New Design of Pulse Width Modulation for the Performance Improvement of Multilevel Inverter

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Abstract

In this paper, new pulse width modulation design is proposed for performance improvement of multilevel inverter. Switching strategy of multilevel inverter decides the performance of multilevel inverter. An effort is made to design new pulse width modulation technique. Switching strategy generated from this new design of pulse width modulation greatly improves the performance of multilevel inverter. Multilevel inverter employing this proposed method produces high output voltage and its total harmonic distortion is less. This new design is assigned for common types of modulation such as phase disposition, phase opposition disposition and alternate phase opposition disposition to examine the multilevel inverter's performance parameters. The newly designed pulse width modulation is simulated in MATLAB/Simulink software under the above said types of modulation and the performance of multilevel inverter is evaluated. These simulation results are compared with the conventional methods.

Keywords — *Multilevel inverter, Pulse width modulation, Total harmonic distortion, switching strategy, carrier.*

I. INTRODUCTION

Now-a-days the power electronics technology is creating a boom in the field of electrical and electronics engineering. It plays a wide role in electrical and electronics engineering oriented applications [9]. Inverter, power electronic semiconductor device which converts DC to AC. Multilevel inverter (MLI) is a new kind of inverter. It has superior features than inverter. It combines more number of DC sources or bank of capacitors to produce nearer sinusoidal voltage waveform which is not possible in case of inverter. Its superior features are (1) generating sinusoidal voltage waveform with less total harmonic distortion, (2) low dv/dt, (3) small size output filter...Due to its superior features, MLI is used in many applications. MLI is categorised into diode clamped, flying capacitor and cascaded H-bridge MLIs [1]-[3], [10]-[13].

Harmonics in the electrical power system is an unwanted issue. Decreasing the total harmonic distortion of output voltage of MLI improves the performance of MLI. Total harmonic distortion is the performance parameter of MLI [4]. In order to reduce the harmonics in MLI output, appropriate control strategy is used in MLI. Many modulation techniques are available to design the control strategy for MLI. Pulse width modulation (PWM) is the most commonly used method due to its simplicity. It is of variable types as phase disposition, phase opposition disposition, alternate phase opposition disposition and phase shift, carrier overlapping and variable frequency PWMs. All these PWM techniques reduce the total harmonic distortion of output voltage of MLI. These techniques provide different control strategies for MLI. These PWM techniques are carrier based PWM in which triangle carrier waveform is used. Triangle carrier provides better harmonic characteristics for output voltage of MLI [5]-[7]. In usual, only triangle carrier and sawtooth carrier are used for the carrier based PWM techniques [8].

In this paper, new carrier waveform is proposed. The switching strategy is designed by using this proposed carrier in the pulse width modulation to reduce total harmonic distortion of output voltage of MLI. This proposed technique is applied on asymmetric cascaded H-bridge MLI and simulated in MATLAB software. Fig.1 shows the power circuit diagram of asymmetric cascaded H-bridge MLI to which the proposed technique provides switching pulses. This paper also involves the comparison of proposed techniques and conventional techniques.

II. PROPOSED PULSE WIDTH MODULATION

The proposed method uses single sinusoidal reference and multiple carriers. Here the carrier used is a proposed trapezoidal stepped triangle carrier.

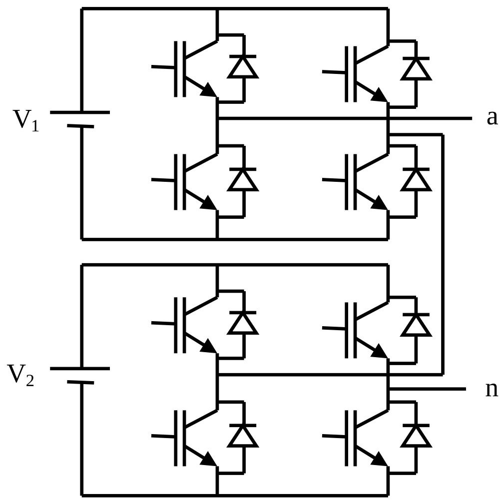


Fig.1 Power circuit diagram of asymmetric cascaded H-bridge MLI

A. Phase Disposition PWM Using Trapezoidal Stepped Triangle Carrier

The basic principle of this technique is as follows: The carriers in all the carrier bands are in phase. Fig.2 is about the reference and carrier waveforms arrangement in which structure of the proposed trapezoidal stepped triangle carrier is shown.

