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Utlization Cat Swarm Optimization Algorithm for Selected Harmonic Elemination in Current Source Inverter

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ABSTRACT

The voltage source inverter (VSI) and Current source inverter (CSI) are two types of traditional power inverter topologies.In this paper selective harmonic elimination (SHE) Algorithm was impelemented to CSI and results has been investigated. Cat swarm (CSO) optimization is a new meta-heuristic algorithm which has been used in order to tuning switching parameters in optimized value.Objective fuction is reduction of total harmonic distortion(THD) in inverters output currents.All of simulation has been carried out in Matlab/Software.

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1. INTRODUCTION

There are two types of traditional power inverter topologies, Vlotage source inverter (VSI) and Current source inverter (CSI).The voltage source inverter produces a specified three-phase PWM voltage waveform for the load while the current source inverter outputs a specified three-phase PWM current waveform. Figure 1 show the CSI .the CSI is able to inject power to the grid without any additional dc/dc converter, but low harmonic is major problem in this kind of inverter and reduction of these harmonic is object of several researchers work.In additional these harmonics limited applications of CSI in frequency domain.CSI derives in the megawatt range are widely used in the industry[1],[2].The conventional three phase current source inverter has the defect of introducing increased lower order harmonics in the output current which give rise in to losses and torque pulsation in the machine.Elimination of low order harmonic is so important in CSIs to avoid possible resonance between the input/output filter capacitance and input/output circuit inductance.

In this paper current source inverter has been investigated and Selected Harmonic Elimination (SHE) switching algorithems has been impelemented. Several types of switching introduced in literature are introduced like: Trapezoidal PWM switching, Selective Harmonic Elimination (SHE) and Space vector Modulation (SVM) [3].

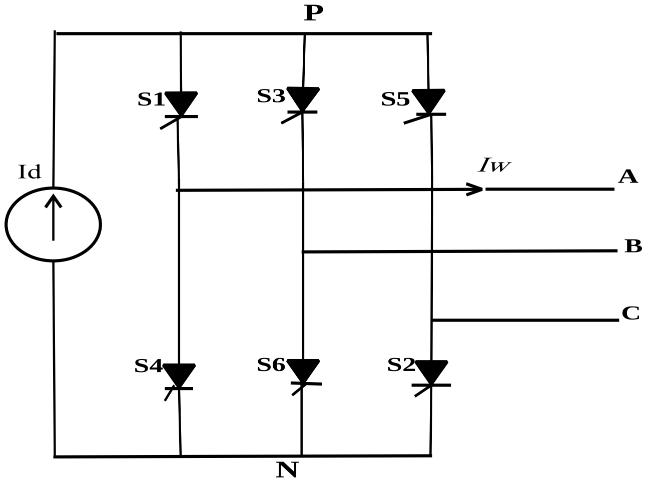

Figure 1. Conventional Current Source Inverter (CSI)

Selective harmonic elimination (SHE) is a method to eliminate a number of low-order harmonic in the inverter PWM current. It is a well-known method for generating PWM signals that can eliminate low order harmonic in specified voltage or current waveform [4]. One of easy way to have qualified output waveform is that eliminate some low harmonic.if number of pulses per half cycle is $N_{p;}$ the number of angles that implemented to harmonic elimination is achived (1):

$$j = \frac{Np - 1}{2} \tag{1}$$

For example with five pulses per half cycle, there are two independent angles,$\boldsymbol{\theta}_1$ and$\boldsymbol{\theta}_2$ .the two switching angles provide two degrees of freedom which can be used to either eliminate two harmonic in current or voltage waveform.in this paper current source inverter has been utilized [5]. The inverter PWM current can generally be expressed (2):

$$i\,(wt) = \sum_{n=1}^{\infty} a_n \sin(\text{nwt}) \tag{2}$$

$$\text{a}_n = \frac{4}{\pi} \int_0^{\pi/2} i\,(wt) \sin(nwt) d\,(wt)$$

The furrier coefficient a_n can be found from (3)

