

# Multiple Harmonics Elimination in Hybrid Multilevel Inverter Using Soft Computing Technique

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**Abstract**— Multilevel inverters are extensively used in various voltage applications. Harmonic elimination in multilevel inverter is a complex optimization problem. A fresh nine level hybrid multilevel inverter using harmonics elimination is presented in this paper. This method involves less number of switches associated with more number of voltage levels. The stages with higher DC link have more advantages like low commutation, reduced switching losses, increased efficiency and low input stages with more number of output levels. In this method the bacterial foraging optimization technique (BFO) algorithm is used to determine the switching angles of the inverter. The proposed method employs multicarrier pulse width modulation technique, this eliminated harmonics component from inverter output. It can be easily implemented using a PIC micro controller. Simulation result reveals the quality of feasible result.

**Keywords**— Hybrid multilevel inverter, Harmonics elimination, MCPWM, Bacterial Foraging Optimization (BFO).

## I.INTRODUCTION

The harmonics elimination is widely utilized on multilevel inverters. Multilevel inverters are applicable in average voltage and high power applications because of their less switching losses and high efficiency than ordinary inverters. The desired output voltage of this inverter is synthesized from several levels of dc voltages [1]. To control the output voltage and reduce the undesired harmonics, different sinusoidal pulse width modulation (PWM)[8] and space-vector PWM schemes are suggested for multilevel inverters; however, PWM techniques are not able to eliminate low-order harmonics completely. Another approach is to choose switching angles [1] so that specific lower order dominant harmonics are suppressed. This method is known as harmonic elimination.

Multiple harmonic elimination methods are used by the harmonic elimination technique in high power inverters[3]; it offers enhanced operations at low switching frequency while reducing cost and bulky size filters. They have been successfully adopted in different multilevel inverter topologies [6],[7]. Numerical iterative techniques, such as Newton–Raphson method, are applied to solve the harmonics problem; however, such techniques need a good initial guess that should be very close to the exact solution. Although the Newton–Raphson method works properly if a good initial guess is available, providing a good guess is very difficult in most cases. This is because the search space of the harmonics problem is unknown, and one does not know the solution is there or not, in case it exists; this is the good initial guess or not. A systematic approach to solve the harmonics problem based on resultant theory method is proposed, where transcendental equations that describe the harmonics problem are transformed into a corresponding set of polynomial equations [1],[2], [5] and then, resultant theory method is utilized to find all possible sets of solutions for this equivalent problem.

Another approach to contract to the harmonics problem is based on modern stochastic search techniques such as genetic algorithm (GA) and particle swarm optimization (PSO)[8],[10], bacterial forage optimization (BFO)[9]. However, by increasing the number of switching angles, the complexity of search space increases dramatically and both the methods trap the local optima of search space. Of course, the exact solution for the no. of switching angles are cannot be calculated by evolutionary based algorithms; however, it can be said that as the number of switching angles increases, also decrease the finding optimum switching angles. Recently, a new active harmonic elimination method is also proposed to eliminate higher order harmonics in multilevel inverters. In this method, first, the switching angles to eliminate the lower order harmonics of staircase voltage waveform are calculated, which is called fundamental switching frequency method. Then, residual higher order harmonics are eliminated by additional PWM switching patterns. Unfortunately, this method uses very high frequency switching to eliminate higher order harmonics; also, it needs a very complicated control procedure to generate the gate signals for power switches. Harmonic elimination

The main drawbacks of existing harmonics methods are their mathematical complexity and the heavy computational loads, resulting high cost of the hardware needed for real-time implementation. The last problem is commonly circumvented by preliminary off-line computation of the switching angles and the subsequent creation [4] of lookup tables to be stored in the microcontroller's internal memory for real-time fetching. In the following, Section II deals with hybrid multilevel inverter, Section III describes the determination of bacterial foraging algorithms, and Section IV multicarrier pulse width modulation describes the procedure for the firing angle. Section V shows some simulation results and deals with some analysis, while Section VI reports experimental results and

their conclusion. Good agreement is noted among experimental and simulation results, confirming the accuracy of the proposed technique.

