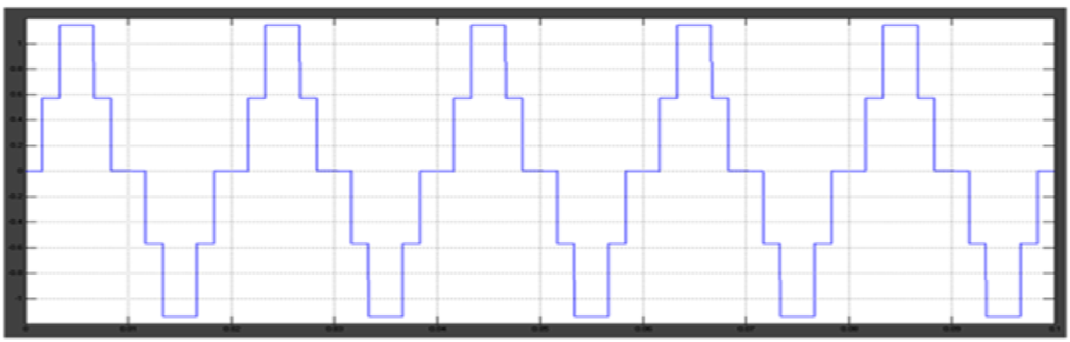
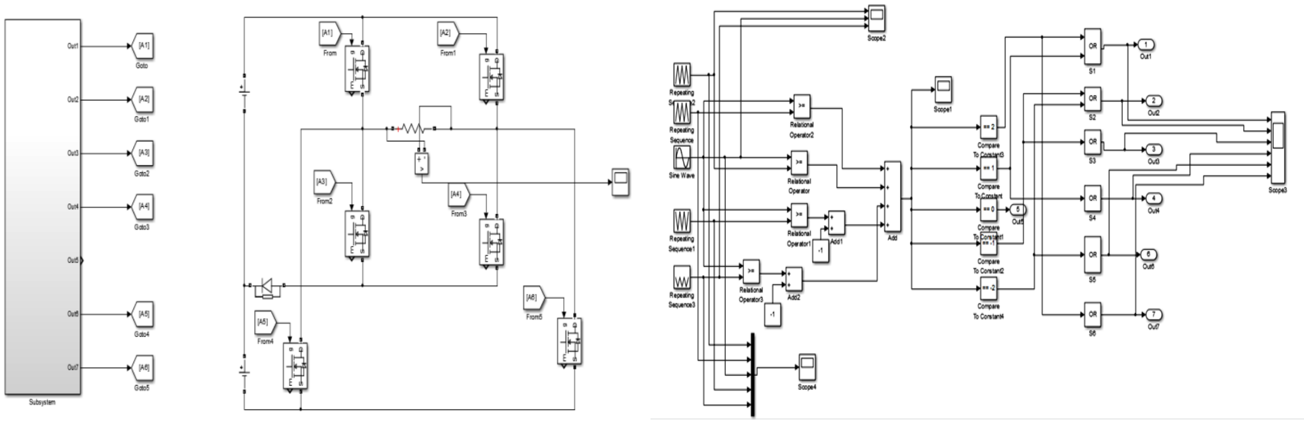


Figure 7: Output Voltage Waveform for Single Phase Five-Level Modified CHB-MLI

The THD can be reduced drastically by applying the SPWM control scheme. The simulation model for the same is shown in figure 8 and output voltage waveform is shown in figure 9. It is observed that with the implementation of SPWM control scheme the THD has reduced to 3.31%.