$$a_n = \frac{4 \times I_{dc}}{n\pi} \begin{Bmatrix} \cos(n\Theta_1) + \cos(n(\frac{\pi}{3} - \Theta_1)) - \cos(n\Theta_2) - \cos(n(\frac{\pi}{3} - \Theta_2)) + ... \\ + \cos(\text{n}\,\Theta_j) + \cos(n(\frac{\pi}{3} - \Theta_j) - \cos(n\frac{\pi}{6}), \text{j} = odd \\ \cos(n\Theta_1) + \cos(n(\frac{\pi}{3} - \Theta_1)) - \cos(n\Theta_2) - \cos(n(\frac{\pi}{3} - \Theta_2)) + ... \\ - \cos(n\Theta_j) - \cos(\text{n}(\frac{\pi}{3} - \Theta_j)) + \cos(n\frac{\pi}{6}), \text{j} = \text{even} \end{Bmatrix} \tag{3}$$

To eliminate j harmonics, j equations can be formulated by setting $a_n = 0$.

2. CAT SWARM OPTIMIZATION (CSO) ALGORITHM

Cat swarm algorithm (CSO) is based on the behavior of cats with exceptionally vigorous vitality of curiosity toward moving objects and possecing good hunting skills. Chu and Tsai proposed a new optimization algorithm that imitates the natural behavior of cats. Even though cats spend most of their time resting, they always remain alert and move very slowly. These two characterictics of resting with slow movement and chasing with high speed represented by seeking and tracing, respectively. In CSO, these two modes of operations are mathematically modeled for solving complex optimization problems. These modes are termed the "seeking and tracing" modes. A combination of these two modes allowes CSO has better performance.

Seeking mode has four essential factors: seeking memory pool (SMP), seeking range of the selected dimention (SRD), counts of dimention to change (CDC), and the self position consideration (SPC). Once a cats goes into tracing mode , it moves according to its own velocities for every dimensions. Every cat has its own position composed of D dimentionse, velocities for each dimension, a fitness value representing the accommodation of the cat to the benchmark functiona and a flag to identify wether the cat is in seeking mode or tracing mode. These two modes are dedicated to join with each other by mixture ratio (MR). The final position would be the best position of one of the cats [6].

The computational procedure of the proposed optimization algorithm in the form of flowchart is shown in Figure 2. Which is now described in detail?

I. Randomly initialize the initial set of cats of size N_{pop} ,where each cat is of dimention D , $Xi=\{xi_1 ,xi_2 ,\ldots,xi_D\}$
II. Initialize the velocity of each cat, i.e., the velocity of cat I in the D-dimentional space as $Vi= \{Vi_1 ,Vi_2 ,\ldots,Vi_D\}$.
III. Evaluate the fitness of each cat and keep the position of the cat that has the higest fitness value.
IV. According to parameter mixing ratio (MR), cats are randomly distributed to seeking and tracing modes.
V. If cat k is in seeking mode then
   a) Create SMP-1 copies of the kth cat and retain the present position as one copy;
   b) For each copy according to CDC, randomly select the dimension to be mutated.
   c) For the dimension selected for each copy, randomly add or subtract the SRD percent of the present value;
   d) Calculate the fitness value of all copies and replace orginal cat k with the copy having best fitness value.
VI. If cat k is in tracing mode ,then
   a) Update the velocity for every dimension of the kth cat :

$$v_k^{j+1} = w \times v_k^j + r \times (GB^j - x_k^j);$$

   b) Check if the velocities are in the range of maximum velocity; in case the new velocity is over range, set it equal to the maximum limit;
   c) Update the position for every dimension of the kth cat:

$$\mathrm{x}_k^{j+1} = x_k^j + v_k^{j+1}$$

   d) Constrain the position of the cat so that it doesn't exceed the limits of interest;
   e) Evaluate the fitness of each cat and store the position of the cat that has the best fitness value and compare the previous global best value with the current best value accordingly;
   f) Check if the maximux pre-specified number of iterations is reached, which is used as the termination critiation, if YES terminate the program, else go to step.

