

# Harmonic Reduction in Single Phase Inverter Using Genetic Algorithm

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**Abstract:** *The elimination of harmonics in a inverter by considering the dc sources by using GA are compared. Solving a nonlinear transcendental equation set describing the harmonic-elimination problem with dc sources reaches the limitation of contemporary computer algebra software tools using the resultant method. The proposed approach in this paper can be applied to solve the problem in a simpler manner, even when the number of switching angles is increased and the determination of these angles using the resultant theory approach is not possible. Theoretical results are verified by simulations results for a 9-level H-bridge inverter. Results show that the proposed method does effectively eliminate a great number of specific harmonics, voltage is and the output resulted in low total harmonic distortion.*

**Keywords:** Genetic Algorithm (GA), selective harmonic elimination, dc sources.

## I. INTRODUCTION

A inverter is a power electronic system that synthesis a desired voltage output from several levels of dc voltage as input. The inverter consists of a series of H-bridge inverter units. Multilevel voltage source inverters are a suitable configuration to reach high power ratings. The different topologies for the inverter have received special attention due to its modularity and simplicity of control. There are different power circuit topologies for inverters. The most familiar power circuit topology for inverters is based on the cascade connection of an 's' number of single-phase full-bridge inverters to generate a  $(2s + 1)$  number of levels. However, from the practical point of view, it is somehow difficult to keep equal the magnitude of separated dc sources of different levels. This can be caused by the different charging and discharging time intervals of dc-side voltage sources. To control the output voltage and to eliminate the undesired harmonics in multilevel converters with equal dc voltages, various modulation methods such as sinusoidal pulse width modulation and space-vector PWM techniques are suggested. However, PWM techniques are not able to eliminate lower order harmonics completely. Another approach is to choose the switching angles so that specific higher order harmonics such as the 5th, 7th, 11th, and 13th are suppressed in the output voltage of the inverter. This method is known as selective harmonic elimination or programmed PWM techniques in technical literature. A fundamental issue associated with such method is to obtain the arithmetic solution of non-linear transcendental equations which contain trigonometric terms and naturally present multiple solutions. This set of nonlinear equations can be solved by related techniques such as the Newton–Raphson method. However, such techniques need a good initial guess which should be very close to the exact solution patterns. Furthermore, this method finds only one set of solutions depending on the initial guess. Therefore, the Newton–Raphson method is not feasible to solve the SHE problem for a large number of switching angles if good initial guesses are not available.

### Single Phase Inverter

A single-phase structure of an m-level cascaded inverter is illustrated in Figure 1. Each separate dc source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs, +Vdc, 0, and –Vdc by connecting the dc source to the ac output by different combinations of the four switches,

S1, S2, S3, and S4. To obtain +V<sub>dc</sub>, switches S1 and S4 are turned on, whereas -V<sub>dc</sub> can be obtained by turning on switches S2 and S3. By turning on S1 and S2 or S3 and S4, the output voltage is 0. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The number of output phase voltage levels  $m$  in a cascade inverter is defined by  $m = 2s+1$ , where  $s$  is the number of separate dc sources. An example phase voltage waveform for a 9-level cascaded H-bridge inverter with 5 SDCSs and 5 full bridges is shown in Figure 2. The phase voltage  $v_{an} = v_{a1} + v_{a2} + v_{a3} + v_{a4} + v_{a5}$ .

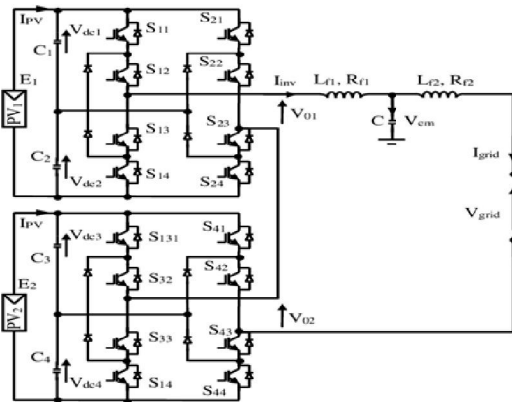


Fig.1 Multilevel cascaded H-bridges.