## II. HYBRID MULTILEVEL INVERTER

There are several topologies such as neutral point clamped or diode clamped multilevel inverter, flying capacitor based multilevel inverter, cascaded H-bridge multilevel inverter and hybrid H-bridge multilevel inverter. The main disadvantage of diode clamped multilevel inverter topology is restriction to the high power operation. The first topology introduced is the series H-bridge design, [7], [12] in which several configurations have been obtained. This topology consists of series power conversion cells which form the cascaded H-bridge multilevel inverter and power levels may be scaled easily. An apparent disadvantage of this topology is the requirement of large number of isolated voltage sources. The proposed topology for multilevel inverter has high number of steps associated with low number of power switches. In addition, for producing the levels at the output voltage, a procedure for calculating the required dc voltage source is proposed. The advantage of the hybrid multilevel inverter is modularized structure. The multilevel inverter has a general structure of the hybrid multilevel inverter is shown in figure. 1. Each of the separate voltage source ( $1V_s$ ,  $2V_s$ ,  $4V_s$ ) is connected in series with other sources via a special circuit associated with it. Each stage of the circuit consists of only one active switching element and one bypass diode that make the output voltage as positive one with several levels [12]. The basic operation of modified hybrid multilevel inverter for producing the output voltage as  $+1V_{dc}$  is to turn on the switch S1 (S2 and S3 turn off) and turning on S2 (S1 and S3 turn off) for producing output voltage as  $+2V_{dc}$ . Similarly other levels can be achieved by turning on the suitable switches at particular intervals; It can be inferred that only one H-bridge is connected to get both positive and negative polarity. The main advantage of modified hybrid multilevel inverter is high number of levels with reduced number of switches.

The Figure below shows the typical output voltage waveform of a Hybrid Multilevel Inverter with 3 separate dc sources.

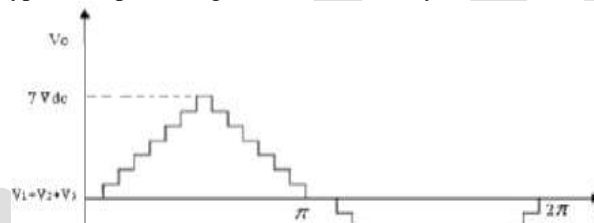


Fig 1. Typical output waveform for Hybrid Multilevel Inverter

## III. BACTERIAL FORAGING OPTIMIZATION

Bacterial Foraging Algorithm (BFA) was planned by Passino is inspired by the social foraging behavior of Escherichia coli. BFA has been widely accepted as a global optimization algorithm of current interest for distributed optimization. BFA has already drawn the attention of researchers because of its efficiency in solving real-world optimization problems in several application domains. This optimization technique is relatively new to the family of nature-inspired optimization algorithms [9]. Soft computing tools like Genetic algorithm (GA) and Simulated Annealing have become standard procedures for designing optimized antennas where analytical optimization becomes tough and does not provide satisfactory result. GA ruled several years for antenna optimization problems. But search for new computationally efficient algorithms to handle computationally large and complex problems are continuing. Apart from the modification of GA new paradigms have been developed. These are Particle Swarm Optimization (PSO), Ant Colony Optimization and Bacteria Foraging Algorithm (BFA). Among them, BFA being the latest trend that is efficient in optimizing parameters of the structures. Nowadays Bacteria Foraging technique is gaining importance in the optimization problems. Because

- Philosophy says, Biology provides highly automated, robust and effective organism
- Search strategy of bacteria is salutary (like common fish) in nature
- Bacteria can sense, decide and act so adopts social foraging (foraging in groups)

Above all Search and optimal foraging decision making of animals can be used for solving engineering problems. To perform social foraging an animal needs communication capabilities and it gains advantages that can exploit essentially the sensing capabilities

of the group, so that the group can gang-up on larger prey, individuals can obtain protection from predators while in a group, and in a certain sense the group can forage a type of collective intelligence.

### Working Principle

In this algorithm, the population comprises of a set of individuals, where each individual is called a bacterium. Bacteria search for nutrients in a manner to maximize energy obtained per unit time[9]. Individual bacterium also communicates with others by sending signals. The flow chart shows the working of BFA optimization algorithm.

