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Research paper

Optimization switching angle based on practical swarm optimization (PSO) of A DSP-TMS320F2812 controlled for multilevel inverter

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Abstract

In this paper optimization switching angle based on practical swarm optimization (PSO) of a Digital Signal Processing DSP-TMS320F2812 controlled for cascaded H-bridge multilevel inverter (CHB-MLI). The selective harmonics elimination (SHE) method was analysed based on Newton Raphson (NR) and PSO techniques for solution non-linear equation's derived for computing optimal switching angles of a modified (CHB-MLI) for harmonic minimization. The proposed techniques have been comparison between NR and PSO techniques related to optimization in order minimize harmonic distortion of output voltage. The main aims of this paper, testing of a laboratory the modified topology of the CHB-MLI for a three phase prototypes for five levels. The Digital Signal Processing (DSP) TMS320F2812 is used to implement these modified inverters control schemes using NR and PSO method. The proposed controller was then coded into a DSP TMS320F2812 board. The inverter offers much less THD using PSO scheme compared with the NR scheme. The performance of the proposed controllers based on NR and PSO techniques are implemented in a prototype, of results are compared.

Keywords: *Harmonics; PSO; Modified Multilevel Inverters; Digital Signal Processor DSP.*

1. Introduction

In inverter was create two level of utilized to generate AC voltage convert from DC voltage [1]–[3]. This inverter have been used as central inverter, PV inverter, string inverter, and multilevel inverter module integrated inverter to generate AC voltage; also, elements associated with inverters, such as Maximum Power Point Tracking (MPPT) and islanding detection[4], [5]. To improved MLI for output voltage waveform content to reduce total harmonic distortion (THD), the level of electromagnetic interference (EMI) and reduce the size of the filter. The concept of MLI used to reduce the THD in the voltage output waveform without decreasing the inverter output power. In MLI have several advantages such as reduce number of switching component, reduces the switching frequency and reduce switching losses, reduction of EMI and interfacing renewable energy sources such as PV to the electric power grid. There are three type of multilevel inverter diode clamped MLI, flying capacitor MLI and separated dc sources cascaded H-bridge CHB-MLI. The single DC source in MLI better then multiple source is the diode-clamped MLI. However, the FC type is designed by series connection of capacitor clamped switching cells and then the CHB has single DC source, for the switches are connected in parallel and series in order to provide high power demand and high-power quality[6]–[11] [12]–[19]. For improving the quality of the output voltage inverter for two types of MLI, as symmetrical and asymmetrical, both types are very effective and efficient for multilevel inverter utilize reduced number of switching devices with Hybrid topologies for the conventional and non-conventional multilevel inverter topologies to create a specified number of output voltage levels in operating in higher voltage levels [20][21]. Reduced number of switches with installation area and cost and has simplicity of control system, with a high number of steps associated using a new topology of cascaded multilevel inverter (CHB-MLI) [22]. A current source inverter (CSI) apply a new topology for multilevel with reduced number of switches to generate desired output current for multilevel based on sinusoidal pulse width modulation (SPWM) method. This topology employs (n+7)/2 switches and (n−1)/2current-sharing inductors for an n-level CSI [23]. For 5-level single-phase inverter has been developed by field-programmable gate array (FPGA). The digital control technique is generated based on multi carrier PWM in Altera DE2 board, which has many features that allow design application of the system device have been implementation Simulation and experiment results in [24] [25].

The PSO technique has been apply in MLI to optimum swathing angle for output voltage inverter in order to decrease THD compare with conventional NR technique of a CHB-MLIs. In this paper a three phase of modified CHB-MLIs for optimization switching angle based on PSO of a DSP-TMS320F2812 controlled of five levels multilevel inverter. In this paper, was derived analysis based on NR and PSO techniques in to SHE method to generate three phase voltage of modified CHB-MLIs.

2. Proposal circuit configuration

Multilevel inverters are known for their initial usage in high-voltage and high-power applications, for their advantages over conventional three-level PWM inverters. The output voltage's carrier frequency and switching functions determine its harmonic components; thus, to some degree, reduction of harmonics is limited. As a solution, this work presents a five-level PWM inverter with output voltages zero, + l/2Vdc, Vdc, -l/2Vdc, and -Vdc. Increased number of output levels reduces harmonic content. Figure.1 shows the proposed single-phase five-level-inverter topology. It adopts a full-bridge configuration, with an auxiliary circuit comprising four diodes and a switch and generates half-level of dc bus voltage. The operating modes of five-level modified of a CHB-MLI topology is shown the switching pattern in Figure 2.