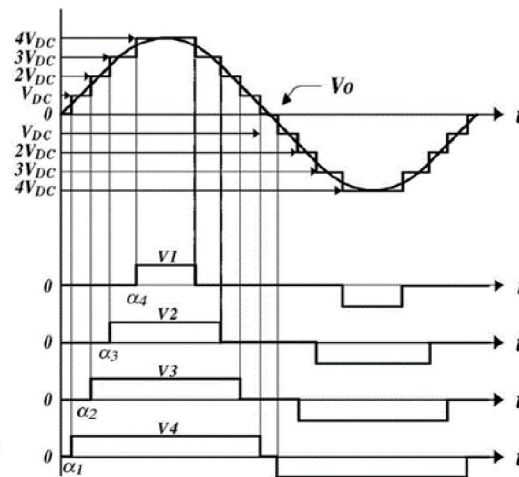


Fig.2 Output phase voltage waveform

For a stepped waveform such as the one depicted in Fig. 2 with  $s$  steps, the Fourier Transform for this waveform follows

$$H(n) = \frac{4}{\pi n} [\cos(n\theta_1) + \cos(n\theta_2) + \dots + \cos(n\theta_s)]$$

Where  $n = 1, 3, 5, 7, \dots$

### Comparisons of DCI, CCI, CMI

| Diode Clamped Inverter (DCI)                                                                        | Capacitor Clamped Inverter (CCI)                                                                     | Cascade Multilevel Inverter (CMI)                                                  |
|-----------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| Switching is easier. At fundamental frequency Efficiency is high.                                   | Control is complicated to track the voltage Levels for Capacitors                                    | Communication between full bridge is requires reference and carrier waveform.      |
| All the phases share a common dc bus, Which minimizes the Capacitance requirements of the converter | Capacitors have large Fraction of dc bus Voltage across them so rating of these is Design challenge. | Needs separate dc Sources for real power Conversions and applications are limited. |
| It is efficient for Motor drives, traction motors and easy to design it.                            | Switching utilization and efficiency is poor for real power transmission                             | DC source is well suited for various Renewable energy Sources.                     |

### Harmonic Elimination Control Technique Using Algorithms using GA

Harmonic Elimination pulse width modulation (HEPWM) method has been widely applied to remove harmonics due to its superior frequency spectra. It requires the solution of a set of transcendental nonlinear equations. Soft computing

(SC) methods are extensively employed to solve this problem because of their effective global search ability. Genetic Algorithm (GA) and Differential evolution

### Harmonic-Elimination Problem with Un-Equal Dc Sources

By applying Fourier series analysis, the staircase output voltage as shown in Figure 1. of multilevel inverters with unequal sources can be described as follows:

$V(\omega t) =$

$$\sum_{n=1,3,5,\dots}^{\infty} \frac{4V_{dc}}{n\pi} X(k_1 \cos(n\theta_1) + k_2 \cos(n\theta_2) + k_3 \cos(n\theta_3) + \dots + k_s \cos(n\theta_s)) \sin(n\omega t)$$

Where,

$K_i V_{dc}$  is the  $i^{\text{th}}$  dc voltage,

$V_{dc}$  is the nominal dc voltage,

$\theta_1 - \theta_m$  is the switching angles

$\theta_1 - \theta_m$  must satisfy the following condition:

The number of harmonics which can be eliminated from the output voltage of the inverter is  $s-1$ . For example, to eliminate the fifth-order harmonic for a five-level inverter, equation set (3.1) must be satisfied. Note that the elimination of triplet harmonics for the three-phase power system applications is not necessary, because these harmonics are automatically eliminated from the line-line voltage

$$\begin{cases} k_1 \cos(\theta_1) + k_2 \cos(\theta_2) + \dots + k_s \cos(\theta_s) = 0 \\ k_1 \cos(5\theta_1) + k_2 \cos(5\theta_2) + \dots + k_s \cos(5\theta_s) = 0 \end{cases} \quad (1)$$

In Eqn. (1), modulation index  $M$  is defined as  $M = V_1/sV_{dc}$  and  $V_1$  is the fundamental of the required voltage.

