REDUCTION OF THD IN MULTILEVEL INVERTERS BY G.A. APPROACH

M. Siva Sankar[1] M. Y. Veeresh[2] U.M. Sandeep Kumar[3]

[1,2,3]*Assistant Professor, Department of EEE, Santhiram Engineering College, Nandyal, A.P, India*

***Abstract* — In power electronic converters the harmonics are introduced during the switching operations of semi-conductor devices. These harmonics can be eliminated by switching ON the switches at the interval of harmonics introduced time period. In this paper Genetic Algorithm approach is taken into account to determine the best switching angles to reduce the effect of harmonics introduced. For analysis in this paper a 11-level multilevel inverter is taken as assignment.**

***Keywords* — MLI, Genetic Algorithm, Harmonics**

I. INTRODUCTION

Multilevel inverters are growing in the recent years especially in the fields of energy transmission and distribution resources area that is due to the batteries, fuel cells, solar cell, and wind turbines can be connected through a multilevel inverter to feed a load or the ac grid without voltage balancing problems. Another major advantage of multilevel inverters is that their switching frequency is lower than a traditional inverter, which means that the switching losses are suppressed. The output voltage and current waveforms of multilevel inverters are in stepped form, therefore the harmonic content is less as compared to square wave output. In order to reduce the harmonics further, different strategies are used in such as PWM, SPWM, SVPWM, MC-SPWM, MSVPWM etc., however, PWM techniques increase the control complexity and the switching frequency. Chiasson [3,4] derived mathematical theory to evaluate switching angles but it is difficult and takes more time to determine.

Here genetic algorithm (GA) approach is used to determine the best switching angles, which solves the same problem with a simpler formulation and with any number of levels without extensive derivation of analytical expressions.

II. CASCADED MULTILEVEL INVERTERS

Cascaded multilevel inverter is one of the topology of multilevel inverters. This can be achieved by connecting 'n' number of single phase H bridges in series and several similar configurations. An eleven level cascaded multi level inverter configuration is shown in the figure 1. The output waveform of the eleven level converters is shown in the figure 2. For suppressing the harmonics the switching angles α1, α2, α3, α4 and α5 of the corresponding Hbridges have to be selected.

III. GENETIC ALGORITHM (GA)

Genetic algorithm is a computational model that solves optimization problems by imitating genetic processes and the theory of evolution. It imitates biological evolution by using genetic operators like reproduction, crossover, mutation etc. Optimization in GA means maximization. In cases where minimization is required, the negative or the inverse of the function to be optimized is used.

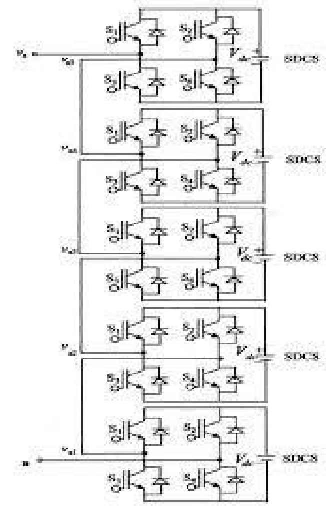


Fig 1: 11 Level H-Bridge Inverter

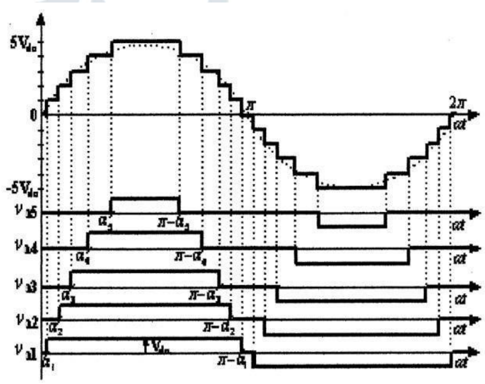


Fig 2: Output wave form of 11 Level H-Bridge Inverter

To minimize a function $f(y_1, y_2, \ldots y_k)$, using GA, first, each y_i is coded as a binary string of length m. In this paper, a binary string is preferred, e.g.

y_1=[011001010101…..0101110]

y_2=[111100101001…..0101001]

…………

y_k=[10000010101…..0101110] The set of { $y_1, y_2, \ldots y_k$ } is called a *chromosome* and y_i are called *genes*. The algorithm works as follows:

A. Initialize population:

Set a population size, *N*, i.e. the number of chromosomes in a population(P). Then initialize the chromosome values randomly. If known, the range of the genes should be considered for initialization. The narrower the range, the faster GA converges.

