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Neighbourhood Crossover Embroiled Binary GA Based SHEPWM for Seven Level MLI

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Abstract

Genetic algorithms (GAs) have always been lucrative in offering probabilistic solutions to optimization problems. This can also be a utensil in identifying the precise switching moments to eliminate the specific order harmonics from an output voltage of power converter for any desired value of fundamental. Pioneering contributions in engineering problems have proved the reliability of such evolutionary techniques which has made it superior in comparison with the other offline computational methods. Selective harmonic elimination (SHE) methods in multi-level inverters (MLIs) involve the arduous process of solving the non-linear transcendental equations. This paper presents a SHE method based on a binary pattern GA combined with neighbourhood crossover for MLIs. Binary GA enjoys the benefits of phenotype-fitness mapping, which is possible by binary form of the integer representation in the genotype-phenotype pool. Neighbourhood crossover concentrates only on cross over between the close neighbours in the euclid space. It offers improved efficiency in terms of predicting the exact switching angles of a seven level MLI. Acute algorithm is developed in Turbo C and the switching moments are calculated offline. They are then simulated in MATLAB/Simulink model. The special property of neighbourhood crossover such as faster convergence, program reliability and solutions to wide operating range are agreed in the results.

Key words

Multilevel inverter (MLI), Neighbourhood cross over, Selective harmonic Elimination (SHE), Genetic Algorithm (GA)

1. Introduction

Voltage source inverters (VSIs) and pulse width modulation (PWM) techniques are tailor made combinations in providing ac voltage with controllable magnitude, frequency and spectral details (J.S.Lai and F.Z.Peng, 1996). Since the adoption of PWM concept in controlling power converters, PWM technique is being modified/ innovated. The variants are due to the application driven specifications/demands. Today a host of PWM methods are researched and practiced for VSI based applications viz. staircase modulation, sinusoidal PWM, space vector modulations, discontinuous PWM, random PWM, inverted sine carrier PWM etc (Gui-Jia, 2005, S.Ramkumar, 2009, Samadi, 2007, Pinheiro, 2002, Hava, 1998, R.L.Kirlin, 2002, and S.Jeevananthan, 2007). Multilevel inverter (MLI) topology can provide the desired voltage from low/medium levels of dc voltages. The resulting staircase like waveform offers better quality output with reduced device stress (B. P. McGrath, 2002, and L Li, 2000).

Presence of lower order harmonics in the output and traditional high frequency PWM strategies make the purpose of MLI vain. But there are many past attempts logically extended to PWM strategies of three-level VSI to multilevel inverters. Even though these methods slaughter the lower order harmonics, they cause higher device losses (W. Fei, 2010 and J. R. Wells, 2005). Selective harmonic elimination PWM (SHEPWM) technique is the existing solution, which can suppress the selected, multiple harmonics without causing an increase in the switching frequency. The desired task is to only accomplish the required output voltage with the calculated switching times. This type of inverters even presents particular advantages to Naval ship propulsion systems which rely on high power quality, survivable drives (K.A.Corzine, 2004).

SHEPWM is a predetermination method without carrier, where the non-linear transcendental trigonometric equations need to be solved to obtain the switching moments (W. Fei, 2010). The linear approximation methods like Newton-Fourier methods demand a closer initial guess to acquire near convergence (S. Sirisukprasert, 2002, and J. Chiasson, 2003). The suggestion of J.Chiasson and Leon Tolbert is based on resultant theory and symmetric polynomials, which involves solving of higher order polynomials and is quite time consuming (Leon M. Tolbert, 2002, John Chiasson, 2005 and L. M. Tolbert, 1999). Modified Walsh function involves piecewise relationship between the solved switching angles and fundamental frequency. Although it works with linear equations it is quite complicated (Tsorng-Juu Liang, 1997). When the procedures of deterministic methods pose such problem there are stochastic methods which give acceptable solutions (Reza salehi, 2011). Though linear methods when combined with optimization procedures like conjugate gradient method yield good results, knowledge of the initial “guess” values to predict the switching states need practice and expertise (I. Maswood, 2001). Recent evolutionary techniques such as Particle Swarm Optimization (PSO) proposed by Kennedy and Eberhart have certain bench to be followed and moreover it is to be fine tuned for handling discrete design variables (R.N.Ray, 2009). Although ant colony optimization techniques provide solutions to meta-heuristic problems their efficiency can be fully realized when combined with other evolutionary algorithms as these pose the problem in arriving at the exact convergence points (K.Sundareswaran, 2007). A more realistic optimization technique applied to multilevel inverter (MLI) to get the switching moments to reduce the lower order harmonics and reduced total harmonic distortion (THD) can be genetic algorithm (GA). GA combines the benefit of overcoming the burden of initial guess to get the switching moments and still arriving at the optimal solution through the process of initialisation, iterative variation and selection (Said Barkati, 2008). Previous work though acutely bothers about the wide range of modulation index, the procedure adopted for harmonic elimination is proposed only via trial and error process (Reza salehi, 2011). Papers with comparison of N-R method with genetic algorithms have completely ignored about the reduction of THD (P.MaruthuPandi, 2010). Even papers which have done justification to complete Genetic algorithm procedures have not dealt with computation efficiency of the method used or about the reliability of the algorithm (Khaled El. Naggara, 2008).