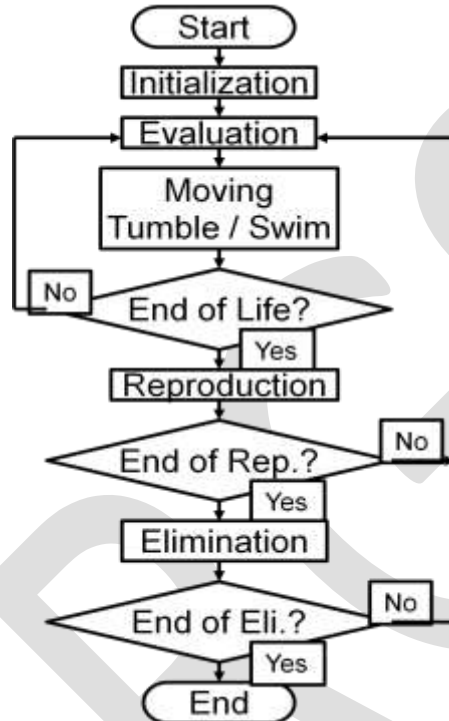


Fig 2. Flow chart (BFA algorithm)

A bacterium passes through the following phases during its lifetime:

1. Chemotaxis
2. Swarming
3. Reproduction
4. Elimination-Dispersal

#### Chemotaxis:

The process, in which a bacterium moves by taking small steps while searching for nutrients, is called chemotaxis. The key idea of BFOA is to mimic the chemotactic movement of virtual bacteria in the problem search space[9]. During chemotaxis, a bacterium moves in one of the two different manners; swim, or tumble. If the bacterium changes its direction of motion, it is called tumbling. If the bacterium moves ahead in the same direction, it is called swimming. Whereas, if it changes its direction of motion, it is called tumbling. During movement, a bacterium aims at moving towards a nutrient gradient and tries to avoid noxious environment. Generally a bacterium moves for a longer distance in a friendly environment. Let  $\theta_i(j, k, l)$  represents  $i$ th bacterium at  $j$ th chemotactic,  $k$ th reproduction and  $l$ th elimination-dispersal step.  $C(i)$  is the size of the step taken in a random direction specified by the tumble.

$$\theta_i(j + 1, k, l) = \theta_i(j, k, l) + C(i)\varphi(j) \quad (1)$$

#### Swarming:

An interesting group behavior has been observed for several species of bacteria including *E. coli* and *S. typhimurium*, where intricate and stable spatio-temporal patterns (swarms) are formed by the cells in semisolid nutrient medium. A group of *E. coli* cells arrange themselves in interesting patterns around the nutrient gradient. The cells release an attractant named aspartate, which helps them to aggregate into groups and move as concentric patterns of swarms with high bacterial density. This cell-to-cell signaling in *E. coli* is termed as swarming.

#### Reproduction

When the bacteria get enough food for growth, they increase in length and in presence of suitable temperature they break in the middle to form an exact replica of itself. This phenomenon inspired Passino to introduce an event of reproduction in BFOA. In the

algorithm, the least healthy bacteria eventually die while each of the healthier bacteria (i.e., those with better fitness value) split into two bacteria, which are then placed in the same location. In this way, the population size is kept constant. Thus, the reproduction step consists of sorting the bacteria in the population  $\theta_i(j, k, l)$ ,  $\forall i, i = 1, \dots, S$  based on their objective function value  $f(\theta_i(j, k, l))$  and eliminating half of them with the worst fitness. The remaining half will be duplicated as to maintain a fixed population size.

### Elimination and Dispersal

Gradual or sudden changes in the local environment, where a bacterium population lives, may occur due to adverse situations like rise in temperature [8],[9]. Events may take place in such a way that all the bacteria in a region may be killed or a group may be dispersed into a new location. To simulate this phenomenon in BFOA, some bacteria are liquidated at random with a very small probability while the new replacements are randomly initialized over the search space [13],[15].

## IV. MULTICARRIER PWM TECHNIQUE

Multicarrier PWM technique is the widely adopted modulation strategy for multilevel inverter. It is similar to that of the sinusoidal PWM strategy except for the fact that several carriers are used [11]. Multicarrier PWM is one in which several triangular carrier signals are compared with one sinusoidal modulating signal. The number of carriers required to produce  $m$  level output is  $m - 1$ . The reference waveform has peak to peak amplitude of  $A_m$  and a frequency  $f_m$ . The reference is continuously compared with each of the carrier signals and whenever the reference is greater than the carrier signal, pulse is generated [11],[14]. Frequency modulation ratio is defined as the ratio of carrier frequency and modulating frequency. Amplitude modulation ratio is defined as the ratio of amplitude of modulating signal and amplitude of carrier signals.

