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Comparative analysis of NR and DE methods for multilevel inverters: An experimental case study

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Abstract - *This paper presents an experimental performance comparison between differential evolution (DE) algorithm and Newton Raphson (NR) method for solving the optimal switching problem for multilevel inverters with the objective of improving the output AC voltage quality. The methods are used to compute optimal switching angles to control a multilevel inverter in such way that allows the elimination of low order harmonics; this control technique is called selective harmonic elimination. The proposed inverter in this article is composed of two H-bridge cells with non-equal DC voltage sources in order to generate seven voltage levels. The differential evolution (DE) optimization and the Newton Raphson (NR) algorithm is used to solve non-linear transcendental equations necessary for the (SHPWM). Computational results obtained from computer simulations presented a good agreement with the theoretical predictions. A laboratory prototype based on STM32F407 microcontroller was built in order to validate the simulation results.*

Résumé - *Cet article présente une comparaison des performances expérimentales entre les algorithmes d'évolution différentielle (DE) et de Newton Raphson (NR) pour la résolution du problème de commutation optimal pour des onduleurs multi niveaux, avec l'objectif d'améliorer la production d'une tension AC de qualité. Les méthodes sont utilisées pour calculer les angles de commutation optimaux pour commander un onduleur multi niveau d'une manière qui permet l'élimination des harmoniques d'ordre faible; cette technique de contrôle est appelée l'élimination sélective d'harmoniques. L'onduleur proposé dans cet article est composé de deux cellules à pont H avec des sources de tension DC non égales dans le but de générer sept niveau de tension. L'optimisation à évolution différentielle (DE) et l'algorithme de Newton Raphson (NR) sont utilisés pour résoudre les équations non linéaires transcendantales nécessaire pour le (SHPWM). Les résultats du calcul montrent qu'il y a une bonne concordance entre les prédictions théoriques. Un prototype de laboratoire basé sur un microcontrôleur de type STM31F407 a été réalisé dans le but de valider les résultats expérimentaux.*

Keywords: Multilevel inverter - Harmonic elimination - Newton Raphson - Optimization - Differential evolution.

1. INTRODUCTION

DC to AC multilevel inverters have drawn tremendous interest in the last few years especially in high voltage applications such as power distribution systems [1], photovoltaic systems [2, 3] and power transfer enhancement [4]. The harmonic content in an AC voltage waveform generated by a power converter can affect significantly the performance of AC motors and electrical equipments in general. For example harmonics can raise the temperature of an AC motor which decreases the lifetime of the insulation

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and consequently the lifetime of the motor itself. One way to fight this problem is by choosing the right modulation strategy.

Multiple modulation methods have been proposed for the control of multilevel DC to AC power converters such as Sinusoidal Pulse width modulation (SPWM) [5, 6] and space vector pulse width modulation (SVPWM) [7-9]. Selective harmonic elimination pulse width modulation (SHE-PWM) was the subject of several studies, it was applied to multiple inverter topologies [10, 11] and studied for different voltage levels [12-14].

The SHEPWM method offers a lot of advantages such as operating the inverters switching devices at a low frequency which extends the lifetime of the switching devices. The main disadvantage of this method is that a set of non-linear equations must be solved to obtain the optimal switching angles to apply this strategy.

The optimal firing (switching) angles are computed by solving a set of non linear equation that represents the desired waveform. Multiple optimization algorithms have been used to solve the optimal switching problem or also known as (SHEPWM) for multilevel inverters such as Genetic Algorithms [15, 16], Differential Evolution [17], Particle swarm optimization [18, 19] and Bat algorithm [20].

Newton-Raphson algorithm which is well known numerical method used for root finding, can be used also to solve the optimal switching problem, it is really easy to program and it can solve the non linear equations in few seconds.

This study compares the performance of a numerical method (Newton-Raphson) and an optimization method (Differential Evolution) for the optimal switching problem.

2. SELECTIVE HARMONIC ELIMINATION PWM (SHEPWM)

Cascaded Multilevel Inverter topology rely on a simple principle based on the summation of voltages generated by each individual cell (H-bridge) to obtain a staircase output voltage waveform. Figure 1 illustrates the voltage waveform of a seven level inverter.

