iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** IX **Month of publication:** September 2017

DOI: http://doi.org/10.22214/ijraset.2017.9026

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue IX, September 2017- Available at www.ijraset.com

Multi Level Inverter Based Power Quality Improvement By Flower Pollination Algarithm

Madasamy P [1], Subashini.B[2]
Assistant Professor[1], PG Scholar[2], Department of Electrical and Electronics Engineering, Alagappa Chettiar College of Engineering and Technology, Karaikudi

Abstract: Elimination of low order harmonics is the major challenging task during the design of multilevel inverters. Involvement of the selective Harmonic Elimination (SHE) methodology in the design of multilevel inverter has greatly reduced the above challenge. SHE is considered as a low frequency technique, in which the switching angles are predetermined based on solving a system of transcendental equations. In this paper, the design of eliminating the low order harmonics in the cascade 11 levels H-bridge inverter with the support of SHE based Flower Pollination optimization algorithm (FPA) is presented. The results of the FPA based SHE method shows that the required switching angles are calculated competently to eliminate low order harmonics up to 13 orders from the inverter voltage waveform while keeping the magnitude of the fundamental at the desired value which resulted in minimum total harmonic distortion (THD). In addition, for a low number of switching angles, the proposed FPA approach reduces the computational burden to find the optimal solution compared with iterative methods and the resultant theory approach. The results prove that the FPA algorithm provides greater amount balance between exploitation and exploration process compared to other legacy algorithm such as Genetic algorithm (GA) in determining the global solutions.

Keywords: Flower pollination algorithm (FPA), selective harmonic elimination (SHE), total harmonic distortion (THD), genetic algorithm (GA).

I. INTRODUCTION

In recent days, the utilization of multilevel inverters for harmonics elimination has been increased a lot in average voltage and high power applications because of their less switching losses and high efficiency. The output voltage of this inverter is synthesized from several levels of dc voltages with different methodologies such as diode clamped and cascaded [1-4]. To limit the output voltage and suppress the undesired harmonics, different sinusoidal pulse width modulation (PWM) [5] and space-vector PWM schemes are suggested for multilevel inverters; however, PWM techniques are not able to suppress harmonics which are in lower order fully. Another approach is to choose switching angles [1] so that specific lower order dominant harmonics are suppressed. This method is known as harmonic elimination.

To eliminate the undesired harmonics in multilevel inverters with equal dc voltages, various modulation methods such as sinusoidal pulse width modulation and space vector pulse width modulation techniques are suggested [6]. Lower order harmonics cannot be completely eliminated by PWM techniques. Programmed PWM technique or Selective harmonic elimination (SHE) PWM technique is used to suppress the specific higher order harmonics such as 5th,7th,11th& 13th by choosing the switching angles suggested in [7]-[8]. Obtaining the arithmetic solution of nonlinear transcendental equations is one of the main problem associated in this method. Newton-Raphson method is one of the iterative techniques which is used to solve the set of nonlinear equation [9]-[12].But this method is not feasible to solve the SHE problem for a large number of switching angles. More recently, the total harmonic distortion (THD) of the output voltage of multilevel inverter is minimized by the real time calculation of switching angles with analytical proof. However this method is only valid for minimizing all harmonics including triple and cannot be extended [13]. Particle swarm optimization technique is one of the modern stochastic techniques which deal with the problem of equal dc sources [14]. Fig1 shows the series connection of the single phase H-bridge units with Independent DC sources (SDCSs). These SDCSs may be of constant voltage sources such as batteries, capacitors, fuel cells or solar cells. Each unit produces a positive DC (+ Vdc), zero and a negative DC (– Vdc) voltage at the output. The number of the units depends upon the output voltage.

