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A New Method of Selective Harmonic Elimination PWM for H-Bridge Cascaded Multilevel Inverter

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Abstract: ***The quality of power of the cascaded H-bridge multilevel inverter is affected due to harmonics. In this paper, a Selective Harmonic Elimination Pulse Width Modulation (SHE-PWM) method including controllable DC link voltage is introduced for the multilevel inverter. Novel mathematical modeling of SHE-PWM is established concerning the DC link voltage. Compared to ordinary selective harmonic elimination, the proposed method has an increased number of degrees of freedom because of its variable DC link voltage. On the other hand, the selective harmonic elimination utilizes constant DC link voltage. In the proposed scheme, the nonlinear equations are solved only once in the entire voltage range. As a result, the computational burden will decrease. Also, the Total Harmonic Distortion (THD) of the output voltage remains constant for various values of the operating points. The simulation is performed using Matlab Simulink and the comparison is performed with the conventional PWM method. It is intended that the proposed SHE-PWM based cascaded H-bridge multilevel inverter provides better performance in terms of lower-order harmonics and less THD compares to conventional PWM method.***

Keywords : multilevel inverter, pulse width modulation, harmonic elimination, harmonic distortion.

I. INTRODUCTION

In recent years, the power conversion system (FACTs devices, HVDC transmission, and custom power devices) requires high voltage and high power converters [1]. The voltage limitations and the power requirement of the electronic components can be managed by a new family of inverters called multilevel inverters. It has different advantages such as low harmonic components, less loss profile, high power rating, and less electromagnetic interference [2]. The multi-level inverters are designed in such a way that the output can be adjusted based on the required level. There are three different topologies: 1) cascaded H-Bridge [3], multi-cell with flying capacitor [4], and diode clamped multi-cell [5] are widely used.

The output voltage level of multi-level topology and the harmonic components present in the output voltage has an inverse relationship. To increase the number of voltage levels, various challenges such as increasing the number of clamping devices, balancing of capacitor voltage, and managing the losses in different devices are difficult to solve [6]. Various modulation techniques and control system has been developed by the different researcher on multilevel topologies. Additionally, the simplicity and modularity of cascaded H-Bridge, the high-resolution output is possible by adjusting the switching frequency [7]. Recently, several multilevel constructions are developed by various industrial communities by utilizing less number of components [8-10]. The harmonic components of the output voltage are important criteria for evaluating the performance of a multilevel inverter. The switching techniques and many control systems are used to manage the output voltage of the multilevel inverter [11]. The popularly used switching techniques are: 1) multilevel space-vector modulation [12], sinusoidal pulse width modulation [13], and SHE-PWM [14,15]. The SHE-PWM has different advantages such as direct control of the output, low switching frequency, and harmonic elimination in the output waveform [16,17]. Dalidah and Agelidis proposed a reformulated method in the selective harmonic elimination problem in a multilevel converter based on the PWM waveform [18]. The optimum switching angle of the selective harmonic elimination equation is determined transcendental equation which is solved using the Newton Rapshon method [19]. A transistor clamped H-bridge converter is a special type of inverter used to develop a selective harmonic elimination modulation technique. In the present method, the exact angle of switching is estimated by a transcendental non-linear equation. Moreover, the equal amplitude of the DC link voltage is considered in most of the SHE-PWM methods, but practically it is not acceptable [20]. The DC link voltage is adjusted suitably to get a quality output of the multilevel inverter [21]. In the same way, the quality of the output waveform of the converter can be improved by adjusting the amplitude of the DC link voltage of the cascaded H-Bridge topology.

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In this paper, a new method is introduced for SHE-PWM by adjusting the amplitude of DC-link voltage. This method can be used in cascaded H-Bridge multilevel inverter also. Compared to existing selective harmonic elimination method, the number of freedom angle can be easily adjusted by varying the DC-link voltage of the proposed SHE-PWM, the selective harmonic elimination method utilizes constant DC link voltage. Further, the equation