Figure 2 demonstrates the proposed single phase seven level asymmetrical inverter. It is formed by two H-bridges connected in series each bridge is powered by electrically isolated power supplies to generate the desired waveform.

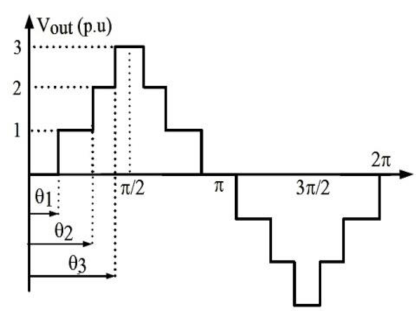

Fig. 1: The desired seven level voltagewaveform

Each H-bridge module is connected to its respective isolated DC source: each module can generate three voltage levels in different patterns, $+V$ which is the positive voltage of the DC source, $0V$ and $-V$ which is the negative voltage of the DC source, and as it can be observed in figure 2 in order to obtain seven levels at the output of the inverter, the DC voltage source connected to the lower cell has to be twice the value of the DC source connected to the upper cell ($V_{dc2} = 2 \times V_{dc1}$).

To control the peak value of the output voltage to a desired value and eliminate the 3rd and 5th harmonic the resulting equations and since the voltage waveform has quarter and half wave symmetry characteristics, the Fourier series expansion is given as,

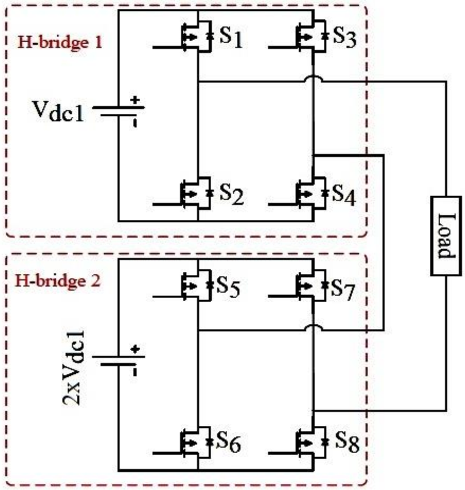

Fig. 2: The topology of the proposed seven level inverter

$$V(\omega t) = \sum_{n=1,3,5,}^{\infty} \left(\frac{4V_{dc}}{n\pi} \sum_{i=1}^{p} \cos(n\theta_i) \right) \sin(n\omega t) \quad (1)$$

where n is rank of harmonics, and $p=(N-1)/2$ is the number of switching angles per quarter waveform, and θ_i is the i^{th} switching angle, and N is the number of voltage levels per half waveform. The optimal switching angles θ_1, θ_2 and θ_3 can be determined by solving the following system of non-linear equations,

$$\begin{cases} H_1 = \cos(\theta_1) + \cos(\theta_2) + \cos(\theta_3) = M \\ H_3 = \cos(3\theta_1) + \cos(3\theta_2) + \cos(3\theta_3) = 0 \\ H_5 = \cos(5\theta_1) + \cos(5\theta_2) + \cos(5\theta_3) = 0 \end{cases} \quad (2)$$

where $M = (((N-1)/2)r/4)$, r is the modulation indes. The obtained solutions must satisfy the following constraint,

$$0 < \theta_1 < \ldots < \theta_p < \pi/2 \quad (3)$$

3. NEWTON RAPHSON FOR SHEPWM

The Newton- Raphson (NR) method is one of the most widely used and also one the fastest iterative methods for root-finding. In this study the NR is used to solve the system of transcendental equations expressed in (2) to obtain the optimal switching angles. The system can be written in following form,

$$F(\theta) = B \quad (4)$$

where $F(\theta) = \begin{bmatrix} \cos(\theta_1) & \cos(\theta_2) & \cos(\theta_3) \\ \cos(3\theta_1) & \cos(3\theta_2) & \cos(3\theta_3) \\ \cos(5\theta_1) & \cos(5\theta_2) & \cos(5\theta_3) \end{bmatrix}$