This paper aims at effective use of the genetic algorithm operators such as selection, crossover and mutation. A crossover operator combines the good features of two parents to produce better offspring. Alteration in the crossing over pattern by employing neighbourhood crossover operators (NHCOs) and segmented selective three point crossover can yield better results (F.Herrera, 2004). The concept has been well tested using a Computational iterative algorithm which focuses on better convergence, non-multiple solutions (Switching Moments), good reduction of specific harmonics and THD ultimately.

2. Genetic Algorithm as an Optimization Tool

The more recent evolutionary computational methods for SHE like particle swarm optimization offers solution based on particles which are in velocity with the other particles in a multidimensional search space to obtain the global best value. The particle velocity is expressed as a linear inertia function. It has to be adjusted accordingly which is fiddly (R.N.Ray, 2009). Ant colony search algorithm proposed for the estimation of the switching angle endures to strike a steadiness between the aims of finding quality solutions and speed of convergence (K.Sundareswaran, 2007). Such inefficient methods can be overcome by intelligent biological mimicking optimization methods like genetic algorithm which are heuristic in nature and guarantee exact switching instant to minimize or reduce harmonics (Reza salehi, 2011).

GA came into existence with some pioneering work from J.H.Holland (K.F. Man, 1996). Evolutionary process allows the variety of species to reproduce by the process of natural selection. The fit individual will have the ability to survive the environment and reproduce. GA is very co-operative in this domain as it reduces the cumbersome procedure of predicting the initial guess values for need optimization or the exuberant procedure of solving the higher order polynomials to find the unknowns (J.Chaisson, 2003, Leon M.Tolbert, 2002 and John Chiasson, 2005). GA is simple and direct solution for problems which require optimization (F.Herrera, 2004).

Genetic Algorithm and its Operators

GA proceeds through success of generation (K.F.Man, 1996). It is well documented for providing solution to search and optimization problems (Said Barkati, 2008). The seeds of genetic engineering are based on natural evolution. The success of GA lies based on the logical application of its operators. Previous works done clearly states that enhancement of GA is based effective utilisation of its vital operators in a more sagacious way (S.H.Ling, 2003). Algorithm revolves around a set of solutions in a high dimensional search space. The search space has number of points which could guarantee feasible solutions. Adding credibility to the algorithm is its stochastic nature. Actually algorithms stochastic in nature suffer from the problem of local minima. The algorithm can work for a wide range of search space and number of possible solutions to provide global maxima or global minima. The recombination of algorithm is always possible to yield best results. The fundamental of GA is an iterative process. This makes the process more rugged. The essential steps of any genetic algorithm revolves the around the operators involved. Fig.1 shows it diagrammatically.

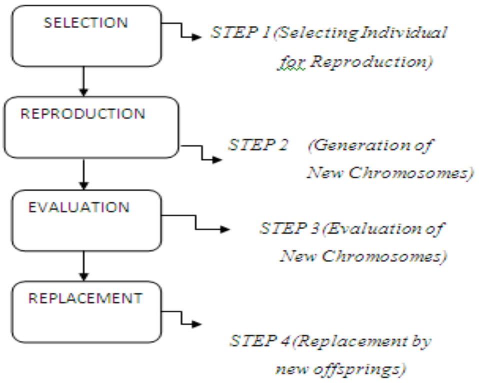


Fig.1. Pictorial Representation of a Genetic Algorithm Process

Genetic Mechanisms

The main challenge in finding the fit population lies in having a perspective about the desired outcome. This is called fitness measurement. The fitness is calculated based on the cost function. This needs to be done for every consecutive generation, so that the rank of the fit chromosomes can be identified before getting the desired outcome. This is the most vital step to be carried out so that the 'fit' population is selected. The fitness calculation may be sometimes complex in nature. The process has (1) the fitness of each individual to be calculated and (2) to be compared with the fit value of the other individuals. The initial population is determined randomly and is directly applied to the mathematical problem to determine fitness. Once the fitness has been calculated the new generation chromosomes are arranged according to their fitness value. The optimization problem aims at minimization of individual harmonics and reduced THD. Selection is made with the fit individuals. As the population size is large the convergence time may be slow, but the probability of arriving at the best solution is good.

Genetic Operators

The genetic operators required to perform the successful genetic algorithm fall under three categories. They are (i) Selection (ii) Cross over (iii) Mutation.