Because the importance of minimizing THD value, the objective function is defined as below (4) [7]:

$$M = \int_0^{t_{sim}} t.\left|THD\right|.dt \tag{4}$$

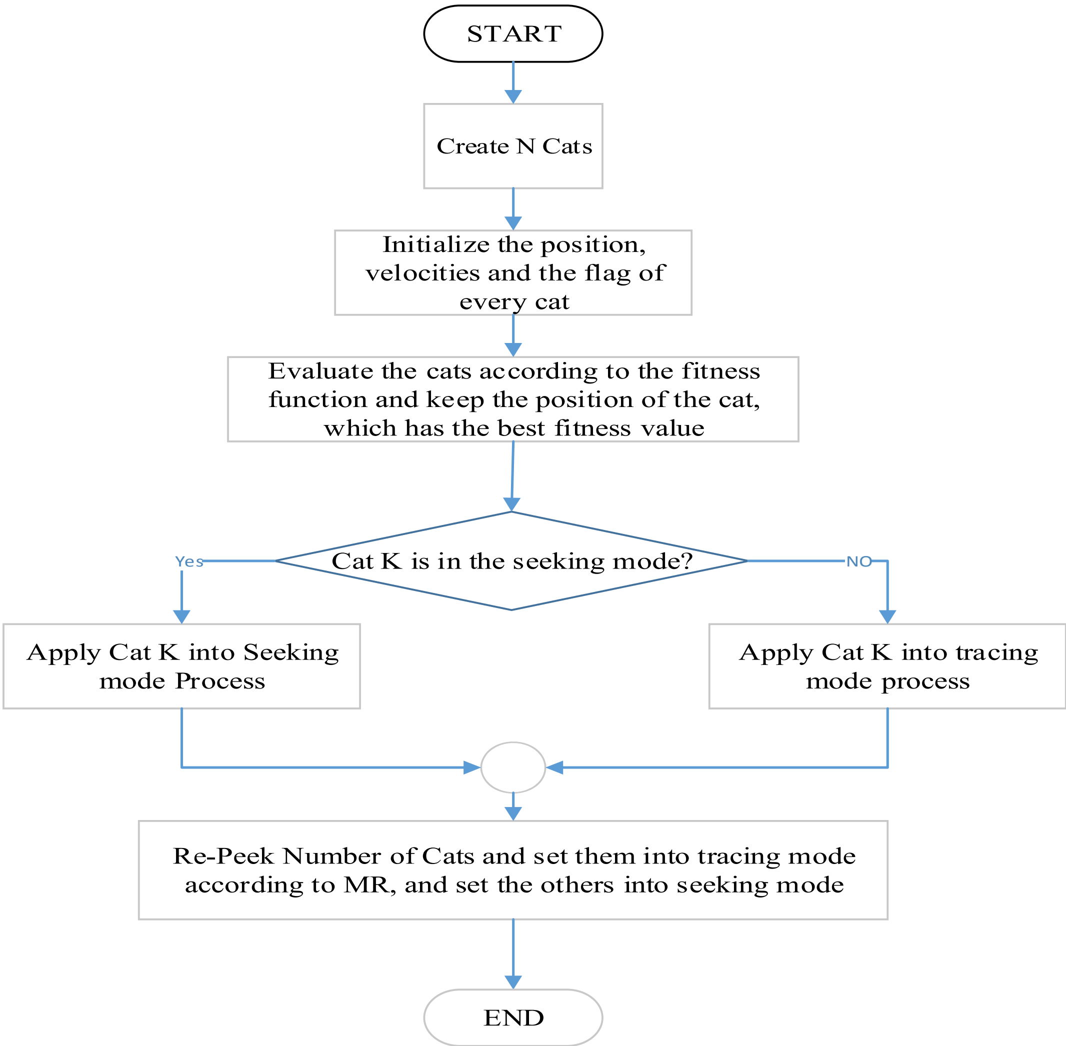

Figure 2. Cat Swarm Optimization (CSO) Flowchart

3. TUNING SIMULATION PARAMETERS

In this paper CSO algorithm implement to tuning switching parameters to minimize objective function. Objective function (OF) is minimization of total harmonic distortion (THD). For example for reduction THD in waveform with N_p =5, and to eliminate 5th and 7th harmonics, the following two equation can be drive (5);

$$\begin{aligned}&\cos(5\Theta_1)+\cos(5(\frac{\pi}{3}-\Theta_1))-\cos(5\Theta_2)-\cos(5(\frac{\pi}{3}-\Theta_2))-\frac{\sqrt{3}}{2}=0\\&\cos(7\Theta_1)+\cos(7(\frac{\pi}{3}-\Theta_1))-\cos(7\Theta_2)-\cos(7(\frac{\pi}{3}-\Theta_2))-\frac{\sqrt{3}}{2}=0\end{aligned} \quad (5)$$