(5)

and

$$B = \begin{bmatrix} rn \\ 0 \\ 0 \end{bmatrix} \quad (6)$$

Which represents the desired amplitudes for the fundamental component, 3rd and 5thharmonic respectively. In order to solve this system of equations of any value of r the following steps must be achieved,

•Guess the initial values of the optimal angles θ^0 where,

$$\theta^0 = \begin{bmatrix} \theta_1^0 \\ \theta_2^0 \\ \theta_3^0 \end{bmatrix} \quad (7)$$

•Evaluate $F(\theta)$ et $B(r)$ using (5) and (6) then compute the jacobian matrix $J(\theta)$ where,

$$J(\theta) = \begin{bmatrix} -\sin(\theta_1) - \sin(\theta_2) - \sin(\theta_3) \\ -3\sin(3\theta_1) - 3\sin(3\theta_2) - 3\sin(3\theta_3) \\ -5\sin(5\theta_1) - 5\sin(5\theta_2) - 5\sin(5\theta_3) \end{bmatrix} \quad (8)$$

•Compute $d\theta$ using the following relation,

$$d\theta = INV\left[J(\theta)\right](B - F) \quad (9)$$

•Update the values of θ using the following relation,

$$\theta^{k+1} = \theta^k + d\theta^k \quad (10)$$

where k is the current iteration.

• Repeat steps 2 (evaluation) to 4 (update) for a number of iterations (k) to reach an acceptable error value $d\theta$.

The following figure presents the computational process using NR algorithm for different value of r .

4. DIFFERENTIAL EVOLUTION FOR SHEPWM

In the case of Differential Evolution an objective function is necessary to perform the optimization operation (finding the optimal solution), the function must be chosen in such way that allows the elimination of low order harmonics while maintaining the amplitude of the fundamental component at a desired value. Therefore the objective function is defined as,

$$F(\theta) = \left(\sum_{n=1}^{p} \cos(\theta_n) - M\right)^2 + \left(\sum_{n=1}^{p} \cos(3\theta_n)\right)^2 + \left(\sum_{n=1}^{p} \cos(5\theta_n)\right)^2 \quad (11)$$

The optimal switching angles are obtained by minimizing {Eq. (11)} subject to the constraint {Eq. (3)}. The main problem is the non-linearity of the transcendental set of {Eq. (2)}, the differential algorithm is used to overcome this problem.

The differential evolution algorithm (DE) is an optimization method is composed of three main steps initialization, mutation and crossover. The general structure of a DE program is shown in figure 4. The algorithm perturbs the population of vectors by employing the mutation, whereas its diversity is controlled by the cross-over process [21].

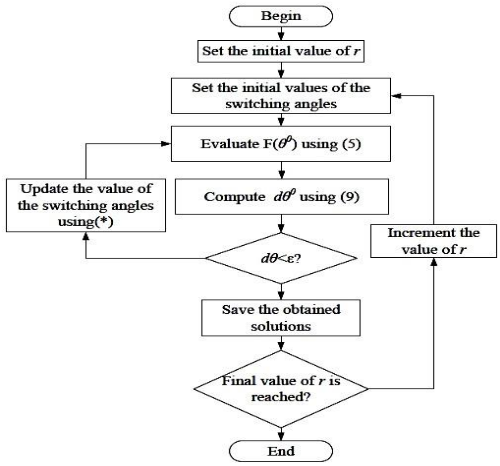

Fig. 3: Flowchart of the NR algorithm

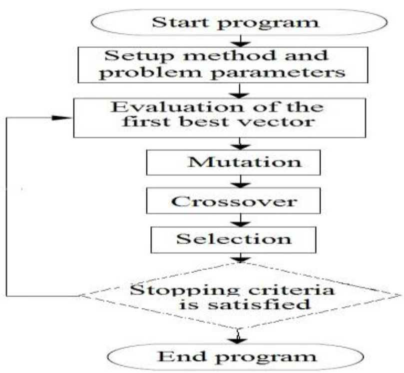

Fig. 4: Flowchart of DE algorithm

In the case of SHPWM, differential evolution algorithm is used as an optimization tool to perform a random search for the global minima, which is forcing the objective function (11) towards an allowable error value.The optimization process starts by initializing the necessary parameters of the algorithm, such as the population size (NP), crossover probability (CP), upper and lower bounds (θ_{min} and θ_{max}) and the maximum number of iterations. It should be noted that the boundaries must satisfy equation (3). The next step is to randomly generate an initial population of switching angles in this process the algorithm creates.

