

Management switching angles real-time prediction by artificial neural network

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ABSTRACT

Artificial neural networks (ANNs) is an efficient way for different types of real-world prediction problems. In the past decade, it has given a tremendous surge in a global research activities. ANNs embody much certainty and provide a great deal of promise. This paper has present artificial neural network (ANN) technique analysis and prediction for management switching angles real-time. The proposes to be used ANN for prediction and selected obtine angles for implement the timing diagram for multilvel inverter circuit. In order to control the fundamental component, ANNs are used to solve the analysis of non-linear equation of the output timing diagram in order to determine the switching angles. Substantially, the number of switching devices are reducing as possible basically for reducing a switching loss in the system, also have been used ANNs technique to optimize a switching angles behavior to reduce total harmonic distortion (THD) at voltage and current output waveform equal THDV 8.05% THDA 5.1%. For the proposed controllers, the performance and results by the ANNs were obtained and compared by using MATLAB software.

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1. INTRODUCTION

A multilevel inverter is an electronic circuit with multi-level power, this inverter/circuit can be converted into a direct power (DC) output supply and supplies an alternate voltage (AC) waveform. "Renewable sources of energy such as photovoltaics, wind and water turbines are now essential energy sources due to their renewable and environmental friendliness" [1]-[3]. Most of these renewable pathways generate a DC waveform as an output that is not appropriate for transmissions, distributions and uses. Based on this, the DC output power should be converted to AC power waveform and this can be achieved through the MLI circuit [2]-[5]. In general, based on their principal structure, MLI structures have been categorized into three main topologies namely cascaded h"bridge (CHB-MLI) which is the most common and reliable, diode-clamped (DC-MLI) and fly"capacitor (FC-MLI). A connected cells in series in the load compose a CHB-MLI topology, while conventional structure of CHB-MLI uses four switches producing three levels for each cell [4], [5]. Several modulation methods for eliminating a harmonic during the output waveform, such as the pulse wide module (PWM), called a high frequency switching technique, including S-PWM and SV-PWM have been used. Secondly, selective harmonic elimination (SHE-PWM) method, often called the best

modulation method, as the space vector control (SVC), is a fundamental technique for frequency changes [6]-[11]. “In addition, a complex transcendental not linear equation (SHE-PWM) can be found which has to be resolved, which cannot be easily solved by simple methods [12], while means of iterative control methods can overcome this complex equation (SHE-PWM) such as optimisation of artificial neural network (ANN), firefly algorithm (FFA), particle swarm optimization (PSO), and newton-raphson (NR) [13]-[15] to define and calculate unique switching Angles for lower THD and more smooth wave form of a multiplex” [7], [12]-[15]. THD can essentially be defined as the ratio of high harmonics with low harmonics as shown, when an is a high harmonic and a1 low harmonics [16]. Therefore, output voltage can be generated by a nine level CHB-MLI based on Figure 1 and Figure 2,

$$THD = \frac{\sum_{n=1,3,5...}^{\infty} (a_n)}{a_1}$$

$$V_{out} = V_{c1} + V_{c2} + V_{c3} + V_{c4} + V_{c5}$$

2. SHE-PWM TECHNIQUE PROPOSED METHOD

A selective harmonic elimination SHE-PWM technique from a fundamental switch frequency strategy is a modulation technique that has been used in this research paper. “To produce a symmetrical quarter waveform in this approach, the equation of the fast fourier series (FFT) is applied to the output voltage staircase waveform to satisfy the best switching angles [11]”. The (Vout) FFT statement can be computed as,