In SHE algorithm minimized value for THD is obtioned with tuning angles in best value. In Figure 3 number of signals for eliminating two harmonic and its manner has been shown. In Figure 4 proposed way to generating pulses for switches has been illustrated [8],[9].

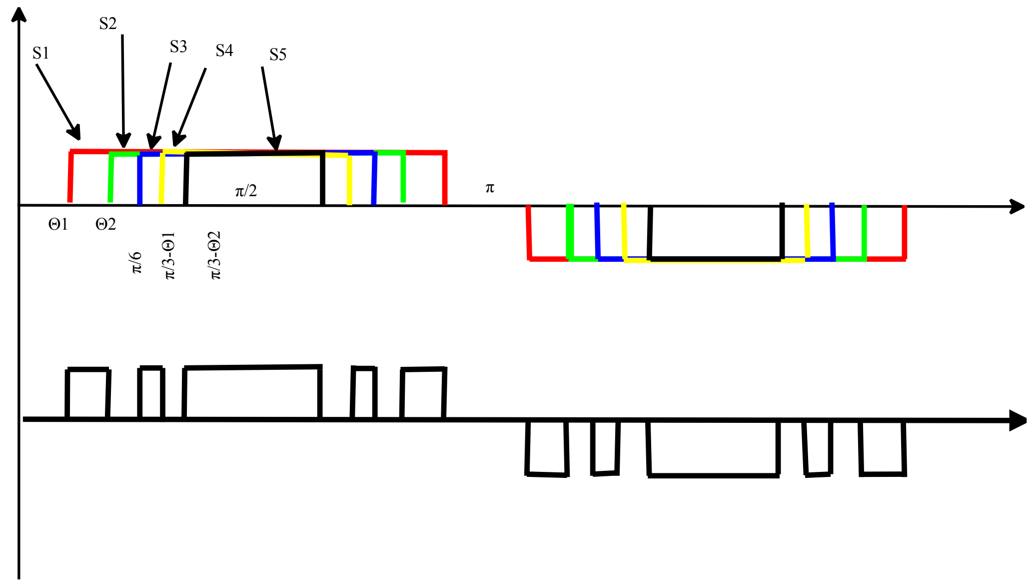

Figure 3. Switching signals for 5 th and 7 th Harmonic Elimination

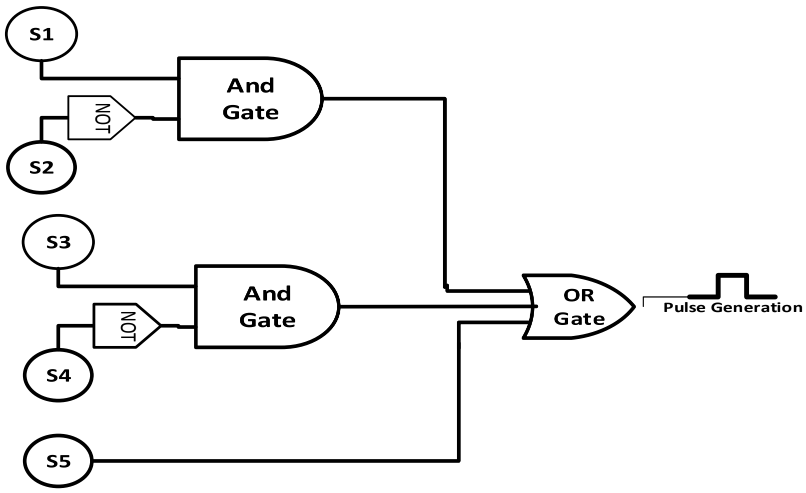

Figure 4. Proposed Method for pulse generating in Selective Harmonic Elimination

3.1. Simulation Results

Simulation was conducted with the configuration shown in Figure 5. The simulation parameters are: Idc=6A, C=40µF, L=10mH, R=10Ω. The simulation results with CSO are shown in Figure 6. This Figure