$$\theta_{ij}^{(0)} = \theta_{\min ij} + \text{rand}_i (\theta_{\max j} - \theta_{\min j}) \tag{12}$$

with, $i = 1, 2, \ldots NP$ and $i = 1, 2, \ldots N$

where, $\theta_{ij}^{(0)}$, is the initial population, i presents the population size in this study $NP = 50$. j , is the number of decision variables which represents the number of switching angles, in case of a seven level inverter $N = 3$. After the initialization process, the generated population is evaluated; the evaluation of the fitness of each individual is carried out by using (11).

The mutation process creates a mutant v_{ij} vector based on the initial population; this process is described by the following expression,

$$V_{ij} = X_{r1} + F(X_{r2} - X_{r3}) \tag{13}$$

X_{r1}, X_{r2} and X_r are vectors randomly sampled from the generated population, $X_r = [\theta_{i1}, \theta_{i2}, \ldots, \theta_{iN}]$, the indices $r1$, $r2$ and $r3$ are integers randomly chosen from the range $[1\ NP]$, they are also chosen to be different from the index i, the parameter F is the mutation constant which controls the amplification of the differential variation $(X_{r2} - X_{r3})$, the value of this parameter is randomly generated from the range [0 1], it should be noted that multiple mutation methods were reported in [22].

To improve the diversity of the population, the crossover operation comes into play, after generating the mutant vector $v_{i,j}$ through mutation, this operation assures the production of fitter individuals, the result of this process is a vector *u* obtained by mixing the components of $v_{i,j}$ and X_i the process can be expressed as,

$$u = \begin{cases} v_{ij} & \text{if} \quad rand \leq CP \quad \text{or} \quad j = j_{rand} \\ X_i & \text{otherwise} \end{cases} \tag{14}$$

where $rand$ is a random number in the range of [0 1], CP is the crossover probability constant, it controls the diversity of the population and it has a value between 0 and 1 [23], j_{rand} is randomly chosen index. Once the crossover process is completed, the selection process comes into play to decide whether the u_i or X_i vector survives for the next generation, this process is carried out to choose the fittest individual. The selection process can be expressed mathematically as,

$$X_i^{G+1} = \begin{cases} u_i^{G+1} & \text{if} \quad f(u_i^{G+1}) \leq f(X_i^G) \\ X_i^G & \text{otherwise} \end{cases} \tag{15}$$

where $f(X)$ is the objective function to be minimized, and G is the generation count. Once the selection operation is completed, the algorithm loop is repeated until the stopping criteria is satisfied, in this study the DE algorithm is limited by maximum number of iterations $N_{itr} = 1000$.

5. SIMULATION AND EXPERIMENTAL RESULTS

In order to prove the theoretical predictions and to test the effectiveness of the proposed algorithms, the control methods and the proposed inverter were developed and simulated using Matlab/Simulink scientific programming environment.

The optimization program was executed on a computer with Intel (R) Core (TM) i3 CPU@ 2.13GHz Processor and 4GB of RAM.

To verify the effectiveness of the proposed method, total harmonic distortion (THD) is used as a performance indicator to evaluate the quality of output AC voltage waveform generated from the multilevel inverter.

The THD is defined as the total amount of harmonics related to the fundamental, and it can be calculated using the following formula,

$$\mathrm{THD\%} = \frac{\sqrt{\sum_{n=3}^{19} H_n^2}}{H_1} \times 100 \qquad (16)$$

The differential evolution and Newton Raphson algorithms are used to find the switching angles for each value of modulation index r ; the total harmonic distortion is computed also for each r using both methods.

Figure 5 and figure 6 present the optimal switching angles (in degrees) versus modulation index r obtained by the NR and DE methods respectively.