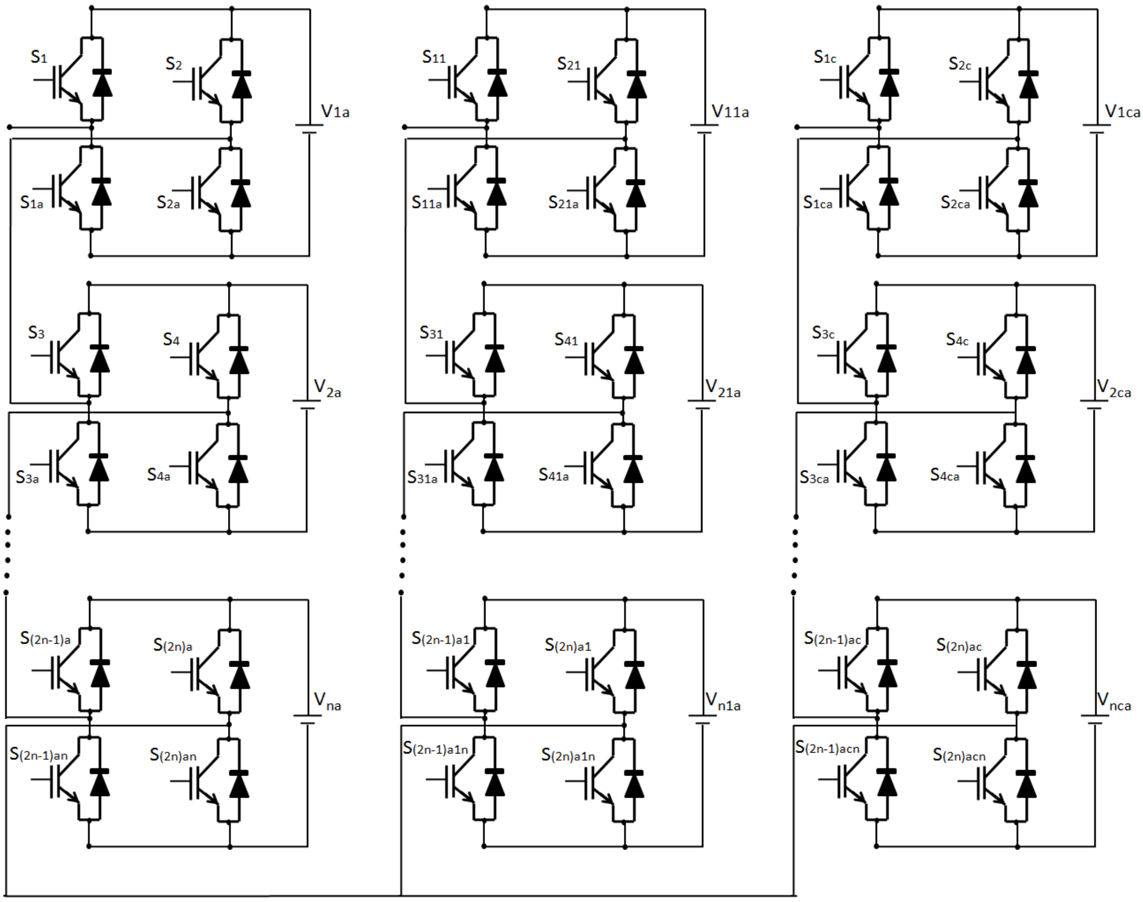


Fig. 1. General structure of 3-phase cascaded H-bridge multilevel inverter.

related to the entire range of output waveform is solved only one time. So that the speed of operation of the proposed SHE-PWM method will increase. Compare the proposed method with other methods used in [11] and [22], the proposed method used multiple searching in each step of the output voltage. This approach provides a better quality output waveform. On the other hand, SHE-PWM utilizes freedom degrees in the width and the height of the output waveform. The proposed SHE-PWM estimate the switching angle only one time for each level, verify the switching level for each level in the previous methods. The performance of the proposed method is tested by simulation and experimental results of a seven-level converter. This paper is organized as follows: Section 2 describes the structure of cascaded H-bridge inverter and the mathematical modeling, Simulation result of the proposed SHE-PWM is explained in section 3. The experimental result is illustrated in section 4. The conclusions are given in section 5.

II. PROBLEM FORMULATION

A. Structure of cascaded H-bridge multilevel inverter

The general structure of 3-phase cascaded H-bridge multilevel inverter is shown in Fig. 1. From Fig. 1 one can easily understand that the series connection of three single-phase H-bridges and the isolated DC link is provided to each inverter. The isolated DC link can be obtained from fuel cells, ultra-capacitors, and batteries, etc. [23]. The dc-dc converters are used to control the input isolated DC links. The gate signals are properly set in the switches $S_{(2n-1)m}$ and $S_{(2n)m}$ (n=1,2,…,k, and m=a,b,c) to get appropriate output. The complementary switches $S_{(2n-1)mx}$ and $S_{(2n)mx}$ does not have the gating signals. Hence, the output voltage of the cascaded H-bridge inverter is the sum of isolated DC link voltage with coefficients 0, 1, and -1. The seven-level cascaded H-bridge inverter is taken as an example and study the performance of the proposed method. Here, each H-bridge inverter generates a 3 level waveform in each quarter of output waveform. The degree of freedom to eliminate the harmonics of output voltage increases if the number of notches is added. The output voltage waveform of the inverter can be expressed based on Fourier series as:

$$V_o(\omega t) = \frac{4}{\pi}\sum_{n=1}^{\infty}\frac{1}{n}[V_1\cos(n\varphi_1) - \cdots + V_s\cos(n\varphi_k)]\sin(n\omega t) \qquad (1)$$

Where V_1, V_2, V_3,…., V_s are the amplitudes and φ_1, φ_2,…, φ_k are the switching angles.

To evaluate the quality of the output voltage waveform of the inverter, a common index named the total harmonic distortion (THD) is used.

