Application of Artificial Bee Colony Algorithms in Smart Grid

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Abstract: The operation of modern society cannot be separated from the power network. The power output from power stations is transmitted to all walks of life through the power network. The same people's activities are inseparable from electricity. In recent years, the scale of the power grid has become larger and larger, and communication technology and control technology have also developed rapidly. The emergence of smart grid is to meet the needs of users, optimize resources, balance supply and demand relations, etc. The development of artificial bee colony algorithm also provides a new dispatching method for smart grid. This paper studies the application of artificial bee colony algorithm in fault location of distribution network, so as to make the smart grid develop better.

1. Introduction
Smart grid is a large power system with real-time, changing, real-time interaction of energy flow and information flow. It integrates modern sensing, communication, automation and other technologies, has real-time monitoring function, keeps abreast of the operation status of equipment, and relies on the advanced information processing ability of modern computers to make the most reasonable choice for various complex situations in the actual power system. It guarantees the quality of electric energy, greatly enhances the security, reliability and economy of power grid, provides cleaner energy for users, and achieves the goal of environmental friendliness.

Ant colony algorithm is an optimization algorithm which imitates the process of ants searching for food in nature. Ants leave pheromone substances on the way to find food. Pheromones attract subsequent ants to choose this path. The more pheromones there are, the more ants they attract, thus forming a positive feedback mechanism, and the concentration of pheromone will dissipate over time. The steps of ant colony algorithm to solve the problem are: initialization, building system model and ant colony selection path. Ant colony algorithm is widely used in combinatorial optimization problems. Therefore, the application of artificial ant colony algorithm in smart grid will make the power system more efficient and make the grid more secure and stable.

2. Artificial bee colony algorithm

2.1 Basic principles of artificial bee colony algorithms
For a global minimum optimization problem described by formula 1, when the artificial bee colony algorithm is used to solve the optimization problem, there is a corresponding relationship between the algorithm model and the function optimization problem as shown in Table 1. The feasible solution of the problem is the same as the food source, and the continuous update of the solution in the iteration process is the same as the bee's constant search for the food source. The higher the quality of food
source, the better the solution. At the same time, the quality of food source is evaluated by the corresponding fitness function.

\[
\begin{align*}
\min \{ f(x) &= f(x_1, x_2, \ldots, x_n) : x \in S \subseteq R^n \} \\
X_i(x_1, x_2, \ldots, x_n)' &\in S
\end{align*}
\]  

(1)

Among them, \( f(x) \) denotes the objective function, \( D \) denotes the dimension of solution space, and \( N \) denotes the number of variables to be optimized.

Table1. Relationship between optimization problem and honey harvesting process

| Honey Collection Behavior of Bee Colony | Optimization problem |
|----------------------------------------|----------------------|
| Food Source Location                   | Feasible Solution    |
| The Benefit Degree of Food Source      | Quality of Feasible Solutions |
| Finding Food Sources and Speed of Honey Collection | Speed of Solution |
| Maximum Benefit Location of Food Sources | Optimal Solution |

2.2 Standard artificial bee colony algorithm
In ABC algorithm, artificial bee colony has three roles: leader, followers and scouts. Leading bees exploit nectar in search space, that is, to find the optimal solution, while leading bees to record information about food sources. The following bee chooses to lead the bee by roulette selection strategy and collects honey nearby. When the leading bee abandons the food source, it becomes the Scout bee to search for food again. In practical optimization problems, the location of honey source represents the feasible solution of optimization problem, and the abundance of honey source represents the quality of solution. In the process of bee colony search, the initial solution \( X_i(i = 1,2,\ldots,SN) \) is produced in the search space, and \( SN \) is the number of honey sources. Each initial solution \( X_i \) is a vector of \( d \) dimension. Then, the pilot bee searches according to Formula 2:

\[
V_{ij} = x_{ij} + R_{ij}(x_{ij} - x_{kj})
\]  

(2)

\( V_{ij} \) is the location of a new food source, \( R_{ij} \) is a random number in the range of \([-1,1]\), \( k \in \{1,2,\ldots,SN\} \), and \( k \neq i; j \in \{1,2,\ldots,d\} \). After the search, the optimal solution and the search solution are compared, and the optimal solution is replaced when the search solution is better than the optimal solution. On the contrary, the optimal solution remains unchanged.

2.3 Adaptive Cauchy mutation artificial bee colony algorithm
When the fitness of the pilot bee \( X_i \) remains unchanged after successive iterations of \( Limit \) times, the pilot bee becomes a reconnaissance bee. Cauchy distribution is introduced into the search formula of reconnaissance bees in order to improve the perturbation ability of the algorithm, make it easier for artificial bees to jump out of local extremum, make full use of the information currently searched, and improve the search efficiency. Cauchy distribution is a kind of common distribution in probability theory and mathematical statistics. Fig. 1 is the curve of probability density function of standard Cauchy and standard Gauss distribution. Fig. 1 shows that the peak value at the origin of Cauchy distribution is smaller than that of Gauss distribution in order to improve the perturbation ability, and the speed at which the shape of long and flat ends tends to zero is slower than that of Gauss distribution, which makes the algorithm easier to avoid premature phenomena.
3. Application of artificial bee colony algorithms in smart grid

3.1 Distribution network fault location based on standard bee colony algorithm

In the process of fault location based on intelligent algorithm, a function is needed to give full play to the function of link section state and switch state, which is the switch function. The switching function reflects the relationship between the fault of the line section and the over current of the switch. It transforms the state information of the line section into the expected state information of the switch in the distribution network, and then uses this information to best approximate the current limit information of the switch reported by FTU, which is the process of fault location. The fault location process consists of two stages. Firstly, some sections that have not been faulted are identified, and the number of these sections is stored with a vector No-fault. Then, the artificial bee colony algorithm is used to optimize the status of the remaining sections and find the fault sections. Because the switching function of the section to be determined may be related to the section that has been determined to be fault-free, it is necessary to take them into account when calculating the switching function by inserting a new vector into the individual of the algorithm population and then calculating the switching function. Artificial bee colony algorithm can accurately locate fault intervals, and has good fault tolerance in the case of a small amount of information distortion, which shows the feasibility and effectiveness of the artificial bee colony algorithm to solve the problem of fault location, and broadens the application field of the algorithm.

3.2 Distribution network fault location based on improved bee colony algorithm

Standard bee colony algorithm has the advantages of few parameters and easy implementation, but like other intelligent algorithms, it also has the drawbacks of easy falling into local optimum. Moreover, the randomness of bee colony algorithm is strong, and it does not use the information of the current optimal solution, so it has the drawback of slow convergence speed. The improved bee colony algorithm divides into several sub-groups and iterates independently and exchanges information with each other. The leading bees of each sub-group have different methods to search for new individuals in the field. When the bee chooses food sources, the operation of individual concentration calculation is increased, and then the selection probability is obtained by concentration calculation. The simulation results of the improved bee colony algorithm and the standard algorithm are compared. The four standard tests are Sphere function, and Rastrigin function. When their variable space is two-dimensional, the three-dimensional images in MATLAB are shown in Figure 2 (a), (b), respectively.
Figure 2. MATLAB simulation results

The simulation results of the standard test function show that the convergence accuracy, convergence speed and stability of the improved bee colony algorithm are better than those of the standard bee colony algorithm.

4. Conclusions
Artificial intelligence technology has made great progress in recent years and is widely used in various fields. Applying artificial bee colony algorithm to smart grid will solve many problems that are difficult to solve in traditional grid, and make the power market develop better. For example, the application of fault location in distribution network studied in this paper will make the operation of power network more efficient and better serve the people.

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