Genetic Algorithm Based Elimination of Harmonics in Three Phase Inverter

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Abstract- *In recent years multilevel inverter has taken a vast place in industrial application and is also used in various other applications such as static power converter for high power applications, FACTS devices, HVDC and also as electric drives for all ac motors when DC supply is used. Another major advantage is that their switching frequency is lower than a traditional inverter, for this it has less switching losses and higher voltage capability. To drive this inverter Pulse Width Modulation (PWM) is used. Space Vector Modulation (SVM) is the popular PWM method and possibly the best among all the PWM techniques as it generates higher voltages with low total harmonic distortion and works very well with field oriented (vector control) schemes for motor control. High quality output spectra can be obtained by eliminating several lower order harmonics by adopting a suitable harmonic elimination technique. Genetic Algorithm (GA) optimization technique is used to achieve proper switching angles to reduce the THD and elimination of a selective lower order harmonics with fundamental components at the desired values.*

Keywords- Three phase inverter, harmonic elimination, Space vector PWM, Genetic algorithm.

I. INTRODUCTION

A power inverter is an electronic device or circuitry that converts direct current (DC) into alternating current (AC). The input voltage, output voltage, frequency and overall power handling depends on the design of the specific device or circuitry. The inverter does not produce any power, the power is provided by the DC source.

From the late 19th century through the middle of the 20th century the DC to AC power conversion was accomplished using rotary converters or motor-generator sets (M-G sets). In the early 20th century vacuum tubes and gas filled tubes began to be used as switches in inverter circuits. The most widely used type was the thyratron.

A typical power inverter device or circuit requires a relatively stable DC power source capable of supplying enough current for the intended power demands of the system. The input voltage depends on the design and purpose of the inverter. The inverter produces an output waveform of square wave, modified sine wave, pulsed sine wave, pulse width modulated wave (PWM) or sine wave depending on the circuit design.

An inverter can be classified into single phase inverter and three phase inverter. A single phase inverter converts the direct current (DC) input into single phase alternating current (AC) and is further classified as half bridge inverter and full bridge inverter. A three phase inverter converts a DC input into three phase AC output.

The structure of a typical 3-phase power inverter is shown in Fig.1, where VA, VB, VC are the voltages applied to the star-connected motor windings, and where E is the continuous inverter input voltage.

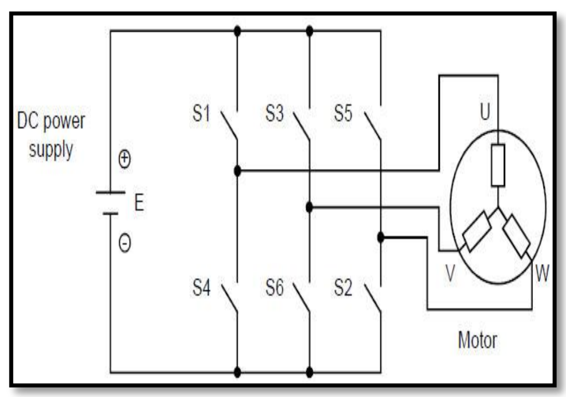

Fig .1 Basic scheme of three phase inverter and an AC motor

II. PULSE WIDTH MODULATION

(Pulse Width Modulation) PWM is a technique developed by a combination of electronic components formed as a circuit to generate a variable analog signal. It uses a simple concept where they open and close the switch at different intervals. PWM controls within the inverter to operate when a fixed dc input voltage is given to the inverter while a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. It is the most efficient method to adjust the output voltage from an inverter. Nowadays, PWM techniques are widely used to control the motor, current, voltage, and Uninterruptable Power Supply (UPS).