The THD of the cascaded H-bridge inverter output voltage with m-level can be expressed as:

$$THD = \frac{\sqrt{\sum_{k=3,5,7,..}^{\infty} V_k^2}}{V_1} \tag{2}$$

$$V_k = \sum_{n=1}^{m} V_n \cos(k\varphi_n), \quad n = 1,3,5 \ldots \tag{3}$$

The modulation index (m_i) can be expressed as:

$$m_i = \frac{V_o}{V_{o\,max}} = \frac{V_o}{4V/\pi} \tag{4}$$

$$V_{oh}(\omega t) = \frac{4}{\pi}\sum_{n=1,3,5,..}^{\infty} \frac{1}{n}\left[V_1(\cos(n\varphi_1) - \cos(n\varphi_1) + \cdots \pm \cos(n\varphi_k)) + \ldots V_N\left(\cos\left(n\varphi_{N(k-1)+1}\right) - \cos\left(n\varphi_{N(k-1)+2}\right) + \ldots + \cos(n\varphi_{Nk})\right)\right]\sin(n\omega t) \tag{5}$$

Where N is the number of notches in the output voltage waveform of H-bridge and k is the number of isolated DC links.

The sum of notches present in the output voltage of cascaded H-bridge is equal to the number of independent notches present in the output voltage waveform of the inverter. i.e. N*k. As a result, the output voltage harmonics can be adjusted in the N*k amplitudes. In this study, the number of unwanted harmonics (N*k) present in the output voltage waveform is eliminated and the output fundamental harmonics can be adjusted based on the required level. The main aim is to choose the amplitude (V_1, V_2, V_3,…., V_N) and the notch point switching angle (φ_1, φ_2, …, φ_{Nk}) properly. So that the unwanted output voltage harmonics can be suppressed and the amplitude becomes equal to the desired value.

The output voltage waveform consists of the harmonic components produced by N*k notches. By using Fourier expansion the first-order components of the resultant waveform can be expressed as:

$$V_o(\omega t) = \frac{4}{\pi}\left[V_1(\cos(\varphi_1) - \cos(\varphi_2) + \cdots \pm \cos(\varphi_N)) + \cdots V_2(\cos(\varphi_{N+1}) - \cos(\varphi_{N+2}) + \ldots + \cos(\varphi_{2N})) + \cdots V_k\left(\cos\left(\varphi_{N(k-1)+1}\right) - \cos\left(\varphi_{N(k-1)+2}\right) + \cdots \pm \cos(\varphi_{Nk})\right)\right] \tag{6}$$

The n[th] harmonics can be represented using Fourier expansion is given by

$V\_nh\ (\omega t) = 4/n\pi\ [V\_1\ (\cos\ ([\![n\varphi]\!]\_1\ ) - \cos\ ([\![n\varphi]\!]\_2\ ) + \cdots \pm \cos\ ([\![n\varphi]\!]\_N\ )\ ) + \cdots V\_2\ (\cos\ ([\![n\varphi]\!]\_(N + 1)\ ) - \cos\ [\![([\![n\varphi]\!]\_(N + 2)\ ) +]\!] \ldots + \cos\ ([\![n\varphi]\!]\_2N\ )\ ) + \cdots V\_k\ (\cos\ ([\![n\varphi]\!]\_(N(k - 1) + 1)\ ) - \cos\ (n\varphi\_(N(k - 1) + 2)\ ) + \cdots \pm \cos\ (n\varphi\_Nk\ )\ )\ ]$

(7)

The negative and positive sign of equation 6 and 7 indicates that the isolated DC-link increasing and decreasing amplitude steps of the cascaded H-bridge output voltage. Now a constraint can be formed because the switching angle (φ_1… φ_k) is in the increasing order.

$$\varphi_1 < \varphi_2 < \cdots < \varphi_k < \varphi_{Nk} \tag{8}$$

The major aim is to eliminate the unwanted harmonics present in the output. Hence, (8) should be satisfied to suppress the harmonics of the cascaded H-bridge output voltage waveform.

$$V_1\left(\cos(n\varphi_1) - \cos(n\varphi_2) + \cdots \pm \cos(n\varphi_N)\right) + \cdots + V_k\left(\cos\left(n\varphi_{N(k-1)+1}\right) - \cos\left(n\varphi_{N(k-1)+2}\right) + \cdots \pm \cos\left(n\varphi_{Nk}\right)\right) = 0 \tag{9}$$

Where the angles φ_1… φ_{Nk} are unknown.

