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REVIEW OF MULTILEVEL INVERTERS USING PARTICLE SWARM OPTIMIZATION (PSO)

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ABSTRACT

The problems of harmonics of the output voltage of the multilevel inverters is considered as a big issue that need to addressed seriously by the researchers of the power electronics field. There are so many types of controllers have been applied to the multilevel inverters in order to reduce the contains of harmonics of the multilevel inverters output.The aimed of this paper is to review the application of Particle Swarm Optimization (PSO) algorithm for harmonics reduction of the output of the multilevel. Hence a modified of a Cascaded H-Bridge Multilevel Inverters (CHB-MLIs) inverters based on modified PSO has been proposed for harmonics reduction. A proposed model using the PSO algorithm of a modified CHB-MLIS has been simulated based on MATLAB/SIMULINK. Based on the simulation results showed that the effectiveness of the proposed model using in harmonics reduction of the multilevel inverter output.

KEYWORDS: Multilevel Inverters, Particle Swarm Optimization (PSO), harmonics,CHB-MLIs.

1. INTRODUCTION

Normally practical inverters will produce non-sinusoidal waveform and contain certain harmonics. Pulse width modulation (PWM) technique which is applied in conventional two level inverters provides less distorted current and voltage.However, the configuration of this type provides higher switching losses due to high switching frequencies. A single-phase inverter is usually used for residential or low-power applications of power ranges that are less than 10 Kw.[1] Types of single-phase grid-connected inverters have been investigated.[2] A common topology of this inverter is full-bridge three-level. The three-level inverter can satisfy specifications through its very high switching, but it could also unfortunately increase switching losses, acoustic noise, and level of interference to other equipment. Improving its output waveform reduces its harmonic content and, hence, also the size of the filter used and the level of electromagnetic interference (EMI) generated by the inverters switching operation.[3,2]

Multilevel inverters are promising; they have nearly sinusoidal output-voltage waveforms, output current with better harmonic profile, less stressing of electronic components owing to decreased voltages, switching losses that are lower than those of conventional two-level inverters, a smaller filter size, and lower EMI, all of which make them cheaper, lighter, and more compact.[3,4]

Various topologies for multilevel inverters have been proposed over the years. Common ones are diode-clamped,[5,7] flying capacitor or multicell,[8] cascaded H-Bridge,[9] and modified H-bridge multilevel,[10-22] The advantage of a three phase inverter of the diode clamped is that all three phases have a share as in a common DC bus.The diode clamped topology can be applied for high-voltage application or an adjustable speed drive.The efficiency of diode clamped is considerably high at fundamental frequency switching. However the disadvantages are the difficulty in real power flow and the output voltage of theinverter is limited.

Meanwhile one the major advantages of using a flying capacitor multilevel inverter is its ability to operate at voltage higher than the blocking capacity of each power cell consisting of diode and switching element. Another advantage is that one DC source is used and it has switching redundancy within the phase in order to balance the flying capacitor. There is no transformer used in flying capacitor multilevel inverter so the power losses can be reduced. Hence, real and reactive power flow can be easily controlled. The disadvantages of this topology are that the uses of a large number of capacitors will cause short duration outages and deep voltage sags and pre charging of capacitors is important and difficult.[3]

The main advantage of a Modified H-Bridge Multilevel Inverter is that the regulation of the DC buses is simple and modularity of control can easily be implemented. Even though in Modified H-Bridge Multilevel inverter the number of components is reduced it can still produce the same number of voltage levels as conventional topology. Moreover in order to avoid bulky and lossy resistor-capacitor-diode snubbers soft-switching technique can be applied in Modified H-Bridge Multilevel Inverter. Nevertheless, some of the disadvantages of Modified H-Bridge Multilevel inverter are that the communication between the full-bridges is required to meet the synchronization between the reference and the carrier waveforms. In this topology the DC sources have to be separated for real power conversions, therefore its applications are very limited.

2. Review The Concept of The PSO

The Particle Swarm Optimization (PSO) has been applied to five and several levels of the cascaded H-Bridge multilevel inverters as illustrated in,[4] The proposed concept of PSO is aimed to compute the optimum switching angles of the cascaded multilevel inverter (MLI).