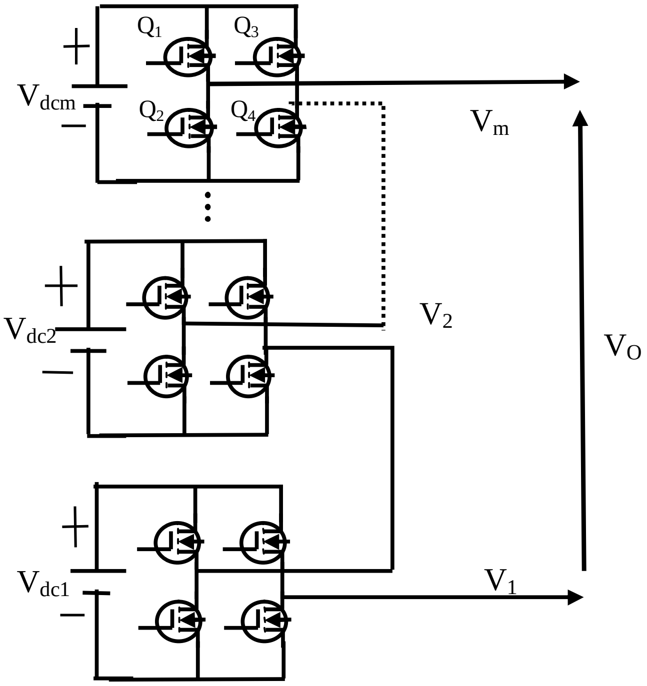


Fig 1.Cascaded Multilevel Inverter

A cascaded MLI consists of a group of single phase full bridge inverter with four switches of each phase in series. The outputs of single full-bridge converter are connected in series. So the output is the summation of individual converter outputs, which is staircase waveform. The number of total output voltage levels are p=2N+1, Where N = total number of DC sources of each bridge. With control strategy, it is possible to bypass the fault bridge without stopping the load, with decrease output. Due to the above features, the cascaded H-Bridge multilevel inverter has been more advantages than clamping diode, flying capacitor multilevel inverters.

II. HARMONIC-ELIMINATION PROBLEM WITH NON EQUAL DC SOURCES

Because of odd quarter-wave symmetry, the dc component and the even harmonics are equal to zero. By applying fourier series analysis,the staircase output voltage of multilevel inverters with nonequal sources can be described as follows:

$$V(\omega t) = \sum_{n=1,3,5,\dots}^{\infty} \frac{4Vdc}{n\pi} x(k_1\cos(n\theta_1)+k_2\cos(n\theta_2)+k_3\cos(n\theta_3)+\dots\dots+k_s\cos(n_s))\sin(n\omega t) \qquad (1)$$

Where k_iV_{dc} is the i^{th} dc voltage ,V_{dc} is the nominal dc voltage,and the switching angles θ_1-θ_m must satisfy the following condition:

$$0\leq \theta_1\leq\theta_2\leq\dots\leq\theta_s\leq \pi/2. \qquad (2)$$

The number of harmonics which can be eliminated from the output voltage of the inverter is s-1. For example,to remove the fifth-order harmonic for a five- level inverter,equation set(3) must be satisfied.Note that the elimination of triple harmonics for the three-phase power system applications is not necessary,because these harmonics are automatically eliminated from the line to line voltage

$$k_1\cos(\theta_1)+k_2\cos(\theta_2)=(\pi/2)M \qquad (3)$$

$$k_2\cos(5\theta_2)+k_2\cos(5\theta_2)=0. \qquad (4)$$

In eqn (3),modulation index M is defined as $M=V_1/sV_{dc}$ and V_1 is the fundamental of the required voltage.

III. FPA APPROACH TO DEAL SHE PROBLEM

In this paper, the FPA approach is developed to deal with the SHE problem with non-equal dc sources while there is a increase in number of switching angle and these angles are determined using conventional iterative methods as well as the resultant theory is not possible.

In addition, for a low number of switching angles, the proposed FPA approach reduces the computational burden to find the optimal solution compared with iterative methods and the resultant theory approach. This method solves the asymmetry of the transcendental equation set, which has to be solved in cascade multilevel inverters. The switching angles θ_1, θ_2,…….θ_s in a multilevel inverter for the output waveform can be calculated such that odd and non-triple low order harmonics up to the 3s-2th order while s is odd and up to the 3s-1th order when s is even can be eliminated so that the cost function gets minimized as follows:

Fitness function

$$f(\theta 1+\theta 2+\cdots\cdots\theta s)=100*\left[\left|M-\left[\frac{V1}{SVdc}\right]\right|+\left(\frac{|V5+V7+\dots V(3S-2)or(3S-1)\ \ |}{SVdc}\right]\right. \qquad (5)$$.

IV. DETERMINATION OF BESTSWITCHIN ANLE FOR ELIMINATING THE ODD HARMONICS AND FOR BEST CONTROL OF FUNDAMENTAL VOLTAGE

A. Step1: Initialize the objective function as given in FPA approach to deal SHE problem.

B. Step2: Initialize a population of flowers X with the population size of NFxN,where NF is the number of flowers as 30 and N is the dimension size depends on the number of switching angle based on the number of separated dc sources SDCS's used for the multilevel inverter.

C. Step3: Calculate the fitness cost function for each flower.

D. Step4: Find the best minimized Cost function for each flower.

E. Step5: Define a switch probability P € [0,1]

F. Step6: While (t<Maximum Generation (1000))

For i=1:n(all n flowers in the population)

If rand<P,

Global pollination has been using below equation.

$$v_i^{t+1}=v_i^t+L(v_i^t-d_*)$$

$$L\sim\frac{\mu\Gamma(\mu)\sin(\pi\mu/2)}{\pi\pi}\frac{1}{s^{1+\mu}}$$

Where v_i^t is the pollen i or solution vector v_i at iteration t, and d_* is the current best solution found among all solutions at the current generation/iteration is the strength of the pollination, which is a step size. Pollinators can move over a long distance with various distance steps, Levy flight distribution is used to mimic this characteristic efficiently.is the standard gamma function, and this distribution is valid for large steps s>0. In all our simulations, we have used μ=1.5 and s€ [0, 10]. L>0 is assumed for Levy distribution.