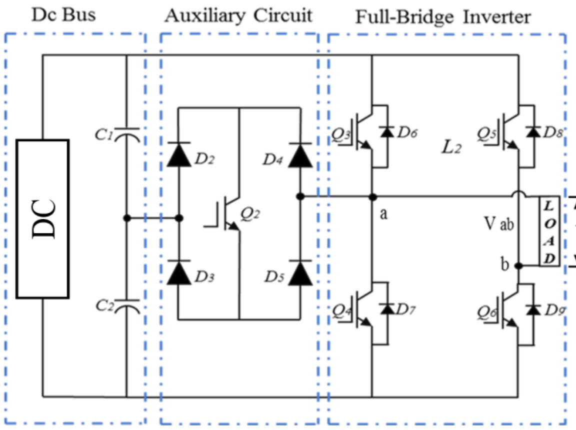

Fig. 1: Proposal Modified of A CHB-MLI, Five-Level Topology.

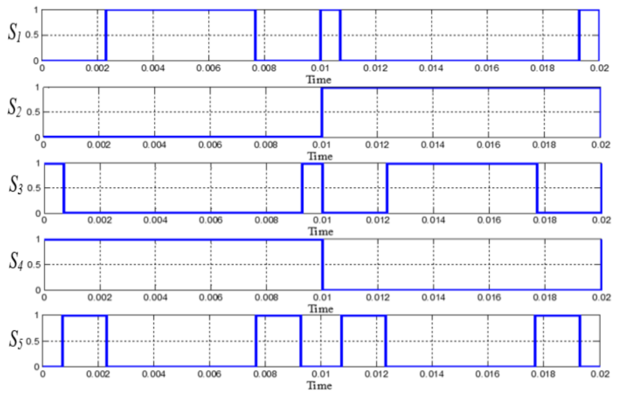

Fig. 2: Switching Pattern for Five Level Modified of A CHB-MLI.

Table 1: Output Voltage for Five Level to the Switches' on=1-off=0 Condition

State	S_1	S_2	S_3	S_4	S_5	Vo
A	1	0	0	1	0	Vdc
B	0	0	0	1	1	Vdc/2
C	0	0	1	1	0	0
D	1	1	0	0	0	0*
E	0	1	0	0	1	-Vdc/2
F	0	1	1	0	0	-Vdc

3. Fourier series analyses for output voltage of a five levels CHB-MLIs

The equations for 5-levels based on the Fourier series are described below, Vdc: voltage source that was in unity θi : The switching angles [16]:

$$f(t) = f_{\theta 1}(t) + f_{\theta 2}(t) = \sum_{n=1,2,5}^{\infty} \frac{2Vdc}{n\pi}(V_{dc1}\cos(n\alpha_1) + V_{dc2}cos(n\alpha_2)) \tag{1}$$

$$V_{AN} = V_{dc1}$$

$$b_n = \frac{2V_{dc}}{\pi}\{\cos(n\alpha_1) + \cos(n\alpha_2)\} n = 1,3,2 \tag{2}$$

Eq. (2) has variables (θ1, θ2), where 0 < θ1< θ2 < π/2

$$V_1cos(\theta_1) + V_2cos(\theta_2)\ 6m \quad V_1cos(5\theta_1) + V_2cos(5\theta_2) = 0 \tag{3}$$

Modulation index $m = Vf/(2Vdc/\pi)$

$$F(\theta_1, \theta_2, \ldots, \theta_s) = [\textstyle\sum_{n=1}^{s} V_1\cos(\theta_n)\text{-}m]^2 + [\textstyle\sum_{n=1}^{s} V_2\cos(3\theta_n)]^2 + .[\textstyle\sum_{n=1}^{s} V_s\cos(2s-1)\theta_s]^2 \tag{4}$$

Eq. (4) subject to the constraint $0 < \theta_1 < \theta_2 < \pi/2$

3.1. NR technique

The NR technique can be obtained angles $\theta_{1,}$ $\theta_{2,}$ by using non-leaner equations as shown flow-chart in Figure 4. The five-level inverter have eight angles for θ_3 and θ_8 it can be obtained from at the equations below:

$\theta_3 = \pi - \theta_{2,}$

Modulation index, Mi,

$$M = \frac{\pi V f}{2V_{dc}}\ (0 \le M \le 1) \tag{5}$$

$$THD_V = \frac{\sqrt{\sum_{n=1}^{\infty} V_n^2}}{V_1} \tag{6}$$

In Figure 3 five-levels inverter of optimised angles are α_1, and α_2, to impact the THD with different Mi. By using MATLAB coding for number of iterations, it can be easily concluded that the Mi equal 0.949. However, the THD value of 5-levels equal to 16.19 %.