The reduction of the harmonics of the output voltage in term of THD is the main target of the research using PSO. The model of single-phase cascaded 7-Level inverter with 3 H-bridges can be illustrated in Fig1, meanwhile the 3-phase model of 7-level inverter[11]. Each model can produce the voltage of the output.

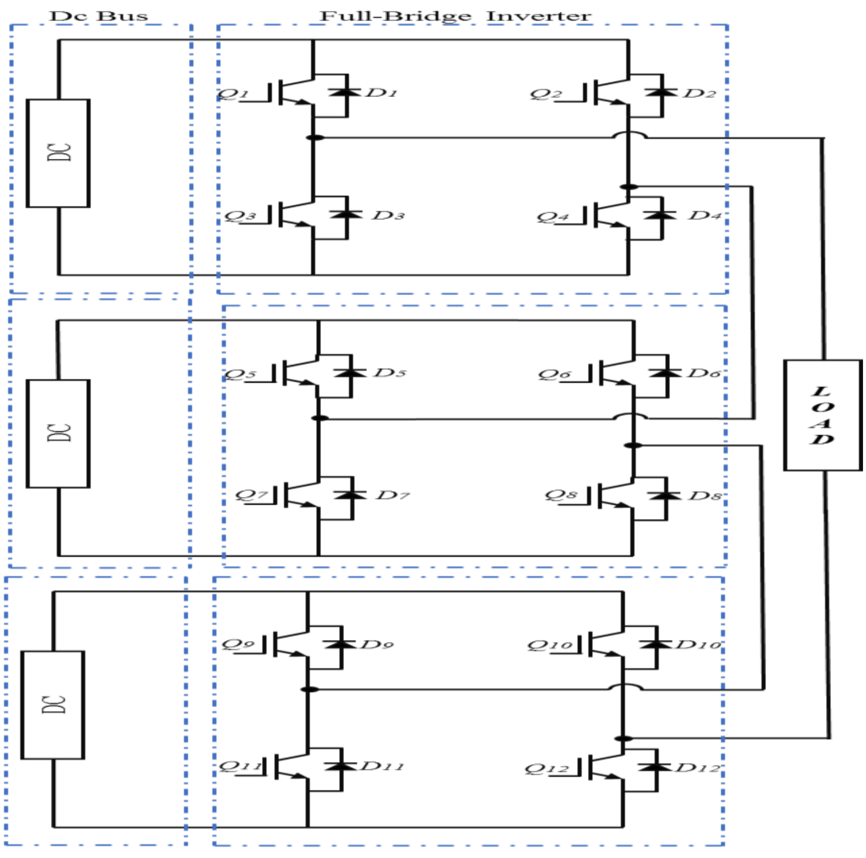

Figure 1: Seven level single phase for cascaded ML.[4]

The harmonic elimination of the cascade multilevel inverter by using particle swarm optimization method are discussed in.[5] The lowest order of harmonics up to the 11th of the inverter voltage waveform at the desired value using PSO method is the main focus of this research. Figure1 shows a cascaded multilevel inverter has advantages that have been presented.Few components, the absence of extra clamping diodes orvoltage balancing capacitors, and easy adjustment of thenumber of output voltage levels are some of them. Switchingdevices turn ON and OFF only once per cycle to overcomethe switching loss problem.

The main issues of the generation of the harmonics produced by the inverters, which affects the induction machine performance has been presented in.[6,7] This paper discussed many types of the inverters such as Voltage Series Inverters, PWM fed Inverters.The optimization of the output inverters has considered the main issues that need to be tackled.This research also highlights a pulse width selection for optimization of each level of the multilevel inverters, which the purposes of harmonics reduction for better THD of the multilevel output especially voltages of output.

Particle Swarm has been used for harmonic reduction with non equal DC source has been discussed in [Analysis & reduction Of THD In multilevel inverter using the PSO algorithm].

Multicarrier PWM control using the PSO algorithm has been proposed for the multilevel inverters. The proposed Scheme for multilevel inverter is multicarrier PWM control using the PSO algorithm. Based on this research the proposed systems are capable to reduce switching losses by controlling switching angles to obtain a minimum of THD.