Else

Draw ϵ from a uniform distribution in [0,1]

Randomly choose jth and kth flower among all the solutions

Do local pollination via below equation.

$$v_i^{t+1}=v_i^t+\varepsilon(v_j^t-v_k^t)$$

Where, vjt and v_k^t are pollens from the same plant species with different flowers.
This essentially mimics the flower constancy in a limited neighborhood
End if
Evaluate new solutions using the objective function
If new solutions are better, update them in the population
End for
Find the current best solution d based on the objective fitness value
End while

V. RESULTS AND DISCUSSIONS

In order to validate the computational results as well as the Simulation results are presented for a single phase 11-level cascaded H-bridge inverter. The circuit configuration in the experimental circuit is the same as that in Fig. 1. The inverter uses 30-A 200-V MOSFETs as the switching devices, and the nominal dc-link voltage for each H-bridge is considered to be 20 V. Since the number of output-phase-voltage levels in a cascade multilevel inverter is 11, the number of SDCSs 11 level H-bridge inverter is 5. In the given circuit, there are twenty switching devices connected with diodes in anti-parallel. Among the Five H- Bridges in the circuit the MOSFETs are classified into two, which are upper and lower. We have numbered the upper with the odd numbers and the lower with the even numbers. Actually, there are fourteen instants in the synthesized output voltage. For each instant particular devices should only work and the rest should turned off. Here the MOSFET are turned on only in the presence of the gate signal. In case of the zero level there are two possible switching patterns to synthesize the zero level. Unequal DC Source has been used so the K^{th} Coefficient of each DC Source is

K1 = 1.08;
K2=0.98;
K3=0.9;
K4=0.86;
K5=0.8.

The magnitudes of the dc voltage levels in the experiment are considered as follows, which correspond to the $K_i$coefficients, are

Vdc1 = 21.6;
Vdc2 = 19.6;
Vdc3 = 18;
Vdc4 = 17.2;
Vdc5 = 16.

FPA algorithm has been used to determine the optimum five switching angles for the objective minimizing cost function given in equation 5. Two experiments are done to verify the robustness of the FPA. The First experiment is done for a lower modulation index M = 0.47 and second experiment is done for a higher modulation index M = 1.075. To validate the results of the proposed FPA, the legacy algorithms results such as GA has been compared. GA algorithm has been designed to extract the results. The details of the designed GA algorithm have been elaborated below.

Step-1: Initialization or Random population Generation
Generation of Switching angles in Degrees
No of Individuals = 30
No of Dimension = 5 (No of Switching Angle)
Population Size = [30 x 5]

Step-2: Fitness Evaluation
The Fitness Evaluation Evaluates the population using the
Fitness Function is same as equation 5.

Step-3: Parent Selection
Best Parents of this generation are selected based on the roulette wheel selection for creating next generation

Step-4: Crossover
The crossover operator creates the two new child vector by mating the two best parent using arithmetic crossover method. Crossover site is 0.5 to 0.8.

Step-5: Mutation
The Mutation operator mutates a child by changing any of its genes.
Mutation site is 0.01

Step-6: Survival Selection
The Survival selection operator chooses the vectors that are going to compose the population in the next generation. This operator selects the mixture consists of best parent from current generation and mutated child selects the parent that performs better (i.e Minimum fitness Value). Survival selection criteria are around 0.8.
Best fitness = Minimized switching angles selected in each iteration
Best fitness value= Minimized Fitness Value of Each Iteration

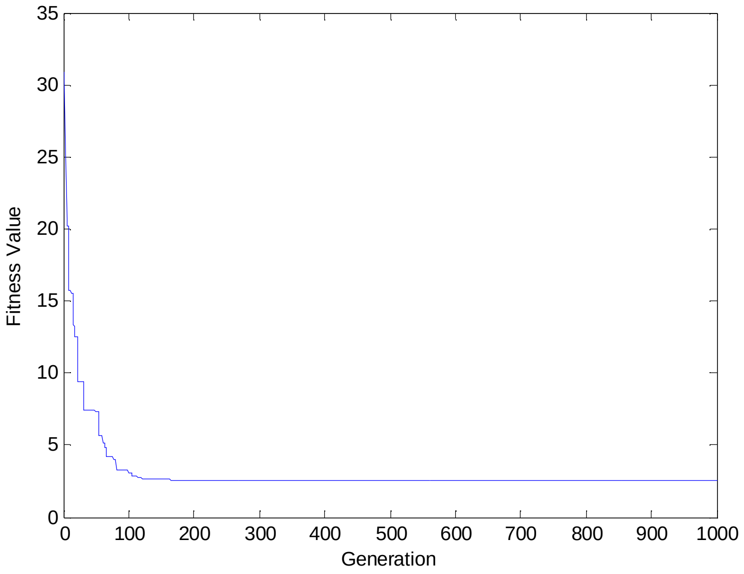
Step-7: Repeat the step-2 to step-7 until maximum iteration reached