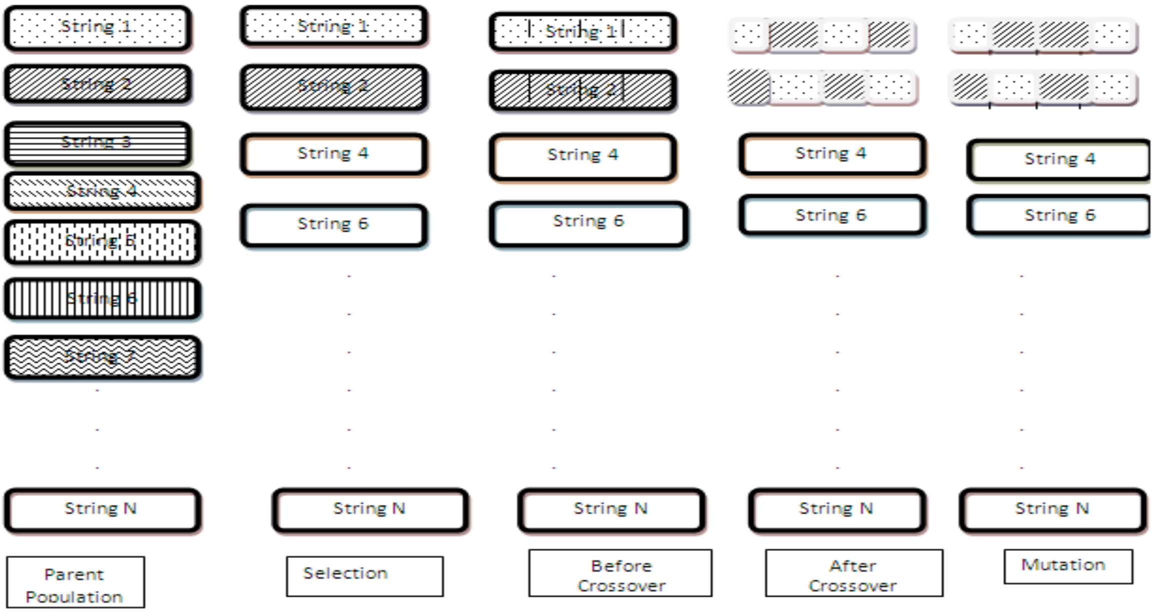


Fig.2. Schema of the Genetic Algorithm Process

Selection refers to the process of selecting a fit individual who is eligible to undergo reproduction to produce a healthy offspring for the next generation. More "fit" means that parent chromosomes may be selected to reproduce again and again. The set of variables is called the chromosomes and each bit of the chromosome is the gene. In this paper chromosomes are selected based on individual chromosome's length. Rank selection process proposed by Baker ranks the randomly selected fit chromosomes in the ascending order based on the fitness function.

The function of crossover operator is to randomly choose a locus and exchange the bit information before or after the locus between two eligible chromosomes. They further produce two new chromosomes. For examples if one sample of the chromosome is 100100111 and the other is 111000011 and cross over takes place after the fourth bit (single point) then the chromosomes turns out to be 100100011 and the other as 111000111. Although discrete crossover operators (DCO'S) are available which two-point and uniform crossover, are the paper is fortified with a Neighbourhood crossover occurring at three points selectively. Multipoint point cross over is possible here as the string of chromosome is quite lengthy. This also aims at parento – efficiency solutions. The genes of the offspring are extracted in such a way that the values from the intervals defined in neighbourhood associated with the genes of the parent probability distribution. Fig.2 pictorially indicates the working of genetic algorithm procedure.

It includes random component of crossover, and they are non-deterministic. Mutation occurs within the bit of the same chromosome. Usually the mutation probability is kept less. It is a controlled process which introduces random changes to the characteristics of an individual member, to form a unique and unexpected solution. The paper works with a mutation probability of 0.01.

Section B - Formulation of SHE Harmonic Equations

Cascaded MLI

The cascaded MLI consists of several single-phase H-bridge inverters with separate dc sources is illustrated in Fig.3, (J.S.Lai, 1996). The structure witnesses the avoidance of extra clamping diodes or voltage clamping capacitors (Gui-Jia Su, 2005).

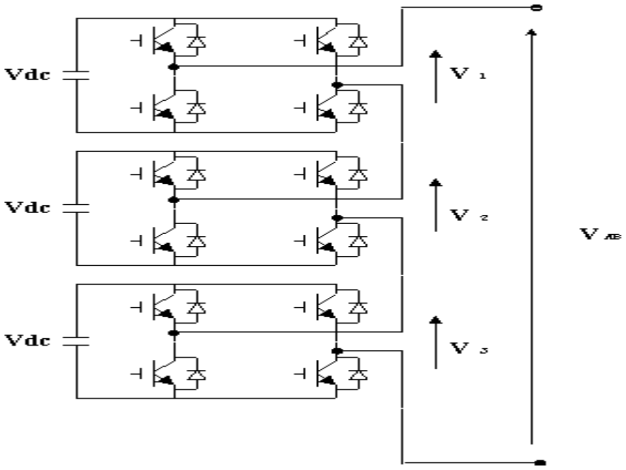


Fig. 3. Structure of a Seven Level Cascaded H-Bridge Inverter

The output voltage waveform for a seven-level cascaded inverter is diagrammed in Fig.5, with its synthesis. For a cascaded MLI, the number of output voltage levels, m=2S+1, where 'S' is the number of dc sources. The output voltage is given by $V_{AB} = V_1+V_2+V_3$. The quarter wave symmetry of the wave makes the calculation procedure easy, as the cosine component and even order sine component do not exist. The typical spectrum of output voltage presented in Fig.4, clearly indicates the presence of the dominant lower order harmonics, which are the prime cause for poor performance of the static power conversion and ac motor drive systems (W.Fei, 2010). The key issue of elimination of lower order harmonics has been addressed in many ways. Prime importance is given to the same as they can reduce quality output, increase current ripple and torque pulsations (W.Fei, 2010 and J.R.Wells, 2005).