(a) Complete System with SPWM Control for Five-Level MLI **(b) Modulator Block of Five-Level MLI**

Figure 8: Simulation Model for Five-Level Modified MLI with SPWM Control

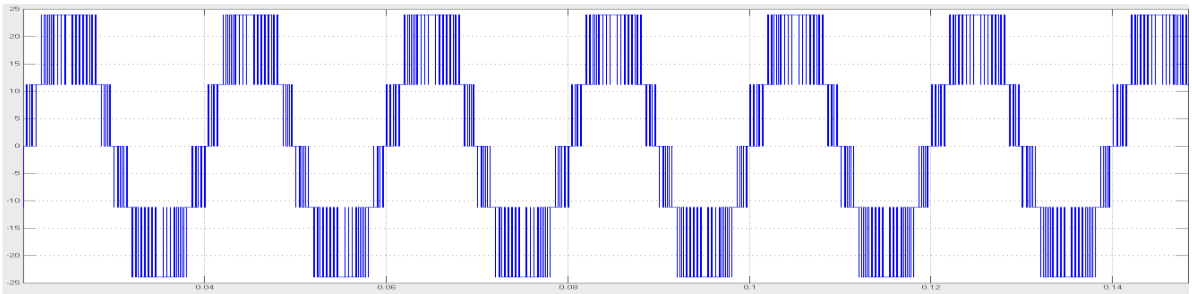
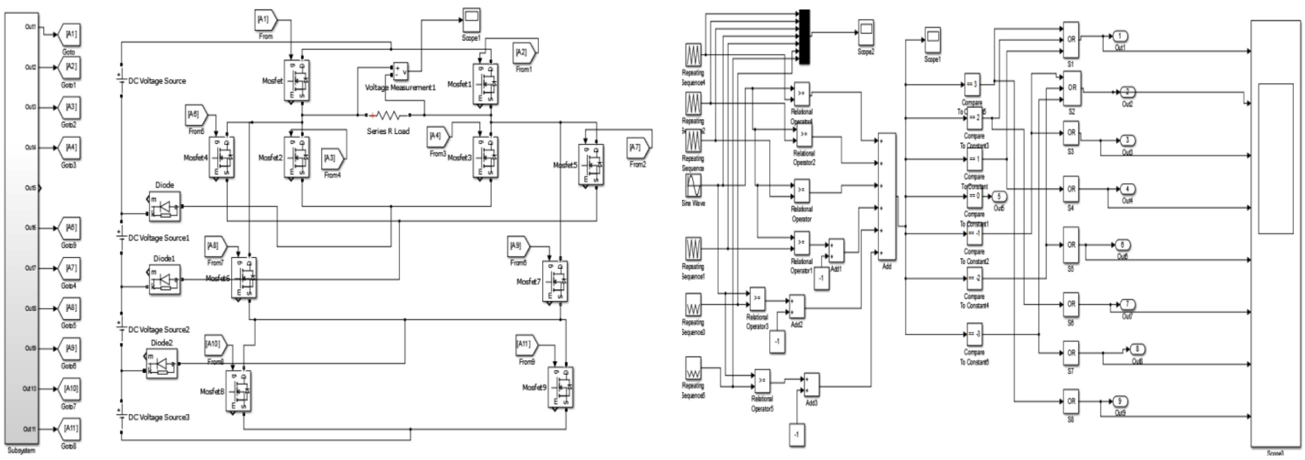


Figure 9: Output Voltage Waveform for Single Phase Five-Level Modified H-Bridge MLI with SPWM Scheme

Similarly, the simulation is done for seven-level modified MLI. The simulation model is shown in figure 10 and output voltage waveform is shown in figure 11. It is observed that with the implementation of SPWM control scheme the THD has reduced to 2.35%.



(a) Complete System with SPWM Control for Seven-Level MLI **(b) Modulator Block of Seven-Level MLI**