The results show that the solutions obtained using DE algorithm range from 0.50 to 1.2 where as the solutions generated using NR algorithm range only from 0.70 to 1.04 this means that the DE algorithm allows the control of the output voltage generated by the multilevel inverter for a wider range of r than the NR algorithm.

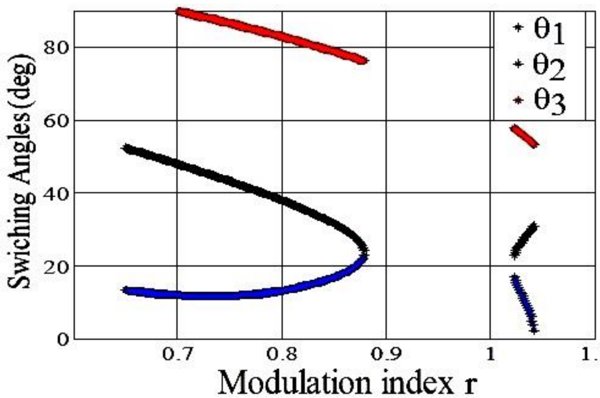

Fig. 5: Switching angles versus modulation index using NR algorithm

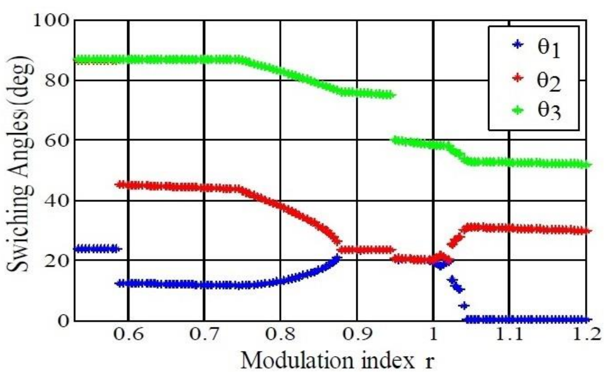

Fig. 6: Switching angles versus modulation index using DE algorithm

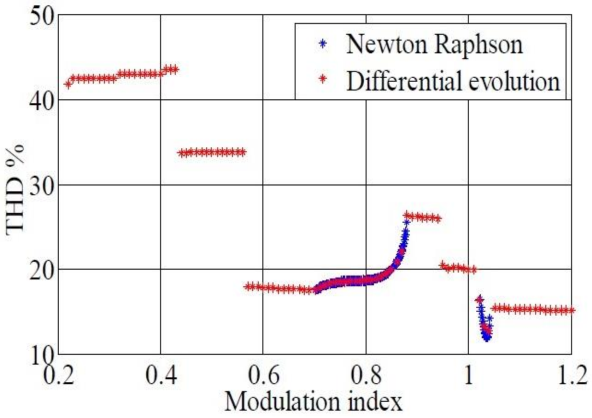

Fig. 7: Total harmonic distorsion versus modulation index r obtained by using differential evolution and Newton Raphson

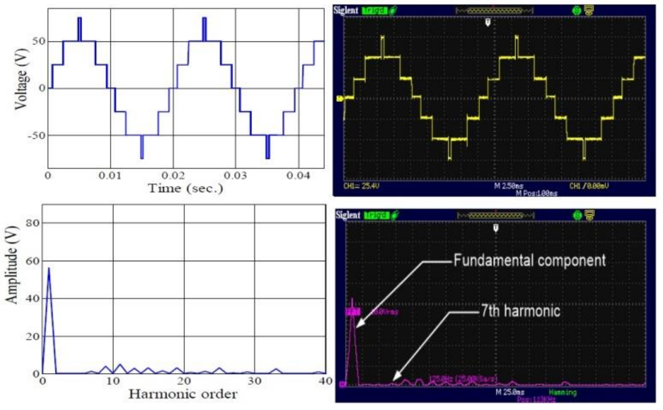

Fig. 8: Obtained simulation and experimental results of the output voltage waveform (up) and the corresponding FFT analysis (bottom) for $r = 0.701$ using Newton Raphson method

