# REVIEW ON IWD BASED LOW LEVEL HARMONIC REDUCTION TECHNIQUE IN CASE OF MULTILEVEL INVERTERS

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**Abstract -** This paper focuses on, elimination of harmonics in multilevel inverter using different fitness functions. Here the basic concept is to eliminate specific harmonics with a proper choice of switching angles. Harmonics reduction is one of the most challenging problems related to multilevel inverters. In the past many heuristic techniques have been implemented to get the solution of transcendental equations. So, genetic algorithm (GA) and particle swarm optimization (PSO) [6], [7] is used. Ant colony optimization (ANT), neural networks (NN) and fuzzy logic also provided good solution for these equations. Moreover many derivatives of above mentioned algorithms have also been used. Firefly algorithm (FFA) is used for solving nonlinear transcendental equations from SHE-PWM and to minimize the low-order harmonics in multilevel inverters. Each algorithm has its own pros and cons. Some algorithms take much computational time but provide better result and vice-versa.

***Key Words***: Multilevel Inverter, Cascaded H Bridge Multilevel Inverter, Selective Harmonic, Firefly Algorithm, Total Elimination Harmonic Distortion-(THD).

# 1. INTRODUCTION

Electric Power quality is a term which has captured increasing attention in power engineering in the recent years. Even though this subject has always been of interest to power engineers, it has assumed considerable interest in the 1990's. Electric power quality means different things for different people. To most electric power engineers, the term refers to a certain sufficiently high grade of electric service but beyond that there is no universal agreement. The measure of power quality depends upon the needs of the equipment that is being supplied. What is good power quality for an electric motor may not be good enough for a personal computer. Usually the term power quality refers to maintaining a sinusoidal waveform of bus voltages at rated voltage and frequency. The waveform of electric power at generation stage is purely sinusoidal and free from any distortion. Many of the Power conversion and consumption equipment are also designed to function under pure sinusoidal voltage waveforms. However, there are many devices that distort the waveform. These distortions may propagate all over the electrical network. In recent years, there has been an increased use of non-linear loads which has resulted in an increased fraction of non-sinusoidal

currents and voltages in Electric Network. Classification of power quality areas may be made according to the source of the problem such as converters, magnetic circuit non linearity, arc furnace or by the wave shape of the signal such as harmonics, flicker or by the frequency spectrum (radio frequency interference). The wave shape phenomena associated with power quality may be characterized into synchronous and non synchronous Phenomena. Synchronous phenomena refer to those in synchronism with A.C waveform at power frequency. The main aspects of electric power quality may be categorized as:-

**a)** Fundamental concepts     **d)** Modeling
**b)** Sources     **e)** Analysis
**c)** Instrumentation     **f)** Effects

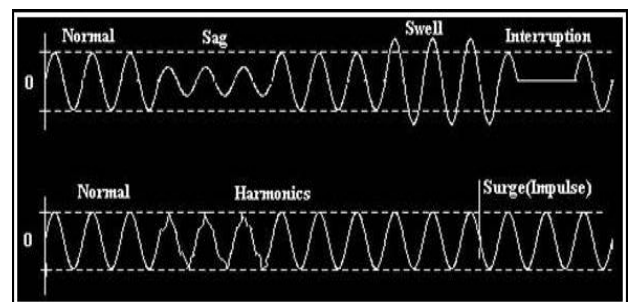Figure 1 shows some of the typical voltage disturbances.



**Figure 1:** Typical Voltage Disturbance.

Custom power devices are the latest development of interfacing devices between distribution supply and consumer appliances to overcome voltage/current disturbances and improve the power quality by compensating the reactive and harmonic power generated or absorbed by the load.