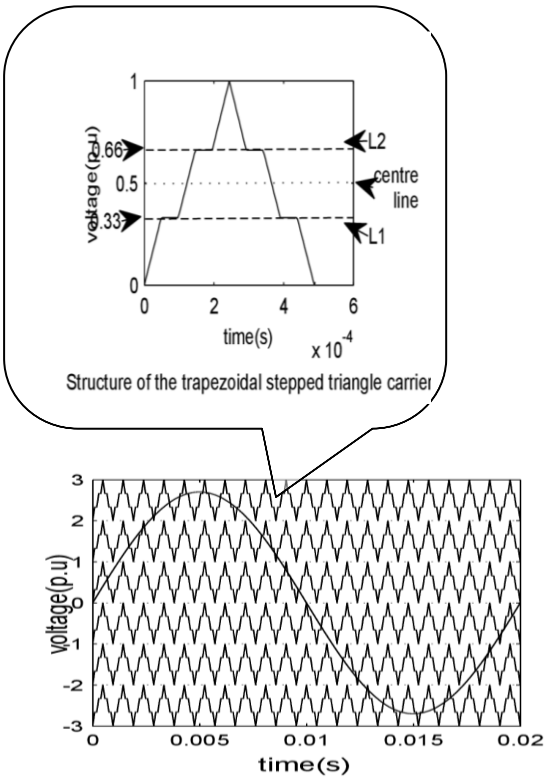


Fig.2 Reference and trapezoidal stepped triangle carrier waveforms arrangement of phase disposition PWM

All the trapezoidal stepped triangle carriers are compared with the reference waveform respectively to generate switching pulses. When the reference waveform magnitude is higher than the trapezoidal stepped triangle carrier waveform magnitude, switching pulse state is 'ON' otherwise it is 'OFF'. These generated switching pulses are sent to MLI under logical operations. Instead of triangle carrier, the proposed trapezoidal stepped triangle carrier is used for designing the control strategy of MLI to reduce total harmonic distortion. Therefore performance of MLI gets improved.

The following steps are carried out to generate trapezoidal stepped triangle carrier:

- Change is made at the centre of the triangle waveform without change in amplitude and frequency.
- The total time period of triangle waveform is divided into ten intervals. These intervals are equal.
- Amplitude lines 'L1' and 'L2' are drawn below and above the centre line of triangle waveform respectively.
- During the first half time period, carrier starts from zero, touches 'L1' at T/10 timing instant, keeps amplitude constant up to 2T/10 timing instant, touches 'L2' at 3T/10 timing instant, again keeps amplitude constant up to 4T/10 timing instant and reaches its peak value at 5T/10 timing instant.
- In the next half time period, carrier runs from its peak value, reaches 'L2' at 6T/10 timing instant. Its amplitude remains constant up to 7T/10 timing instant. It touches 'L1' at 8T/10 timing instant, keeps amplitude constant up to 9T/10 timing instant and reaches zero at T.

B. Phase Opposition Disposition PWM Using Trapezoidal Stepped Triangle Carrier

In this technique, carriers in all the carrier bands above the zero reference are in phase but in phase opposition with carriers below the zero reference. Fig.3 shows reference and trapezoidal stepped triangle carrier waveforms arrangement.

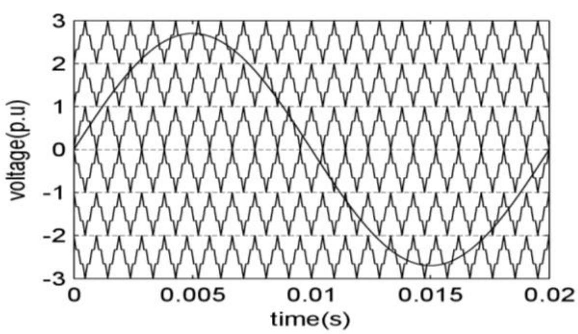
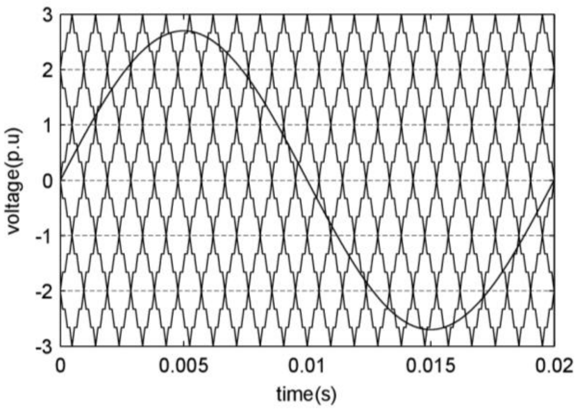


Fig.3 Reference and trapezoidal stepped triangle carrier waveforms arrangement of phase opposition disposition PWM

All the trapezoidal stepped triangle carriers are compared with reference waveform respectively to produce switching pulses for MLI. This proposed control strategy reduces total harmonic distortion in MLI. It improves the performance.