Where $V = \sum_{i=1}^{m} V_i$

B. Mathematical Modeling

To study the performance of the SHE-PWM, it is applied to cascaded H-bridge multilevel inverter. Consider φ_1, φ_2, …, φ_{Nk} are the switching angles and amplitude of isolated DC link is V_1, V_2, V_3,…., V_k, the harmonics present in the output voltage waveform is expressed as:

The slope of the sine wave moves from the tangential to the center of each half-wave. As a result, the waveform amplitude at the top section should be lower than that of the bottom section. So that the amplitude of the isolated DC link can be expressed as:

$$V_j = U.V_o\cos\left(n\varphi_{N(i-1)+1}\right), i = 1,2,\ldots,k \tag{10}$$

Where U is the unknown parameter added in (10). Now equation 6 and 9 can be written using (10) as:

$$cos_{\varphi_1}^2 - cos\varphi_2 + \cdots \pm cos\varphi_N + cos^2\varphi_{N+1} - cos\varphi_{N+2} + \cdots \pm cos\varphi_{2k} + \cdots cos^2(\varphi_{N(k-1)+1} - \cos(\varphi_{N(k-1)+2}) + \cdots \pm cos(\varphi_{Nk}) = \frac{\pi}{4U} \tag{11}$$

$$cos\varphi_1(\cos(n\varphi_1) - \cos(n\varphi_2) + \cdots \pm \cos(n\varphi_N)) + cos\varphi_{N+1}(\cos(n\varphi_{N+1}) - \cos(n\varphi_{N+2}) + \cdots \pm \cos(n\varphi_{2N})) + \cdots + cos\varphi_{(N(k-1)+1)}\left(\cos\left(n\varphi_{N(k-1)+1}\right) - \cos\left(n\varphi_{N(k-1)+2}\right) + \cdots \pm \cos(n\varphi_{Nk})\right) = 0 \tag{12}$$

Initially, a set of resultant equations is solved using an appropriate switching angle and φ_{Nk} is estimated. In the proposed method, N*k number of equations are solved only one time, so that less computation time. Various other methods such as the Homotopy method [24], the theory of resultant [11], the direct search method [25], and Newton's algorithm [26] are used. In this study, we consider (12) and appropriate switching angles for the required output voltage. The selective harmonic elimination method provides the best solution for quality output. The amplitude of the THD for the output voltage based on (6), (7), and (2) can be expressed based on [27] as:

$$THD = \frac{4U}{\pi}\sqrt{\sum_{n=3,5,\ldots}^{\infty}\sum_{j=1}^{N} \times \sqrt{\frac{cos\varphi_{(N(j-1)+1)}\left(\cos\left(n\varphi_{N(k-1)+1}\right) - \cos\left(n\varphi_{N(k-1)+2}\right) + \cdots \pm \cos(n\varphi_{Nk})\right)}{n}}} \tag{13}$$

THD is independent of the fundamental components of the output voltage. By controlling the isolated DC-link the amplitude of the fundamental component can be set to the desired value. The proposed method is suitable for improving the quality of the output of the multilevel inverter.

III. VALIDATION OF THE PROPOSED MODEL

In this section, a seven-level cascaded multilevel inverter is considered and the proposed method is applied, three independent isolated DC link is provided to the seven-level inverter. The direct search method with N=k=3 is taken. As a result, nine harmonics in the output voltage can be eliminated. Based on equation 12, the harmonic elimination can be determined based on [28] as:

$$\begin{cases} cos\varphi_1(\cos 5\varphi_1 - \cos 5\varphi_2 + cos5\varphi_3) + \\ cos\varphi_4(\cos 5\varphi_4 - \cos 5\varphi_5 + cos5\varphi_6) \\ +cos\varphi_7(\cos 5\varphi_7 - \cos 5\varphi_8 + cos5\varphi_9) = 0 \\ Cos\varphi_1(\cos 7\varphi_1 - \cos 7\varphi_2 + cos7\varphi_3) + \\ cos\varphi_4(\cos 7\varphi_4 - \cos 7\varphi_5 + cos7\varphi_6) + \\ cos\varphi_7(\cos 7\varphi_7 - \cos 7\varphi_8 + cos7\varphi_9) = 0 \\ \vdots \\ Cos\varphi_1(\cos 29\varphi_1 - \cos 29\varphi_2 + cos29\varphi_3) + \\ cos\varphi_4(\cos 29\varphi_4 - \cos 29\varphi_5 + cos29\varphi_6) + \\ cos\varphi_7(\cos 29\varphi_7 - \cos 29\varphi_8 + cos29\varphi_9) = 0 \end{cases} \quad (14)$$

Matlab 2018 is used to solve the (14) and get the optimum switching angles. The estimated switching angles are listed in Table 1. From Table 1 it is observed that the values are estimated for all the modulation indices. Moreover, equation 14 does not contain the modulation index.

The equation 13 is used to solve the optimum switching angle which is independent of the modulation index. Based on the switching angles the PWM signal switches are generated. The unknown parameter U is used to estimate the DC link amplitude and it can be expressed based on [29,30] using (11) as:

$$U = \frac{\pi}{4} \times \left(\frac{1}{\cos^2\varphi_1 - \cos\varphi_1\cos\varphi_2 + \cos\varphi_1\cos\varphi_3}\right) \times \left(\frac{1}{\cos^2\varphi_4 - \cos\varphi_4\cos\varphi_5 + \cos\varphi_4\cos\varphi_6}\right) \times \left(\frac{1}{\cos^2\varphi_7 - \cos\varphi_7\cos\varphi_8 + \cos\varphi_7\cos\varphi_8}\right) \quad (15)$$

Table-I: Estimated switching angles for the seven-level inverter.