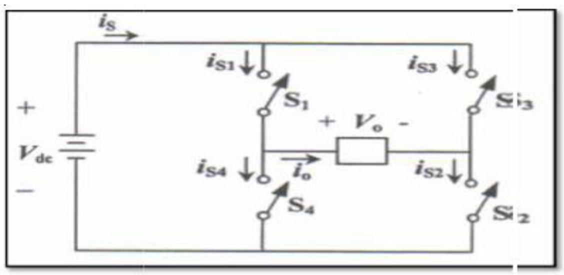

Fig. 2 PWM Inverter

Based on the Fig. 2, In the positive cycle of the output, switch S1 and S2 will be ON while switch S3 and S4 are OFF. In the negative cycle of output switch S3 and S4 now are ON and switch S1 and S2 will OFF. It will produce a full wave output.

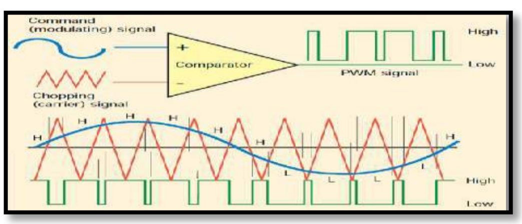

Fig. 3 PWM Signal Produce and influence command signal to the wider of pulse

The output of PWM signal produced from the comparison between two different signal which are modulating signal (sinusoidal wave) and carrier signal (saw tooth wave). This comparison process is done by the comparator. The frequency size of PWM output signal is varying based on the size of intersection between carriers and modulating signal as Fig. 3.

In PWM technique to produce the compensation current, the error signal from reference and a sensed voltage is compared and considered as the reference waveform. It can be compared with sensed carrier waveform to produce the switching pulses. The pulses are produced according to the inputs given to the controller. The various PWM techniques are:

1. Sine PWM current controlled method
2. Hysteresis current controlled method
3. Space vector pulse width modulation
4. Predictive PWM technique

III. SPACE VECTOR PULSE WIDTH MODULATION

The main objectives or advantages of space vector pulse width modulation generated gate pulse are the following.

- Wide linear modulation range
- Less switching loss
- Less total harmonic distortion in the spectrum of switching waveform
- Easy implementation and less computational calculations

With the emerging technology in microcontroller the SVPWM has been playing a pivotal and viable role in power conversion. It uses a space vector concept to calculate the duty cycle of the switch which is imperative implementation of digital control theory of PWM modulators.

SVPWM is the best computational PWM technique for a three phase voltage source inverter because of it provides less THD & better PF.

IV. GENETIC ALGORITHM

The use of genetic algorithms (GA) for problem solving is optimal solution. The pioneering work of J. H. Holland in the 1970’s proved to be a significant contribution for scientific and engineering applications. Since then, the output of research work in this field has grown exponentially although the contributions have been, and are largely initiated, from academic institutions world-wide. It is only very recently that we have been able to acquire some material that comes from industry.

Furthermore, the GA is not considered a mathematically guided algorithm. The optima obtained are evolved from generation to generation without stringent mathematical formulation such as the traditional gradient-type of optimizing procedure. In fact, GA is much different in that context. It is merely a stochastic, discrete event and a nonlinear process. The obtained optima are an end product containing the best elements of previous generations where the attributes of a stronger individual tend to be carried forward into the following generation. The rule of the game is “survival of the fittest will win.” The following fig. 4 depicts the same.

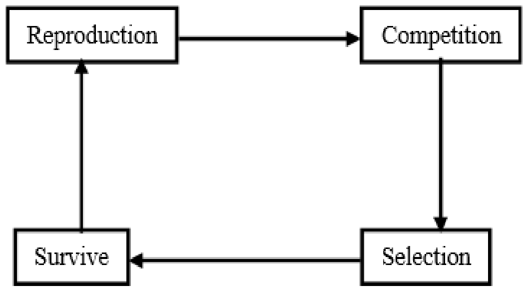

Fig.4 Block diagram of operation of Genetic Algorithm

The genetic algorithm differs from a classical, derivative-based, optimization algorithm in two main ways, as summarized in the following table 1.

Table 1 Comparison between classical and genetic algorithm

Classical Algorithm	**Genetic Algorithm**
Generates a single point at each iteration. The sequence of points approaches an optimal solution.	Generates a population of points at each iteration. The best point in the population approaches an optimal solution.
Selects the next point in the sequence by a deterministic computation.	Selects the next population by computation which uses random number generators.