The reduction of the output voltage of a single phase multilevel inverter using PSO has been discussed in.[8] In this research highlights the parameters of the multilevel inters have been changed in term of its number of stages, voltage source and switching pattern of multilevel inverter. The changes of multilevel inverter configurations are aimed to reduce THD values of the multilevel inverter output of voltages less than 5% based on the IEC standard.

Multilevel inverter technology has emerged recently as a very important alternative in the area of high-power mediumvoltage energy control. Using multilevel inverters application in fuel cell, solar cell & wind turbines is increasing now a day‘s rapidly. Therefore, Harmonic reduction techniques in multilevel inverters are considered very important task Over the past decades, depending upon the topologies and control strategies, numerous optimization techniques have been proposed for desired output waveform. This paper presents a review of optimization techniques used for multilevel inverters. The pros and cons of optimization techniques are discussed. The objective of these optimization techniques is to find out the optimum firing angles of multilevel inverters, which results in minimum harmonics.This paper presents a review application of PSO for harmonic reduction in multilevel inverters. As a preferred option for proposed work, reduction of total harmonic distortion with the aid of particle swarm optimization technique to multilevel inverters is suggested.

A The Technique of The Particle PSO

Step 1 The first step of the PSO Technique is that need to initialize the parameter system of the PSO Which comprises of the velocity vector VI, location vector Xi, personal best particle vector Pi, particle inertia weight C0, and global best vector Pg. Then need to set the parameter values of generations, population size, cognitive parameter and finally the social paramete. The table 1 below illustrated the setting of the parameter's values;

Table 1: The Parameter values setting.

The Generation	100
The size of Population	40
The Cognitiveof ,C1	0.5
The Social of C2	1.25

Step 2 The second step of the PSO concept is that is to check the two cases of the two equations below;

$0 < (C1 + C2) < 2$ (1)

and $(C1 + C2)/ 2 < C0 < 1$ (2)

if the two of the equations are satisfied or yes means that the system towards to converge and it is considered as a stable equilibrium point. If in case of not correct or false, back to Step 1.

Step 3: The following steps need to update the Velocity, Vi (t + 1).

Step 4: Then the Position of Xi (t + 1) to be updated .

Step 5 Now, utilize the THD Function in order to evaluate the particle,

$f(Xi) = 100*(|f(2)|)/(|f(1)|)$ (3)

$F(1)=(\cos(\alpha_1) + \cos(\alpha_2))-MI;$

For harmonic reduction elimination. For switching angles 5-level and are selectedion in order to selective harmonics 3th 5th eliminated.

$$F(2)=(\cos(3*\alpha_1)+\cos(3*\alpha_2)) \quad (4)$$

Step 6 Check for the case P(xi) < P(Pi), if i = i + 1 not satisfied then execute to Step 3.

Step 7 If the produced location of the particle is the best then update by change with the previous location as Pi = Xi.

Step 8 Update the global best location as Pg = min (P neighbour).

Step 9 Switching angles are optimisedthe best. Accomplish the solution of the problem.

The general flow chart of the PSO algorithm of a modified CHB-MLIs is shown in Fig 2 and each step is explained below:

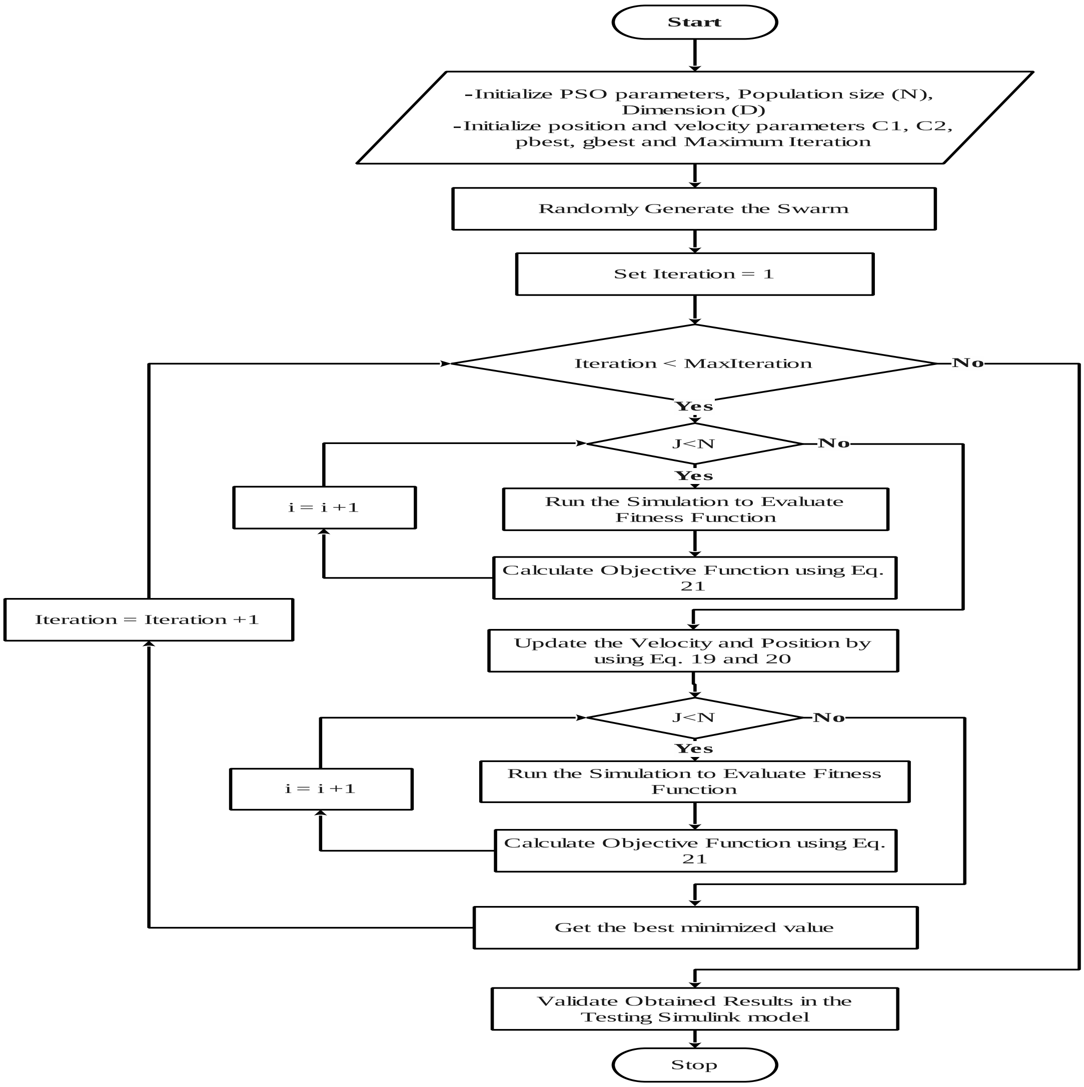

Fig. 2: General flow chart of PSO of a modified CHB-MLIs.

3. Modelling Of The Proposed Modified Chb-Mlis

In order to validate the effectiveness of the proposed system. The proposed topology of a CHB-MLIs for five levels based on the PSO algorithm has been modeled using MATLAB/SIMULINK software. The analysis and mathematical and engineering issues of the PSO algorithm can be performed via MATLAB/SIMULINK. In Fig 3 shows the circuit diagram of the proposed of a three-phase modified CHB-MLIs for five-levels. The configuration of this model consists of 5 switches of the conventional inverter in addition to a three-bi-directional switch. The main purposes of this paper is to review the PSO algorithm which is applied to the conventional Multilevel inverters then a modified of a CHB-MLIs has been proposed based on the PSO algorithm using SHE method for getting the best firing angles for harmonics elimination and have to compare with the conventional Newton Raphson (NR). The system operation was simulated at low switching frequency. In this simulation model, three DC supply sources are equal to 100V. The generator pulse blockis used to obtain the switching pattern and the results of generating pulse will control the MLIs based on NR and PSO algorithms.The resistor load of 100kΩ used and its connection in a star connection.. The output phase voltage of modified CHB-MLIs is 300 volts with frequency 50Hz. There are two capacitors C1 and C2 were used and the values of C1 and C2 is 2500uF each which is connected to the DC bus in the series, an auxiliary circuit, a full-bridge inverter configuration, which split the DC bus voltage for each cell: VDC/2, 0, -VDC/2. The middle point n of the capacitors is defined as the neutral point.