$$V(t)_{out} = \sum_{n=1}^{\infty} a_n \sin(n\omega t) + b_n \cos(n\omega t)$$

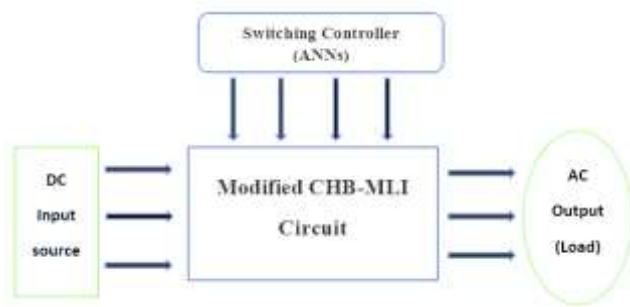


Figure 1. One of cell for nine level CHB-MLI

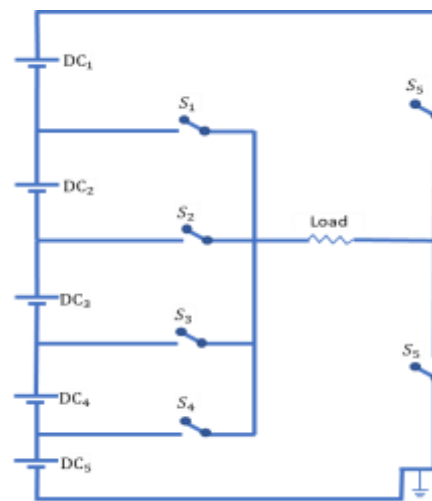


Figure 2. Proposal for nine-level CHB-MLI circuit

“Which cleared all kinds of harmonics (b nequal zero) and presented only the odd harmonics”. “The odd coefficient (an) can therefore be determined, and the switching angles can only be calculated at the initial quadrant waveform.” Thereby, 4 Switching Angles at level-9 MLI should be defined and calculated as the critical angle at first quadrant waveform ($\theta_1, \theta_2, \theta_3$ and θ_4) as shown in Figure 4 based on Table 1 [17]. The odd (a_n) coefficient can, however, be calculated in,

$$a_n = \frac{4}{\pi} \int_0^{\pi/2} V \sin(n\theta) d\theta$$

therefore the input supply units are required, assuming that the MLI which proposes the symmetrical CHB-MLI is equivalent. The MLI output voltage waveform can then be defined by FFT expansion,

$$V(\omega t) = \frac{4V_{dc}}{n\pi} \sum_{n=1,3,5,\dots}^{\infty} [\cos(n\theta_1) + \cos(n\theta_2) + \cos(n\theta_3) + \cos(n\theta_4)] \frac{\sin(n\omega t)}{n}$$

in fact, the odd coefficient (a_n) of fourier series (FFT), “which can be obtained by taking $V(\omega t)$ as the common factor for every equation side, needs to be further analysed” [18]. until the final equation of odd series coefficients for harmonic order components can be obtained in,

$$a_n = \frac{4V_{dc}}{n\pi} [\cos(n\theta_1) + \cos(n\theta_2) + \cos(n\theta_3) + \cos(n\theta_4)]$$

numerically, 4 orders can be obtained for each strange harmonic order at 9-level CHB-MLI in (Figure 3),

$$[\cos(\theta_1) + \cos(\theta_2) + \cos(\theta_3) + \cos(\theta_4)] = \frac{4\pi M_1}{2}$$

$$[\cos(3\theta_1) + \cos(3\theta_2) + \cos(3\theta_3) + \cos(3\theta_4)] = 0$$

$$[\cos(5\theta_1) + \cos(5\theta_2) + \cos(5\theta_3) + \cos(5\theta_4)] = 0$$

$$[\cos(7\theta_1) + \cos(7\theta_2) + \cos(7\theta_3) + \cos(7\theta_4)] = 0$$

and modulation index $M_1 = \frac{a_1}{IV_{dc}}$ when l “the number of independent DC sources., in fact, a mathematical equation cannot determine the complex SHE-PWM equation. Complicated approaches ANN, FFA, PSO, and N-R must virtually be calculated” [19], [20].

Table 1. Output voltage switching behavior for nine-level M-CHB-MLIs

S_1	S_2	S_3	S_4	S_5	S_6	V_o
1	0	0	1	0	1	V_{dc}
1	0	0	1	0	0	$V_{dc}/2$
0	0	0	1	1	0	$V_{dc}/3$
0	0	0	1	1	0	$V_{dc}/4$
0	0	1	1	0	0	0
1	1	0	0	0	1	0*
0	1	0	0	1	1	$-V_{dc}/4$
0	1	0	0	1	0	$-V_{dc}/3$
0	1	1	0	0	0	$-V_{dc}/2$
0	1	1	0	0	0	$-V_{dc}$