V. Computation flow of Genetic Algorithm

Genetic algorithm is a computational model that solves optimization problems by imitating genetic processes and the theory of evolution by using genetic operators like reproduction, crossover, mutation etc. Amounts of applications have benefited from the utilization of genetic algorithm. Genetic algorithm is still a novel technique for PWM-SHE technique.

This algorithm is usually used to accomplish a near global optimum solution. Each iteration of the GA is a new set of strings, which are called chromosomes, with improved fitness, is produced using genetic operators.

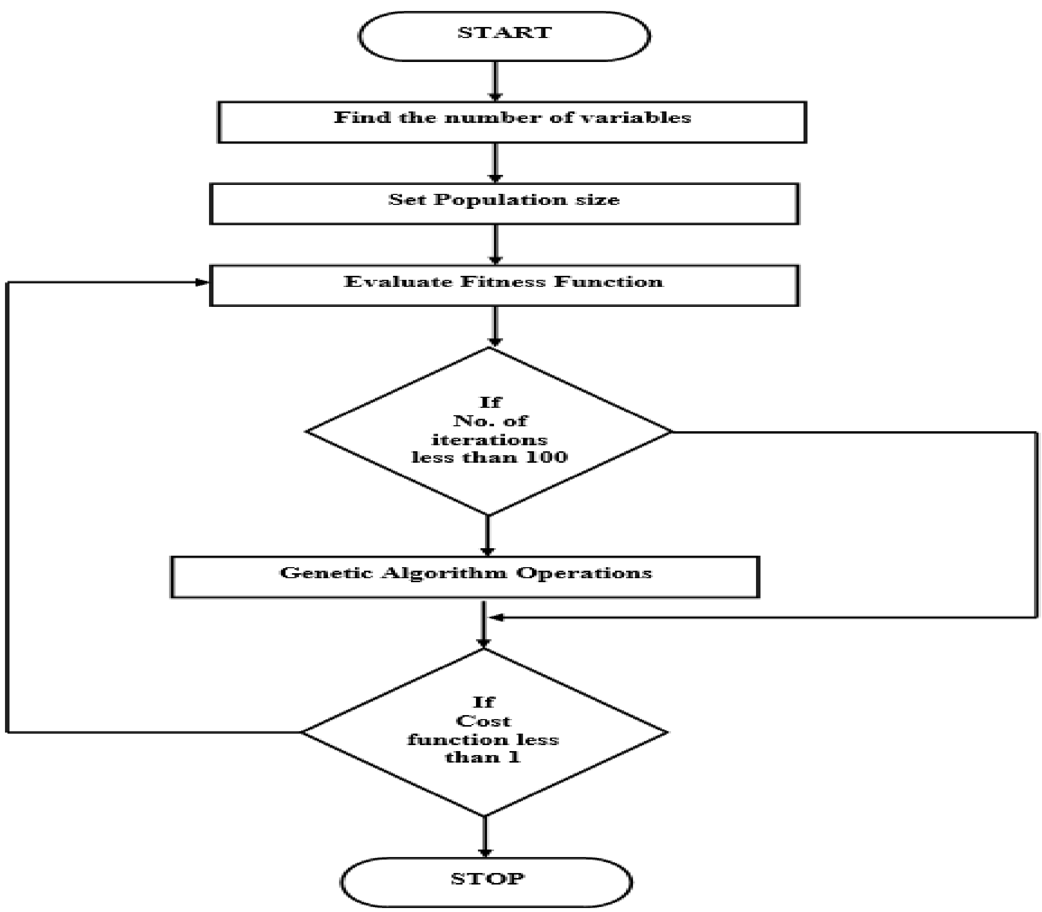

Fig.5 Flowchart of computation process of Genetic Algorithm

Chromosome representation

In GA, each chromosome is used as a feasible solution for the problem, where each chromosome is developed based on single dimensional arrays with a length of S, where S is the number of angles.