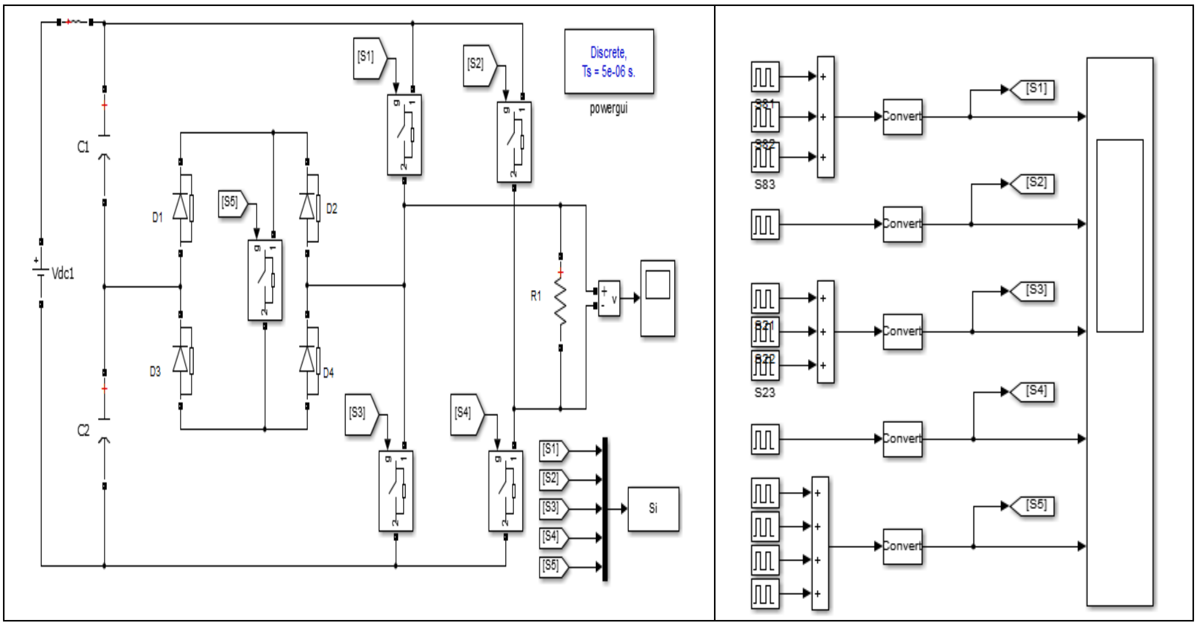

Fig. 3: Simulations of a single phase of modified CHB-MLIs for five-levels model.

The Simulation model of a single-phase modified CHB-MLIs of five levels is then verified using the PSO technique, whereby the optimised switching angles is calculated using the PSO technique. The calculation of switching angles obtained is θ_1= 13.4043260^0 and θ_2 =41.908579$^{0'}$ calculated by using MATLAB code. The Fig.4shows the timing diagram of switch pulses and bi-directional switches of a single-phase modified CHB-MLIs using the PSO technique. The timing diagram pattern of a single-phase modified CHB-MLIs using the PSO technique; however, the results in Fig 2. obtained from PSO are found to be very close with those from the numerical method.