included of Line to Line voltage and Load Current and output current of Inverter (I_w). In additional FFT analysis of I_w has been shown in Figure 7. This figure proving CSO algorithm operation in 5^{th} and 7^{th} harmonic elimination with SHE switching method [10],[11]. For additional example to prove CSO algorithm operation this metod done in three harmonic elimination (5^{th} ,7^{th},11^{th}) and results have been illustrated in Figure 8 and Figure 9.

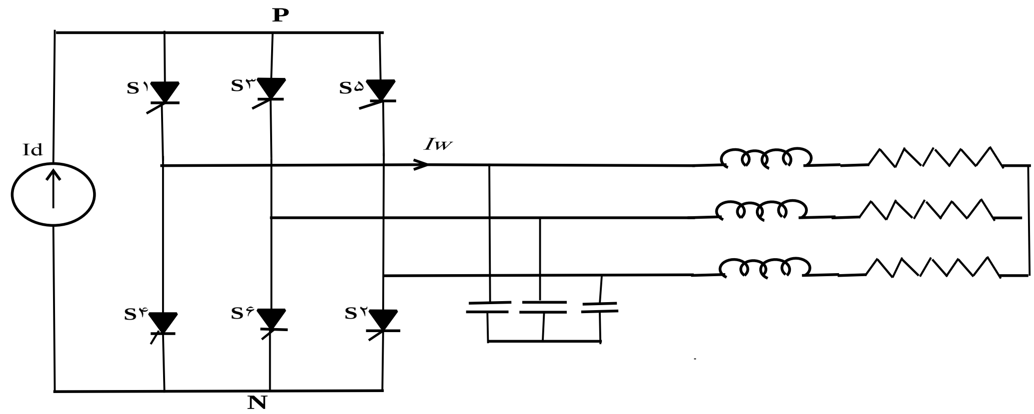

Figure 5. Simulated circuet

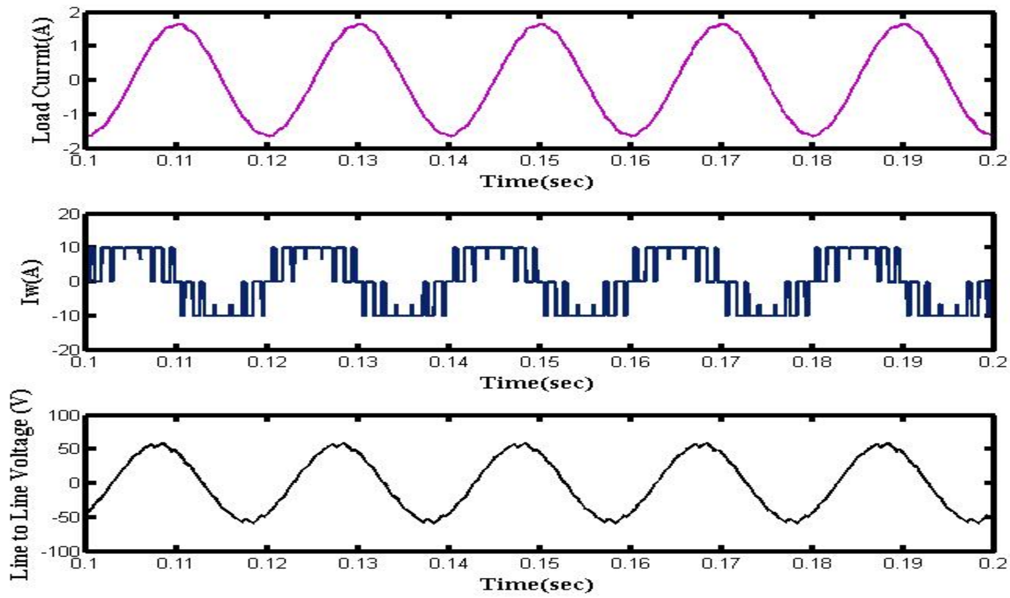

Figure 6. Simulation Results for Two Harmonic Elimination (5 th , 7 th), Load Current (Is), Inverter output Current(Iw), Line to Line Voltage(V)