A. *Computational Results Of Flower Pollination Algorithm Based Selective Harmonic Elimination*

The Proposed flower pollination algorithm for extracting the optimum five switching angles with the objective of minimizing the cost function as given in the equation 5 for 11 level cascaded H-bridge inverter has been implemented for the two modulation index such as 0.47 and 1.075 respectively. The FPA codes were done on the MATLAB version R2014a (8.03) script. The FPA based optimized switching angles for the modulation index are given in the table 1 and the fitness convergence graphs are depict in the fig 2 and fig 3

Table 1: FPA based optimized switching Results

Modulation Index	Θ1	Θ2	Θ3	Θ4	Θ5	Fitness value
0.47	37.7136	52.8114	68.1956	86.2504	89.3959	2.5298
1.075	7.57815	7.7203	21.9435	27.9225	42.9554	0.942



.Fig.2 FPA convergence graph for 0.47 modulation index

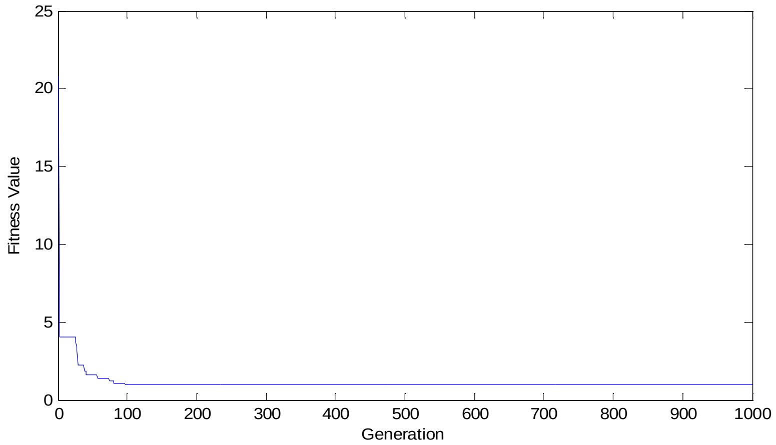


Fig3. FPA convergence graph for 1.075 modulation index

To validate the results of the Proposed FPA algorithm, the designed Genetic algorithm as described has been implemented for the same 11 level cascaded H-bridge inverter for the two modulation index such as 0.47 and 1.075 respectively. The GA based optimized switching angles for the two modulation index are given in the table 2 and the fitness convergence graphs for modulation index 0.47 and 1.075 are depict in the fig.4 and fig.5 respectively.

Table 2: GA based optimized switching Results

Modulation Index	Θ1	Θ2	Θ3	Θ4	Θ5	Fitness value
0.47	37.6822	52.9461	67.9876	86.7978	87.8544	2.648
1.075	7.4716	8.8975	22.2958	27.5544	44.4584	1.548