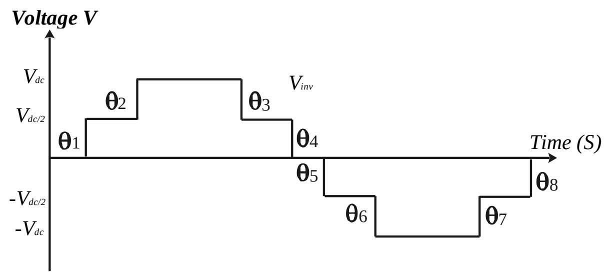

Fig. 3: Output 5-Levels Inverter.

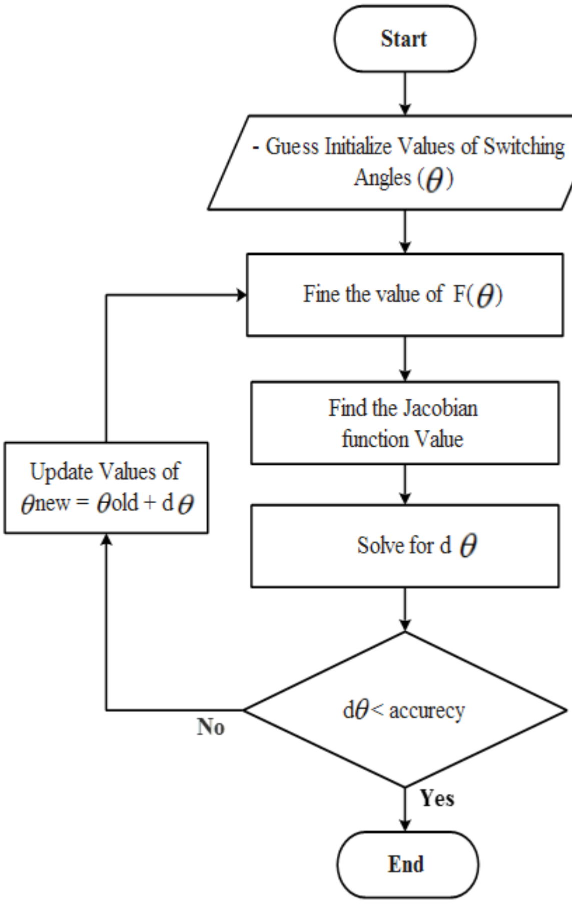

Fig. 4: General Flow-Chart of NR of the Modified CHB-Mlis.

3.2. PSO technique

In PSO technique have been apply in multilevel inverter, there are several advantages for PSO are that is easy to implement, speed for iteration and more accuracy for optimization switching angles [26]–[29]. The non-leaner transcendental equation can be applied to SHE method in order to solving equation based on PSO for obtained optimum switching angles. The output voltage can be optimized and minimization for THD based PSO technique. From number of iterations PSO algorithm.

Step 1. Xi, Vi, Pg, C0.

Step 2. 0 < (C1 + C2) < 2 and (C1 + C2)/ 2 < C0 < 1.

Step 3 Update the Velocity, Vi (t + 1).

Vij(t+1)=Vi(t)+γ_1i(P_i-x_i (t)) + γ_2i (G_i- x_i (t)) (7)

Step 4 Update the Position, Xi (t + 1).

Xij (t+1) = Xij (t) + Vij (t+1) (8)

Step 5. THD function

$$THD_V = \frac{\sqrt{\sum_{n=1}^{\infty} V_n^2}}{V_1} \quad (9)$$

F (1) = (cos (α_1) + cos (α_2))-ma;
F (2) = (cos (5 ∗ α_1) +cos (5 ∗ α_2)) (10)

Step 6 Check the constraints 0 ≤α_1≤α_2 ≤π/2.
Step 7. P(xi) < P(Pi), i = i + 1go to Step 3.

Step 8 Pi = Xi.

Step 9 Pg = min (P neighbour).

Step 10 Optimised switching angles are obtained. Terminate the problem.

The general flow chart of PSO of a modified CHB-MLIs is shown in Figure 5 and each step is explained below:

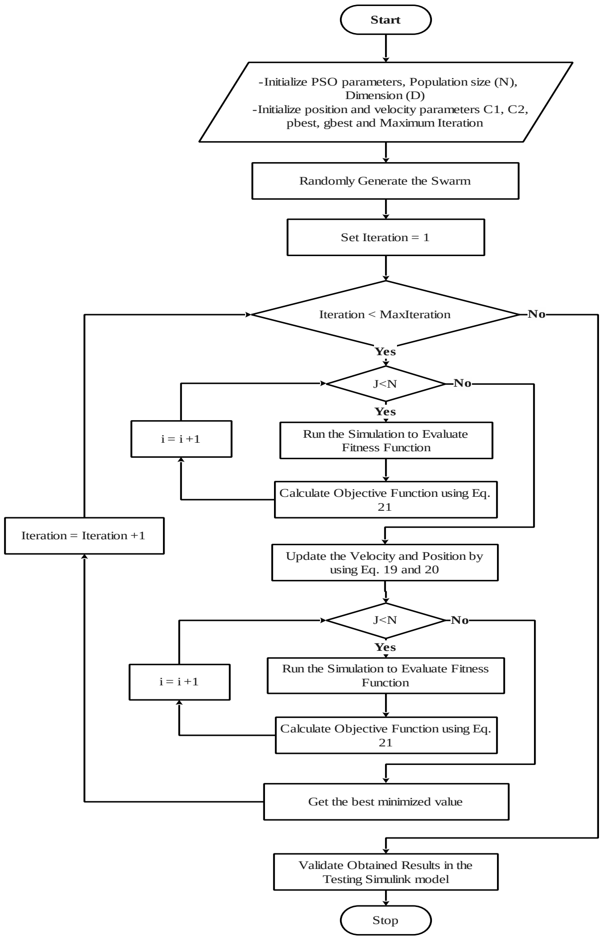

Fig. 5: General Flow Chart of PSO of A Modified CHB-Mlis.

4. Experimental validation

The five, levels of three phase modified CHB-MLIs constructer have been 15 pieces of power switching semiconductor IGBTs with snubber circuits, as shown in Figure 6 IGBT possessed the capability of operating up to 100 Hz switching frequency and in supplying electric current at 60 A at 25C, and in becoming 30 A when the temperature of the IGBTs reached 100C. These IGBTs can accept a maximum of ±300V gate to emitter voltage pulse. More information pertaining to this IGBT-IHW30N90T. Besides, the three-phase switching signal to those IGBTs came from the gate drives circuits. The important aspects in the selection of IGBT had been the voltage of the IGBT collector to emitter. If the output phase voltage inverter designed had been 300 volts AC (peak to peak), then a voltage source DC at $\sqrt{2} \times 300V$ or 424.27volt DC would be needed to avoid break down voltage on IGBTs as the inverter output was loaded with resistance and inductance.

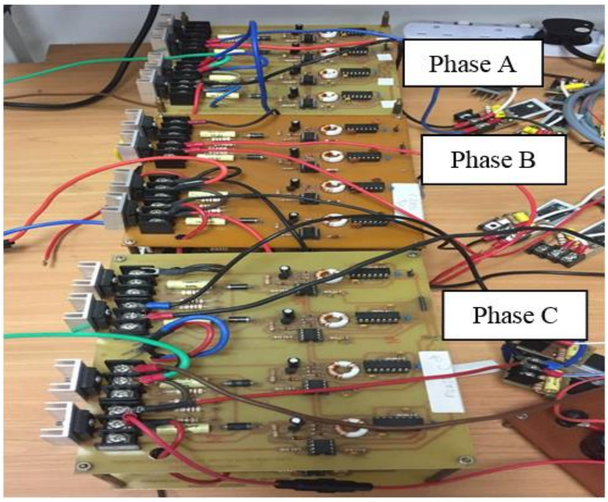

Fig. 6: The Excremental Setup of A Three-Phase CHB-Mlis for Five-Levels.

5. Experimental setup of results of a three phase of modified CHB-MLIs (Mi=0.949)

Three-phase modified CHB-MLIs, a source code of optimisation switching angles using NR and PSO, has been built and developed and stored in DSP-TMS320F2812. The control signals based on NR and PSO were created then coded into DSP-TMS320F2812. In Mi has been used equal to 0.975, for both techniques using NR and PSO were calculated. Figure 7, Figure 8 and Figure 9 illustrate the controlling pulses of modified CHB-MLIs switches generated by the DSP board controller with 2500Hz switching frequency for Phases A, B, and C, respectively using the NR technique.

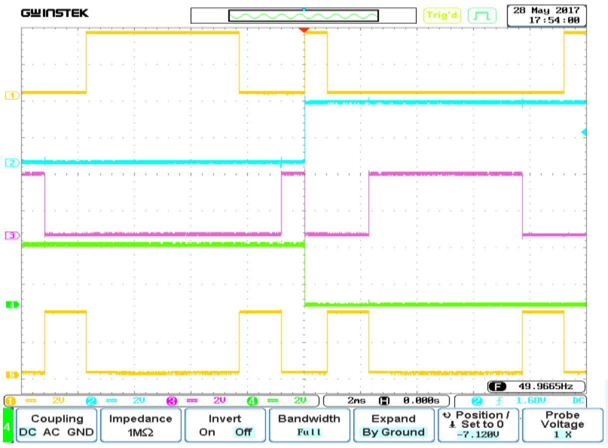

Fig. 7: At Phase A of Three-Phase Modified CHB-Mlis of Five Levels for Timing Diagram Comprising Switches S_1, S_2, S_3, S_4, and S_5 Using NR Technique.