The fitness function is given by

$$f(\theta_1, \theta_2, \dots, \theta_s) = 100 \times \left[ \left| M - \frac{|V_1|}{sV_{dc}} \right| + \frac{|V_5| + |V_7| + \dots + |V_s|}{sV_{dc}} \right] \quad (2)$$

$$0 \leq \theta_1 \leq \theta_2 \leq \dots \leq \theta_s \leq \pi/2$$

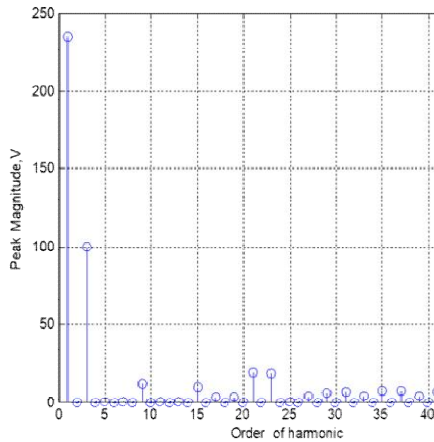
### Genetic Algorithm

Genetic algorithms are inspired by Darwin's theory about evolution. Solution to a problem solved by genetic algorithms is evolved. Algorithm is started with a set of solutions (represented by chromosomes) called population. Solutions from one population are taken and used to form a new population. This is motivated by a hope, that the new population will be better than the old one. Solutions which are selected to form new solutions (offspring) are selected according to their fitness - the more suitable they are the more chances they have to reproduce. This is repeated until some condition (for example number of populations or improvement of the best solution) is satisfied.

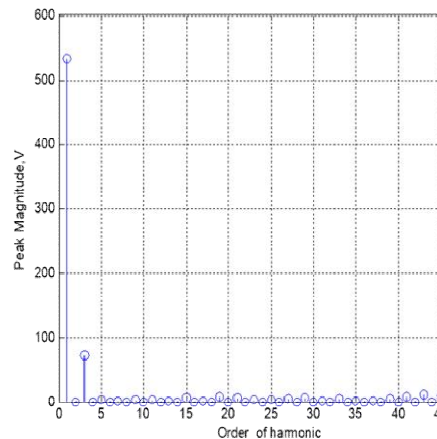
## II. RESULT AND DISCUSSION

GA

Modulation index:0.7



Modulation index: 1.075



**Table 1: GA (Nominal voltage 25V)**

| Sr. No. | Modulation index | Angle   |         |         |         |         | Best fitness value | THD    |
|---------|------------------|---------|---------|---------|---------|---------|--------------------|--------|
| 1       | 0.7              | 27.7364 | 45.1437 | 52.7554 | 67.0311 | 73.9256 | 1.8798             | 2.9785 |
| 2       | 1.075            | 4.5004  | 12.0497 | 21.3627 | 29.8443 | 44.9095 | 1.3775             | 2.4137 |

## III. CONCLUSION

This paper is used to determine the switching angles and THD of cascaded multilevel inverters by using Differential Evolution Algorithm. Simulations are carried out to verify the algorithm when applied to a single-phase multilevel inverter. In this paper Differential Evolution optimization technique is used to generate optimal switching angles in order to eliminate a certain order of harmonics. The algorithm was developed using MATLAB software and is run for a number of times independently to ensure the feasibility and the quality of the solution. Differential Evolution Algorithm solves the nonlinear transcendent equations with a much simpler formulation. Also, the results show that the differential evolution algorithm optimization technique effectively eliminates low order harmonics and the switching angles are used to optimize the total harmonic distortion (THD) of the output voltage.

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