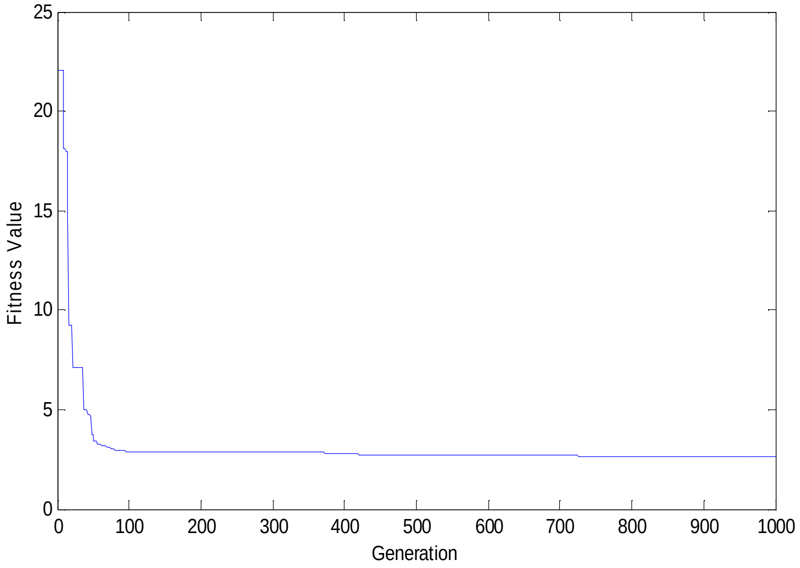


Fig 4. GA convergence graph for 0.47 modulation index

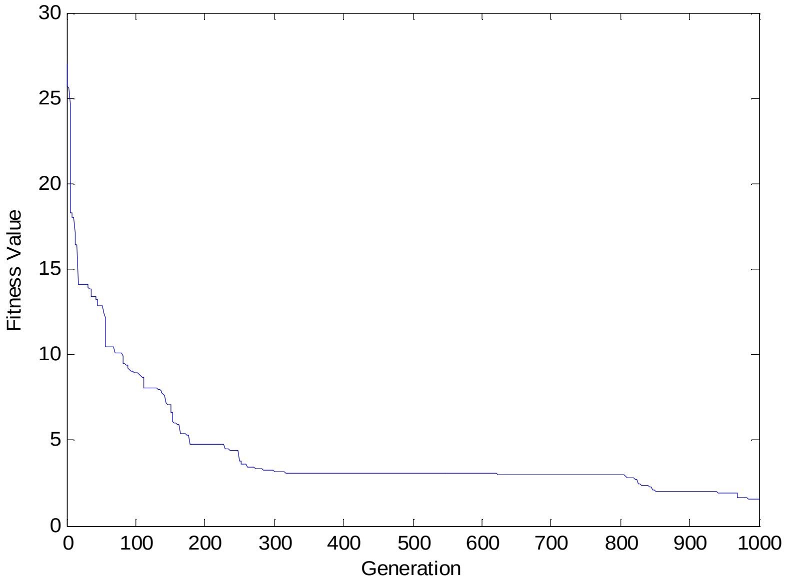


Fig5.convergence graph for 1.075 modulation inde

From the FPA result table 1 and GA result table 2, it is inferred that the better fitness cost function is achieved using FPA. Also from the convergence graphs it is inferred that the FPA shows better convergence compared to GA for both the modulation index. As results it is evident that the FPA provides better balance in achieving best global solution at the faster convergence rate.

B. Simulation Results Of Flower Pollination Algorithm Based Selective Harmonic Elimination

The first simulation is done for a lower modulation index *M* = 0.47. The output phase voltage and the corresponding fast Fourier transform (FFT) analysis are shown in Fig.6 and 7 respectively. The second simulation is done for M = 1.075. The output phase voltage and also the corresponding FFT analysis for this case are shown in Fig.8 and 9, respectively