B. Evaluation each chromosome:

Use a cost function specific to the problem at hand to evaluate the fitness value (*FV*) of each chromosome,

$$Fitness\ value = \frac{1}{(y1,y2,\ldots.yk)}$$

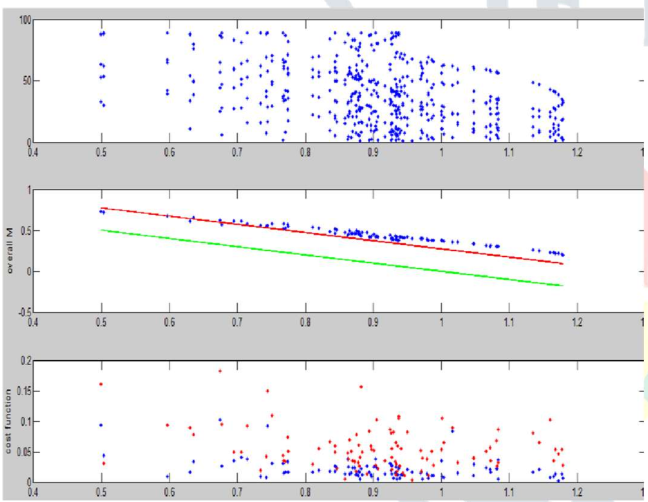
To get the total fitness value add all the *FV*s. Divide each *FV* by the total *FV* and find the weight/probability of selection, p_i, for each chromosome. The integer part of the product, p_iN gives the number of descendents (offspring) from each chromosome. At the end, there should be *N* descendent chromosomes. If the number of descendents calculated is less then *N*, the rest of the descendents are found randomly considering the reproduction probabilities, p_i of each chromosome.

C. Crossover Operation:

A floating number (between 0 and 1) for each chromosome is assigned randomly. If this number is smaller than a preselected *crossover probability*, this chromosome goes into *crossover*. The chromosomes undergoing crossover are paired randomly. In this case assume x_1 and x_2 are paired. The crossing point is randomly selected, assume 3 in this case.

Then, before crossover,
y_1=[011001010101…..0101110]
y_2=[111100101001…..0101001] and
after crossover, y_1=[011001010101…..0101001]
y_2=[111100101001…..0101110]

D. Mutation Operation:



A floating number (between 0 and 1) for each bit is assigned randomly. If this number is smaller than a pre-selected *mutation probability*, this bit mutates. Assume that the 2nd and 4th bits of y_1 and 2nd, 3rd and 5th bits of y_2 need to be mutated.

Then, before mutation and after crossover,
y_1=[001101010101…..0101001]
y_2=[100110101001…..0101110] Finally, the new population is ready for another cycle of genetic algorithm. The algorithm runs a certain number of times as required by the user. At the end, the chromosome with the maximum *FV* is the answer.

IV. Formulating the problem

algorithm procedure is same for any application. There are only a few parameters to be set for GA to work. The steps for formulating a problem and applying GA are as follows:

1- Select binary or floating point strings.

2- Find the number of variables specific to the problem; this number will be the number of genes in a chromosome. In this application, the number of variables is the number of controllable switching angles, which is the number of Hbridges in a cascaded multilevel inverter. A 11-level inverter requires five H-bridges; thus, each chromosome for this application will have three switching angles, i.e. {$\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$}.

3- Set a population size and initialize the population. In this application a population size of 20 is selected. Higher population might increase the rate of convergence but also increases the execution time. The selection of optimum sized population requires some experience in GA. The population in this paper has 20 chromosomes, each containing three switching angles. The population is initialized with random angles between 0 and 90 degrees taking into consideration the quarter-wave symmetry of the output voltage waveform.

4- The most important item for the GA to evaluate the fitness of each chromosome is the cost function. The objective of this study is to minimize some harmonics; therefore the cost function has to be related to these harmonics. As an example assume that the 5th and 7th harmonics at the output of a 11level inverter have to be minimized. Then, the cost function, *f* can be selected as the sum of these two harmonics normalized to the fundamental, normalized to the Fundamental,

$$f(\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5) = \frac{|V_5| + |V_7|}{|V_1|}$$

where α_i are the switching angles and V_n are the *n*th order voltage harmonics.

harmonics is negligible compared to the fundamental. As seen Fig. 5. Normalized (with respect to the fundamental) FFT in Fig. 3, GA resulted in cost functions even smaller than 0.4.

VI. Conclusions

The results obtained in the simulation are similar as in the literature and shows that the GA approach for the reduction of Total Harmonic Distortion of multilevel inverters works properly. By observing the results the total THD for a eleven level multilevel inverter is 5.85. It is considerable value. As in this approach, GA can be applied to any problem where optimization is required. This method will give best performance in HVDC transmission system to compensate power quality issues

For each chromosome, a multilevel output voltage waveform Fig-2 is created using the switching angles in the chromosome and the required harmonic magnitudes are calculated using FFT techniques.

The fitness value for each chromosome is evaluated as,

$$FV(\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5) = \frac{|V_5| + |V_7|}{|V_1|}$$

The switching angle set producing the max *FV* is the best solution of the first iteration.