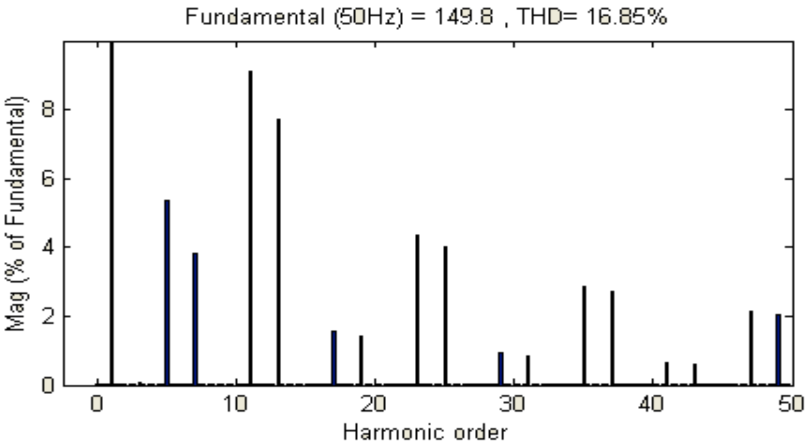


Fig. 4. Harmonic Spectrum without Harmonic Elimination

Mathematical Derivation of the Specific Harmonic Equation:

The real valued Fourier series of the (stepped) output voltage waveform of the multilevel inverter is written as

$$v_0(\omega t) = a_0 + \sum_{n=1}^{\infty} a_n \sin n\omega t + \sum_{n=1}^{\infty} b_n \cos n\omega t$$

(1)

Here a_0 is simply the dc harmonic component. For periodic functions with half-wave symmetry $a_0=0$ and $b_n=0$ (for even n)

$$a_n = \frac{4V_{dc}}{n\pi}[\cos n\alpha_1 + \cos n\alpha_2 + \cos n\alpha_3]$$

(2)

Substituting the values of a_o, a_n and b_n, the instantaneous output voltage equation can be obtained.

$$V_{0(\omega t)} = \frac{4V_{dc}}{\pi} \sum_{n=1,3,5}^{\infty} \frac{1}{n} [(\cos n\alpha_1) + (\cos(n\alpha_2) + (\cos(n\alpha_3)] \sin n\omega t \quad (3)$$

The instantaneous voltage equation will help to make two objectives (i) To eliminate or minimize the lower order (S-1) odd harmonics from the output voltage waveform (ii) to control the output fundamental. It is worthwhile to note that the third objective of minimizing THD can be added if SHE problems are solved with optimization tools like GA (J.R.Wells, 2005 and Leon M.Tolbert, 2002). Here, 'n' is the order of harmonics and it exists only for odd. For a given desired fundamental peak voltage V_1, it is required to determine the switching angles such that $0 \le \alpha_1 < \alpha_2 < \ldots.\ \alpha_s \le \pi/2$. The single-phase seven-level MLI considered has three dc sources and the default eliminations are for third, fifth and seventh harmonics as they tend to dominate the spectrum. The switching angles are chosen in such a way that they eliminate the lower frequency harmonic and also that the THD is minimized. Instants α_1, α_2 and α_3 in Fig.5, represent a sample indication of optimal angles used in the proposed method with the condition $0 \le \alpha_1 < \alpha_2 < \ldots.\ \alpha_s \le \pi/2$. The switching instants, output of individual H-bridges and total output are presented in Table. 1. Moreover, the relation between the fundamental voltage and the maximum obtainable voltage is given by modulation index is given as, $m = V_1 * \pi / (s * 4 * V_{dc})$.

$$\begin{aligned} &\frac{4V_{dc}}{\pi}(\cos\alpha_1 + \cos\alpha_2 + \cos\alpha_3) = V_1 \\ &(\cos 3\alpha_1 + \cos 3\alpha_2 + \cos 3\alpha_3) = 0 \\ &(\cos 5\alpha_1 + \cos 5\alpha_2 + \cos 5\alpha_3) = 0 \\ &(\cos 7\alpha_1 + \cos 7\alpha_2 + \cos 7\alpha_3) = 0 \end{aligned} \quad (4)$$

The total number of harmonics to be eliminated is taken as two. It can be either 3rd and 5th or 5th and 7th or 3rd and 7th. To attain such an objective a specific set of equations is to be formulated. The equations obtained by using the trigonometric identities are quite lengthy and contains many common terms. Down the line many methods have been proposed and successfully implemented for selective harmonic elimination (SHEPWM) to MLI topology, which may produce more than one solution set.