Switching angle	Estimated values (degrees)
φ_1	0.578
φ_2	2.783
φ_3	7.394
φ_4	18.294
φ_5	20.739
φ_6	24.194
φ_7	34.280
φ_8	37.633
φ_9	42.472

The fundamental components of the cascaded H-bridge output voltage waveform can be controlled in the modulation index range from 0-1 p.u regulate the DC link amplitude from 0-37, 0.282, and 0.217 p.u respectively. The variation of V1, V2, and V3 to produce the desired output is shown in Fig. 2. The amplitude of the input voltage of the H-bridge is different and isolated to each other. The THD of the proposed method is determined for the line-line voltage, obtained the values from the simulation is applied in (13) is around 9.65 %.

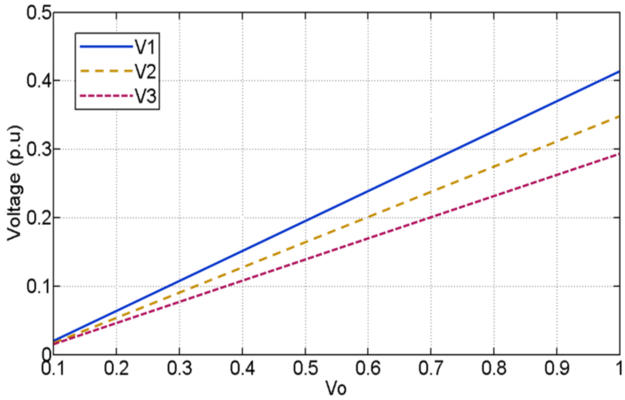


Fig. 2. Variation in DC voltage source to produce desired output.

The value of THD is independent of the amplitude of the output voltage. The modulation index variation concerning the THD is shown in Fig. 3. From Fig. 3 it is observed that if the modulation index increases the THD of the line voltage slowly decreases. The THD of the proposed method has a slight variation when the modulation index is lesser than 0.7 p.u.

The frequency spectrum of the output voltage up to 91st harmonic is illustrated in Fig. 4. The percentage of THD is around 9.38% with this harmonic component. The proper value of N and k results in the suppression of harmonics. It can be seen that the increased number of lower-order harmonics can be eliminated when the number of switching is increased.

Table-II: Performance comparison of THD using SHE-PWM.

Level	Method	φ_1	φ_2	φ_3	φ_4	φ_5	φ_6	φ_7	Simulation THD (%)	
									Voltage (V)	Current (A)
7	PWM	0.162	0.317	0.463	0.602	0.739	0.892	0.983	5.384	5.193
	SHE-PWM	0.134	0.153	0.317	0.418	0.516	0.627	0.718	4.624	4.014

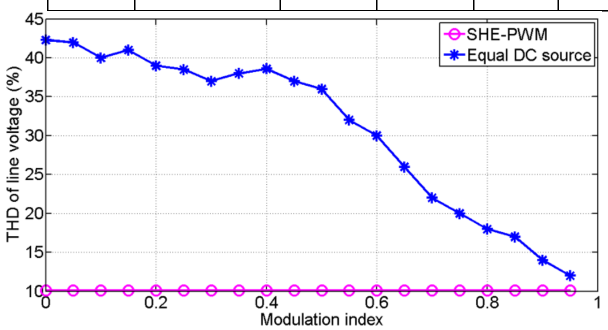


Fig. 3. Comparison of modulation index and output voltage THD.

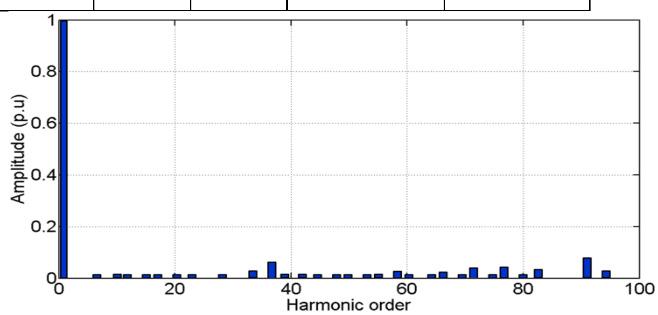
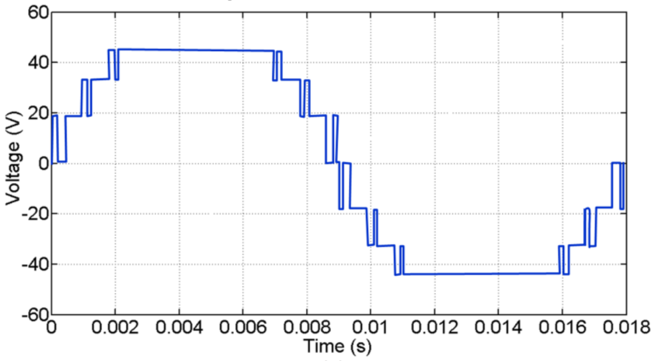