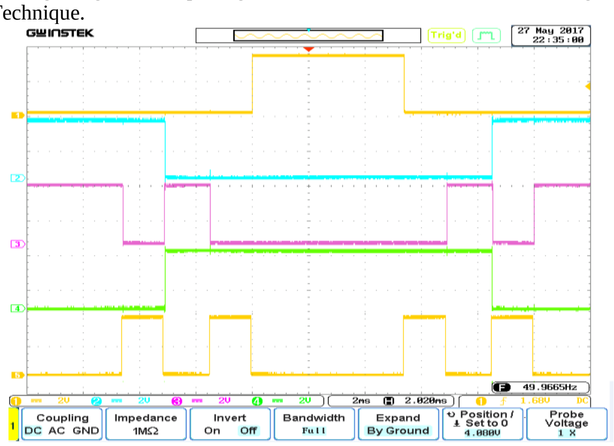

Fig. 8: At Phase B of Three-Phase Modified CHB-Mlis of Five Levels for Timing Diagram Comprising Switches S_1, S_2, S_3, S_4, and S_5 Using NR Technique.

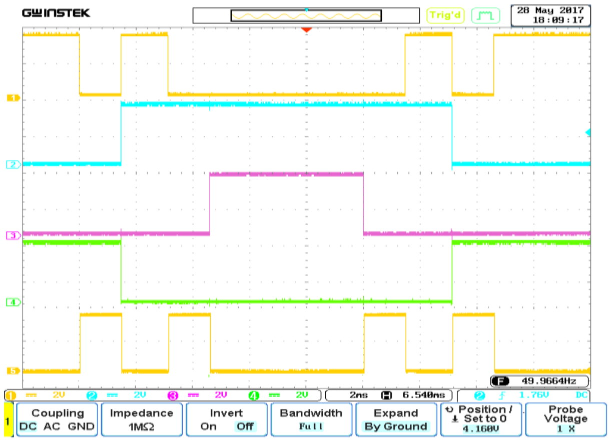

Fig 9: At Phase C of Three-Phase Modified CHB-Mlis of Five Levels for Timing Diagram Comprising Switches S_1, S_2, S_3, S_4, and S_5 Using NR Technique.

Figure 10 shows the output voltage waveform for the phase voltage of a three-phase modified CHB-MLIs of five levels for phases A, B, and C. The three phase output voltage waveforms based on the accurate calculation of the optimisation switching angles obtained is θ1=14.63130 and θ2 =41.34340 with MI=0.949. The NR technique, as shown in Figure 11 the optimisation harmonic spectrum of the output voltage waveform of a three-phase modified CHB-MLIs of five levels using NR with THD values equivalent to 16.3%.

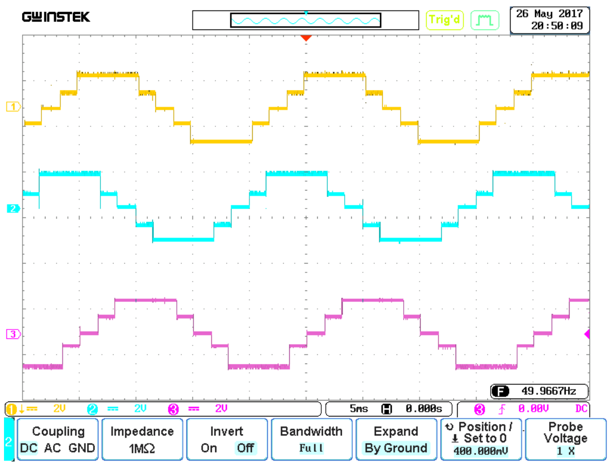

Fig. 10: Output Voltage Waveform for Phase Voltage of A Three-Phase Modified CHB-Mlis of Five Levels for Phases A, B, and C Using NR Technique.