### Types of Multicarrier PWM Method

There are a few types of the multicarrier PWM method. There are,

1. Alternate Phase Opposition Disposition (APOD)
2. Phase Opposition Disposition (POD)
3. Phase Disposition (PD)

### Alternate Phase Opposition Disposition (APOD)

The carrier waves have to be displaced from each other by 180 degrees alternately as shown in Figure 3. In this modulation, the inverter switching frequency and the device switching frequency is given by and respectively. It was found and can be implemented in all types of multilevel inverter, but it is best suitable for NPC. It is do because each carrier signal can be related to each semiconductor devices. It is not suitable for CHB as there is an uneven disturbance of power because each vertical shift related to each carrier and level to a particular bridge.

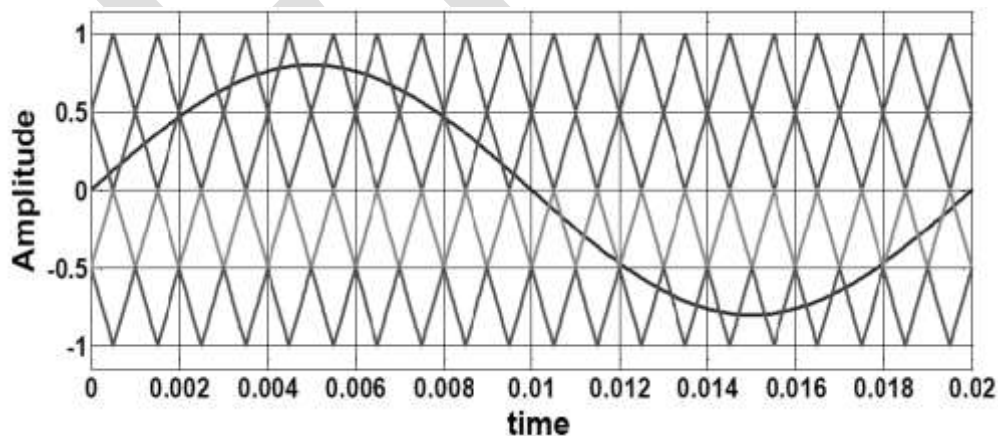


Fig 3. Alternate Phase Opposition Disposition PWM

### Phase Opposition Disposition (POD)

The carrier waveform are in all phase above and below the zero reference value; however there is 180 degree phase shift between the ones above and below zero respectively as shown in figure 4.

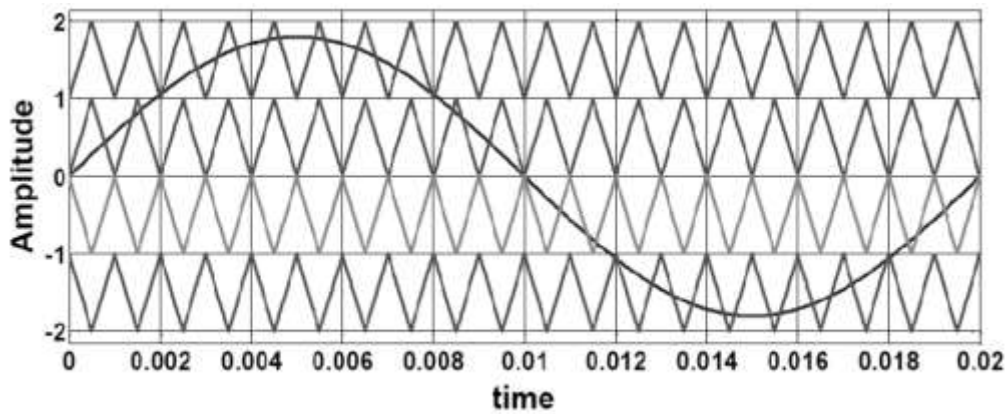


Fig 4. Phase Opposition Disposition PWM

**Phase Disposition (PD)**

For the phase disposition technique, a zero point is set as the reference point. The carrier signals are set to be in phase for above and below reference point (zero line). Figure 5 show that the phase disposition multicarrier PWM.