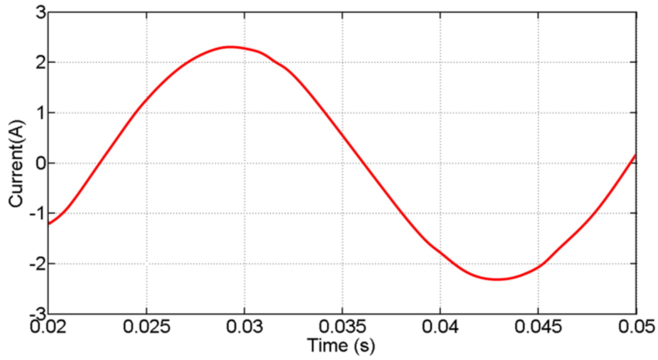
Fig. 4. The line voltage harmonic spectrum by the proposed method.

IV. SIMULATION RESULTS

The simulation is carried out using Matlab Simulink software executed in the i5 computer with 3.2 GHz CPU, 8 GB RAM. The proposed cascaded H-bridge 7-level inverter was developed and the switching angle was implemented. The voltage, current, and harmonic distortion of cascaded multilevel inverter were studied. In this study, the Y-phase and the corresponding current is taken. The simulation circuit is shown in Fig. 6.



(a)



(b)

Fig. 5. Simulation output (a) phase voltage (b) output current.

The output voltage of Y-phase and the corresponding current of the cascaded H-bridge 7-level inverter is shown in Fig. 5. Fig. 5(a) shows the output voltage of cascaded H-bridge inverter and it does not have triple harmonics. The output current for the corresponding phase is shown in Fig. 5(b). Fig. 5(b) indicates that the load current has very less harmonic components.