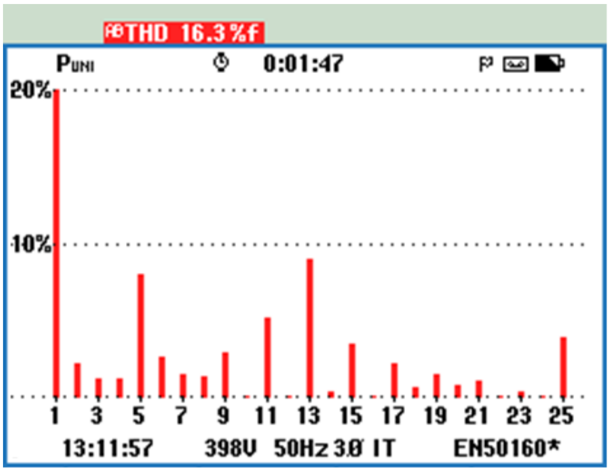

Fig. 11: Optimisation Harmonic Spectrum for Experimental Results Output Phase Voltage at Phase A Waveform Output of Five Levels with MI=0.949 Using NR Technique.

Figure 12 shows the line-to-line output voltage waveform of a three-phase modified CHB-MLIs of five levels using the NR technique. The output of the line-to-line voltage waveform will produce nine levels due to Vline to line = Vphase. As shown in Figure 13 the THD values for the line-to-line voltage are equivalent to 14.5%.

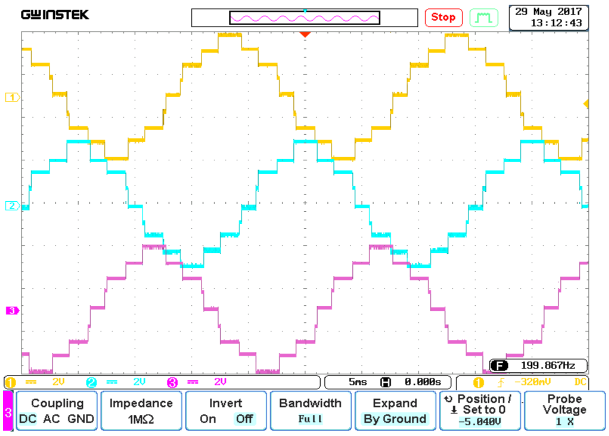

Fig. 12: Results for A Three-Phase Five-Level Output Line Voltage at Phases A, B, and C with MI=0.949 for θ 1=14.63130 Andθ 2=41.34340 Using NR Technique.

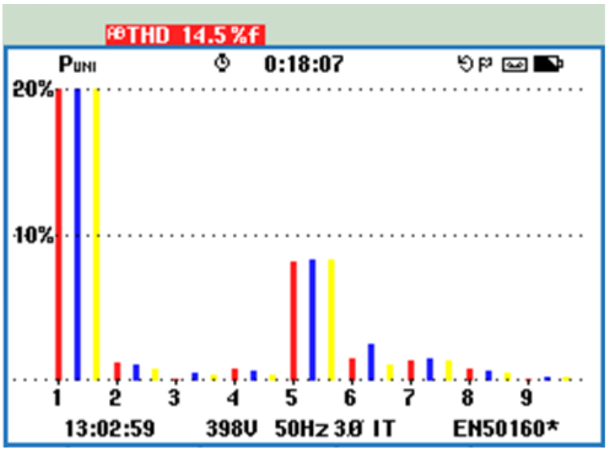

Fig. 13: Harmonic Spectrum for Line-to-Line Output Voltage Waveform of A Three-Phase Modified CHB-Mlis for Five Levels with MI=0.949 Using NR Technique.

Figure 14, Figure 15 and Figure 16 show a timing diagram of phase A, phase B and Phase C respectively using PSO technique, each phase has five switches including bi-directional switch. The calculation of switching angles obtained is θ1=13.4043260 andθ2 =41.9085790 with MI=0.975.

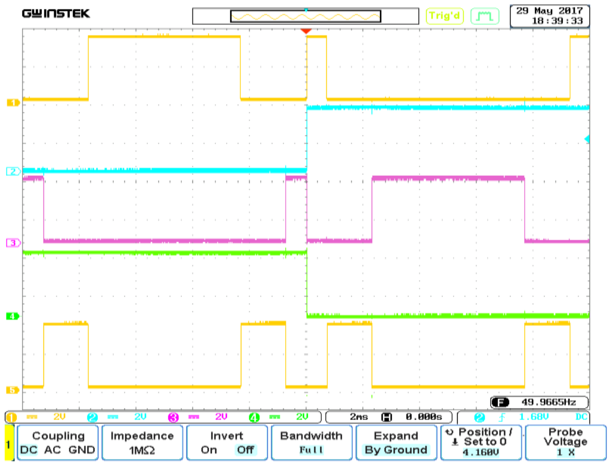

Fig. 14: At Phase A of Three-Phase Modified CHB-Mlis of Five Levels for Timing Diagram Comprising S1, S2, S3, S4, and S5 Using PSO Technique.