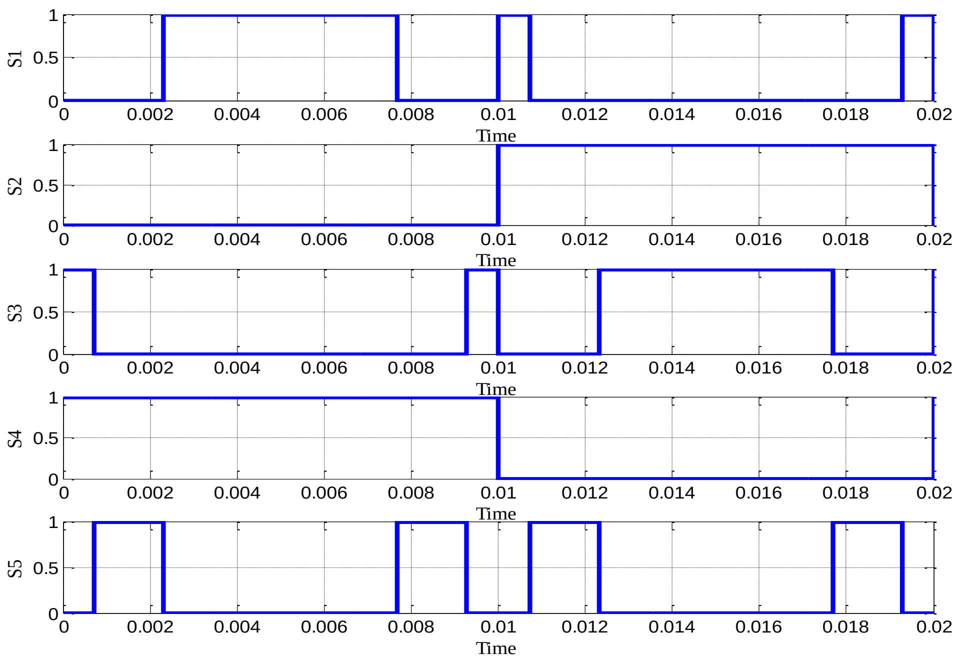

Fig 4. Simulation model of timing diagram of a modified CHB-MLIs comprising switches S_1, S_2, S_3, and S_4 and bi-directional switch S_5 with MI=0.975 using PSO technique.

The timing diagram is a benchmark to obtain a smooth output voltage waveform. The optimisation of output voltage waveform of a single-phase modified CHB-MLIs of five levels using PSO can be described in Fig. 5.The harmonic spectrum of the output voltage waveform of a single phase modified CHB-MLIs produced by PSO can be illustrated in Fig.6 with 15.34% of THD which is lower than the THD values obtained using the NR conventional technique. As shown in Table 1 overall values of MI, switching angles and THD for voltage of modified CHB-MLI for five-levels based on NR and PSO Techniques.

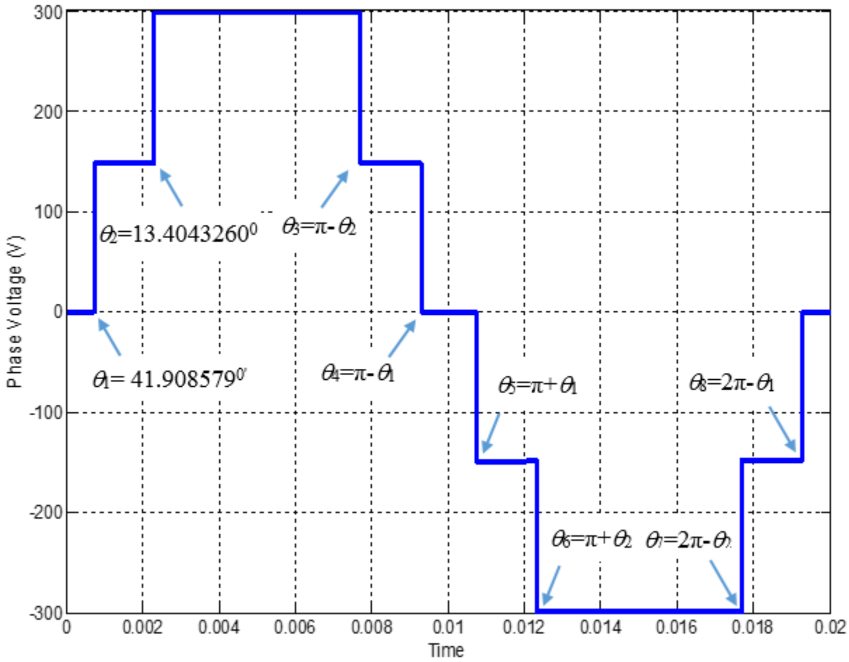

Fig. 5: Optimisation of output voltage waveform of a five-level CHB-MLIs with MI=0.975 using PSO technique.

