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A High Efficient Cross Connected H-bridge Style Multilevel Inverter with Lower Power Components

Vijayaraja Loganthan [1,*], Dhanasekar Ravikumar [1], Kesav Sanadhan S [1] and Rupa Kesavan [2]

[1] DEEE, Sri Sairam Institute of Technology, Chennai, Tamilnadu, India; dhanasekar.eee@sairamit.edu.in (D.R.); sit20ee025@sairamtap.edu.in (K.S.S.)
[2] DCSE, Sri Venkateswara College of Engineering, Sriperumbadur, Tamilnadu, India; rupakesavan@svce.ac.in
* Correspondence: vijayaraja.eee@sairamit.edu.in
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Abstract: Compared to the classical inverters, the multilevel inverter finds remarkable advantages, which can be suitably implemented in green energy power generation. Here an asymmetric multilevel inverter with fewer components is proposed for renewable energy applications. The proposed inverter is a cross between two H bridge-style devices. To maximize the output voltage three different algorithms to fix the amplitude of the DC sources are proposed and the best among them is chosen for implementation. The recommended inverter can generate 19 levels of output voltages using three DC sources with reduced power components. The nearest level modulation is used as the control course for the inverter. Here MATLAB software is used to simulate the proposed inverter and the performance of the inverter is observed. The proposed inverter is constructed in real-time, and the performance of the inverter is studied by testing with fixed and variable reactive loads. A comparative study is made between the simulation model and real-time work results in-terms of efficiency and harmonics in the load wave-forms.

Keywords: Asymmetrical sources; Cascaded H-bridge; multilevel inverter; Pulse width modulation; total harmonic distortion

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1. Introduction

An electrical inverter transforms DC power into AC power from sources like batteries, fuel cells, or solar cells. Current source inverters (CSI) and voltage source inverters (VSI) are two different types of inverters. A multilevel inverter is a device which uses power electronic devices as switches and produces higher voltage levels compared to traditional inverters depending upon the voltage sources used. These multilevel inverters are used in renewable energy systems with high efficiency, electric vehicles, industrial motor drives to improve the motor's performance, power factor corrections to reduce the reactive power consumptions, etc. These inverters have high voltage stress which causes reliability and durability issues, complex control algorithms, and harmonic distortions in low switching frequencies and have a high challenge in balancing capacitor voltage. There are different types of MLI such as diode clamped MLI, Flying Capacitor MLI, Cascaded MLI, Diode Clamped MLI, Capacitor Clamped MLI. These conventional MLIs use capacitors, diodes and voltage sources, providing simple topology. A multilevel inverter is proposed on the basis of series connection [1,2]. The invented MLI gives output voltages of 11 levels, 15 levels and 19 levels. These inverters are coupled with the renewable energy systems as well as fuel cell applications [3]. The designed MLI produces output voltage of 17 levels with two asymmetrical DC sources. The module had a simple inherent charging for capacitors without any additional circuit. The negative voltage capability is involved [4]. The proposed D type MLI produces output voltage at 7 levels. The Nearest Level

Modulation (NLM) technique is used to control the inverter. The input voltage can be boosted by synthesizing capacitors voltage [5]. Integrating the solar PV system with the inverter is the main goal of the power quality improvement, and performance of an asymmetric multilevel inverter with different PWM approaches for harmonic suppression is also examined [6]. Three induction motors are driven by a cascaded multilevel inverter using a hybrid control approach. Lower voltage DC sources are used to improve the voltage rating and solar photovoltaic system power quality. Switching Frequency Optimum (SFO) and Nearest Level Control (NLC) control approaches are used [7]. The control strategy of the neutral point clamped inverter is limited since only one basic vector may be selected as the optimal output during a control period. An extended control set that accelerates the search for the appropriate vector and enhances control performance. The proposed inverter generates three output voltage levels [8]. This proposed topology collects maximum power from the sources and transmits it to the grid in pure AC form with minimal switching and power loss. In this proposed solution only two switches are switched ON for a single state, greatly reducing switching losses and thus the efficiency is increased [9]. The proposed inverter produces 19 levels of output voltage without the H bridge circuit which is used for the power quality improvement in the grid [10]. The proposed inverter produces the 7 levels of output voltage in the symmetric case and 15 levels of output voltage in the asymmetric case with 9 switches; however the total harmonic distortion is high, where the efficiency is reduced [11]. Considering the above papers, the multilevel inverter is proposed which produces the 19 levels of output voltage with 3 DC sources and 12 switches. The inverter is simulated using the MATLAB software and tested for real time application. This paper comprises Section 2 which discusses the proposed inverter structure, Section 3 presents the comparative analysis of various trends on multilevel inverters, Section 4 consists of the simulation findings and in Section 5, conclusion.

