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Design of LCL filter for renewable energy sources using Bacterial Foraging Optimization

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Abstract: As the traditional resources have become rare, renewable energy sources are developing quickly. The grid connected renewable sources is one of the most importance problem in smart grid fields. To reduce harmonic in this grid, many filter techniques have been developed. Compared traditional L filter, a LCL filter is more effective on reducing harmonic distortion at switch frequency. So, it is important to choose the LCL filter parameters to achieve good filtering effect. In this paper, a design method of LCL filter by bacterial foraging optimization is proposed. Simulation result and calculate data are provided to prove that the proposed method is more effective and simple than traditional methods.

Keywords: Renewable energy sources, Smart grid, LCL filter Bacterial foraging optimization**.**

I. INTRODUCTION

Voltage-source PWM method has many advantages such as bidirectional power flow, controllable power factor and sinusoidal input current. A PWM converter with higher switching frequency will result in smaller LC filter size. However, switching frequency is generally limited in high power applications. As an alternative solution, LCL filter is more attractive for two reasons: [1]

- It has better attenuation than LC filter given the similar size.
- LCL filter provides inductive output at the grid interconnection point to prevent inrush current compared to LC filter.

In 2005, Marco Liserre presented a step by step design method to design the LCL filter [2]. But the method is complicated.

Recently, artificial intelligence has become a popular search technique used in computing to find exact or approximate solutions to optimization and search problems. There are many kinds of artificial intelligence and Genetic Algorithm (GA) is used mostly[3]. Genetic algorithms are a particular class of evolutionary algorithms the use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover [4]. It becomes successful because of its concise arithmetic describing. On the other hand, as natural selection tends to eliminate animals with poor foraging strategies through methods for locating, handling, and ingesting food and favor the propagation of genes of those animals that have successful foraging strategies. Based on this conception, Passino proposed an optimization technique known as the Bacterial Foraging Optimization (BFO). The BFO mimicking biological bacterial food-searching behavior has been applied in the field of optimization. Optimization methods inspired by bacteria can be categorized based on the chemotaxis algorithm and bacterial foraging algorithm. The chemotaxis algorithm was proposed for analogy to the way bacteria to react chemoattractants in concentration gradients. The bacterial foraging algorithm is based on bacterial chemotaxis, reproduction and elimination-dispersal events and has been variously applied to some problems such as optimal control design [5], harmonic estimation [6], transmission loss reduction [7], active power filter synthesis[8], and learning of artificial neural networks [9]. This paper presents a new design method of LCL filter using bacterial foraging optimization.

II. SIMPLIFIED DESIGN PRINCIPLE OF LCL FILTER

The Three-phase Voltage Source PWM converter with LCL filter is shown in Fig.1. The filter has three unknowns, L_1,C_f and L_2. In the following, three considerations that lead to three equations for determining the three unknowns will be discussed.

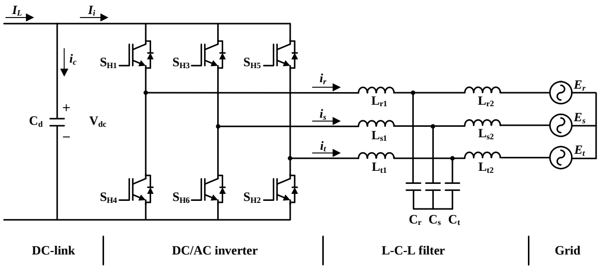

Fig.1. Topology of three phase VSC with LCL filter

The traditional design method can be calculated by following equations[4].

$$L_1 = \frac{V_g}{2\sqrt{6}\, f_s i_{ripple,peak}} \tag{1}$$

$$C_f \le 0.05 C_b \tag{2}$$

$$C_b = \frac{1}{(\omega_n Z_b)} \tag{3}$$

$$Z_b = \frac{V_{gLL}^2}{P_n} \tag{4}$$

V_g is the RMS value of grid voltage, f_s is inverter switching frequency, is the base capacitance, Z_b is base impedance, V_{gLL} is grid line voltage and P_n is inverter rated power.

$$C_f = 0.025 C_b \tag{5}$$

The grid side inductance of LCL filter L_2 is computed as follow.

$$L_2 = 0.8 L_1 \tag{6}$$

III. BACTERIAL FORAGING OPTIMIZATION

Search and optimal foraging of animals can be used for solving engineering problems. To perform a social foraging, an animal needs communication capabilities and it gains advantages to 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 [10].

1. Optimization Function for the Bacterial foraging

For applying the bacterial foraging to optimization problem, conventional BFO was described as following [11].