# 2. Literature Review

Harmonics reduction is one of  the most challenging problems related to multilevel inverters. In accordance with modulation and control for multilevel converters a number of techniques have been developed, some of which are selective harmonic elimination (SHE-PWM), space vector modulation (SVM), and sinusoidal pulse width modulation (SPWM) [5]. The selective harmonics elimination involves the solution of transcendental equations which are nonlinear; these equations have many possible solutions. Currently, the researchers are most widely using SHE-PWM

due to its benefits over other modulation techniques. A good initial guess is needed to acquire the result of transcendental equations using Newton-Raphson method. The next leap forward was to use the resultant theory method for harmonics reduction. In this method the equations are converted to polynomials in order to obtain required solution but it is a very cumbersome process when degrees of polynomials increase. It was then suggested that these equations can only be solved using optimization techniques, in the past many heuristic techniques have been implemented to get the solution of transcendental equations. So, genetic algorithm (GA) and particle swarm optimization (PSO) [6], [7] is used. Ant colony optimization (ANT), neural networks (NN) and fuzzy logic also provided good solution for these equations. Moreover many derivatives of above mentioned algorithms have also been used. Each algorithm has its own pros and cons. Some algorithms take much computational time but provide better result and vice-versa. Firefly algorithm (FFA) is proposed for solving nonlinear transcendental equations from Selective Harmonic Elimination Pulse Width Modulation (SHE-PWM) and to minimize the low-order harmonics in multilevel inverters. This paper consists of five sections. Section II presents a theoretical overview of design and case setup. One phase of a cascaded H-Bridge multilevel inverter is discussed in Section III. Selective Harmonic Elimination Pulse width Modulation is discussed in Section IV. About firefly algorithm is discussed in Section V. About Total Harmonic Distortion is presented in Section VI. Lastly, discussions and concluding remarks are presented in Section VII.

## 2.1 H-Bridge Multilevel Inverter

A multilevel inverter, a power electronic device, is capable of providing desired alternating voltage level at the output using multiple lower level DC voltages as input. H-Bridge inverter shown in Figure 2 has been selected for the implementation of firefly algorithm (FFA) because of its modularity, simplicity of control, requires less number of components, overall less weight and price as compared to the other types of inverters [8].
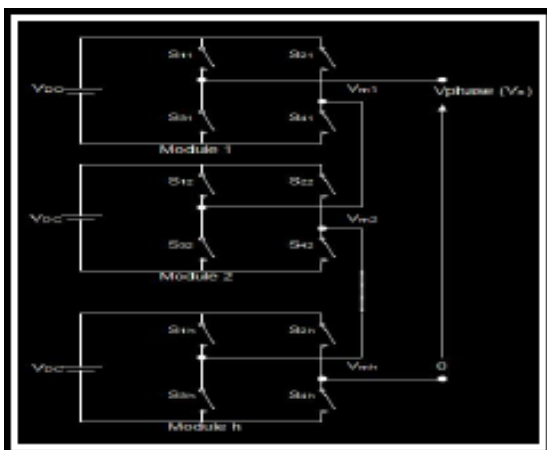


**Figure 2:** Cascaded H-Bridge Multilevel Inverter.

To provide a sinusoidal output, several H-bridge inverters are connected in series. Each cell contains one H-bridge and output voltage generated by this multilevel inverter is actually the sum of all the voltages generated by each cell i.e. if there are k cells in H-bridge multilevel inverter then the numbers of output voltage levels would be *2k+1* [9]. 11-level H-Bridge inverter is selected for implementation of firefly algorithm (FFA).

## 2.2 Selective Harmonic Elimination

In case of SHE, selected lower order harmonics are eliminated while remaining harmonic components are reduced to minimize THD. In this paper lower order harmonics i.e. i.e. 5th, 7th, 11th, 13th are eliminated. The expression desire fundamental voltage $b_1$ in equation (1). Moreover, the relation between the fundamental and the maximum obtainable voltages is given by modulation index (M) is defined as the ratio of the fundamental output voltage $V_1$ to the maximum obtainable fundamental voltage $V_{1\,max}$. The maximum fundamental voltage is obtained when all the switching angles are zero i.e.