Figure 10: Simulation Model for Seven-Level Modified MLI

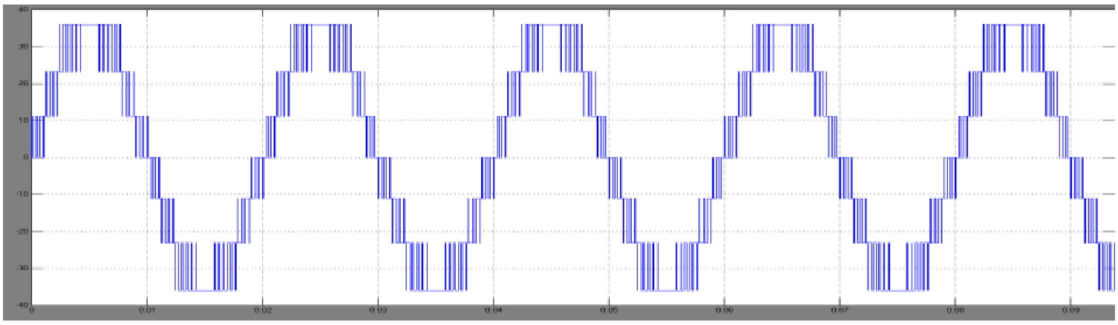
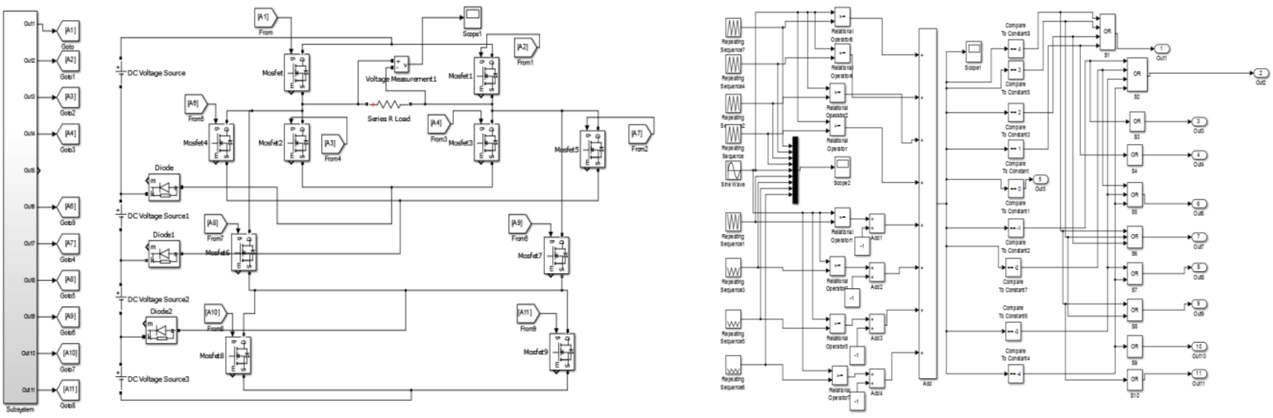


Figure 11: Output Voltage Waveform for Single Phase Seven-Level Modified H-Bridge MLI with SPWM Scheme

Likewise, the THD is observed to be 1.84% for nine level modified MLI. The output voltage waveform is shown in figure 13 and simulation model is shown in figure 12.



(a) Complete System with SPWM Control for Nine-Level MLI

(b) Modulator Block of Nine-Level MLI

Figure 12: Simulation Model for Nine-Level Modified MLI

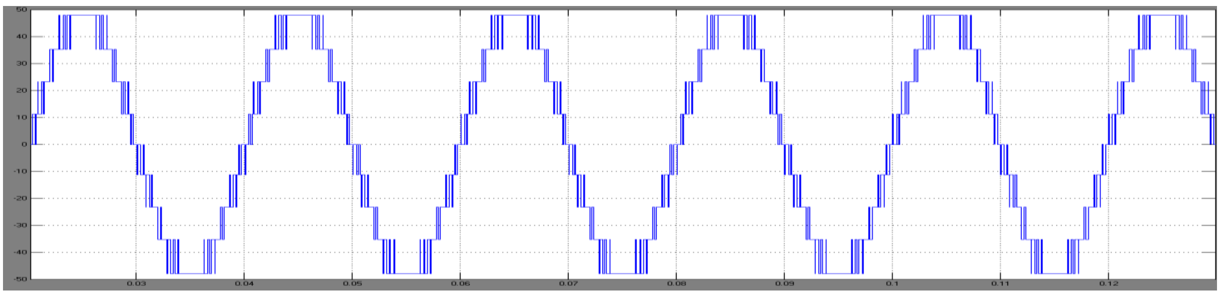


Figure 13: Output Voltage Waveform for Single Phase Nine-Level Modified H-Bridge MLI with SPWM Scheme