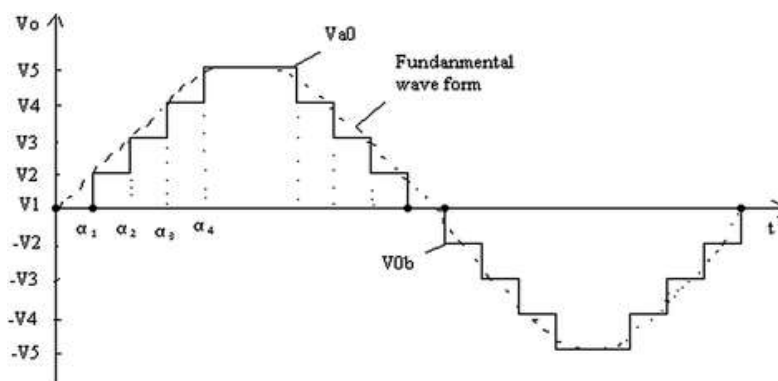


Figure 3. Output waveform voltage of 9-level MLI

3. ANN PERFORMANCE EVALUATION

ANNs are inspired by biological nervous system, it can organise and process information and evaluate the desired data as shown in Figure 4 [15], it is a powerful technique that has been successfully applied and solved various types of real-world problems, particularly in the field of electronic control. A fundamental structure model for ANNs are compiled by the number of layers that have a limited number of

activation functions that called neurons; they are interconnected by connecting weight so that each layer has a bias parameter, in which a regulatory value is used, to control a processing method [16] ANNs generally have three major layers of weight connection: input layer to hold the input parameters, hidden layers as a processing layer and finally the output layer of the result from input and processing layers [17]-[19].

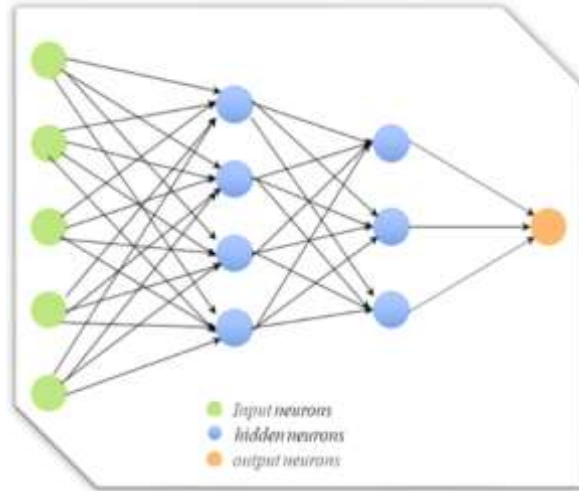


Figure 4. ANNs structure

Feedback (FB-ANNs) which contain feedback and feedback unit (FF-ANNs) and which do not contain the feedback unit, may also be divided into two main structures. In fact, it has been established that all ANNs need first of all to train data to understand and to form a link between the output and input layers in order to respond more quickly and temporarily [21]. There is different training algorithms used in ANNs. However, the most appropriate algorithm in this work is Levenberg-Marquardt-algorithm, which is required to reduce the memory compared to other methods because of faster tanning [22]. Results with high performance compared to other studies that used different control methods were achieved by using ANNs as a control system to calculate nonlinear transcendental equation because the ability to map the fundamental relationship between input and output data during the training process was achieved [23]. As an input neuron, the first neuron of the output layer is used to generate a switching signal for the proposed M-CHBMI [24]. For i^{th} neuron at m^{th} ayer the network transfer function can then be described in,

$$n_i^m = \sum_{j=1}^{S^{m-1}} W_{ij}^m a_j^{m-1} + b_i^m$$

the parameter of bias of j^{th} layer at i^{th} neuron is the W_{ij}^m weight relations parameter for the m^{th} and i^{th} neurons at the m^{th} layer and the b_i^m . a_j^m is also the at m^{th} layer neuron output function that can be defined as:

$$a_i^m = f^m (n_i^m)$$

In the hidden layer, a tangent hyperbolic function is selected as the activation function (f) for our network design, it can be defined as,

$$f^m (n_i^m) = \frac{2}{1 + e^{-2n_i^m}} - 1$$

whereas f is unity at the output layer [25]-[27]. The above describes a harmonic minimization equation using ANNs. Figure 5 shows the ANN harmonic minimization procedure flow chart and Figure 6 provides the resulting optimal switching angles. ANNs consisting of two hidden neurons have been training the output are shown in Figure 7(a) and Figure 7(b) showing the gradient mean squared error and ANN performance validation of 9-level modified CHB-MLI that has also been used to update and correct both network device weight and bias values, validation is used via the training process to track the error.