Initialize population

Set a population size, N, i.e. the number of chromosomes in a population. Then initialize the chromosome values randomly. If known, the range of the genes should be considered for initialization. Population size depends only on the nature of the problem and it must achieve a balance between the time complexity and the search space measure. The narrower the range, the faster GA converges. In this paper, population size is considered as 100.

Reproduction

The reproduction operator determines how the parents are chosen to create the offspring. This operator is a process in which chromosomes are copied according to their objective function values i.e. the degree of conformity of each object is calculated and an individual is reformed under a flat rule depending on the degree of conformity.

Crossover

Crossover is the most significant operation in GA. It creates a group of children from the parents by exchanging genes among them. The new offspring contain mixed genes from both parents. By doing this, the crossover operator not only provides new points for further testing within the chromosomes, which are already represented in the population, but also introduces representation of new chromosomes into the population to allow further evaluation on parameter optimization.

Mutation

Mutation is another vital operation. It works after crossover operation. In this operation, there is a probability that each gene may become mutated when the genes are being copied from the parents to the offspring. This process is repeated, until the preferred optimum of the objective function is reached.

Evaluation of fitness function

The most vital item for the GA to evaluate the fitness of each chromosome is the cost function. The purpose of this study is to minimize specified harmonics; therefore the fitness function has to be associated to THD. In this work the fifth, seventh, eleventh, and thirteenth harmonics at the output of an eleven-level inverter are to be minimized.

Harmonic Analysis and Elimination Using Genetic Algorithm

The genetic Algorithm is classified into three types of operation. There are encoding, cross over, selection and mutation. The evaluation usually starts from a population of randomly generated individuals and happen in generation. In each generation, the fitness of every individuals in the generation is evaluated, multiple individuals are selected from the current generation based on their fitness value, and modified (recombined and possibly mutated) to form a new generation. The new generation is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced or a satisfactory fitness level has been reached for the generation. If the algorithm has terminated due to a maximum number of generations, a satisfactory solution may or may not have been reached.

VI. HARMONIC ANALYSIS OF OUTPUT VOLTAGE BY CONVENTIONAL TECHNIQUE

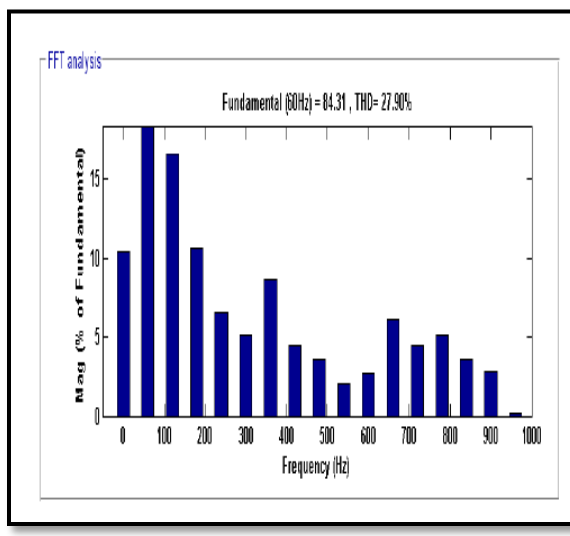

Fig. 6 Harmonic analysis of conventional method of generation of PWM

The above fig. 6 represents harmonic analysis performed on output voltage of the inverter, as its seen that the total harmonic distortion is found to be 27.90% its too huge to eliminate the same genetic algorithm is applied to produce a PWM pulse so as to minimize or mitigate harmonics in output voltage.

VII. HARMONIC ANALYSIS OF OUTPUT VOLTAGE WHEN PWM SIGNAL IS DEVELOPED USING GENETIC ALGORITHM TECHNIQUE

The following analysis depicts that, 5th, 7th, 11th and 13th harmonics magnitudes are negligible relatively to the fundamental component. The obtained switching angles for various values of modulation index using GA for inverter is shown in Table 2.

