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A COMPARATIVE STUDY OF HARMONIC ELIMINATION OF CASCADE MULTILEVEL INVERTER WITH EQUAL DC SOURCES USING PSO AND BFOA TECHNIQUES

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ABSTRACT

In this paper harmonics are eliminated using a eleven level inverter with equal separate DC sources using two heuristic techniques, which can be considered from the drives of renewable energy sources. Different nonlinear transcendental equations are solved for harmonic elimination problem but there is a limitation of contemporary computer algebra software tools using the resultant method. Here to solve this problem two proposed methods are applied in a simpler manner. We are using particle swarm optimization and bacteria foraging optimization algorithm for minimization of harmonics from multilevel inverter and also a comparative analysis is done.

KEYWORDS: Harmonics, Equal Voltage Source, Cascade Multilevel Inverter, Particle Swarm Optimization, Bacteria Foraging Optimization Algorithm

According to IEEE standards [1] harmonics should be always limited below its threshold value. Filtering is one of the method to limit the harmonics. but due to certain disadvantages different techniques have been adapted to cancel out high amplitude harmonics. One of the method is programmed harmonic elimination with multilevel inverter which does not require high frequency switching [2] as required by PWM techniques. Due to this reason multilevel inverter is more suitable in high power application. For high power ratings and high quality output waveforms, multilevel voltage source inverters are suitable configuration[3].Among different topologies cascade multilevel invertes are very efficient due to its modularity and simplicity control The operational principle of this inverter is normally based on how to synthesize the required output voltage waveform from different steps of voltages from dc voltage sources. In a cascade multilevel inverter if 's' number of single phase full-bridge inverters are used then it will generate a (2s+1) number of levels. For controlling the output voltage and eliminating the undesirable harmonics in multilevel inverters with equal dc sources different modulation methods such as sinusoidal pulse width modulation (SPWM), space vector PWM techniques are suggested in [4] and [5].In Selective harmonic elimination techniques by choosing suitable switching angles some specific order of harmonics such as 5th, 7th, 11th, and 13th are suppressed in the output voltage of the inverter[6].This method required the arithmetic solution of nonlinear transcendental equations which contain trigonometric terms. By using iterative technique as Newton–Raphson method we can solve the set of nonlinear equations. But this technique required a good initial guess which should be very close to the exact solution pattern and also this method can find only one set of solution depending upon the initial guess. So this method is not the perfect one to solve the SHE problem for large number of switching angels. In this the asymmetry of the transcendental equation set are solved and the simulation results for an 11-level cascaded multilevel inverter are discussed and a comparative analysis is done among these methods

CASCADE MULTILEVEL INVERTER

A cascade H-bridge inverter can be designed by connecting number of single phase H-bridge inverter in series as shown in Fig. 1.This is modular and the number of levels can be extended as per the requirements. It is supplied from several separate dc sources (SDCSs. One SDC is connected to one single phase H-bridge inverter and it can generate three different output voltage, +Vdc, 0, and –Vdc. The dc output can be converter to ac by different connection of 4 switches of the inverter. The desired output voltage waveform can be get by connecting the single H-bridge inverter in series and the synthesized waveform is the sum of all of the individual output waveform. .Level of inverter can be calculated by the formula: n=2s+1.where "s" is number of individual source connected (Fig a, b).

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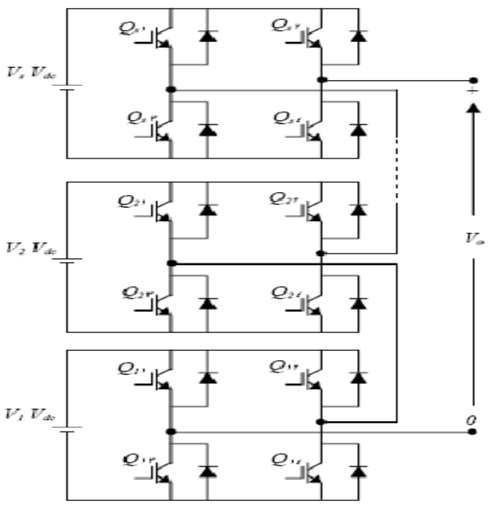

Figure (a)