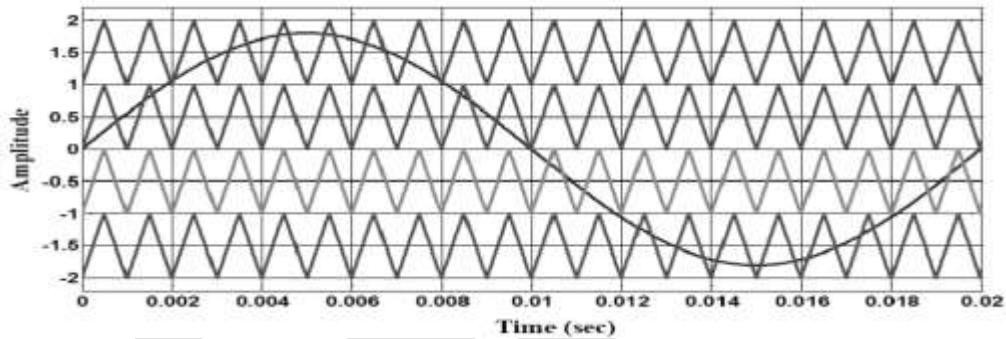


Fig 5. Phase Disposition PWM

**V.SIMULATION RESULTS**

The simulation model of proposed system is shown in the Figure 6. The nine level hybrid multilevel inverter to validate the computational results for switching angles, a simulation is carried out in MATLAB/SIMULINK software tool for a nine level hybrid multilevel inverter. The proposed method is used to get sinusoidal waveform and reduced harmonics with minimum number of components. The three different dc input are used, It is in the order of  $V_1$ ,  $2V_1$ ,  $3V_1$ . Given input dc voltage are  $V_1=60v$ ,  $2V_1=120v$ ,  $3V_1=180v$ . Therefore the efficiency of the multilevel inverter is increased. Soft computing method gives the switching angles. The low order harmonics are reduced significantly.