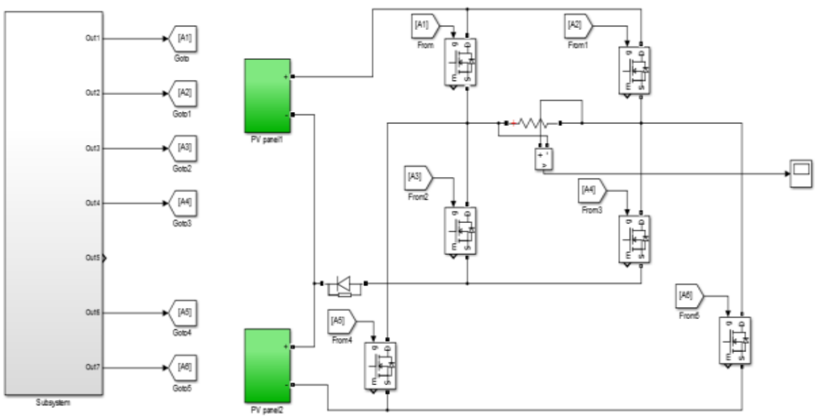
The comparison of THD of five-level, seven-level and nine-level of modified Cascaded H-bridge MLI with and without using the controlling scheme is shown in Table 3.

Table 3: Comparison of THD (%) without and with Control Scheme

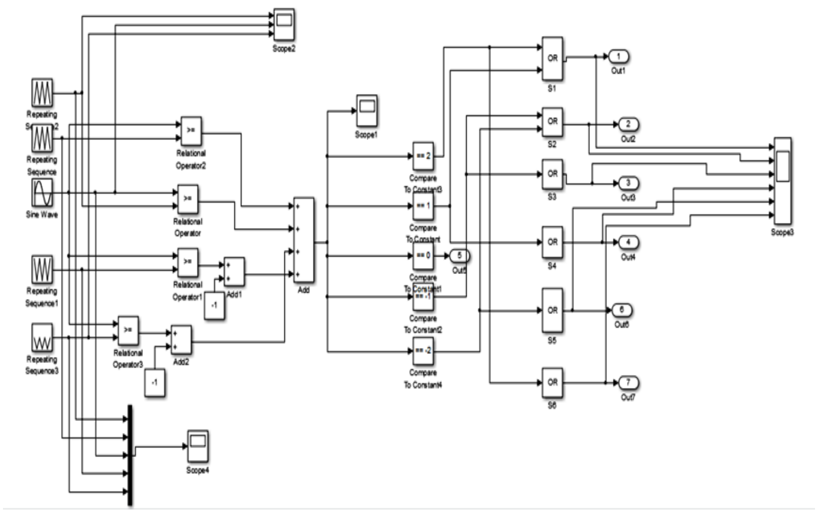
Levels	THD % (without SPWM Control)	THD % (with SPWM Control)
Five-level	31.92%	3.31%
Seven-level	25.46%	2.35%
Nine-level	22.03%	1.84%

APPLICATION OF PROPOSED SYSTEM IN SOLAR PV

The modified five-level single-phase CHB multi-level inverter is used to convert the dc voltage obtained from the solar panels for feeding the ac loads. The two solar panels of 40V output are connected as the input to the inverter and SPWM control scheme is implemented to get the output near to sine wave. The simulation model of the above system is shown in figure 14. The circuit is tested for resistive load and the output voltage waveform is shown in figure 15.