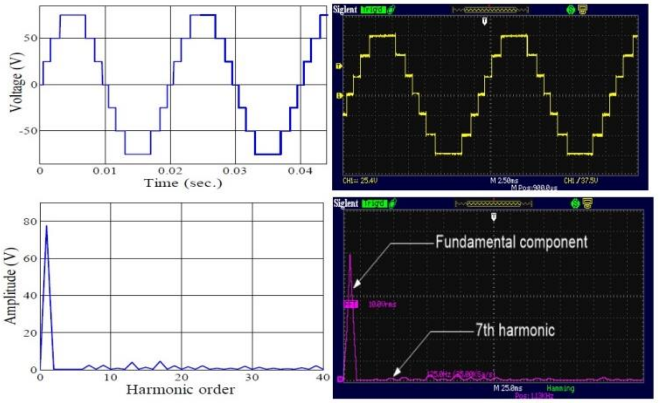

Fig. 9: Obtained simulation and experimental results of the output voltage waveform (up) and the corresponding FFT analysis (bottom) for $r = 1.036$ using Newton Raphson method

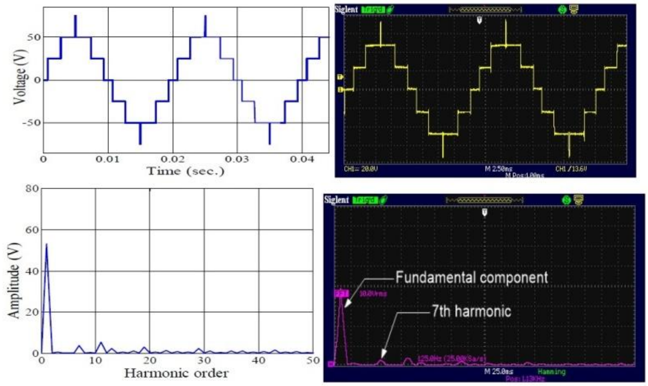

Fig. 10: Obtained simulation and experimental results of the output voltage waveform (up) and the corresponding FFT analysis (bottom) for $r = 0.62$ using differential evolution algorithm

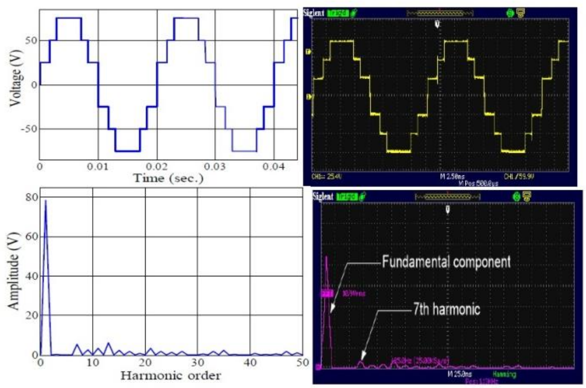

Fig. 11: Obtained simulation and experimental results of the output voltage waveform (up) and the corresponding FFT analysis (bottom) for $r = 1.1$ using differential evolution algorithm

It can be seen that in some ranges of the modulation index, the obtained solutions exceeded the 90 degrees limit, those solutions are not going to be taken in consideration. Figure 7 shows the variation of the total harmonic distortion versus the modulation index, these results are obtained by using equation (16) and (2).

To confirm the validity of the proposed algorithm, angles extracted from the obtained switching angles for both methods were applied to a mathematical model of a seven-level inverter. The fundamental frequency used in this simulation is 50 Hz, the input voltages of the first bridge (upper cell) and the second bridge (lower cell) are respectively $V_{dc1} = 25V$, $V_{dc2} = 50V$. The applied angles are presented in **Table 1**.

A small scale seven level inverter was built to validate the results obtained from the simulation process; IRF640 Mosfets were used as switching devices for the proposed inverter. TLP250 optocouplers were used to protect the microcontroller used in this experiment. Siglent SDS 1000 oscilloscope with FFT functionality was used to view analyze the generated waveforms.

Figure 8 and figure 9 show the output voltage waveforms obtained from the multilevel inverter and the respective FFT analysis for $r = 0.701$ and $r = 1.036$

respectively using NR algorithm. Whereas figure 10 and figure show the output voltage waveforms obtained from the multilevel inverter and the respective FFT analysis for $r = 0.62$ and $r = 1.1$ respectively using DE algorithm. The obtained results show that the targeted harmonics ($3^{rd}$and 5^{th}) are completely eliminated and simulation results match perfectly experimental results.