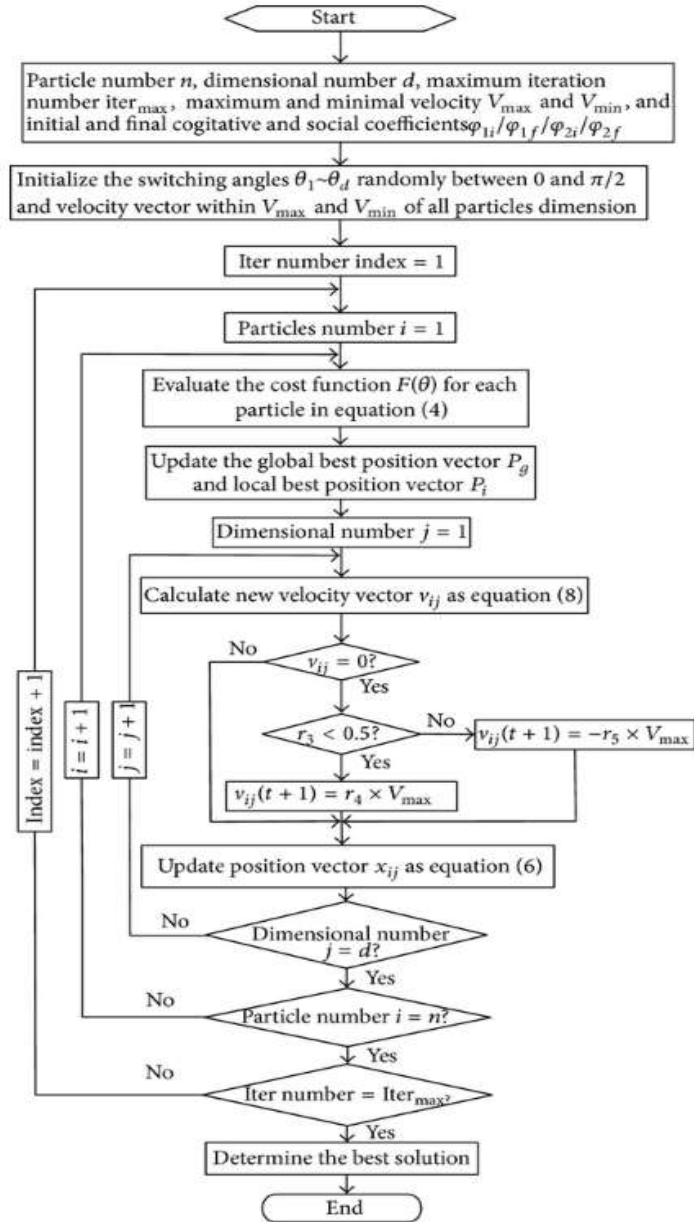


Figure 5. ANN flow chart for harmonics problem of minimization

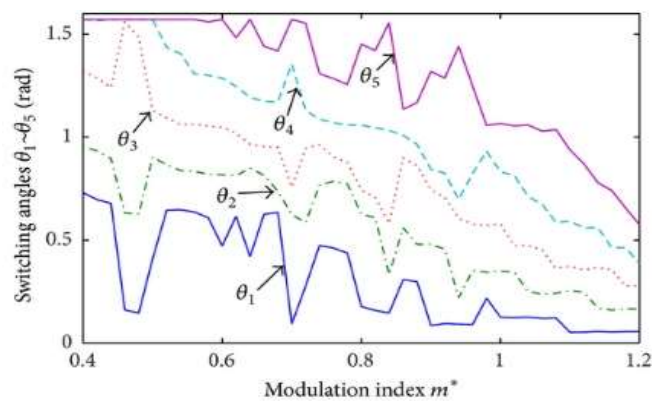


Figure 6. Calculated switching angles $\theta_1, \theta_2, \theta_3,$ and θ_4

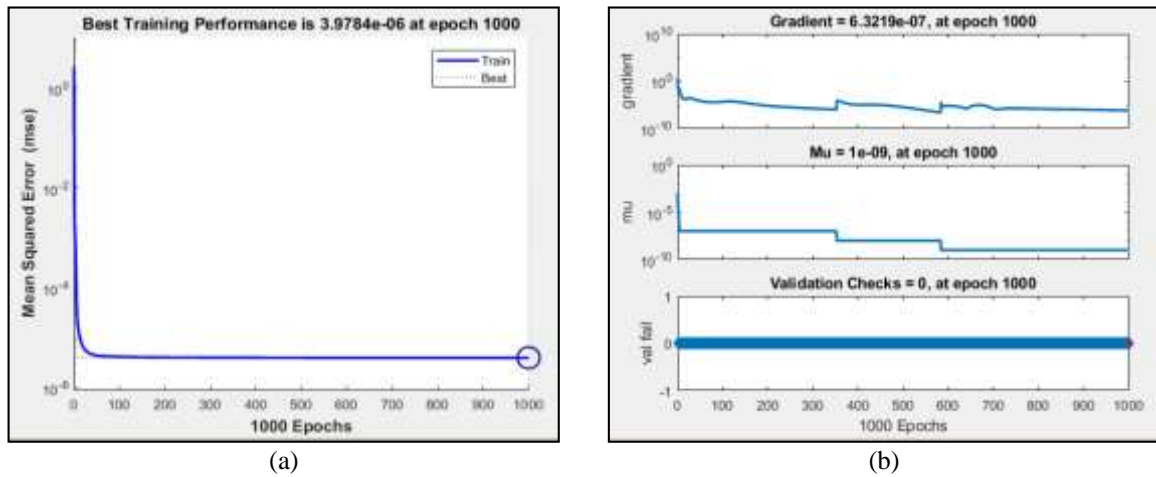


Figure 7. ANN Performance at training with 2 neurons in hiding

4. NINE LEVEL CHB-MLI MATLAB SIMULABION OF MODIFIED

The proposed system consists of one modified cell connected to a series each containing pulse generating unit, as a switching control system, as shown in Figure 8, using MATLAB simulation software.