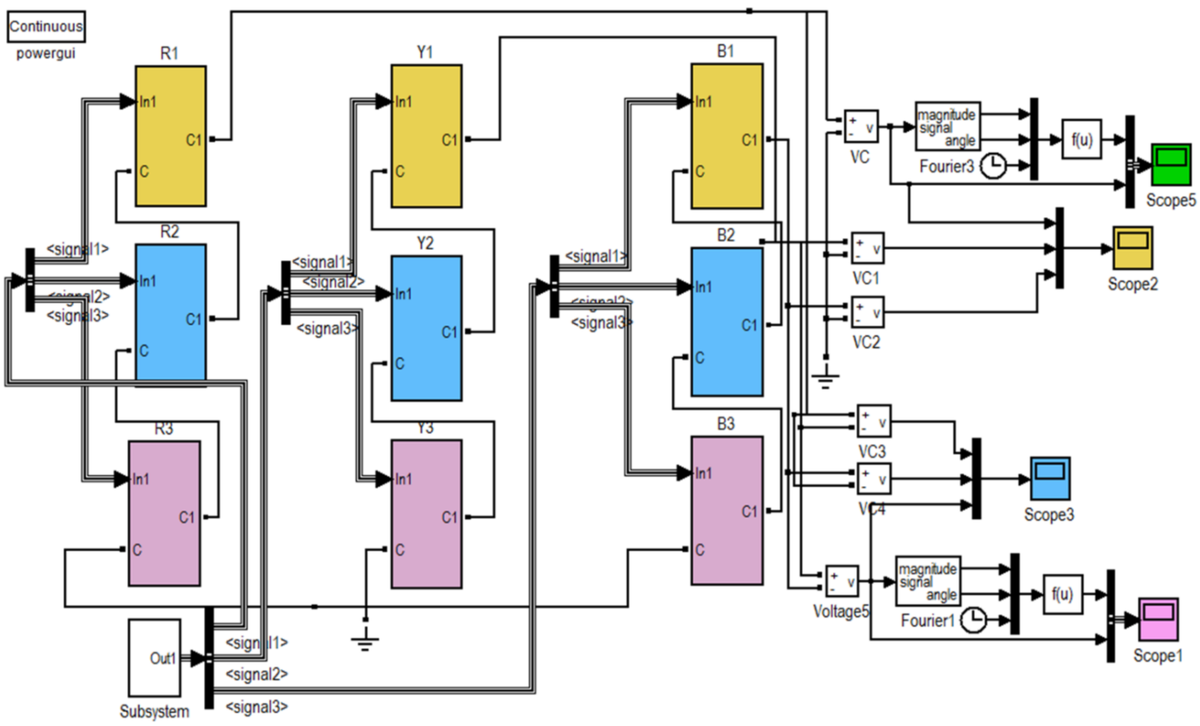


Fig. 6. Simulation diagram of the propose SHE-PWM

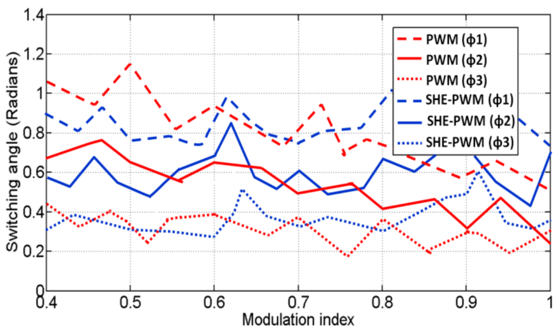


Fig. 7. Various switching angles for the proposed SHE-PWM and PWM

The plot of the switching angle versus modulation index for the proposed cascaded 7-level inverter is shown in Fig. 7. From Fig. 7 it is observed that if the switching angle increases more oscillation is present in the modulation index. Compare the proposed method with the PWM method, the variations present in the proposed SHE-PWM is lesser than conventional PWM. The plot of the THD versus modulation index of the current and voltage for cascaded H-bridge 7-level inverter is shown in Fig. 8. From Fig. 8 one can understand that the THD value is slowly decreased when the modulation index increases.

The THD of the

Table-III:. Comparison of percentage of THD on output for R load.

Switching frequency = 2 kHz				Switching frequency = 4 kHz				Switching frequency = 8 kHz			
Voltage THD		Current THD		Voltage THD		Current THD		Voltage THD		Current THD	
PWM	SHE-PWM	PWM	SHE-PWM	PWM	SHE-PWM	PWM	SHE-PWM	PWM	SHE-PWM	PWM	SHE-PWM
4.523	3.183	4.528	3.193	3.183	1.016	3.293	1.092	5.261	3.622	5.284	4.281
5.165	3.382	5.183	3.481	3.296	1.083	3.502	1.281	5.421	3.726	5.410	4.382
5.839	3.892	5.892	3.927	3.794	1.291	3.920	1.320	5.822	3.902	5.792	4.621
6.027	4.062	5.927	3.982	4.263	1.359	4.189	1.521	6.271	4.284	5.911	4.862

proposed method is compared with conventional PWM and the result shows that SHE-PWM provides lesser variation than conventional PWM. Further, a numerical analysis was carried out for these switching angles and the corresponding modulation index is listed in Table 2. The circuit inside the block of H-bridge is shown in Fig. 9.

The performance comparison was done between the SHE-PWM and the conventional PWM for the line voltage frequency spectrums is illustrated in Fig. 10. From Fig. 10 it is clear that the proposed SHE-PWM produces lower order harmonic 5th, 7th, 11th, and 13th are below the standard created by the IEEE i.e. less than 3% level.

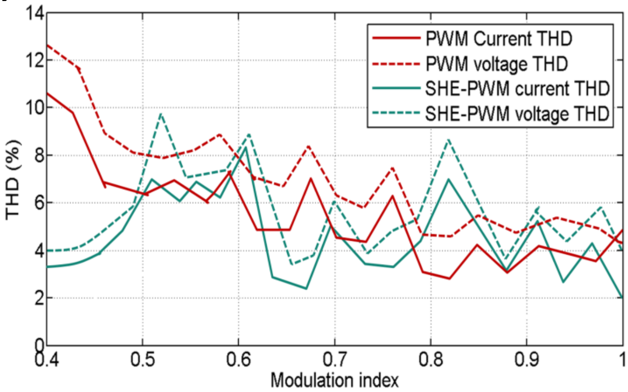


Fig. 8. THDs of the current and voltage for the proposed SHE-PWM and PWM

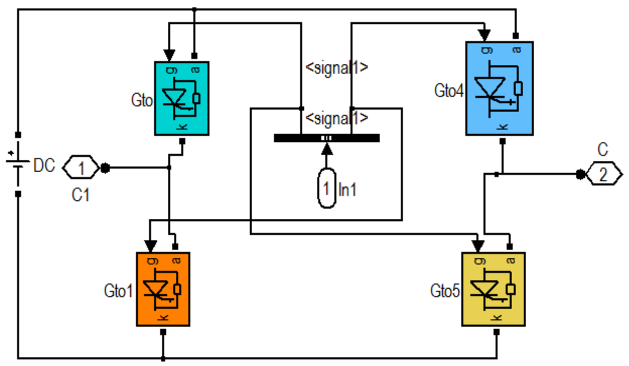


Fig. 9. Internal circuit of the H-Bridge

On the other hand, the proposed SHE-PWM produces 3rd harmonics due to the magnetizing effects of the load. The 3rd harmonics are less than 1% in the proposed method. The performance comparison was done between the SHE-PWM and the conventional PWM for the frequency spectrums of the line current is illustrated in Fig. 11. The current THD level of the proposed SHE-PWM is less compared to the conventional PWM method.