Table 1: Computed switching angles using NR and DE

Method	r	θ_1	θ_2	θ_3
Newton- Raphson	0.701 1.036	11.968 8.466	47.829 28.849	89.880 54.828
Differential evalution	0.62 1.1	12.5356 0.5000	47.5501 30.7880	89.0000 52.6877

6. CONCLUSIONS

This paper presents a brief performance comparison between Differential Evolution algorithm and Newton Raphson method for solving the optimal switching problem for multilevel inverters with the objective of improving the harmonic quality of the generated output voltage waveform.

The methods are used to solve a set of non-linear equations in order to obtain the optimal switching angles to perform the (SHE) modulation strategy. The obtained solutions were applied to a seven level asymmetrical inverter.

Simulation results obtained in this study showed that the differential evolution generated optimal switching for a wider range of modulation index than Newton Raphson algorithm thus allowing better control of the inverter.

The validity of the methods has been proven by computer simulation using Matlab/Simulink scientific programming environment and verified by experimental hardware set-up based on STM32F407 microcontroller.

The obtained results from the simulation and hardware show a good agreement with the theoretical prediction.

REFERENCES

[1] B. Sun, F. Wu, M. Savaghebi and J. M. Guerrero, '*A Flexible Five-Level Cascaded H-Bridge Inverter for Photovoltaic Gird-Connected Systems*', 9th International Conference on Power Electronics and ECCE Asia (ICPE-ECCE Asia), Seoul, pp. 2369 - 2375, 2015.

[2] P. Jana, S. Chattopadhyay, S. Maiti, P. Bajpai and C. Chakraborty, '*Hybrid Modulation Technique for Binary Asymmetrical Cascaded Multilevel Inverter for PV Application*', IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), Trivandrum, pp. 1-6, 2016.

[3] S.K. Rai, P. Chaturvedi and S.L. Shimi, '*SHE-PWM Based Multilevel T-Type Inverter Topology for Single-Phase Photovoltaic Applications*', IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), Trivandrum, pp. 1-4, 2016.

[4] J. Amini and M. Moallem, '*A Capacitor Voltage Balancing Method for Cascaded H-Bridge Multilevel Inverters with Application to Facts*', IECON 2016 - 42nd Annual Conference of the IEEE Industrial Electronics Society, Florence, pp. 6447 - 6452, 2016.

[5] B. Karami, R. Barzegarkhoo, A. Abrishamifar and M. Samizadeh, '*A Switched-Capacitor Multilevel Inverter for High AC Power Systems with Reduced Ripple Loss Using SPWM Technique*', The 6th Power Electronics, Drive Systems & Technologies Conference (PEDSTC2015), Tehran, pp. 627 - 632, 2015.

[6] Z. Bai, Z. Zhang and Y. Zhang, 'A Generalized Three-Phase Multilevel Current Source Inverter with Carrier Phase-Shifted SPWM', IEEE Power Electronics Specialists Conference, Orlando, FL, pp. 2055-2060, 2007.

[7] Z. Ben Mahmoud, M. Hamouda and A. Khedher, '*Implementation of a Fast and Simple Space Vector Modulation Scheme for a Three-Phase Five-Level Neutral Point Clamped Inverter*', 16th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA), Monastir, pp. 570 - 575, 2015.

[8] F. Chen and W. Qiao, '*A General Space Vector PWM Scheme for Multilevel Inverters*', IEEE Energy Conversion Congress and Exposition (ECCE), Milwaukee, WI, pp. 1 - 6, 2016.

[9] H. Saidi, R. Taleb, N. Mansour and A. Midoun, '*DSP Based Space Vector PWM Control for Solar Electric Vehicle*', Revue des Energies Renouvelables, Vol. 19, N°2, pp. 321 - 331, 2016.

[10] L. Manai, F. Armi and M. Besbes, '*New Topology of Cascaded Multilevel Inverter with Reduced Number of Switches Control Considering Lower Order Harmonics Elimination*', 4th International Conference on Control Engineering & Information Technology (CEIT), Hammamet, Tunisia, pp. 1 - 8, 2016.