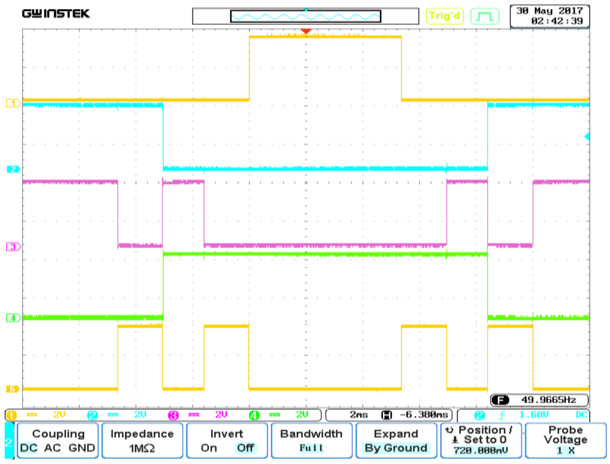

Fig. 15: At Phase B of Three-Phase Modified CHB-Mlis of Five Levels for Timing Diagram Comprising S1, S2, S3, S4, and S5 Using PSO Technique.

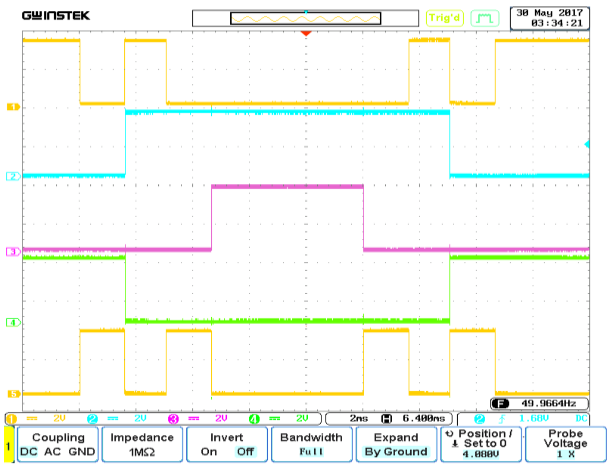

Fig. 16: At Phase C of Three-Phase Modified CHB-Mlis of Five Levels for Timing Diagram Comprising S1, S2, S3, S4, and S5 Using PSO Technique.

Figure 17 shows the output voltage waveform of a three-phase modified CHB-MLIs of five levels using PSO, with THD values equivalent to 15.5.3% as shown in Figure 18. The calculation of optimisation switching angles obtained is θ1=13.4043260 and θ2 =41.9085790 with MI=0.975.

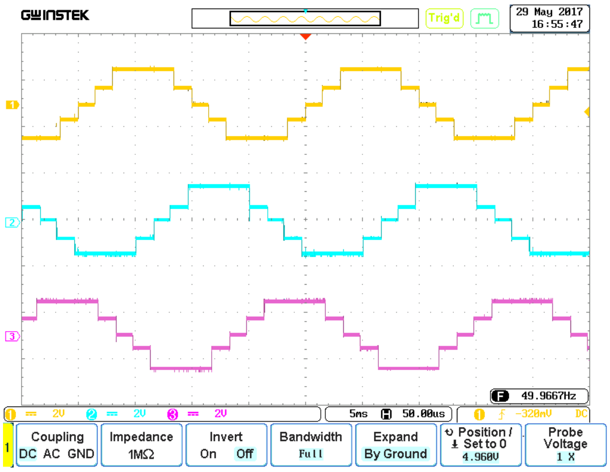

Fig. 17: Experimental Results for A Three-Phase Five-Level Output Phase Voltage at Phases A, B, and C Using PSO Technique.

Figure 19 illustrates the line-to-line voltage output waveform. The THD values for the line to line voltage can be illustrated in Figure 20 and its values are equal to 13.5%. The calculation of switching angles obtained is θ1=13.4043260 and θ2 =41.9085790 with MI=0.975.

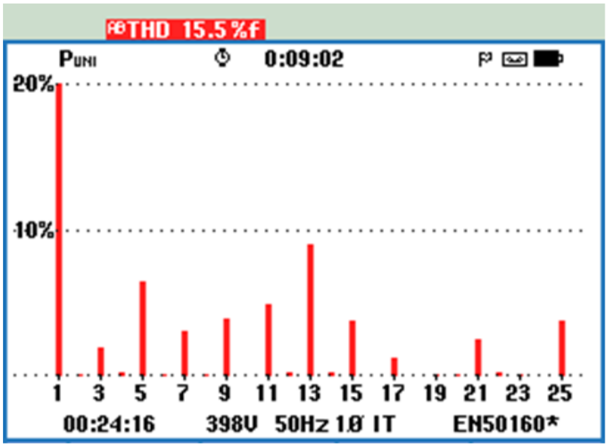

Fig. 18: Harmonic Spectrum for Experimental Results Output Phase Voltage at Phase A Waveform Output of Five Levels with MI=0.949 Using PSO Technique.