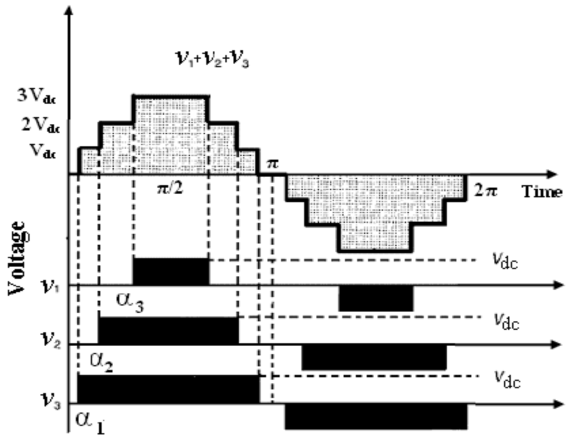


Fig. 5. Output Waveform of a Seven Level Cascaded H-Bridge Inverter

Table. 1. Switching States of Cascaded Seven Level Inverter

Switching angles	V_{a1}	V_{a2}	V_{a3}	V_{an}
$\alpha \leq \alpha_1$	0	0	0	0
$\alpha_1 < \alpha < \alpha_2$	V_{dc}	0	0	V_{dc}
$\alpha_2 < \alpha < \alpha_3$	V_{dc}	V_{dc}	0	$2V_{dc}$
$\alpha_3 < \alpha < \pi/2$	V_{dc}	V_{dc}	V_{dc}	$3V_{dc}$

3. Harmonic Reduction Using Newton Raphson (N-R) Method

The traditional linear approximation methods like Newton-Raphson (N-R) method used for elimination of the selective harmonic does not provide the flexibility in terms of the initial guess. As the level of the inverter increases the solution of the nonlinear transcendental equation posses the problems of approximation in the method to find the roots which form the exact switching angle of the inverter. There is also the issue of finding the global optima (S.Sirisukprasert, 2002, J.Chiasson, 2003, John Chiasson, 2005, L.M.Tolbert, 1999, I.Maswood, 2001, and Leon M.Tolbert, 1999). So such a method is not an efficient and feasible method to calculate the switching angle to eliminate the lower order dominant harmonics.Fig.6, indicates the harmonic spectrum obtained from N-R method, which is figured accurately in Table.2. It forms clear proof from the findings that though N-R method cannot completely help in achieving the aim of reducing the specific harmonics or the THD. It is seen that for a overmodulation range of m=1.75 the THD is 42.40%.

Table. 2. Switching Angle to Obtain 5th and 7th Harmonic Minimization

Modulation Index	α_1	α_2	α_3	V_1(p)	V_1(rms)	V_3	V_5	V_7	V_9	THD (%)
	degrees					%V_1				
1.75	34.83	54.47	68.47	110	77.79	39.75	0.04	0.01	1.23	42.40
1.85	31.22	54.89	65.35	115	81.3	35.85	0.04	0.01	7.03	39.21
2.2	14.18	37.88	62.25	139.8	98.86	9.79	0.00	0.00	3.01	16.56
2.35	11.86	32.10	59.12	145.1	102.6	4.16	0.01	0.01	4.52	13.32
2.4	13.10	22.63	53.75	157.5	111.38	2.76	0.01	0.01	8.65	13.77

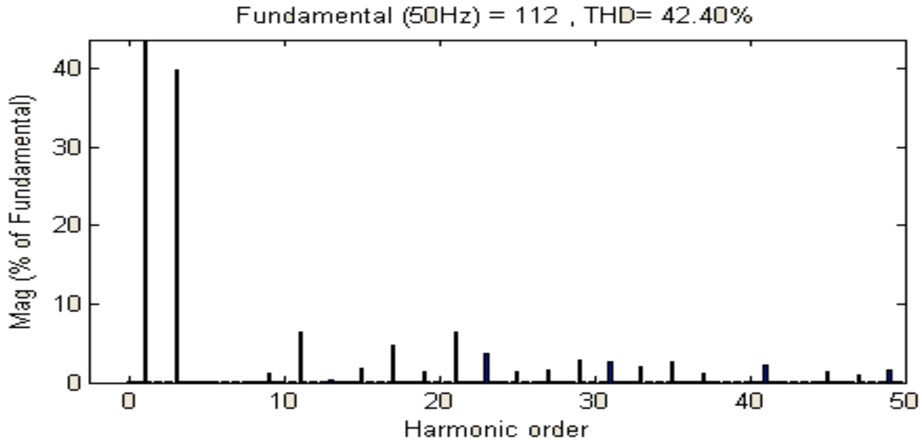


Fig. 6. Harmonic Spectrum for a Seven Level Inverter Using Newton – Raphson Method

4. Proposed Genetic Algorithm Method

Application of GA is case specific and depends upon few factors. There are certain sequential steps to be followed while applying the optimization method. In this paper invariably GA is employed for SHE PWM technique in a 7-level MLI. Before applying the algorithm the basic design procedure is to be adopted (Said Barkati, 2008, P.Maruthu Pandi, 2010, Khaled El.Naggara, 2008, F.Herrera, 2004, and K.F.Man, 1996) the sequential steps are:

(i) Identifying the need for optimization (whether for maximization or Minimization)

(ii) Choose the design variables which will enhance efficiency and speed of the algorithm

(iii) Formulate the constraints (boundary conditions)

(iv) Formulate the objective Function

(v) Applying GA

(vi) Obtain best solution

As Applied to SHEPWM Problem:

(a) Selection of Binary point strings.