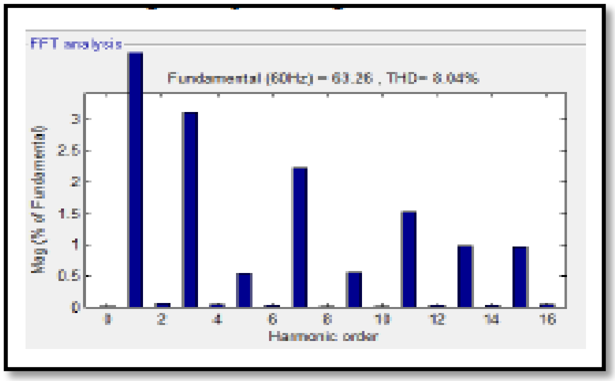

Fig. 7 Harmonic analysis of genetic algorithm method of generation of PWM

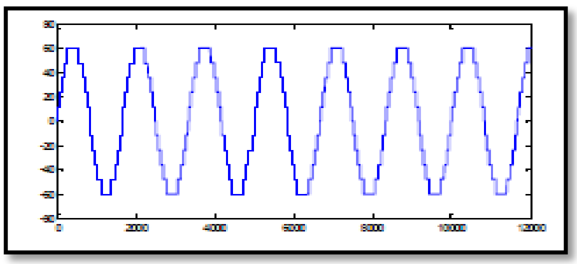

Fig. 8 Output voltage signal of the converter

Table 2 Switching angle generated by GA

Modulation Index (M)	Switching Angles				
	Θ1 (rad)	Θ2 (rad)	Θ3 (rad)	Θ4 (rad)	Θ5 (rad)
0.1	0.215	0.373	0.621	0.973	1.083
0.2	0.212	0.356	0.602	0.952	1.086
0.3	0.225	0.358	0.61	0.978	1.074
0.4	0.19	0.524	0.723	1.108	1.503
0.5	0.348	0.633	0.907	1.013	1.218
0.6	0.475	0.777	0.896	1.099	1.27
0.7	0.041	0.236	0.592	0.724	1.467
0.8	0.098	0.299	0.514	0.760	1.087
0.9	0.154	0.419	0.721	1.063	1.543

VIII. CONCLUSION

Genetic algorithm optimization technique is applied to find the switching angles of the inverter for the reduction of harmonics. The use of the GA is proposed to solve the selective harmonics elimination problem in PWM inverters. The proposed concept successfully demonstrates the validity of genetic algorithm for the estimation of optimum switching angles of staircase waveform generated by inverters. GA can be applied to any problem where optimization is required; therefore, it can be used in many applications in power electronics.

REFERENCES

[1] J. R. Wells, X. Geng, P. L. Chapman, P. T. Krein, and B. M. Nee, “Modulation-based harmonic elimination,” IEEE Trans. Power Electron., vol. 22, no. 1, pp. 336–340, Jan. 2007.

[2] J. Wang, Y. Huang, and F. Z. Peng, “A practical harmonics elimination method for multilevel inverters,” in Conf. Rec. IEEE IAS Annu. Meeting, Oct. 2005, vol. 3, pp. 1665–1670.

[3] M.S.A. Dahidah and V.G. Agelidis, “Selective harmonic elimination PWM control for cascaded multilevel voltage source converters: A generalized formula,” IEEE Trans. on Power Electronics, 2008, vol.23, no. 4, pp.1620 – 1630.

[4] Mohamed azab, “Particle Swarm Optimization-Based Solutions For Selective Harmonic Elimination In Single-Phase PWM Inverters”, International Journal of Power electronics, Vol. 2, No. 2, 2010, Inderscience Enterprises Ltd- UK.

[5] Reza Salehi, Naeem Farokhnia, Mehrdad Abedi, and Seyed Hamid Fathi “Elimination of Low Order Harmonics in Multilevel Inverters Using Genetic Algorithm” Journal of Power Electronics, Vol. 11, No. 2, March 2011.