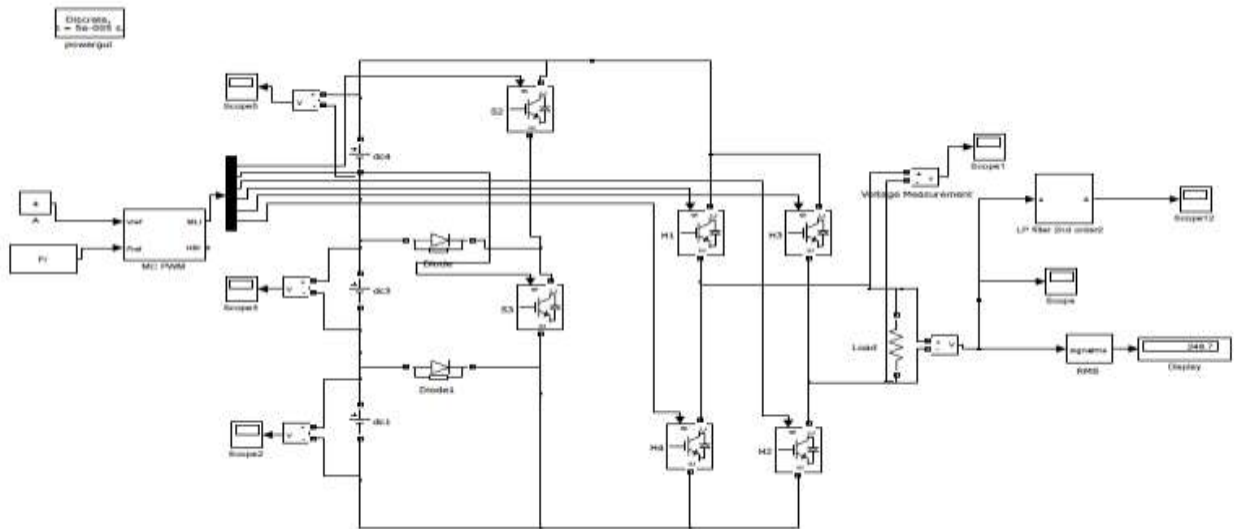


Fig 6. Simulation Diagram of Proposed System

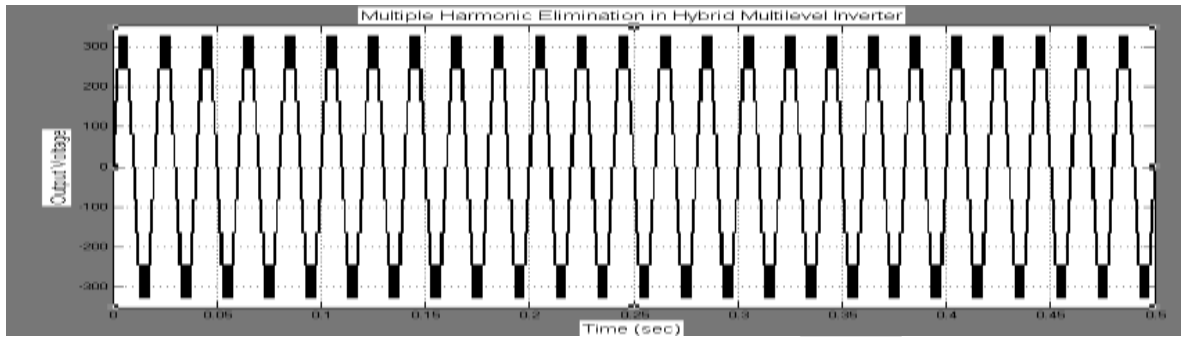


Fig 7. Output waveform

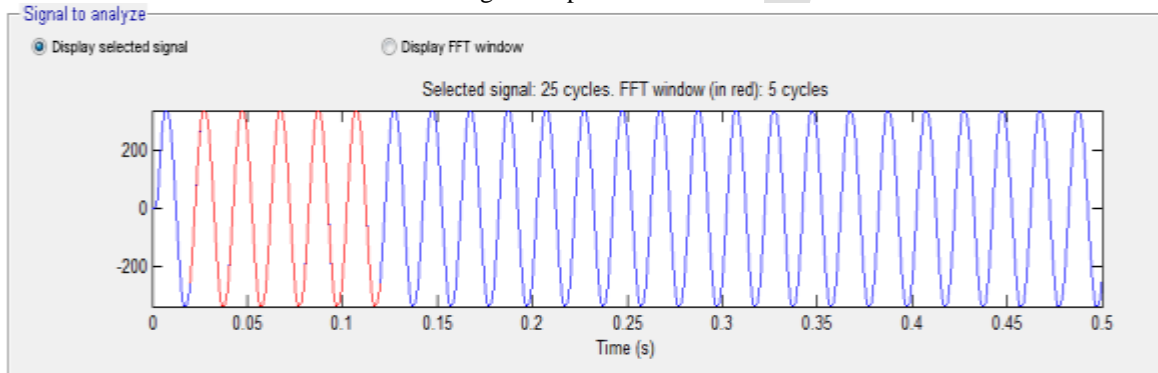


Fig 8. FFT Analysis of a nine Level Hybrid Inverter

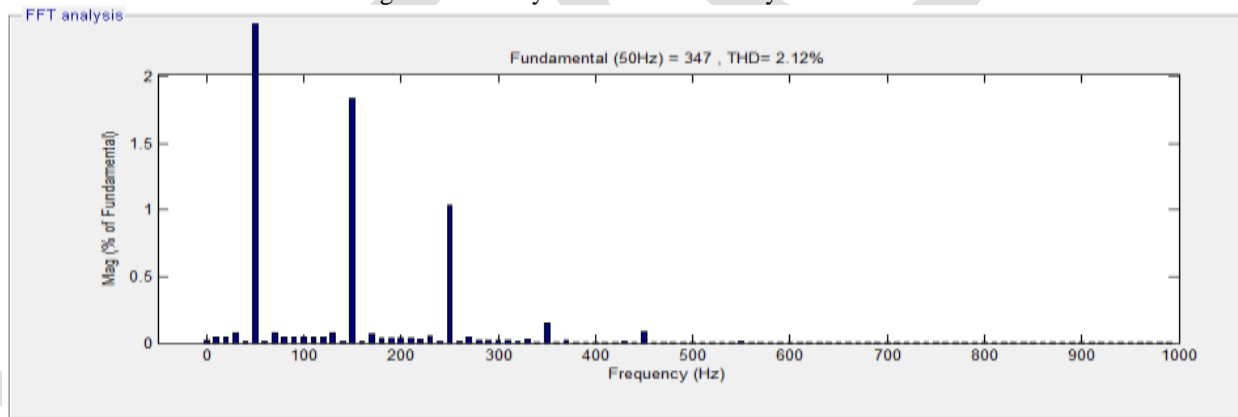


Fig 9. Percentage of Harmonics of a nine Level Hybrid Inverter

## VI.CONCLUSION

In this paper, a nine level hybrid multilevel inverter is used to get sinusoidal waveform and also to increase the efficiency of the inverter. The simulation results shows nine level hybrid multilevel inverter have been illustrated using MATLAB software. Multilevel inverter is generally used to obtain a high resolution and produces near sinusoidal output waveform using reduced number of switches and low switching losses. The harmonic reduction is achieved to a greater extent than the other conventional inverters. The basic structure details and operating characteristics of hybrid multilevel inverter have been described by taking a nine level configuration and also extend the design flexibility. These proposed control schemes have been demonstrated through simulation.

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