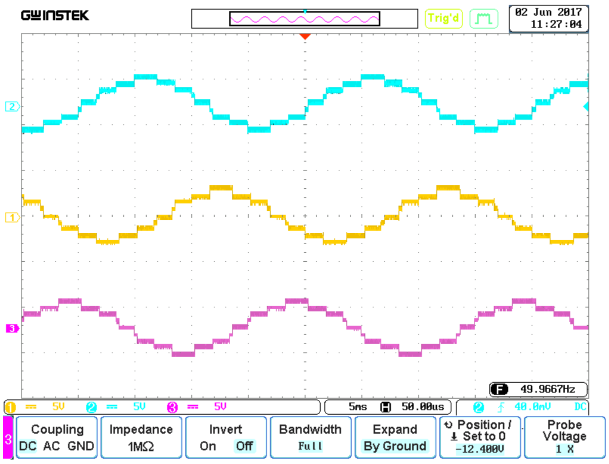

Fig. 19: Experimental Results for A Three-Phase Five-Level Output Line Voltage at Phases A, B, and C Using PSO Technique.

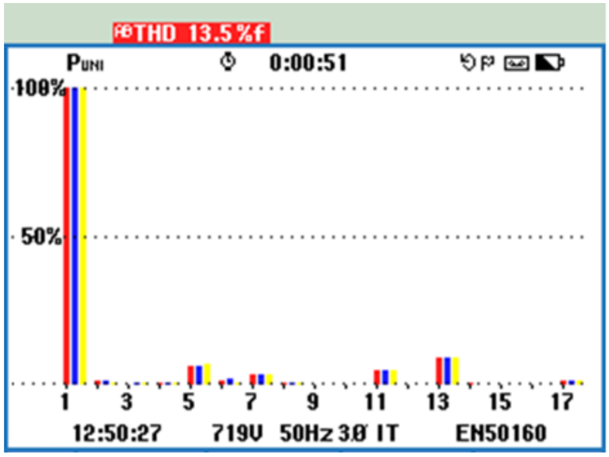

Fig. 20: Harmonic Spectrum of A Three-Phase Modified CHB-Mlis for Line-To-Line Voltage for Five Levels with MI=0.975 Using PSO Technique.

As shown in Table ۲overall values of MI, switching angles and THD for voltage of modified CHB-MLI for five-levels based on NR and PSO Techniques. Fig 37 shows the MATLAB plotting output for switching angles and the THD values for voltage based on NR and PSO techniques. Based on of a three phase of modified CHB-MLs for simulation and experimental results showed that the higher level of inverter it will produce lower harmonics contents of the modified CHB-MLIs using the both techniques. However, PSO technique produce lower content of THD of the modified CHB-MLIs output voltage waveform compared to NR technique due to switching angles of the PSO technique is simple and efficient.

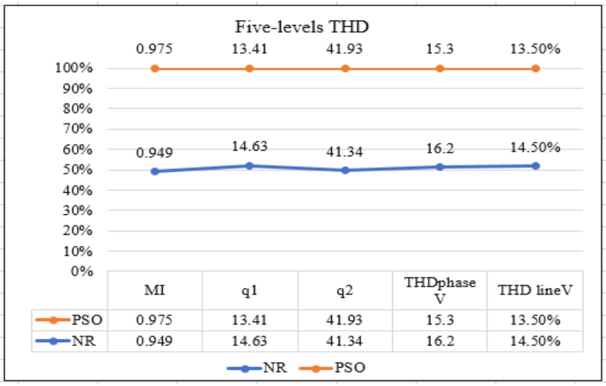

Fig. 21: Overall Values of MI, Versus the Switching Angles and the Values of THD For Voltage of Modified CHB-MLI of 5-Levels Based on NR and PSO.

Table 2: 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	THDphaseV	THD lineV
NR	0.949	14.63	41.34	16.2	14.5%
PSO	0.975	13.41	41.93	15.3	13.5%

6. Conclusion

This work conducted a theoretical analysis, and experimental results of a three phase of modified CHB-MLIs for five levels using NR and PSO techniques were proposed. Three-phase of a modified CHB-MLIs were successfully developed and tested. The low switching frequency control schemes operation can be considered to implemented in the modified CHB-MLIs for five levels. The outcome of the results from prototype showed that the higher level of inverter it will produce lower harmonics contents of the modified CHB-MLIs using NR and PSO techniques. However, PSO technique produce lower content of THD of the modified CHB-

MLIs output voltage waveform compared NR technique due to switching angles of the PSO technique is simple and efficient.

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