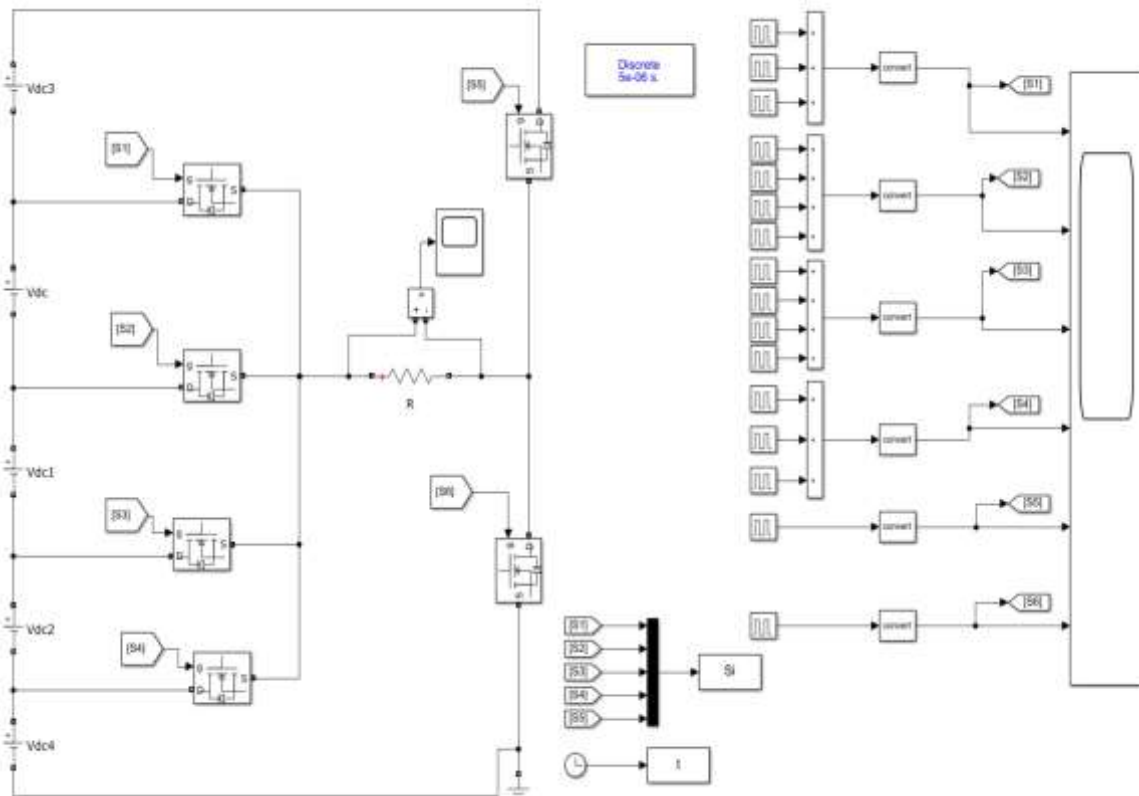


Figure 8. Matlab 9-level CHB-MLI simulation

5. SIMULATION OPTIMIZATION RESULTS FOR SINGLE-PHASE MODIFIED CHB-MLIS NINE- LEVEL WITH MI= 0.9 BASED ON ANN TECHNIQUES

In order to produce 4 initial switching angles that are used to control a 9-level modified CHB-MLI, an artificial neural network (ANN) of a single-phase waveform system has been developed using MATLAB/software code. Five separate DC input sources, each equal to 300 V and 2500 Hz switching

frequency, were also assumed. This system generates AC waveforms on the load side to feed a single-phase load of $R\ 80\ \Omega$, $H\ 35e-3\ L$ and $C\ 50e-6mF$. The initial 4 switching angles using an ANN approach for the time frame of $M_i=0.9$ have resulted $\theta_1 = 7.871$, $\theta_2=20.054$, $\theta_3=44.125$, $\theta_4=52.831$ $\theta_5=52.831$ and $\theta_6=52.831$, even the time frame for each loop for each output waveform is equal to 0.02. The prediction data and original data for total harmonic distortion (THD) are listed in Figure 9 during test time. Training performance of ANN testing angles set are illustrated in Figure 10 that indicating error resultant are $R=80$. A 9-level CHB-MLI at have been developed by simulation mode in which include one modified cell each cell at the system contains two units (switching circuit scheme unit and control unit) each cell consisting 4 switching devices in structure scheme with one pulse generator at control unit for each one of them. Figure 11 shows the timing of control pules with real switching times of each switch on the device using ANN optimization angles of switching during a three-cell cell model one S_1, S_2, S_3 and S_4 . The resultant total harmonic distortion (THD) that have been provide using ANN switching angles optimization technique to control a single-phase modified 9-level CHB-MLI are reduced as compared with other optimization techniques like NR and PSO at both of current and voltage parameters in which a voltage THD have been reached into 5% and current THD have been reached into 1.3% as shown in Figure 12-15.