C. Alternate Phase Opposition Disposition PWM Using Trapezoidal Stepped Triangle Carrier



In this technique, carriers in all the carrier bands are alternatively in phase opposition. Fig.4 is about the reference and trapezoidal stepped triangle carrier waveforms arrangement.

Fig.4 Reference and trapezoidal stepped triangle carrier waveforms arrangement of alternate phase opposition disposition PWM

Using this technique, control strategy is designed and switching pulses are generated for MLI. This control strategy also decreases the total harmonic distortion in output voltage of MLI.

III. RESULTS AND DISCUSSION

The proposed control strategies are applied for asymmetric cascaded H-bridge MLI and simulated in MATLAB. The required parameters for simulation are trapezoidal stepped triangle carrier frequency=2050Hz, sinusoidal reference frequency=50Hz, DC input voltages, V_1=50V, V_2=100V. Fig.5 (a) & (b) shows the MLI output voltage and its harmonic spectrum respectively by using trapezoidal stepped triangle carrier based phase disposition PWM.

5(a)

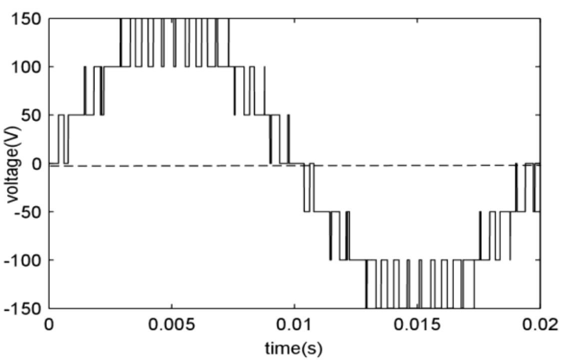
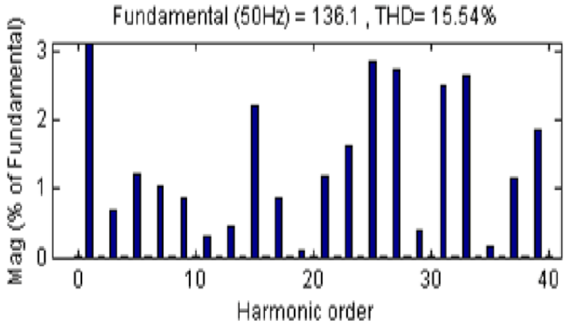


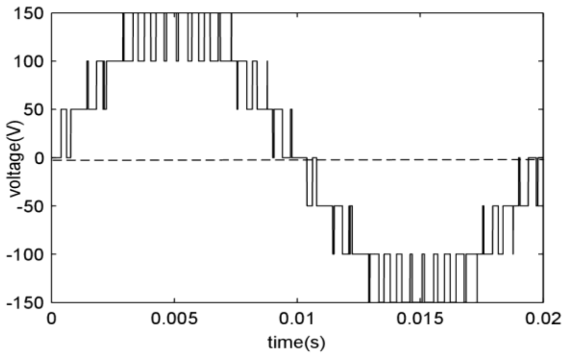
Fig.5 (a) MLI output voltage by using proposed carrier based phase disposition PWM for m_a=0.9

Fig.6 (a) & (b) is about the MLI output voltage and its harmonic spectrum respectively by using trapezoidal stepped triangle carrier based phase opposition disposition PWM.

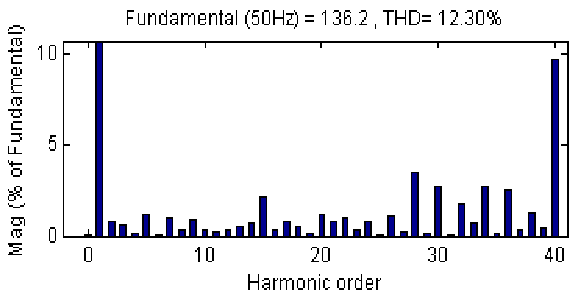


5(b)

Fig.5 (b) Harmonic spectrum of output voltage of MLI shown in Fig.5



6(a)