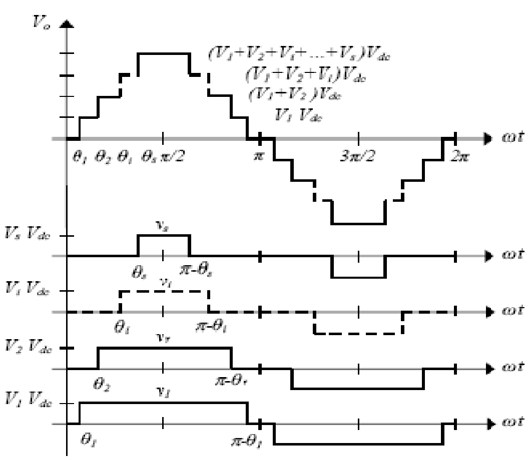

Figure (b)

A.PROBLEM FORMULATION

Assuming the equal DC source is applied to each of the inverter and taking into consideration the characteristics of the inverter waveform Fourier series expansion of stepped output voltage waveform of the multilevel inverter with equal dc sources can be expressed as:

$$Vo(\omega t)=\sum_{n=1,3,5}^{\infty}\frac{4vdc}{n\pi}\{\cos(n_{\varphi}1)+\cos(n_{\varphi}2)+\cos(n_{\varphi}3)+\cos(n_{\varphi}4)+\cos(n_{\varphi}5)\}\sin(\omega t) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where vdc is the nominal dc voltage.Equation (1) has 5 variables (φ1, φ2, φ3, φ4, φ5) .

Where 0< φ1< φ2< φ3< φ4< φ5<π/2. and a set of solutions is obtainable by equating s-1 harmonics to zero and assigning a specific value to the fundamental component, as given below:

$$\cos(\varphi 1)+\cos(\varphi 2)+\cos(\varphi 3)+\cos(\varphi 4)+\cos(\varphi 5)=m$$

$$\cos(3\varphi 1)+\cos(3\varphi 2)+\cos(3\varphi 3)+\cos(3\varphi 4)+\cos(3\varphi 5)=0$$

$$\cos(5\varphi 1)+\cos(5\varphi 2)+\cos(5\varphi 3)+\cos(5\varphi 4)+\cos(5\varphi 5)=0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

$$\cos(n\varphi 1)+\cos(n\varphi 2)+\cos(n\varphi 3)+\cos(n\varphi 4)+\cos(n\varphi 5)=0$$

Where m = V1/(4Vdc/π) and the modulation index ma=m/S.

For 11 level inverter where S=5, 3rd ,5th ,7th ,9th order harmonics will be eliminated if single phase Supply is given. In 3 phase case triple harmonics are eliminated automatically.

An fitness function is then needed for the optimization procedure. In this paper the fitness Function which is to be minimized is the total harmonics distortion (THD). The fitness function is given by:

$$f(t)=\frac{\sqrt{\sum_{n=3,5,7}^{49}(Vn)^2}}{V1} \quad \ldots 3$$

Where V1 is the fundamental voltage and Vn is the nth order harmonics voltage.

PARTICLE SWARM OPTIMIZATION

Particle Swarm Optimization was developed in 1995 by Kennedy and Eberhart.This optimization is a stochastic optimization algorithm which based on social simulation model .in this algorithm a population size is considered which are moving stochastically in different search space. The best position attainted by each individual from its own experience is retained in memory. This algorithm was developed by the social behavior of swarm particles such as bird flocks, fish schools, and animal herds.

PSO ALGORITHM FOR MINIMIZATION OF THD

Let Vi = [Vi1, Vi2, . . . , Vis] be a trial vector representing the ith particle of the swarm to be evolved. The elements of Vi are the solutions of the harmonic minimization problem, and the dth element of that is corresponding to the dth switching angle of the inverter. The step-by-step procedure to solve the SHE problem with equal dc sources is as follows.

1. Get the data for the system. At the first step, the required parameters of the algorithm such as population size M, maximum iteration number intermax, etc., are determined and the iteration counter is set to iter = 1.
2. Generate the initial conditions of each particle. Each particle in the population is randomly initialized between 0 and π/2; similarly, the velocity vector of each particle has to be generated randomly within −Vmax and Vmax.
3. Evaluate the particles. Each particle is evaluated using the fitness function of the harmonic minimization problem. the cost function is given as follows:

$$f(t) = \frac{\sqrt{\sum_{n=3,5,7}^{49}(Vn)^2}}{V1}$$

4. Update the personal best position of the particles. If the current position of the ith particle is better than it's previous personal best position, replace Pi with the current position Xi. In addition, if the best position of the personal bests of the particles is better than the position of the global best, replace Pg with the best position of the personal bests.
5. Update the velocity and vectors. All particles in the population are updated by velocity and position update rules (4) and (5), respectively.
6. Termination criteria. If the iteration counter iter reaches itermax, stop; else, increase the iteration counter iter = iter + 1 and go back to step(3).