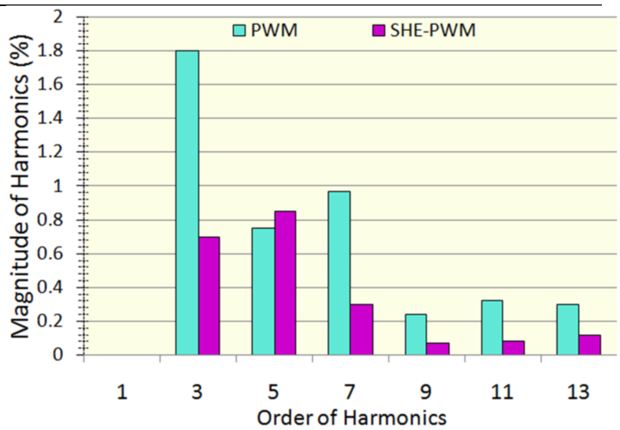


Fig. 10. The line voltage frequency spectrum using SHE-PWM.

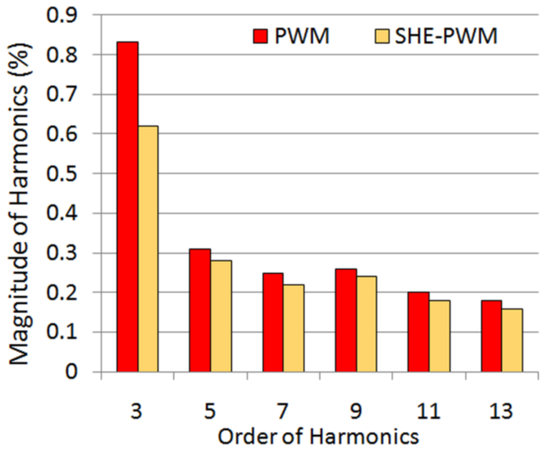


Fig. 11. The line current frequency spectrum using SHE-PWM.

The applicability of the proposed SHE-PWM was tested under R-load and RL-load is given in Table 3 and 4 respectively. The test was carried out for different switching frequencies and the corresponding THD is noted. A comparison of the THD for voltage and current for R load is presented in Table 3. The analysis was performed with different switching frequencies such as 2 kHz, 4 kHz, and 8 kHz. It is observed from Table 3 that the percentage of THD is nearly 30% lesser than the conventional PWM. Moreover, the performance of the proposed SHE-PWM method at 4 kHz switching frequency is better than iin other cases. Similarly, the performance

Table IV: Comparison of percentage of THD on output for RL load.

Switching frequency = 2 kHz				Switching frequency = 4 kHz				Switching frequency = 8 kHz			
Voltage THD		Current THD		Voltage THD		Current THD		Voltage THD		Current THD	
PWM	SHE-PWM	PWM	SHE-PWM	PWM	SHE-PWM	PWM	SHE-PWM	PWM	SHE-PWM	PWM	SHE-PWM
13.32	1.723	10.52	2.381	12.63	1.739	9.34	2.631	13.72	3.845	9.34	7.532
13.61	1.934	11.79	1.935	11.89	1.374	10.38	2.853	14.62	4.194	8.52	7.371
13.82	1.610	11.92	1.804	13.02	1.842	10.93	1.935	15.82	5.274	8.85	7.592
13.98	1.592	12.28	2.045	12.31	1.609	9.62	3.149	17.25	4.652	9.35	7.835

of the proposed SHE-PWM was tested under the RL load is listed in Table 4. In this case, also, the same switching frequencies were used and the result indicates that the percentage of THD is much lesser in the proposed method. Comparing Table 3 and 4, the proposed SHE-PWM is more suitable for RL load and the percentage of reduction is maximum in THD.

To evaluate the performance of the proposed SHE-PWM a statistical analysis was carried out to check the value of THD under different conditions. Two different tests were conducted and collect the data randomly and the result is listed in Table 5. From Table 5 one can understand that the proposed method has less variance compared to the conventional PWM method.

Table V: Numerical results of the propose method.

parameters	PWM	SHE-PWM
Observations	25	25
Mean	4.583	3.818
Variance	0.01738	0.0062

V. CONCLUSION

In this study, a new method of SHE-PWM is proposed and applied to cascaded H-bridge multilevel inverter including controllable DC link voltage. In this method, the resultant output voltage is almost sinusoidal because the DC link voltage ratios are determined related to the fundamental components. Here the switching angles of the H-bridges are estimated only once for the entire modulation index. As a result, the computational complexity of the proposed method will be reduced. The fundamental voltage components of the proposed method are controlled in all the range of modulation index. A Simulink model has been developed and test SHE-PWM under different loading conditions. The THD of the output voltage is almost constant for all the modulation indices. From the result, it is concluded that the proposed method is suitable for RL load than R load. Finally, performance evaluation is carried out using statistical methods and the result shows that the superiority of the proposed method.

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