5- GA is usually set to run for a certain number of iterations (200 in this case) to find an answer. After the first iteration, *FV*'s are used to determine new offspring as explained in Section II. These go through crossover and mutation operations and a new population is created which goes through the same cycle starting from *FV* evaluation. Sometimes, GA can converge to a solution much before 200 iterations are completed. To save time, in this paper, the iterations have been stopped when the cost function goes below 1 in which case the sum of the 5th and the 7th Fig. 3. Solutions for α1,α 2, α 3, α 4, α 5and the cost function

V. Results

For the 11-level inverter, switching angles, which minimize the 5th and 7th harmonics, are shown in Fig. 3, the solution only includes angles that result in zero 5th and 7th order harmonics.

Fig. 4 shows the experimental 11-level voltage waveform. Fig. 5, on the other hand, shows the first 21 harmonics of the waveform in Fig. 4. As seen in this figure, the 5th and the 7th harmonics of the voltage waveform are negligible.

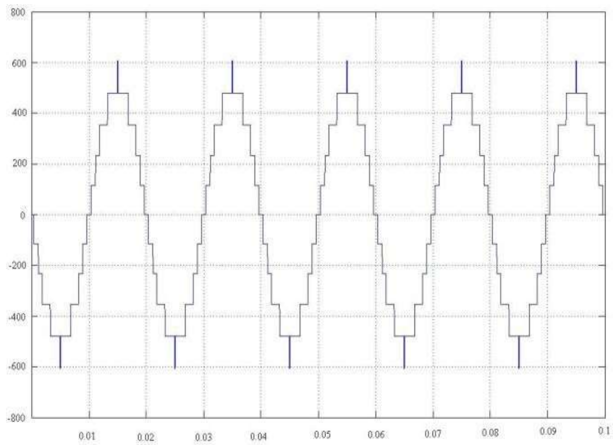
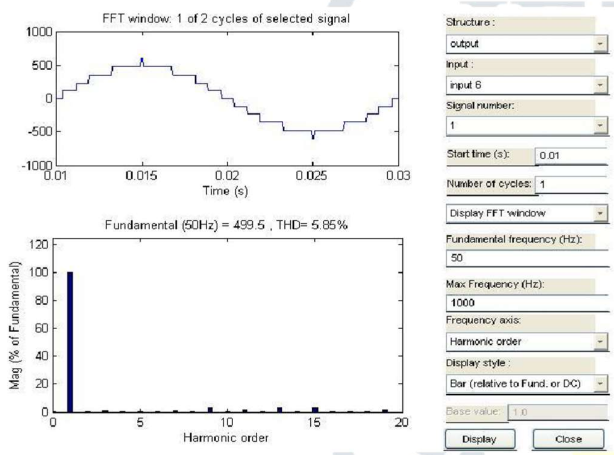


Fig. 4. Experimental output voltage waveform



REFERENCES

1. *L.M Tolbert, F. Z. Peng, T.G. Habetler, "Multilevel PWM methods at low modulation indices," IEEE Transactions on Power Electronics, 15(4), July 2000, pp. 719 – 725.*
2. *L.M. Tolbert, T.G. Habetler, "Novel multilevel inverter carrier-based PWM method," IEEE Transactions on Industry Applications*, 35(5), Sept.-Oct. 1999, pp. 1098 – 1107.
3. J. Chiasson, L. M. Tolbert, K. McKenzie, Z. Du, "Eliminating harmonics in a multilevel converter using resultant theory," *Conference Proceedings of IEEE Power Electronics Specialists Conference*, 2002, vol. 2, 503–508.
4. J. N. Chiasson, L. M. Tolbert, K. J. McKenzie, Z. Du, "A Complete Solution to the Harmonic Elimination Problem," *IEEE Transactions on Power Electronics*, 19(2), March 2004, pp. 491 – 499.
5. J. N. Chiasson, L. M. Tolbert, K. J. McKenzie, Z. Du, "A Unified Approach to Solving the Harmonic Elimination Equations in Multilevel Converters," *IEEE Transactions on Power Electronics*, 19(2), March 2004, pp. 478 – 490.
6. B. Ozpineci, J. O. P. Pinto, L. M. Tolbert, "Pulse-width optimization in a pulse density modulated high frequency ACAC converter using genetic algorithms," *Conference Proceedings of IEEE International Conference on Systems, Man, and Cybernetics*, 2001, pp. 1924 – 1929.
7. A. I. Maswood, S. Wei, M. A. Rahman, "A Flexible Way to Generate PWM-SHE Switching Patterns Using Genetic Algorithms," *Conference Proceedings of IEEE Applied Power Electronics Conference and Exposition (APEC)*, 2001, pp. 1130– 1134.
8. M. J. Schutten, D. A. Torrey, "Genetic Algorithms for Control of Power Converters," *Conference Proceedings of IEEE Power Electronics Specialists Conference*, 1995, pp. 1321– 1326.
9. C. Houck, J. Joines, M. Kay, *The Genetic Algorithm Optimization Toolbox (GAOT) for Matlab 5*, http://www.ie.ncsu.edu/mirage/GAToolBox/gaot.