BACTARIA FORAGING OPTIMIZATION ALGORITHM

Passino proposed Bacteria Foraging Optimization Algorithm (BFOA) in 2002. This algorithm was developed by the foraging technique (searching of food) of group of E-coli bactaria. To maximize the energy obtained per unit time these bactaria searching their nutrients in a particular manner. Each individual bacterium communicates with others by sending signals. A bacterium takes foraging decisions after considering two previous factors. One is chemotactic movement-this is the small steps taken by bacterium for searching nutrients. Another one is modification of algorithm in future.

BFOA ALGORITHM FOR MINIMIZING THE THD

Let Vi = [Vi1, Vi2,…… Vis] be a trial vector representing the ith bacterium step of the swarm to be evolved. The elements of Vi are the solutions of the harmonic minimization problem, and the dth element of that is corresponding to the dth switching angle of the inverter. The step-by-step procedure to solve the SHE problem with equal dc sources is as follows.

1. Get the data for the system. at the first step the required parameters of the of the algorithm such that chemotactic step, reproduction count, elimination dispersal count is set to 1.
2. Generate the initial condition of each bacterium. Each bacterium step in the population is randomly initialized between 0 and л/2. Similarly the direction vector of each bacterium randomly generated within –V_{max} and V_{max} .
3. Each bacterium is evaluated by using objective function of the harmonic minimization problem i.e THD.

$$f(t) = \frac{\sqrt{\sum_{n=3,5,7}^{49}(Vn)^2}}{V1}$$

4. Generate the random vector Δ(i) with each element Δm(i),m=1,2,……….. Vis a random number on [-1,1].update the step of the bacterium .compute the objective function. If the current step is better than the previous then replace the step with current one. This will continue till the maximum chemo tactic step.
5. For the given reproduction count and elimination dispersal count for each bacteria the minimum objective function value find out. Sort bacteria and chemotactic parameters c(i) in order of ascending cost f(t) .the bacteria with highest f(t) values die and the remaining bacteria with best values split. This will be continued till maximum reproduction count.
6. For i= 1,2,3 eliminate and disperse each angel. To do this if a angel is eliminated simply disperse another one to a random location. And calculate the objective function value to get a minimum value. if the elimination dispersal count reaches its maximum value stop else increase the dispersal count and go back to step (3).

EXPERIMENTAL RESULT

For Particle Swarm Optimization

In order to validate the computational result as well as the simulations, experimental results are presented for a single phase 11 lavel cascade H-bridge inverter. The program was developed in matlab and the fitness function i.e the THD was minimized. The THD result up to 49th harmonics was calculated with a supply voltage of 12V. The THD result upto 49th harmonics is 6%.The angle for which this result has come is as below.

$\theta_1=5.2338^0$, $\theta_2=16.3852^0$, $\theta_3=30.9033^0$, $\theta_4=42.9065^0$, $\theta_5=62.6564^0$.

The fourier transform analysis has done and the figure c & d is shown below:

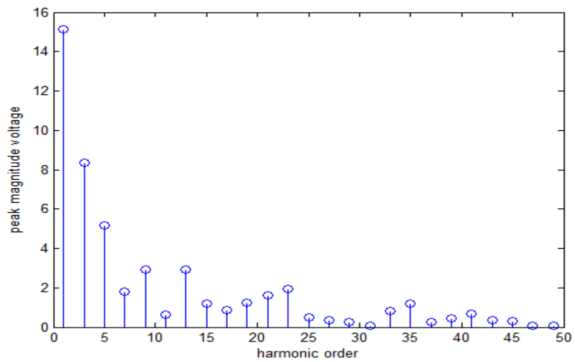

Figure (c) FFT analysis for module index 0.8

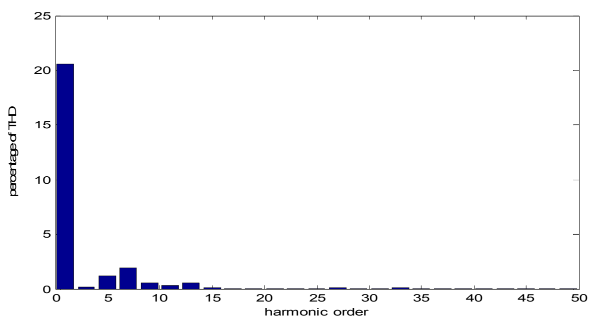

Figure (d) FFT analysis with percentage of THD

For Bacteria Foraging Optimization Algorithm

The THD result up to 49th harmonics was calculated with a supply voltage of 12V. The result is given below.