2. Proposed 19 Level Inverter

The proposed asymmetric multilevel inverter structure is shown in Figure 1. The inverter consists of three asymmetric sources and 12 power electronic switches. The proposed inverter produces 19 levels of output voltage and the inverter is controlled by the Nearest Level Modulation (NLM) technique. The unequal DC magnitude i.e., V1 = V_{DC}, V2 = 3 V_{DC}, V3 = 5 V_{DC}, the configured inverter produces 9 +ve voltage levels, 9 –ve voltage levels and with zero voltage level. The switching combinations of the proposed inverter are shown in the Figure 2 and switching pattern is provided in Table 1.

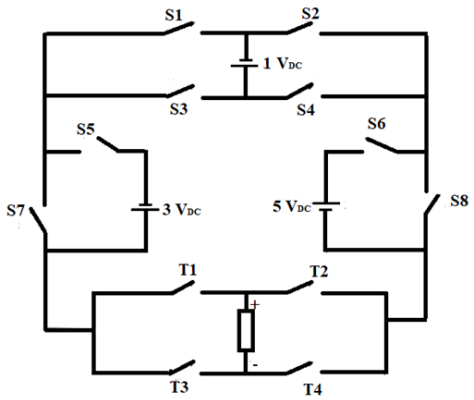

Figure 1. Circuit diagram of the proposed MLI.

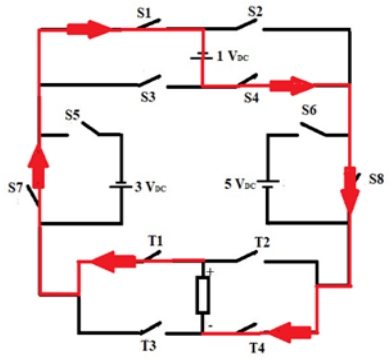

Figure 2. −1 V.

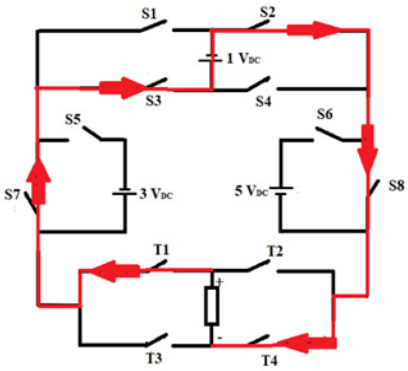

Figure 3. +1 V.

Table 1. Switching pattern of proposed MLI.

V_{DC}	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
0 V	0	0	1	1	0	0	1	1	1	1	0	0
1 V	1	0	0	1	0	0	1	1	1	1	0	0
.	.	.	.	.	.	.	.	.	.	.	.	.	.
9 V	1	0	0	1	1	1	0	0	1	1	0	0
0 V	0	0	1	1	0	0	1	1	1	1	0	0
−1 V	1	0	0	1	0	0	1	1	0	0	1	1
.	.	.	.	.	.	.	.	.	.	.	.	.	.
−9 V	1	0	0	1	1	1	0	0	0	0	1	1

3. Comparative Analysis

In this section, the several kinds of multilevel inverters are compared on the basis of output voltage produced, the number of switches used, voltage sources used, IGBT devices used, total standing voltage (TSV), and the THD of various configurations and it is given in Table 2. The MLI circuit proposed in [3,6] produces eleven levels of output voltage with different switch counts. In [11] the proposed topologies produce thirteen levels of output voltage whereas the THD is reduced. For the 17 levels of output voltage, 13 switches and 10 switches are used in [5]. The configured inverter produces the Total harmonic Distortion of 12.17% with the 7 levels of output voltage [7]. Only one DC voltage source is needed in order to operate at levels 3 and 5 in [7,11].

Table 2. Comparison between various configured MLI.

Ref No	N_L	N_{SW}	N_{DS}	X_{THD}	$N_{(D+C)}$
3	11	8	5	4.56	2D
5	17	13	2	3.12	18D + 2C
6	11	12	5	3.35	12D
7	7	9	1	12.17	2C
11	13	11	1	4.9	3D + 3C
Proposed	19	12	3	4.36	-

4. Simulation and Experimentation

The MATLAB/SIMULINK software is used to model the designed multilevel inverter. The asymmetrical DC voltage magnitudes are V1 = 20 VDC, V2 = 60 VDC and V3 = 100 VDC. The required voltage is attained by operation of selected switches. The load parameters are R = 90 Ω & L = 30 mH. The nineteen level inverter is controlled by Nearest Level Modulation (NLM) technique which reduces THD. The nearest edge control is selected at the nearest voltage level and fed to logic gates to produce appropriate output which is fed to IGBT switches. The load waveforms and harmonics presences are depicted in Figures 4–6.