(b) The problem needs to be optimized for minimization of harmonics so, the inversion function 'f' is chosen so that cost function f (α_1, α_2, α_3) = $100 * \frac{|V_5| + |V_7|}{|V_1|}$

(c) The design variables for a 7-level inverter are chosen so as to eliminate the specific harmonics. The three switching angle are α_1, α_2, α_3.

(d) The size of the population is set to 20.

(e) The variables are subjected to boundary conditions. Here the boundary conditions of switching angle be between 0 and 90 degrees and that $0 \leq \alpha_1 < \alpha_2 < \alpha_3 \leq 90^0$.

(f) After the chromosome length has been calculated, in this case (42) the fitness is checked for all 20 eligible chromosomes generated randomly. The paper deals with elimination of fifth and seventh harmonics.

The fitness value is calculated as: f (α_1, α_2, α_3) = $100 * \frac{|V_5| + |V_7|}{|V_1|}$

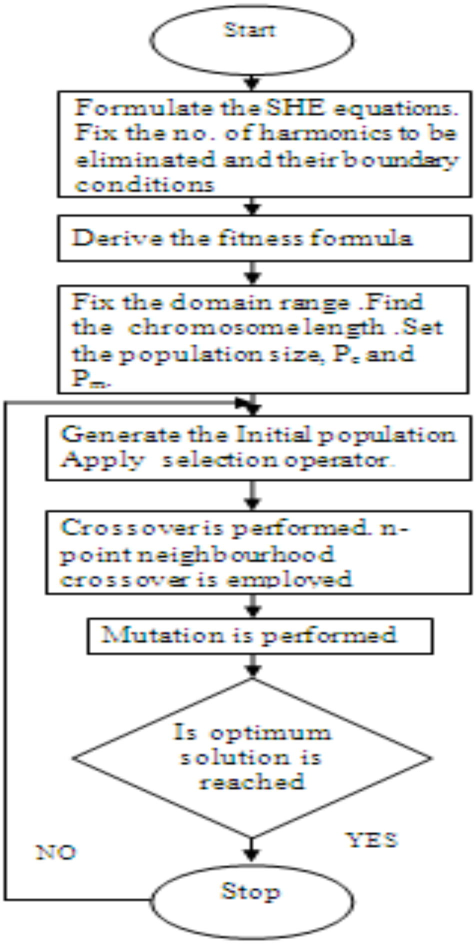


Fig.7. Flow Chart for GA with Neighbourhood Crossover Process.

(g) This forms the fit parent matrix ready to reproduce.

(h) Checking of the fit chromosome is based on the individual value of switching angles and the calculation of the fitness function is based on the cost function.

(i) Once the fitness function is calculated they are ranked and the process of selective three point neighbourhood crossover is carried out. Fig.7 indicates the GA flowchart.

(j) After obtaining the child chromosomes the new population matrix is formed

(k) The ritual of mutation is done with $P_{m=}$ 0.01 (i.e.) for the 840 bits of chromosomes available 8 bits are mutated. After each and every mutation the chromosomes are checked for eligibility. If found eligible the process is stopped otherwise proceeds to next mutation.

(l) Thus if required the process is completed 8 times.

(m) After mutation process the optimal solution is checked.

(n) If "yes" the algorithms comes to a halt. Else the entire steps are repeated again from the process of initial population generation. This is done sequentially until the optimal solution is arrived.

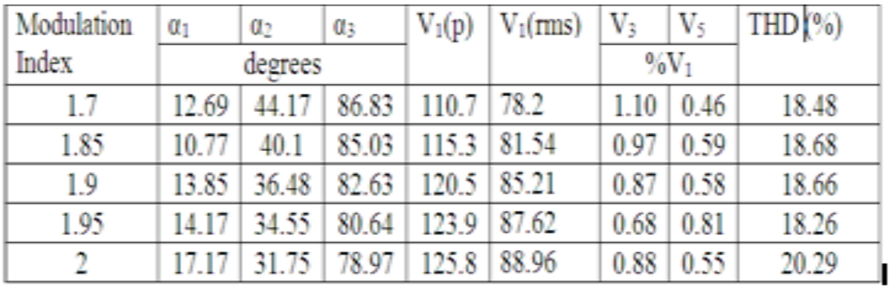
5. Results and Discussion

The GA programme has been executed and the optimum triplen switching angles for minimization of 3rd, 5th and 7th harmonics are calculated offline. The calculated switching angles also propose to reduce the THD. The simulation for 7-level cascaded H-Bridge has been done and the results are tabulated. Table.3 shows the obtained Switching angle for 3rd and 5th harmonic elimination. Table. 4 shows the obtained Switching angle for 3rd and 7th harmonic elimination. Table.5 shows the obtained Switching angle for 5th and 7th harmonic elimination. Fig.8, shows the fundamental voltage and THD (%). Fig.9, and Fig.10, shows the relationship between modulation index and THD (%) and switching angles. Table .6 indicates that the objective of minimization of the specific harmonic voltages has been achieved along with the improvement in fundamental voltage and reduction in THD to 20.12% from 42.40% as in N-R method. Adding value to the obtained results Fig.11 shows the computation efficiency. Fig.12, and Fig.13, are the traditional graphs to indicate the output voltage and the FFT analysis for the specific 3rd and 5th harmonic elimination.