THD=7.2% The angle for which this result has come is as below.

$\theta_1 = 8^0$ $\theta_2 = 24^0$ $\theta_3 = 29^0$ $\theta_4 = 49^0$ $\theta_5 = 63^0$.

The fourier transform analysis has done and the figure e & f is shown below

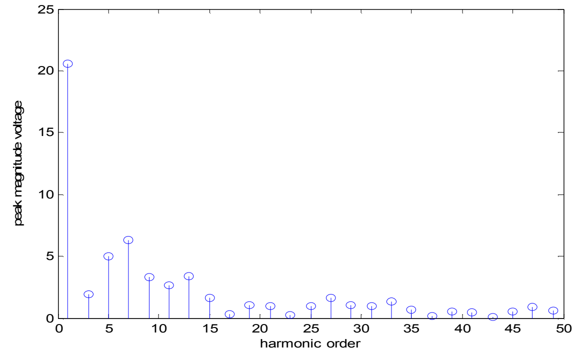

Figure (e) FFT analysis for module index 0.8

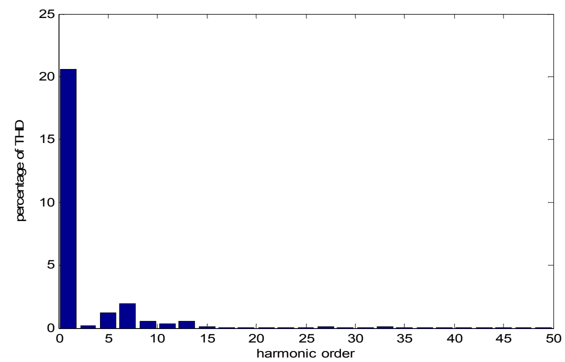

Figure (f) FFT analysis with percentage of THD

Simulation Result

To validate the computational results for switching angles which was found out from the program a simulation is carried out in MATLAB/SIMULINK software for an 11-level cascaded H-bridge inverter. The nominal dc voltage is considered to be 12 V and with modulation index 0.8 the line voltage waveform was shown (Fig g, h).

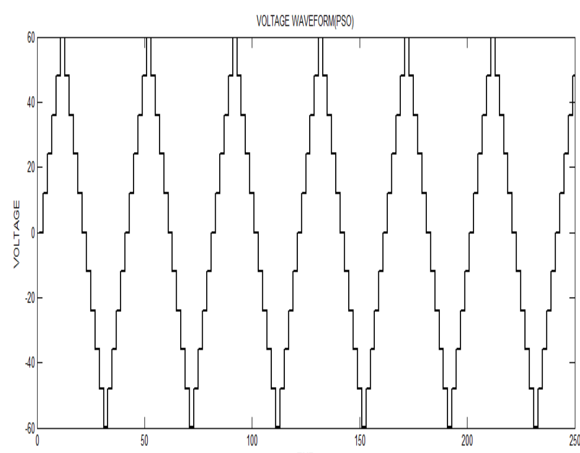

Figure (g) Output Voltage waveform (PSO Techniques)

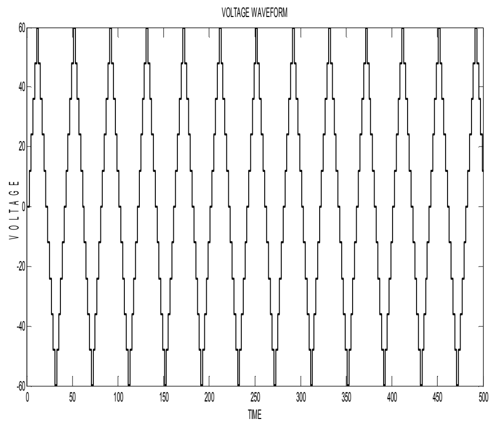

Figure (h) Output Voltage waveform (BFOA Techniques)

CONCLUSION

In this paper programs are developed on different heuristic technique to solve the SHE problem with equal D.C sources in H-bridge cascade multilevel inverter. The PSO and BFOA techniques presented in this thesis achieve this objective and includes:

1. Development of algorithm for minimization of THD.

2. Application of this algorithm in multilevel inverters with equal dc sources which are used in power system to convert the dc power to ac power.

3. Development of simulation to validate the result.

This concludes that when the resultant approach reaches the limitation of contemporary algebra software tools, the proposed methods are able to find the optimum switching angles in a simple manner. The simulation and experimental results are provided for an 11-level cascaded H-bridge inverter to validate the accuracy of the computational results. From the experiment we found that the percentage of THD is more in BFOA technique than that of PSO technique.

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