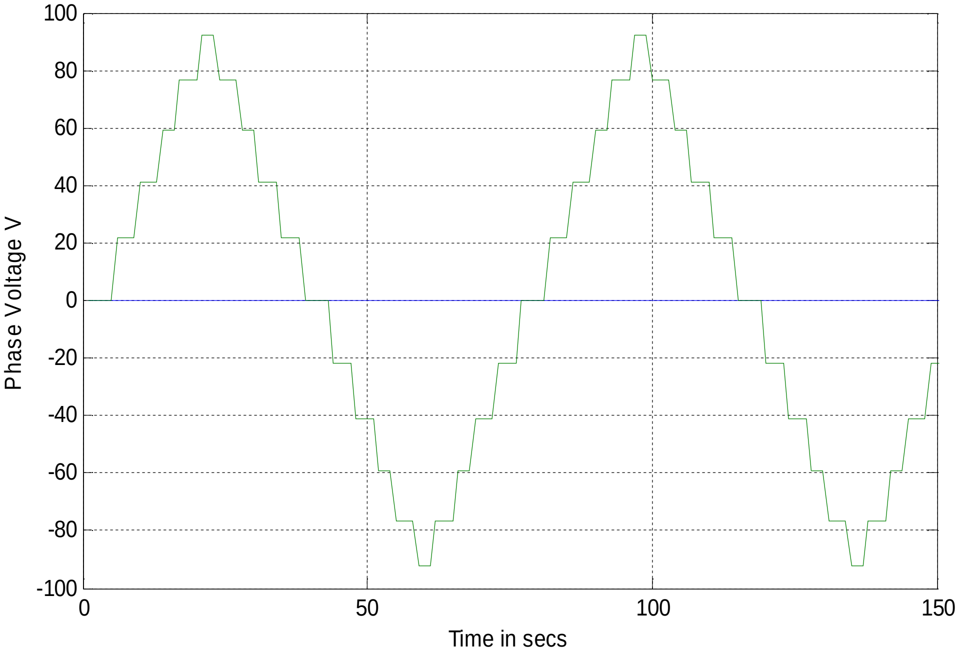


Fig6. Output Phase Voltage for the Modulation Index 0.47

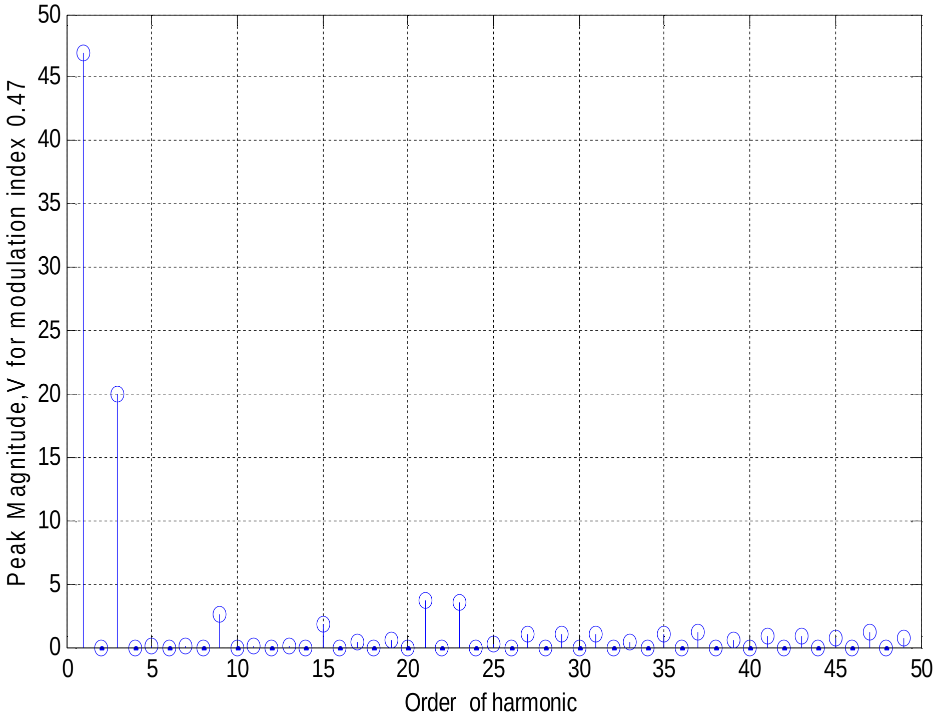


Fig7. Peak Voltage Magnitude for the Modulation Index 0.47 using FFT analysis

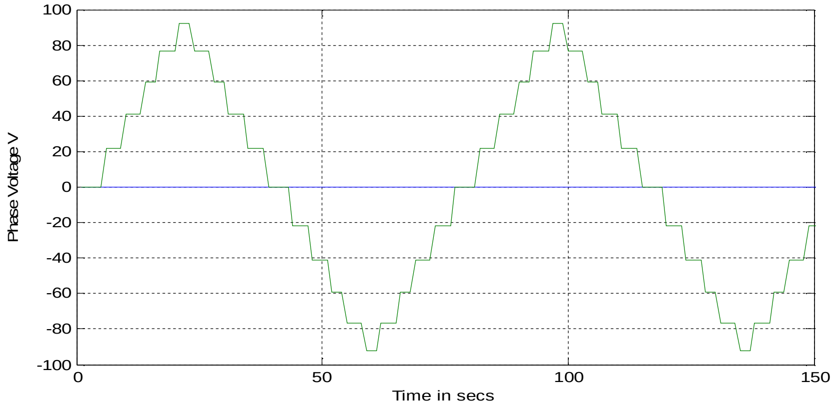


Fig8. Output Phase Voltage for the Modulation Index 1.075

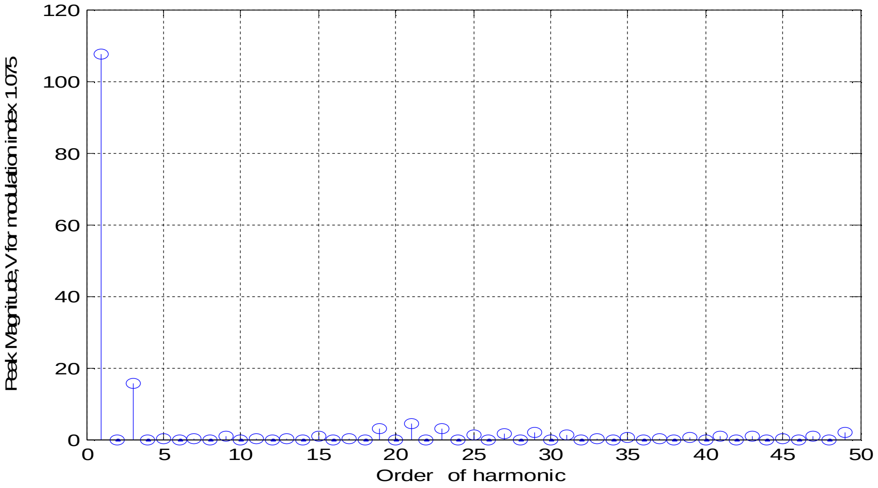


Fig9. Peak Magnitude for the Modulation Index 1.075 using FFT analysis

From the FFT analysis of fig.7 and fig.9 for the modulation index 0.47 and 1.075 it is inferred that 5th, 7th, 11th, and 13th order harmonics are completely eliminated from the output phase voltage of the inverter given in the fig.6 and fig.8. Similarly, simulation has been performed for the GA based switching angle and their output phase voltage, FFT analysis graph are depict in the fig.10, fig.11 and fig.12, fig.13 for modulation index 0.47 and 1.075 respectively. From the FFT analysis, the Total Harmonic Distortion (THD) results has been calculated and provided in the table 3 for GA and FPA respectively. From the THD comparison table 3, it is inferred that the THD has been minimized in the FPA compared to that of GA.