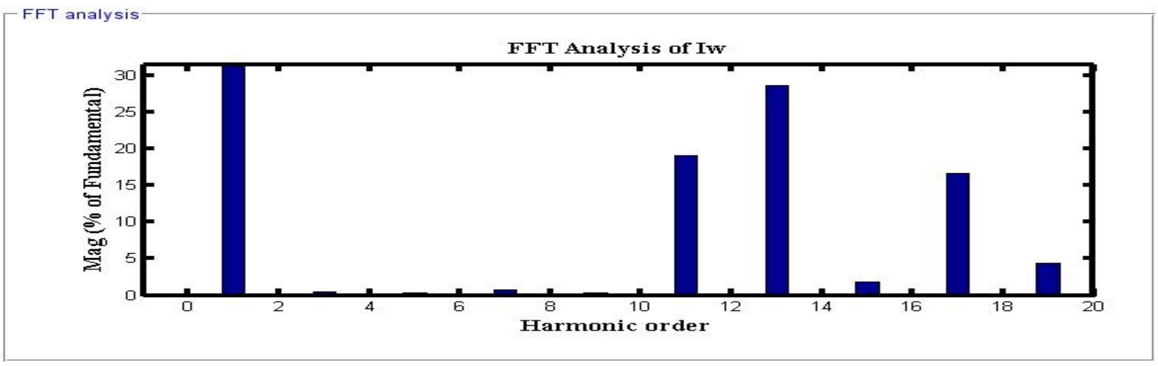

Figure 7. FFT analysis of (I_w)