Table. 3. Switching Angle to Obtain 3rd And 5th Harmonic Minimization

Modulation Index	α_1	α_2	α_3	V_1(p)	V_1(rms)	V_3	V_5	THD(%)
	degrees					%V_1		
1.7	12.69	44.17	86.83	110.7	78.2	1.10	0.46	18.48
1.85	10.77	40.1	85.03	115.3	81.54	0.97	0.59	18.68
1.9	13.85	36.48	82.63	120.5	85.21	0.87	0.58	18.66
1.95	14.17	34.55	80.64	123.9	87.62	0.68	0.81	18.26
2	17.17	31.75	78.97	125.8	88.96	0.88	0.55	20.29

Table .4. Switching Angle to Obtain 3rd and 7th Harmonic Minimization



Modulation Index	α_1	α_2	α_3	V_1(p)	V_1(rms)	V_3	V_5	THD (%)
	degrees					%V_1		
1.7	12.69	44.17	86.83	110.7	78.2	1.10	0.46	18.48
1.85	10.77	40.1	85.03	115.3	81.54	0.97	0.59	18.68
1.9	13.85	36.48	82.63	120.5	85.21	0.87	0.58	18.66
1.95	14.17	34.55	80.64	123.9	87.62	0.68	0.81	18.26
2	17.17	31.75	78.97	125.8	88.96	0.88	0.55	20.29

Table.5. Switching Angle to Obtain 5rd and 7th Harmonic Minimization

Modulation Index	α_1	α_2	α_3	V_1(p)	V_1(rms)	V_5	V_7	THD (%)
	degrees					%V_1		
1.75	14.35	44.4	84.57	112.6	79.6	0.13	1.24	20.12
1.85	8.70	37.75	85.88	117.2	82.88	1.12	0.85	18.55
2.2	13.32	36.75	62.47	141.6	100.14	0.91	0.53	15.74
2.35	10.45	31.75	58.75	148.9	105.3	1.05	1.58	12.88
2.4	12.19	27.79	58.36	158.4	112.02	1.04	2.12	13.16