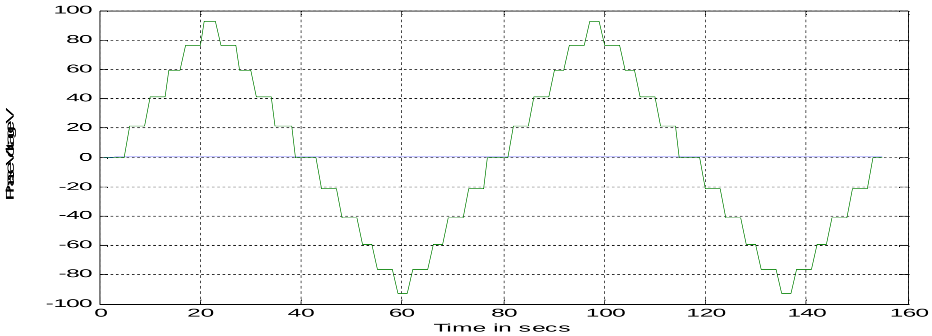


Fig.10 Output Phase Voltage for the Modulation Index 0.47

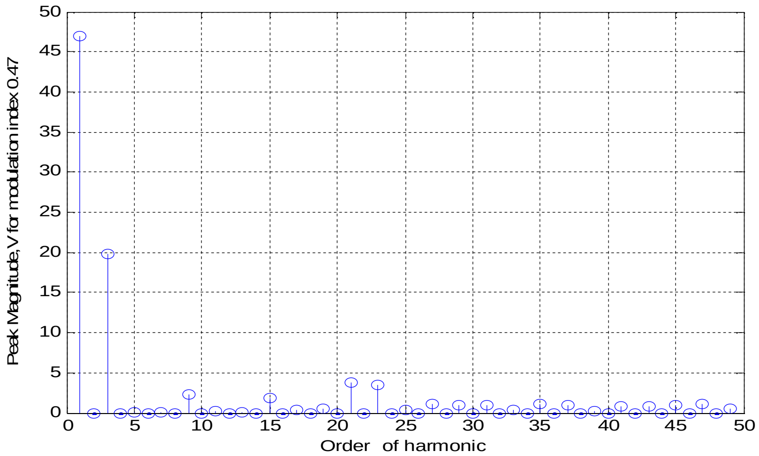


Fig.11 Peak Magnitude for the Modulation Index 0.47 using FFT analysis

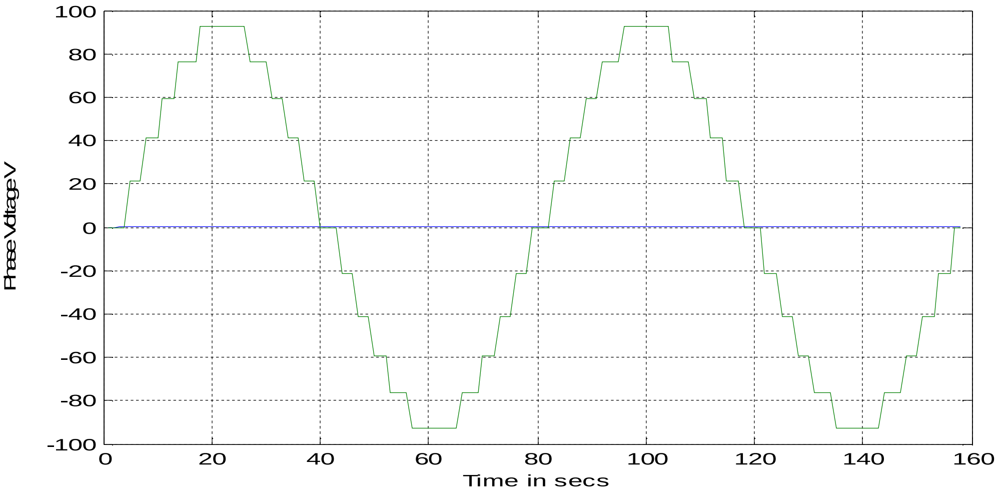


Fig.12 Output Phase Voltage for the Modulation Index 1.075

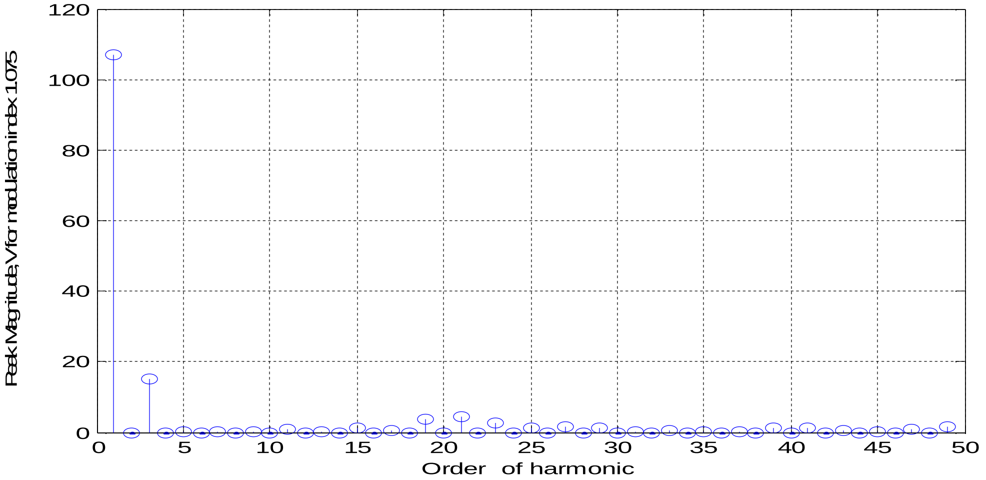


Fig.13 Peak Magnitude for the Modulation Index 1.075 using FFT analysis

Table 3 THD Comparison results of FPA and GA Method

Method	Modulation Index	THD in %
FPA	0.47	14.5419
GA		16.2628
FPA	1.075	6.6844
GA		6.7911