In the minimal problem, the main goal of the BFO based algorithm is to find the minimum of $J(\theta), \theta \in R^p$ not the gradient $\nabla J(\theta)$. Here, θ is the position of a bacterium, and $J(\theta)$ denotes an attractant-repellant profile. That is, where nutrients and noxious substances are located, $J(\theta) < 0$, $J(\theta) = 0$, $J(\theta) > 0$ represent the presence of nutrients, neutral medium, and noxious substances, respectively. On the other hand, the population of bacteria can be defined by

$$P(j,k,l) = \{\theta^i(j,k,l) \mid i = 1,2,\cdots,S\} \tag{5}$$

where $\theta^i(i,j,k)$ represents the position of each member in the population of the S bacteria at the jth chemotactic step, kth reproduction step, and lth elimination-dispersal event. Let $J(i,j,k,l)$ denote the cost at the location of the ith bacterium $\theta^i(i,j,k) \in R^p$ and the bacterial position after the next chemotactic step can be represented by

$$\theta^i(j+1,k,l) = \theta^i(j,k,l) + C(i)\phi(j) \tag{7}$$

where $C(i) > 0$ is the size of the step taken in the random direction specified by the tumble. If the cost $J(i,j+1,k,l)$ at $\theta^i(j+1,k,l)$ is better than at $\theta^i(j,k,l)$, then another chemotactic step of size $C(i)$ in this same direction will be taken and repeated up to a maximum number of steps N_s which is the length of the lifetime of the bacteria as long as it continues to reduce the cost.

During the process of chemotactic, the bacterium which has searched the optimal position tries to provide an attractant or repellent signal for the swarm behaviors of a group. Function $J_{cc}^i(\phi)$, $i = 1,2,\ldots,N$, to model the cell-to-cell attractant and a repellant effect is represented by

$$J_{cc}(\theta, P(j,k,l)) = \sum_{i=1}^{S} J_{cc}^i(\theta, \theta^i(j,k,l))$$
$$= \sum_{i=1}^{S}\left[-d_{attract}\exp\left(-\omega_{attract}\sum_{m=1}^{p}(\theta_m - \theta_m^i)^2\right)\right] + \sum_{i=1}^{S}\left[-h_{repellant}\exp\left(-\omega_{repellant}\sum_{i=1}^{p}(\theta_m - \theta_m^i)^2\right)\right] \tag{8}$$

where $\theta=[\theta_1,\ldots,\theta_p]^T$ is a point on the optimization domain, θ_m^i is the *m*th component of the *i*th bacterium position, $d_{attract}$ is the depth of the attractant released by the cell, $\omega_{attract}$ is a measure of the width of the attractant signal, $h_{repellant}=d_{attract}$ is the height of the repellant effect magnitude, and $\omega_{repellant}$ is a measure of the width of the repellant. Therefore, the final cost at the location of the *i*th bacterium $\theta^i(i,j,k)\in R^p$ reflecting the effect of an attractant and repellant can be defined by

$$J(i,k,k,l)+J_{cc}(\theta,P) \tag{9}$$

After chemotactic steps, a reproduction step is taken. The bacteria with the highest J values (low fitness cost) die and the other bacteria having lower values J (high fitness cost) split into two bacteria, which are placed at the same location, and then elimination-dispersal events is carried out. In these events, each bacterium in the population is subjected to elimination-dispersal with probability. Here, it is noted that each bacterium has the same predefined probability of elimination-dispersal events.

2. Design of LCL filter parameters by Bacterial foraging optimization.

In this paper, the structure of bacterial position is presented as follows.

$$X=[L_1\ \ L_2\ \ C_f] \tag{10}$$

This paper uses harmonic attenuation rate which is defined is equation (11) as the fitness function. To achieve good filter effort, a low harmonic attenuation rate is required

$$\frac{i_g(h_{sw})}{i(h_{sw})}=\frac{z_{LC}^2}{\left|\omega_{res}^2-\omega_{sw}^2\right|} \tag{11}$$

$$\omega_{res}^2=\frac{L_T z_{LC}^2}{L_1},\quad L_T=L_1+L_2,\ z_{LC}=\frac{1}{L_2C_f}$$

$$\omega_{sw}^2=(2\pi f_{sw})$$

VI. SIMULATION RESULTS

This paper uses MATLAB/SIMULINK to simulate photovoltaic(PV) generation systems. Table1 and Table 2 show simulation parameters for PV and Bacterial foraging optimization. Table 3 shows simulation results by the traditional method and BFO.

