Application of firefly algorithm of solving distribution network reconfiguration

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Abstract: In this paper, according to the characteristics of distribution network reconfiguration. A Novel Firefly Algorithm was used to solve distribution network reconfiguration, the algorithm was experimented and the experimental results show that the new algorithm to be successful. Simulations and results indicate that the novel firefly algorithm has better feasibility and validity for solving distribution network reconfiguration.

1. Introduction

Distribution network reconfiguration is defined as altering the topological structures of distribution feeders by changing the open/closed states of the sectionalizing and tie switches. It can not only alter the load level of the feeders, but also improve the voltage profile along the feeders and reduce the loss reduction of the whole system. Thus, reconfiguration is vital to the reliability and security of the distribution system.

Subject to operational and multi-objective constraints, the reconfiguration problem is a large scale nonlinear combinatorial optimization problem. The number of the optimization variables, switches is huge, which will lead to combination explosion. If there are α switches in the system, α^2 possible solution will exit. Some of these solutions will cause isolation of part of a feeder or loop systems, and other solutions violate the operational constraints. Changing the states of the switches will alter the operating conditions of the overall system.

So far, researchers have done a lot of work in distribution network reconfiguration and many algorithms have been proposed. Generally speaking, there are two typical kinds of solutions: the first one is heuristic search method[1,2,3], which is easy understanding、simple and fast. But the methods may lead to local optimal solutions. The second one is humane intelligence algorithm, such as Genetic Algorithm (GA) 、Artificial Neural Networks (ANN)、Tabu Search algorithm(TS) 、plant growth simulation algorithm(PGSA), which is more likely to obtain the global optimal solution.

GA can be applied to ill-structured discrete optimization problems and it searches from a population of points, many researchers apply it to the distribution network reconfiguration problem. The literature 4 describes the problem as a mixed integer programming problem, it firstly use GA to solve the problem. Ref. The literature 5 and the literature 6 refine GA in coding method and crossover and mutation pattern. ANN [7,8] can be used on-line and don't require the load flow solution or evaluation of the loss reduction by branch exchange, but the results depend on the training sets. TS [9,10] is paid high focus on for its local search and up-hill ability. But a large number of infeasible candidates would be produced if coding scheme is impertinent. Ref. introduces PGSA into distribution reconfiguration algorithm.

In this paper, a novel firefly algorithm was used to solve distribution network reconfiguration. The proposed method has been programmed and tested by IEEE 33 bus distribution system. And it is verified that not only the proposed method is both globally optimized and feasible, but also the calculation efficiency is obviously improved.

2. The basic principle of the firefly algorithm

2.1 The bionics principle of algorithm

The firefly algorithm is the development of simulating biological characteristics of l the adults firefly, but the algorithm abandons some biological significance of luminous firefly, the firefly searches partners according to the search area only using the emission properties, and the firefly moves to position better firefly in the neighborhood structure, so as to realize the position evolution. In this algorithm, the firefly attracts one another reason depends on two factors, namely, its brightness and attraction. Among them, the firefly fluorescence brightness depends on the location of the target value, the brightness higher the location of the target value the better. The more light of fireflies has more attractive, it can attract brightness than its weak firefly in sight range to the direction of movement. If the fireflies have the same brightness, then they randomly move. The brightness and attraction are inversely proportional to the distance of the fireflies, they have increased as the distance decreases, which is equivalent to the simulation of the fluorescence characteristics of propagation in the space by the media absorption and fading. The firefly algorithm is adopted to simulate the firefly group behavior to construct a class of stochastic optimization algorithm. The bionic principle is: The points in the search space simulate the nature of firefly individuals, the search and optimization process simulation to attract and movement of the firefly individuals, the objective function of solving the problem is measured into the pros and cons of the location of the individual, the fittest of individual process for search and optimization process of a good analogy of feasible solutions to replace less feasible solutions.

2.2 Mathematical description and analysis of the algorithm

As mentioned above, the firefly algorithm includes two factors: the brightness and the degree of attraction. The brightness of the firefly reflects the pros and cons of location and determines its direction of movement, attraction degree determines the distance of the firefly mobile, constantly update the brightness and the attraction degree, so as to realize the goal of optimization. From a mathematical perspective describes the Firefly algorithm optimization mechanism, the description as follows[11,12].