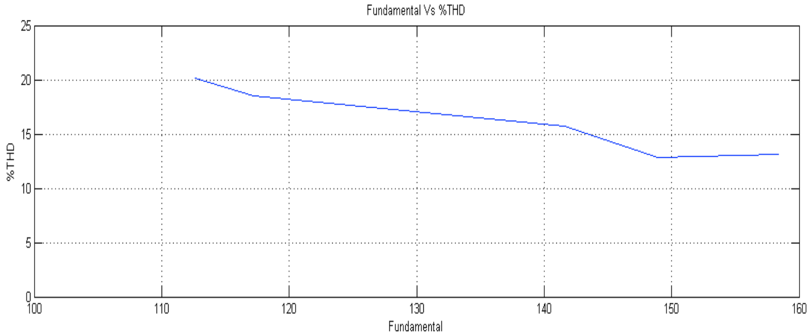


Fig. 8. Fundamental Voltage Vs %THD

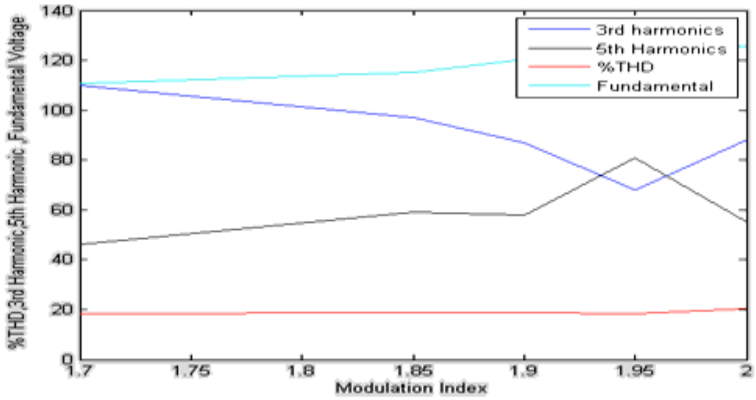


Fig. 9. Modulation Index Vs %THD

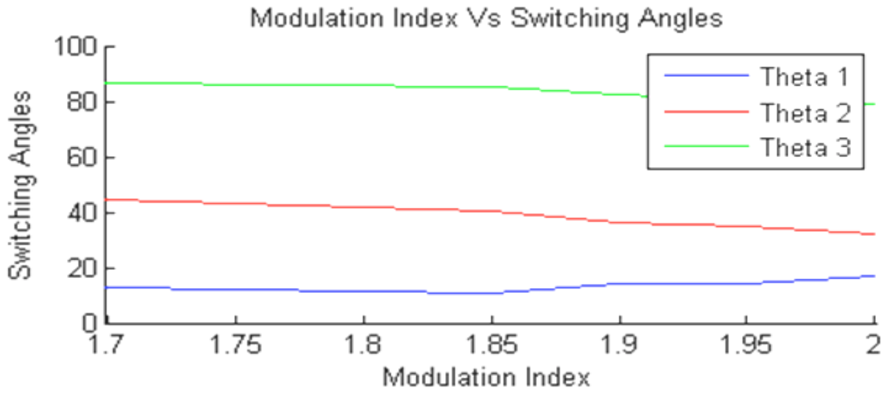


Fig. 10. Modulation Index Vs Switching Angle

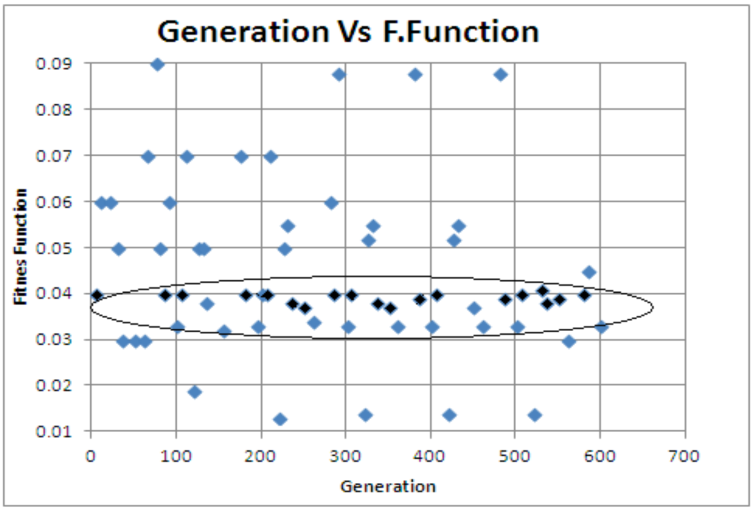


Fig. 11. Generation versus Fitness Function

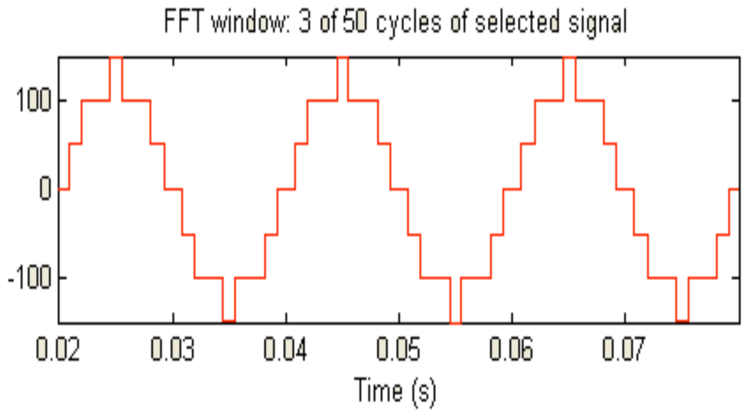


Fig.12. Output Voltage Waveform for 3rd And 5th Harmonic Elimination

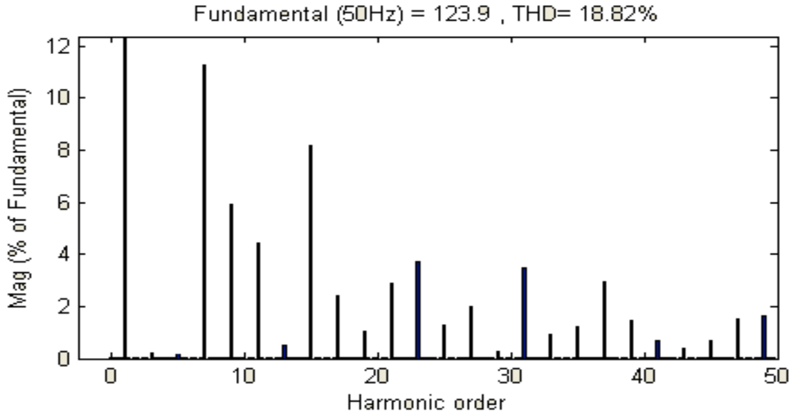


Fig.13. FFT Analysis for 3rd And 5th Harmonic Elimination

Table .6. Comparative Results for N-R Method And GA Methods for 5th And 7th Harmonic Elimination

Method	Fundamental Voltage $V_1(p)$	THD (%)
N-R	110	42.40
Proposed GA	112.6	20.12
N-R	115	39.21
Proposed GA	117.2	18.55
N-R	139.8	16.56
Proposed GA	141.6	15.74
N-R	145.1	13.32
Proposed GA	148.9	12.88
N-R	157.5	14.02
Proposed GA	158.4	13.16

6. Conclusion

Today multilevel inverters have proved their ability and efficiency in many fields from marine applications to HEV applications. Multilevel inverters advantage of producing the stepped waveform has made it very popular option where a good AC power is required.

Although these inverters cater to the needs of supplying required power they suffer from the problem of dominant lower order harmonic voltages and reduced fundamental voltage and increased percentage THD. Research had been carried out in various directions to solve this turmoil and to utilize MLI in a vast arena. Both tradition mathematical methods and optimization methods based on biological mimicking can provide combined benefit of best solutions at quickest time.

One such attempt has been successfully coded and executed in finding the exact switching moment's offline that would solve the problem the dominant harmonic voltages. Justifications to the proposed method have been done by employing genetic algorithm in a suitable way to obtain the required fundamental voltage at reduced THD. The algorithm adopted and developed in such a way it can be successfully impregnated for 'n' level inverter.

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