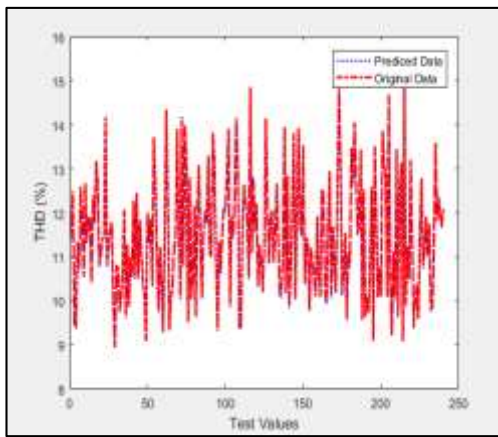


Figure 9. Predicted data and original data for THD

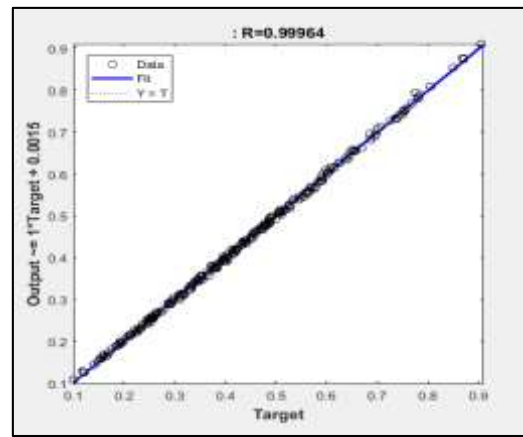


Figure 10. Training performance angles for ANN

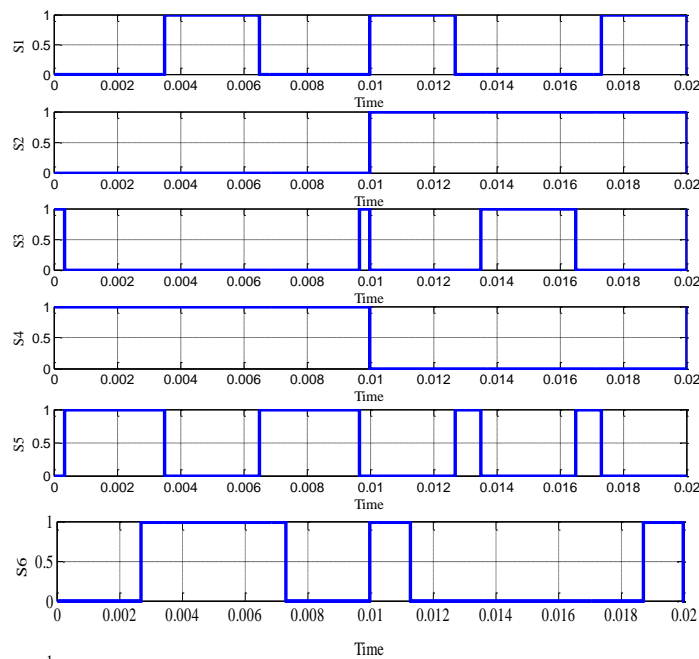


Figure 11. Time switching for S_1, S_2, S_3, S_4, S_5 and S_6

The proposed 5 and 9-level single-phase modified CHB-MLI was previously used by the ANN technique for the purpose of reducing the THD on the voltage and current output waveform as shown in Figure 16. “For five-level and nine-level modified CHB-MLI”, Table 2 “displays switching angles and different THDs in voltage and current”.