(a) Complete System Simulated with PV Array



(b) Modulator Block of Inverter

Figure 14: SPWM Controlled Proposed System for Solar PV

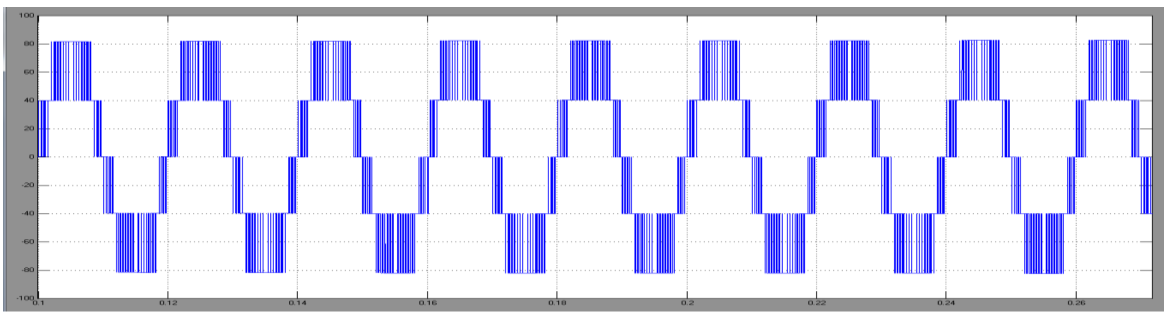


Figure 15: Output Voltage Waveform for Single Phase Five-Level Modified H-Bridge MLI with PV as a Source

CONCLUSIONS

The simulation of the single phase modified cascaded H-bridge MLI is done successfully by using SPWM (PD) scheme in MATLAB/simulink. The modified MLI with SPWM scheme offer improved output waveforms with lower THD i.e 3.31% with resistive load as compared to 31.92% without control scheme. The research also shows the reduction of initial cost and complexity due to reduction in number of devices required. With the increase in levels the number of switches required is very less compared to conventional MLI. The proposed MLI is successfully simulated for Solar PV applications.

REFERENCES

1. Murugesan. G, Jagabar Sathik.M, Praveen.M "A New Multilevel Inverter Topology Using Less Number of Switches" International Journal of Engineering Science and Technology (IJEST), Vol. 3 No. 2 Feb 2011.
2. M. Kavitha, A. Arunkumar, N. Gokulnath , S. Arun, "New Cascaded H-Bridge Multilevel Inverter Topology with Reduced Number of Switches and Sources", IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), Volume 2, Issue 6 (Sep-Oct. 2012), PP 26-36.
3. Pablo Lezana, José Rodríguez, Diego A. Oyarzún, "Cascaded Multilevel Inverter with Regeneration Capability and Reduced Number of Switches", IEEE Transactions On Industrial Electronics, Vol. 55, No. 3, March 2008.
4. M. R. Banaei, E. Salary, "New Multilevel Inverter with Reduction of Switches and Gate Driver", Proceedings of ICEE 2010, May 11-13, 2010.
5. Sun Xing-tao, Gao Sheng-wei, "Research on Topology and PWM Control Method of a Novel Cascaded Multilevel Inverter", Proceedings of the 2010 IEEE International Conference on Mechatronics and Automation, August 4-7, 2010.
6. Ebrahim Babaei, Seyed Hossein Hosseini, "New Multilevel Converter Topology with Minimum Number of Gate Driver Circuits", International Symposium on Power Electronics, Electrical Drives, Automation and Motion, 2008.
7. P. Thongprasri, "A 5-Level Three-Phase Cascaded Hybrid Multilevel Inverter", International Journal of Computer and Electrical Engineering, Vol. 3, No. 6, December 2011.
8. K.K. Gupta S. Jain, "Topology For Multilevel Inverters To Attain Maximum Number of Levels from Given DC Sources", IET Power Electronics, 6^{th} May 2011
9. Tamer H. Abdelhamid, "Reduced PWM Harmonic Distortion for a New Topology of Multilevel Inverters", Asian Power Electronics Journal, Vol. 1, No. 1, Aug 2007.
10. Surin Khomfoi, Nattapat Praisuwanna, "A Hybrid Cascaded Multilevel Inverter Application for Renewable Energy Resources Including a Reconfiguration Technique", Energy Conversion Congress and Exposition (ECCE), 2010 IEEE.
11. Ilhami Colak, Ersan Kabalci, Ramazan Bayindir, "Review of Multilevel Voltage Source Inverter Topologies And Control Schemes", Energy conversion and management, Elsevier, 2010