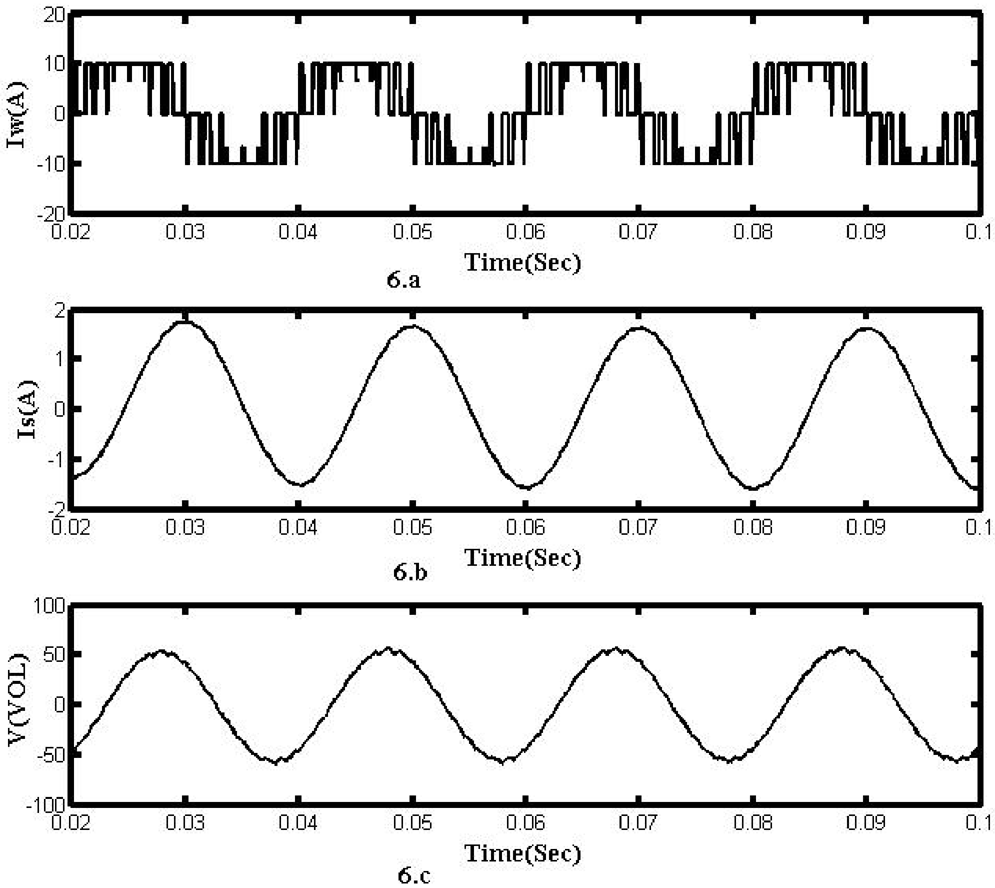

Figure 8. Simulation Results for Three Harmonic Elimination (5 th, 7 th, 11 th). A.Inverter output Current (Iw) b. Load Current (Is) C. Line to Line Voltage (V)

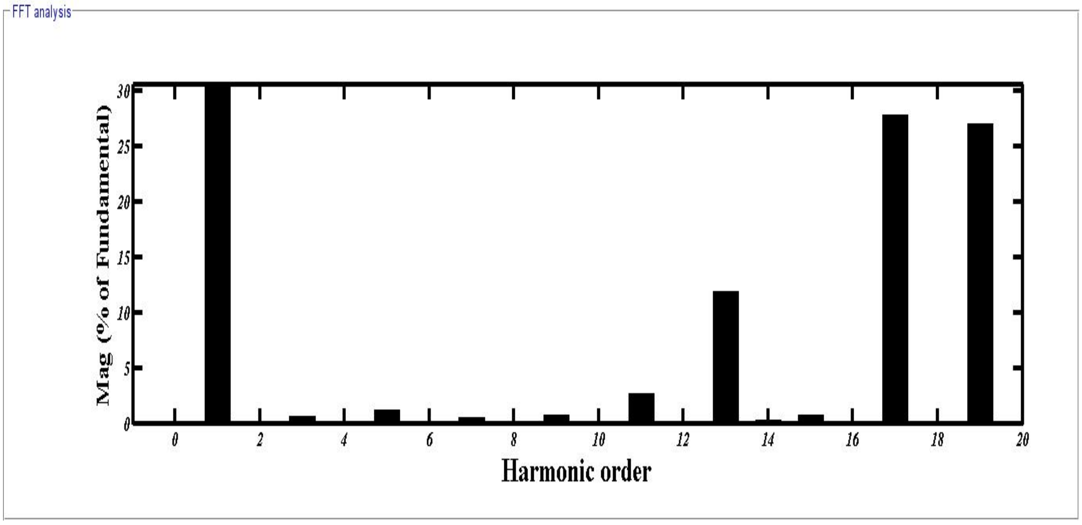

Figure 9. FFT analysis of (*Iw*)

Results that has been achived for eliminate different harmonics by implemention CSO with SHE algorithm, be showed. These angles are optimized value that has been achived with CSO algorithm.

Table 1. Optimized Value for switching angle in SHE Algorithm

Harmonic to be Eliminated	Switching Angles		
	$\theta 1$	$\theta 2$	$\theta 3$
5	17.15	-	-
7	20.56	-	-
11	23.75	-	-
13	25.6	-	-
5,7	7.85	14.2	-
5,11	13	19.5	-
5,13	14.75	22	-
7,11	15.21	19.45	-
7,13	16.23	21	
5,7,11	2.42	5.8	21.43
7,11,13	9.6	11.72	24.13
5,11,13	7.62	10.82	23.4

4. CONCLUSION

As simulation result showed, by tuning selected angles in optimized value, THD of the output current is better then arbitariry chosen values and quality of CSI output is improved.this verifies effectiveness of the Selected Harmonic Elimination (SHE) with Cat Swarm Optimization (CSO). CSO can be applied to any problem where optimization is required.therefore it can be applied in many usage in power electronic and power marketing.the comparation of the results in this paper with similar work in other literature show CSO algorithm befit for optimization issues [12]-[15].

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