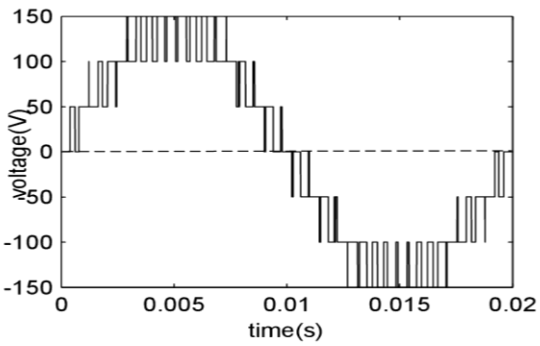


6(b)

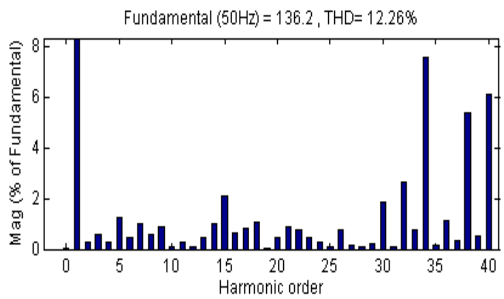
Fig.6 (a) & (b) MLI output voltage and its harmonic spectrum by using proposed carrier based phase opposition disposition PWM for m_a=0.9

Fig.7 (a) & (b) shows the MLI output voltage and its harmonic spectrum respectively by using trapezoidal stepped triangle carrier based alternate phase opposition disposition PWM.

Table I shows comparison of performance parameters of MLI between proposed trapezoidal stepped triangle carriers based phase disposition PWM and conventional phase disposition PWM for various values of m_a. Conventional PWM involves triangle carrier. As m_a varies, total harmonic distortion (THD) and output voltage varies. When m_a=1, THD is very low and output voltage is high. THD is low for proposed trapezoidal stepped triangle carrier based phase disposition PWM when compared to conventional phase disposition PWM.



7(a)



7(b)

Fig.7 (a) & (b) MLI output voltage and its harmonic spectrum by using proposed carrier based alternate phase opposition disposition PWM for m_a=0.9

TABLE I
Comparison of performance parameters of MLI between proposed carrier based phase disposition PWM and conventional phase disposition PWM

m_a	Proposed trapezoidal stepped triangle carrier based phase disposition PWM		Conventional phase disposition PWM	
	THD %	Output voltage (V)	THD %	Output voltage (V)
1	11.42	151.3	13.07	150
0.9	15.54	136.1	17.31	135
0.8	16.33	119.9	18.17	120
0.7	15.12	105.4	17.62	105
0.6	21.76	91.92	25.44	90.02

For all values of m_a, THD of proposed method is decreased by 2% on comparing with conventional method. Output voltage of proposed method is higher than output voltage of conventional method.

Table II compares the performance parameters of MLI between proposed trapezoidal stepped triangle carrier based phase opposition dispositions PWM and conventional PWM.

TABLE II
Comparison between proposed carrier based phase opposition disposition PWM and conventional phase opposition disposition PWM

m_a	Proposed trapezoidal stepped triangle carrier based phase opposition disposition PWM		Conventional phase opposition disposition PWM	
	THD %	Output voltage (V)	THD %	Output voltage (V)
1	9.31	151.4	9.93	150
0.9	12.30	136.2	12.80	135
0.8	12.60	119.8	13.57	120
0.7	11.99	105.4	13.59	105
0.6	17.09	91.92	18.62	90.11

In phase opposition disposition PWM also, proposed method is superior to conventional method in terms of both THD and output voltage.

Table III shows comparison of performance parameters of MLI between proposed trapezoidal stepped triangle carriers based alternate phase opposition disposition PWM and conventional PWM.

TABLE III
Comparison of performance parameters of MLI between proposed carrier based alternate phase opposition disposition PWM and conventional PWM

m_a	Proposed trapezoidal stepped triangle carrier based alternate phase opposition disposition PWM		Conventional alternate phase opposition disposition PWM	
	THD %	Output voltage	THD %	Output voltage

		(V)		(V)
1	9.29	151.3	9.88	150.1
0.9	12.26	136.2	12.78	135
0.8	12.67	119.8	13.47	119.9
0.7	11.94	105.4	13.46	104.9
0.6	16.56	91.94	18.51	90.01

In this alternate phase opposition disposition PWM, proposed method is better than the conventional method. In all the cases, proposed trapezoidal stepped triangle carrier based PWM is superior to conventional PMW. This is due to the structural characteristics of proposed trapezoidal stepped triangle carrier. This proposed carrier is well suited for MLI.

IV. CONCLUSION

From the results, it is found that the proposed trapezoidal stepped triangle carrier is suitable for PWM to generate switching pulses for MLI. It exhibits increased output voltage with less total harmonic distortion. It improves the performance of MLI. It can be used for all the applications of MLI.

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