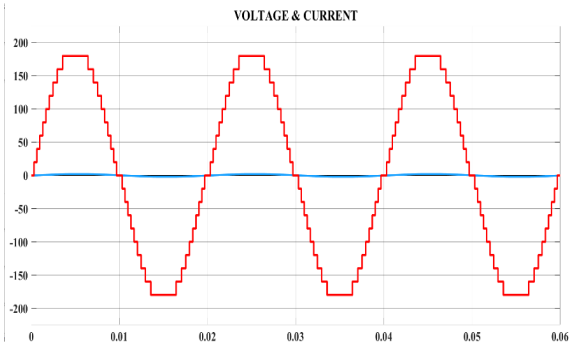

Figure 4. R Load Waveform.

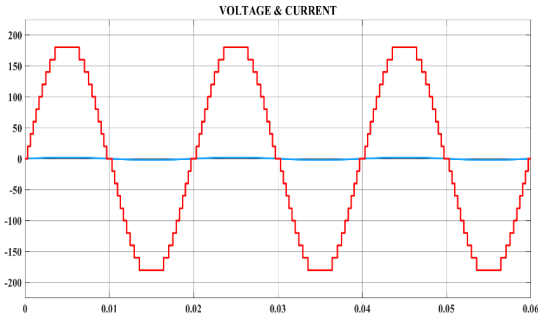

Figure 5. RL Load Waveform.

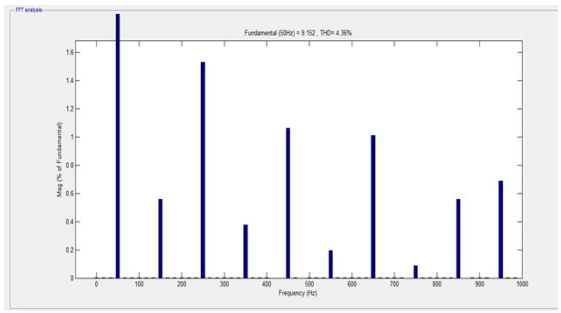

Figure 6. THD Analysis.

The prototype of the proposed inverter is shown in the Figure 7. The inverter receives pulses from the edge control mechanism. The program is flashed to the controller using the FPGA controller. The IGBT devices are used as switches. The four step down transformers are used to step down the grid voltage and fed to the driver circuits. The driver circuits are used to drive the 12 IGBT switches. The prototype is validated with variable and fixed resistive, impedance loads and parameters are provided in Table 3 and load waveform is shown in Figure 8.

Table 3. Performance Parameters-MLI.

Load	V_o	I_o	P_o	%eff	THD
R	180	2	360	95.16	4.30
RL	180	2	360	94.34	4.26

Figure 7. Hardware Model Of 19 Level MLI.

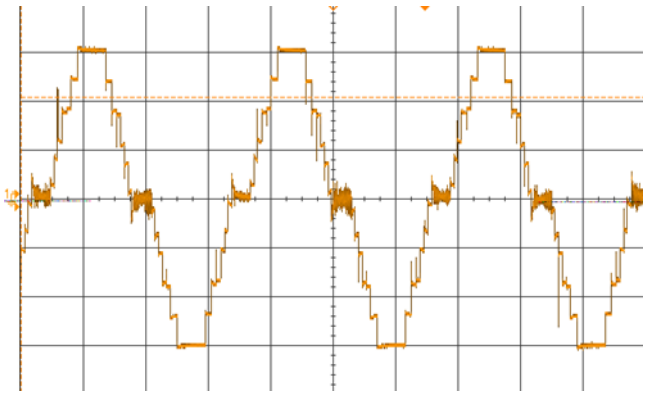

Figure 8. Voltage Waveform.

5. Conclusions

This paper presents the asymmetric multilevel inverter with the reduced number of DC sources and switches count. The proposed inverter produces the 19 levels of output voltage and is controlled using Nearest Level Modulation technique. The inverter voltage sources are set as V1 = V_{DC}, V2 = 3 V_{DC}, V3 = 5 V_{DC}. The inverter is simulated using Matlab software which produces lower THD = 4.26% which is minimum compared to standard IEEE formats. This is also tested in real time for fixed R and RL loads. Because of the variable DC supply the configured inverter is more suitable for renewable energy systems.

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