Table 1. Simulation parameters

Parameter	Values
Inverter Power (P_n)	100kW
Utility line (V_{gLL})	600V
Utility frequency(f_n)	60Hz
Switching frequency (f_{sw})	4.5kHz
DC rated voltage (V_{dc})	1225V
Current(i)	96A (rms)

Table 2. Simulation parameters for BFO

	Parameter	Value
S	The initial bacteria population size for BPO	300
N_c	Chemotactic steps	
N_{re}	The number of reproduction steps	
N_{ed}	The number of elimination-dispersal events	
P_{ed}	Elimination-dispersal with probability,	
C	The step size for a swimming bacteria	

Table 3. Simulation results

Methods	L_1	L_2	C_f	fitness(F)
Traditional method	1.1mH	0.3mH	13.24uF	0.085
BFO	2.32mH	1.03mH	14.24uF	0.035

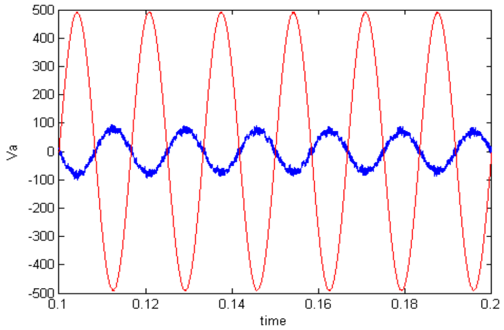

Fig.2. Converter current and voltage by traditional method

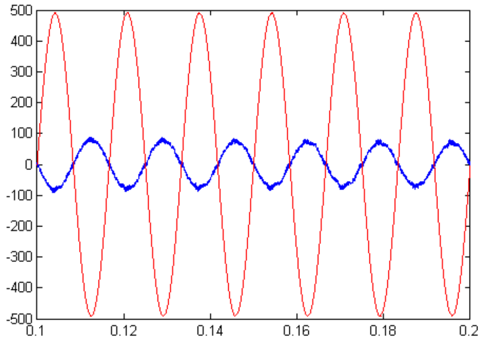

Fig.3. Converter current and voltage by Bacterial Foraging Optimization

Fig. 2 shows converter current and voltage by traditional method and Fig. 3 shows converter current and voltage by BFO. Table 3 and Fig. 3 show that the proposed method is better than traditional method

VI. CONCLUSION

As the traditional resources have become rare, renewable energy sources are developing quickly. The grid connected renewable sources is one of the most importance problem in smart grid fields. To reduce harmonic in this grid, many filter techniques have been developed. In this paper, a design method of LCL filter by bacterial foraging optimization is proposed. Simulation result and calculate data are provided to prove that the proposed method is more effective and simple than traditional methods.

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REFERENCES

[1]Wang, T.C.Y. Zhihong Ye Gautam Sinha Xiaoming Yuan(2003), Output filter design for a grid-interconnected three-phase inverter. Power Electronics Specialist Conference :779-784.

[2] M. Liserre, F. Blaabjerg, S. Hansen (2005), Design and Control of an LCL-filter based Three-phase Active Rectifier. IEEE Trans. Industry Applications : 1281-1291.

[3]Z. Wang, D. Cui(2004), Optimization Design Based on Genetic Algorithm for Rectifier. Trans. Of China Electrotechnical Society[J] 19(5): 7-9.

[4]Wei Sun, Zhe Chen and Xiaojie Wu(2009), Intellignet Optimize Design of LCL filter for Three-Phase Voltage-Source PWM Rectifier. IPEMC 2009 : 970-974:

[5]D. Kim, A. Abraham, and J. Cho(2007),A hybrid genetic algorithm and bacterial foraging approach for global optimization," Information Sciences(177) :3918-3937

[6]S. Mishra(2005), A hybrid least square-fuzzy bacterial foraging strategy for harmonic estimation," IEEE Transactions on Evolutionary Computation(9): 61-73

[7]M. Tripathy, S. Mishra, L. Lai, and Q. Zhang, "Transmission loss reduction based on facts and bacteria foraging algorithm," Lecture Notes in Computer Science, vol. 4193, p. 222, 2006.

[8]S. Mishra and C. Bhende(2007), Bacterial foraging technique-based optimized active power filter for load compensation. IEEE Transactions on Power Delivery(22) : 457-465.

[9]J.H. Cho, M.G Chun, and D.J Lee(2007), Parameter Optimization of Extreme Learning Machine Using Bacterial Foraging Algorithm. International Symposium on Advanced Intelligent Systems : 742-747.

[10]W. O'brien, H. Browman, and B. Evans, "Search strategies of foraging animals," *American Scientist*, vol. 78, pp. 152-160, 1990.

[11]K. Passino, Biomimicry of bacterial foraging for distributed optimization andcontrol. *IEEE Control Systems Magazine*(22): 52-67..