$$V_{1\,max} = \frac{4V_{dc}}{\pi}$$

Therefore the expression for M

$$M = \frac{\pi V_1}{4V_{dc}} \ (0 \le M \le 1)$$

Mathematical SHE problem can be formulated as

$$\cos(\alpha_1) + \cos(\alpha_2) + \cdots + \cos(\alpha_m) = mM$$
$$\cos(5\alpha_1) + \cos(5\alpha_2) + \cdots + \cos(5\alpha_m) = 0$$
$$\cos(7\alpha_1) + \cos(7\alpha_2) + \cdots + \cos(7\alpha_m) = 0$$
$$\cos(11\alpha_1) + \cos(11\alpha_2) + \cdots + \cos(11\alpha_m) = 0$$
$$\cos(13\alpha_1) + \cos(13\alpha_2) + \cdots + \cos(13\alpha_m) = 0$$
$$\ldots$$
$$\ldots$$
$$\cos(n\alpha_1) + \cos(n\alpha_2) + \cdots + \cos(n\alpha_m) = 0 \quad (A)$$

The equation (A) is a system of transcendental equation, known as selective harmonic elimination (SHE) equation. From the equation unknown switching angle $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7, \ldots, \alpha_m$ are calculated with the help of the given value of M (from 0 to 1) for trigger semiconductor switches. m is no of h bridge per phase .

## 2.3 Firefly Algorithm

firefly algorithm (FFA) is inspired by the flashing behavior of fireflies and a metaheuristic algorithm. Firefly has three factors of interest [11].

### A) Attractiveness

Considering two fireflies as i and j, brightness I as a function of x where x is a certain point in a space i.e. I(x). They are at a distance r from each other and intensity I(r) varies monotonically with the distance as:

$$I(r) = I_0 e^{-\gamma r^2}$$

Where $I_0$ original intensity of light, r is is the distance between two fireflies and γ is light absorption coefficient. As intensity is also a function of attractiveness, we can write the relationship as:

$$\beta = \beta_0 e^{-\gamma r}$$

Where $\beta_0$ is the attractiveness at r=0. In most of cases βo=1. β also varies monotonically with r. So, equation can be written as:

$$\beta(r) = \beta_0 e^{-\gamma r^m} \quad (m \geq 1)$$

Characteristic length $\Gamma$ for a fixed $\gamma$ is

$$\Gamma = \gamma^{-\frac{1}{m}} \to 1, \quad m \to \infty$$

### B) Distance

Considering two fireflies $i$ and $j$ at points $x_i$ and $x_j$ respectively, then the distance r can be mathematically defined as:

$$r_{ij} = \|x_i - x_j\| = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2}$$

Where $d$ is the number of dimensions; $x_{i,k}$ is the $k^{th}$ component of coordinate $x_i$ and $x_{j,k}$ is the $k^{th}$ component of coordinate $x_j$.

### C) Movements

While considering two fireflies $i$ and $j$, movement of $i$ is attracted toward $j$ due to extra brightness of $j$ can be summarized as:

$$x_i = x_i + \beta_0 e^{-\gamma r_{ij}^2} (x_j - x_i) + \propto \epsilon_i$$

Where $x_i$ is current position of fireflies; second term is attractiveness as seen by other fireflies; third term of the equation is due to random movement of fireflies with the random variable $\epsilon_i$, which can be replaced by rand-1/2 in simulink to generate a random number for a given range and α is randomization parameter.

## 2.4 Total Harmonic Distortion

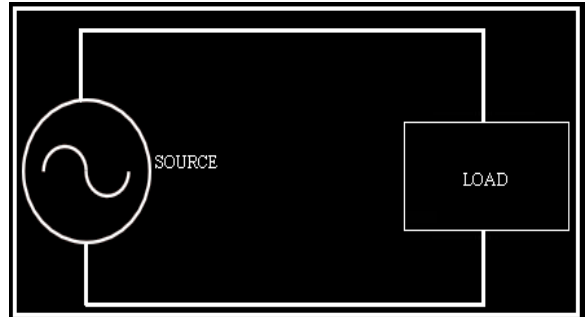Total harmonic distortion is a complex and often confusing concept to grasp.