VI. CONCLUSION

The Proposed FPA based Selective Harmonic elimination helps to improve the output voltages with reduced amount of harmonics by providing optimum switching angles to the MOSFET in H-bridge cascaded 11 level multilevel inverters. From the proposed FPA method performance criteria it is inferred that FPA provides global solution at the faster convergence rate. Hence it is evident the FPA Method provides the better exploitation and exploration balance during searching of the global solution. Also compared to other evolutionary or meta-heuristic algorithm, the FPA utilizes very less control parameter to extract the optimized results. Hence FPA provides less programming burden to the programmer. The FPA computation and experimental results are compared with the GA results for an 11-level cascaded H-bridge inverter to validate the accuracy of the FPA results. The proposed FPA method provides better optimized switching angles to obtain the better cost function by reducing the low level harmonic distortion to get better output voltage.

REFERENCES

[1] Rodriguez, J.Lai, and F.Peng,"Multilevel inverters: A survey of topologies,controls and applications,"IEEE Trans.Ind.Electron.,vol.49,no.4,pp.724-738,Aug.2002 .

[2] J.M.Carrasco,L.G.Franquelo,J.T.Bialasiewicz,E.Galvan,R.CportilloGuisado,M.A.M.Prats,J.I.Leon,and N.Moreno-Alfonso,"power –electronics systems for the grid integration of renewable energy sources:"IEEE Trans.Ind.Electron.,vol.53,no.4,pp.1002-1016,Jun.2006.

[3] Y.Cheng,C.Qian,M.L.Crow,S.Pekarek,and S.Atcitty,"A comparison of diode-clamped and cascaded multilevel converters for a STATCOM with energy storage,"IEEE Trans.Ind.Electron.,vol.53,no.5,pp.1512-1521,Oct.2006..

[4] L.G.Franquelo,J.Rodriguez,J.I.Leon,S.Kouro,R.Portillo,and M.A.M.Prats,"The age of multilevel converters arrives,"IEEE Ind.Electron.Mag.,vol.2,no.2,pp.28-39,Jun.2008.

[5] P.W.Hammond,"A new approach to enhance power quality for medium voltage AC drives,"IEEE Trans.Ind.Appl.,vol.33,no.1,pp.202-208,Jan/Feb.1997.

[6] A.J.Visser,J.H.R.Enslin,and H.T.Mouton,"Transformerless series sag compensation with a cascaded multilevel inverter,'IEEE Trans.Ind.Electron.,vol.49,no.4,pp.824-831,Aug.2002.

[7] M.Malinowski,K.Gopakumar,J.Rodriquez,and M.PEREZ,"A survey on cascaded multilevel inverters ,"IEEE Trans,Ind.Electron.,vol.57,no.7,pp.2197-2206,Jul.2010.

[8] L.M.Tolbert,F.Z.Peng,T.Cunnyngham,and J.N.Chiasson,"Charge balance control schemes for cascaded multilevel converter in hybrid electric vehicles,"IEEE Trans.Ind.Electron.,vol.49,no.5,pp.1058-1064,

[9] D.GHolmes and T.A.Lipo,Pulse width Modulation for power converters.Piscataway,NJ:IEEE Press, 2003.

[10] M. T. Hagh, H. Taghizadeh, and K. Razi, ―Harmonic minimization in multilevel inverters using modified species-based particle swarm optimization,‖ IEEE Trans. Power Electron., vol. 24, no. 10, pp. 2259–2267, Oct. 2009.

[11] H. L. Liu, G. H. Cho, and S. S. Park, ―Optimal PWM design for high power three-level inverter through comparative studies,‖ IEEE. Trans. Power Electron., vol. 10, no. 1, pp. 38–47, Jan. 1995.

[12] J. Kumar, B. Das, and P. Agarwal, ―Selective harmonic elimination technique for a multilevel inverter,‖ in Proc. 15th NPSC, Bombay, India, Dec. 2008, pp. 608–613, IIT

[13] J. Napoles, A. Watson, J. Padilla, J. Leon, L. Franquelo, W. Patrick, and M. Aguirre, Selective harmonic mitigation technique for cascaded H bridge converters with non-equal DC link voltages,‖ IEEE Trans. Ind. Electron., vol. 60, no. 5, pp. 1963–1971, May 2013