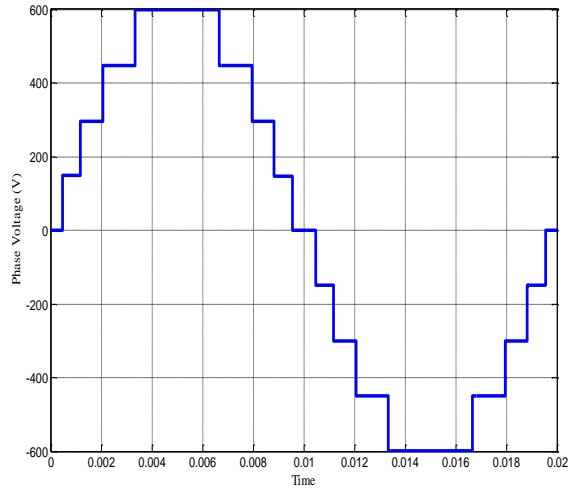


Figure 12. Output voltage waveform for 9-level CHB-MLI simulation

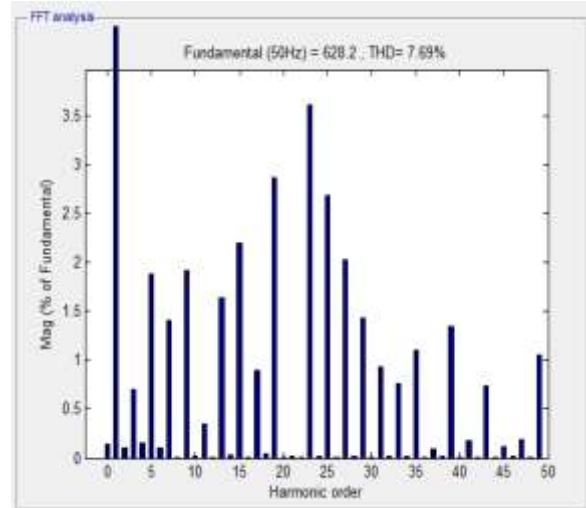


Figure 13. Output harmonic spectrum for voltage waveform using ANN technique

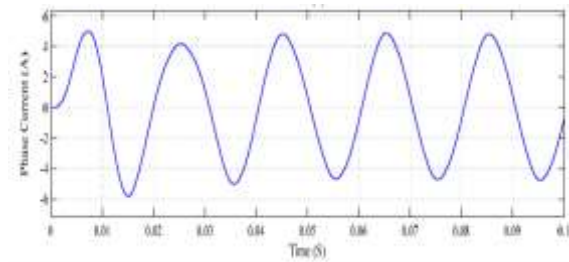


Figure 14. Output current waveform for 9-level CHB-MLI simulation

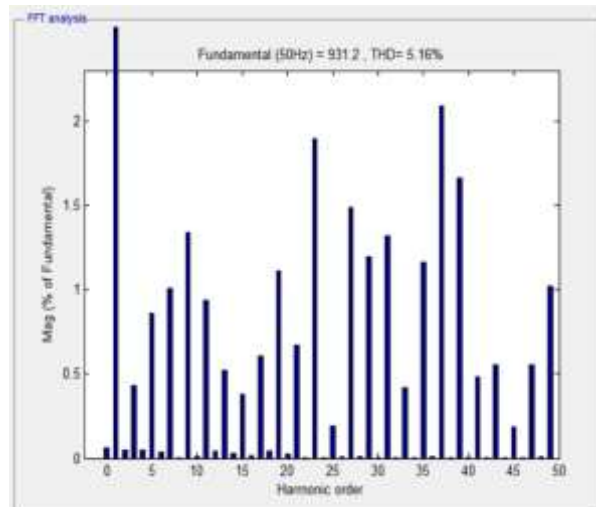


Figure 15. Output harmonic spectrum for current waveform using ANN technique

Table 2. Comparison of the 5 and 9 levels of the modified CHB-MLI based on the ANN proposal

N-level	MI	θ_1	θ_2	θ_3	θ_4	THD _v	THD _A
5-level	0.9	31.41	41.93	0	0	14.48%	8.05%
9-level	0.9	7.871	20.05	44.12	52.83	7.46%	5.1%

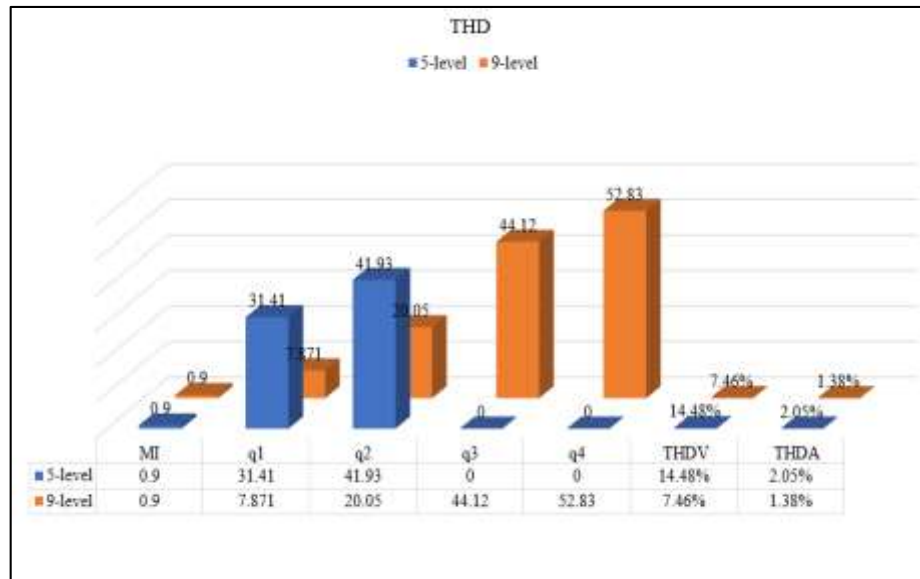


Figure 16. Statistics graph for switching angle values and the THD values of voltage and current based on ANN for 9-levels M-CHB-MLI

6. CONCLUSIONS

The research paper proposes ANNs as the nine-level CHB-MLI optimization method that reduces THD's current waveform and output voltage. The aim of this paper was simulated with MATLAB Simulink to analyse the resulting parameters. The resultant THD output wave form of 9-level has been compared with a resultant THD output waveform of previous work of research papers for 5-level CHB-MLI. In briefly describe of simulation result, the THD at output waveform are reduced when the level stepped of CHB-MLI are increased, also ANNs technique a useful optimization tool that provide lower THD as compared with NR and PSO optimization techniques.

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