[11] J.A. de Almeida, M.D. Bellar, L.F.C. Monteiro, J.F.M. do Amaral and P. Rodriguez, '*Selective Harmonic Elimination For Modflar 5-Level MLC2 Topology Based 7-Level Inverter by Using Genetic Algorithms*', IECON 2016 - 42nd Annual Conference of the IEEE Industrial Electronics Society, Florence, pp. 3594 - 3599, 2016.

[12] C. Buccella, M.G. Cimoroni, H. Latafat, G. Graditi and Rongfeng Yang, '*Selective Harmonic Elimination in a Seven Level Cascaded Multilevel Inverter Based on Graphical Analysis*', IECON 2016 - 42nd Annual Conference of the IEEE Industrial Electronics Society, Florence, pp. 2563-2568, 2016.

[13] B. Zhao, X. Wu, X. Fu and P. Dai, '*A Novel 12-Pulse 3-Level Inverter for STATCOM Using Selective Harmonic Elimination Modulation*', Asia-Pacific Power and Energy Engineering Conference, Chengdu, pp. 1 - 5, 2010.

[14] J. Ren, J. Wang, Y. Hu and Y. Ji, '*Research on Solutions to Selective Harmonic Eliminated PWM Switching Angles for Novel Five-level Inverter*', Asia-Pacific Power and Energy Engineering Conference, Chengdu, pp. 1 - 4, 2010.

[15] E. Deniz, O. Aydogmus, and Z. Aydogmus, '*Implementation of ANN-based Selective Harmonic Elimination PWM using Hybrid Genetic Algorithm-based optimization*', In Measurement, Vol. 85, pp. 32- 42, 2016.

[16] M. Hajizadeh and S.H. Fathi, '*Selective Harmonic Elimination Strategy for Cascaded H-Bridge Five-Level Inverter with Arbitrary Power Sharing Among the Cells*', in IET Power Electronics, Vol. 9, N° 1, pp. 95 - 101, 2016.

[17] F. Chabni, R. Taleb and M. Helaimi, '*Differential Evolution Based SHEPWM for Seven-Level Inverter with Non-Equal DC Sources*', in International Journal of

Advanced Computer Science and Applications (IJACSA), Vol. 7, N°9, pp. 304 - 311, 2016.

[18] A. Kouzou, M.O. Mahmoudi and M.S. Boucherit, '*Application of SHE-PWM for Seven-Level Inverter Output Voltage Enhancement Based on Particle Swarm Optimization*', 7th International Multi- Conference on Systems, Signals and Devices, Amman, pp. 1-6, 2010,

[19] M. Tarafdar Hagh, H. Taghizadeh and K. Razi, '*Harmonic Minimization in Multilevel Inverters Using Modified Species-Based Particle Swarm Optimization*', in IEEE Transactions on Power Electronics, Vol. 24, N°10, pp. 2259 - 2267, 2009.

[20] K. Ganesan, K. Barathi, P. Chandrasekar and D. Balaji, '*Selective Harmonic Elimination of Cascaded Multilevel Inverter Using BAT Algorithm*', in Procedia Technology, Vol. 21, pp 651 - 657, 2015.

[21] R. Vijayakumar, C. Devalalitha, A. Nachiappan and R. Mazhuvendhi, '*Selective Harmonic Elimination PWM Method Using two Level Inverter by Differential Evolution Optimization Technique*', International Conference on Science Engineering and Management Research (ICSEMR), Chennai, 2014, pp. 1 - 6, 2014.

[22] M.I. Mohd Rashid, A. Hiendro and M. Anwari, '*Optimal HE-PWM Inverter Switching Patterns Using Differential Evolution Algorithm*', IEEE International Conference on Power and Energy (PECon), Kota Kinabalu, pp. 32 - 37, 2012.

[23] C. Sun, H. Zhou and L. Chen, '*Improved Differential Evolution Algorithms*', IEEE International Conference on Computer Science and Automation Engineering (CSAE), Zhangjiajie, pp. 142 - 145, 2012.