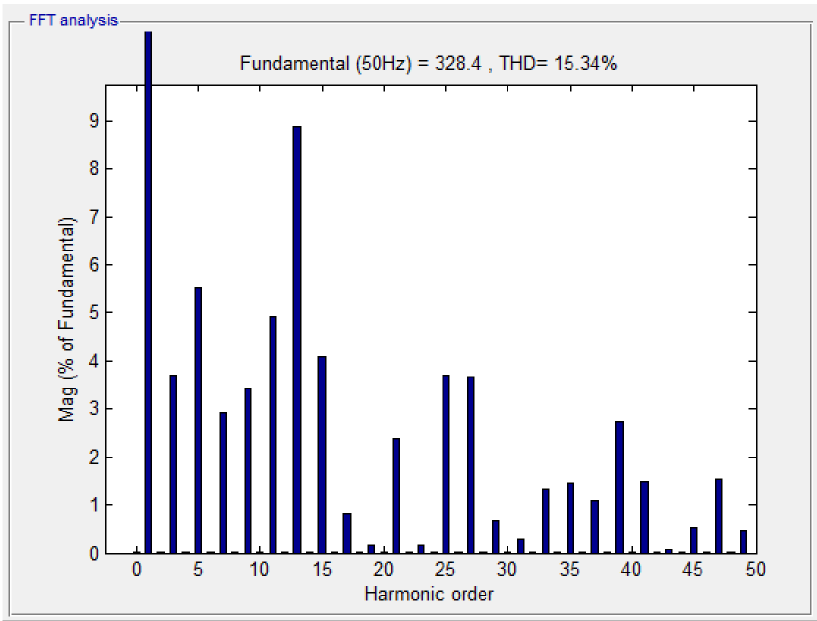

Fig. 6: Harmonic spectrum of the optimisation of a single-phase output voltage waveform using PSO technique.

Table 1: Overall values of MI, switching angles and THD for voltage of modified CHB-MLI for five-levels based on NR and PSO techniques.

5-level	**MI**	θ_1	θ_2	***THD phase V***
Convectional NR	0.949	14.63	41.34	16.2
Proposal PSO	0.975	13.41	41.93	15.3

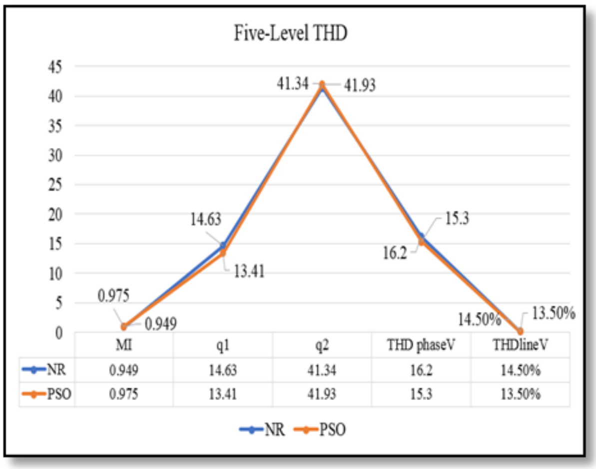

Fig. 7: Overall values of MI, versus the switching angles and the values of THD for voltage of modified CHB-MLI of 5-levels based on NR and PSO.

CONCLUSION

There are many types of controllers has been discussed for harmonics minimization of the output of multilevel inverters. The proposed controllers have their merits and demerits for harmonics minimization purposes as mentioned in the literature.The proposed methods based on the PSO algorithm then has been applied to modified CHB-MLIs is capable to obtain the optimum firing angles in a simple manner. These techniques ensure the accuracy and quality of firing angles of modified CHB-MLIs towards the voltage waveform of the multilevel inverters output results with minimum of distortion hence the THD values are acceptable based on the IEC standard.

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