**Figure 3:** Power System with AC Source and Electric Load. However, when broken down into the basic definitions of harmonics and distortion, it becomes much easier to understand. Figure 3 imagine a power system with an AC source and an electrical load.

Now imagine that this load is going to take on one of two basic types: linear or nonlinear. The type of load is going to affect the power quality of the system. This is due to the current draw of each type of load. Linear loads draw current that is sinusoidal in nature so they generally do not distort the waveform show in Figure 4. Most household appliances are categorized as linear loads. Non-linear loads, however, can draw current that is not perfectly sinusoidal show in Figure 5. Since the current waveform deviates from a sine wave, voltage waveform distortions are created.
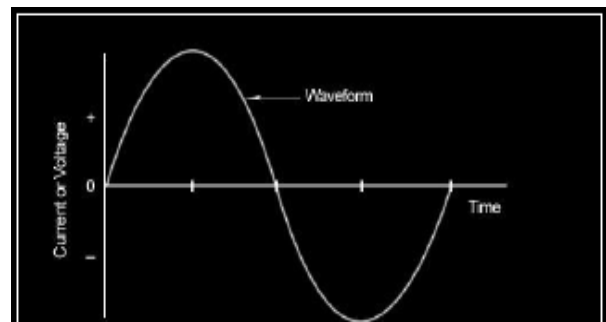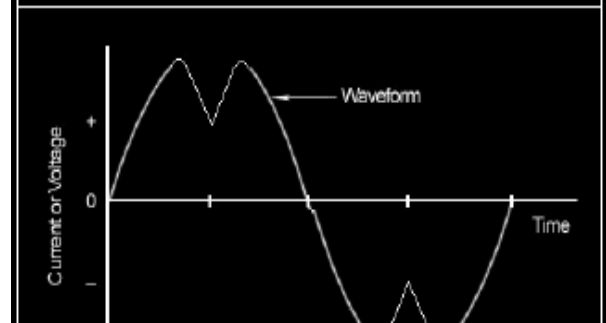


Figure 4: Ideal Sine Wave.

Figure 5: Distorted Waveform.

As can be observed from the waveform in Figure 5, waveform distortions can drastically alter the shape of the sinusoid. However, no matter the level of complexity of the fundamental wave, it is actually just a composite of multiple waveforms called harmonics. Harmonics have frequencies that are integer multiples of the waveform's fundamental frequency. For example, given a 60Hz fundamental waveform, the 2nd, 3rd, 4th and 5th harmonic components will be at 120Hz, 180Hz, 240Hz and 300Hz respectively. Thus, harmonic distortion is the degree to which a waveform deviates from its pure sinusoidal values as a result of the summation of all these harmonic elements. The ideal sine wave has zero harmonic components. In that case, there is nothing to distort this perfect wave. Total harmonic distortion, or THD, is the summation of all harmonic components of the voltage or current waveform compared against the fundamental component of the voltage or current wave:

$$THD = \frac{\sqrt{(V_2^2 + V_3^2 + V_4^2 + \cdots + V_n^2)}}{V_1} \times 100\%$$

The formula above shows the calculation for THD on a voltage signal. The end result is a percentage comparing the harmonic components to the fundamental component of a signal. The higher the percentage, the more distortion that is present on the mains signal.

## 3. Conclusion

According to previous approaches Harmonics reduction is one of the most challenging problems related to multilevel inverters. By methodologies many heuristic techniques have been implemented to get the solution of transcendental equations. So, genetic algorithm (GA) and particle swarm optimization (PSO) is used. Ant colony optimization (ANT), neural networks (NN) and fuzzy logic also provided good solution for these equations. Moreover many derivatives of above mentioned algorithms have also been used Low order harmonics in the H-Bridge multilevel inverter are minimized using selective harmonic elimination through firefly algorithm. Each algorithm has its own pros and cons. Some algorithms take much computational time but provide better result and vice-versa.

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