(1) The relative fluorescence intensity of fireflies as:

$$h = h_0 / (1 + z r_{ij}^2) \tag{1}$$

Among them: h_0 for the maximum fluorescence intensity of fireflies, that is itself (r=0) fluorescence brightness, associated with the value of the objective function, the objective function value is better, its brightness is higher; z as the light absorption coefficient, because the fluorescence decreases with the increasing of distance and media absorption [13], so set the light absorption coefficient to reflect this characteristic, it can set to constant; r_{ij} is the space distance of the firefly i and the firefly j.

(2) The firefly attraction degree is:

$$\rho = \rho_0 * e^{-z r_{ij}^2} \tag{2}$$

Among them: ρ_0 as the biggest attraction, namely the light source (r=0) attraction degree; z, r_{ij} meaning as above.

(3) The firefly i is attracted to move to the firefly j, the location update by formula (3) decision.

$$x_i^{'} = x_i + \rho * (x_j - x_i) + \alpha * (rand - 1/2) \tag{3}$$

Among them: $x_i^{'}$ is the individual i towards a brighter individual j update location, x_i, x_j are the firefly i and the firefly j located before the entire population renewal; α is the step factor, it is constant between 0 and 1, *rand* is a random factor between 0 and 1,it obeys uniform distribution.

The process of optimization algorithm is: Firstly, the firefly populations randomly scattered in the solution space, each firefly has different fluorescence brightness at different positions, by comparing Eq.1, high brightness fireflies can attract low brightness fireflies to move, moving distance depending on the size of the attraction (according to Eq.2). In order to increase the search area, avoid getting into local optimization, and updated measures, according to the formula 3 to calculate the updated position. So by repeatedly movement, all individuals will be gathered in the highest brightness firefly position, so as to realize the optimization.

At present, it has been found that many insects existing Levy flight [14], and Levy flight has been used in the field of optimization, and achieve the expected effect. In order to enhance the algorithm global search performance, avoid the population into a local optimum in the search process, in the firefly algorithm, if the individual is no better than their individual, choose to Levy flight instead of random flight in the original algorithm. In addition, the non - optimal those individuals in a population, the flight formula was improved: when they find more bright than their individual, first generates a random number q by the system, if q is less than 0.5, the formula (4) is updated; otherwise, still use the formula (3) to update the individual position.

$$x_i^{''} = x_i^{'} + \rho * (x_j - x_i^{'}) + \alpha * (rand - 1/2) \qquad (4)$$

Among them,: x_j still expresses renewal position of individual j before the entire population, $x_i^{'}$ expresses the individual i toward the front of j-1 individuals than their bright individual after the update new position, $x_i^{''}$ expresses $x_i^{'}$ toward than their bright individual j after update location, ρ expresses that individual j appeal to the individual i. As can be seen, formula (4) is updated in real time, formula (3) depends only on the entire population before moving. This flight update can increase the randomness of flight, It is helpful to keep the diversity of population, increasing the population search space.

In order to accelerate the convergence of the population, the paper proposes a method of α updating, which α gradually decreases with increasing number of iterations. Update formula is as follows:

$$\alpha = \alpha_0 - e^{-0.001*t} \qquad (5)$$

In the formula (5): α_0 is 0.9, t is number of iterations.

The concrete steps of the algorithm are as follows:

1) Initialization the basic parameter of algorithm. Set the number of fireflies is s, the biggest attraction is ρ_0, light absorption coefficient is z, the random parameters is α_0, the maximum number of iterations is t_{max}=1000, the evolving algebra t=0.

2) Randomly initialization firefly position, calculate the objective function value of firefly as the respective maximum fluorescence intensity of h_0.

3) By formula 1 and formula 2 to calculate the relative brightness of h and attraction ρ, according to relative brightness of h to decide the movement direction of the firefly.

4) The formula 5 is used to update α, the individual, if there is more lighter than its individual, in accordance with the update is improved, by formula (4) to update the individual position; otherwise, the Levy flight is used to update the individual location.

5) According to the updated firefly position, to recalculate brightness of the firefly.

6) The system generates a random number, if the random number is less than the local search probability p, then local search of individuals of the population, and regenerate population.

7) Determine whether meet the conditions of termination of the algorithm. Such as the maximum number of iterations t_{max} is1000 or best solution stagnation does not change, turn to step 7, or t = t+1, turn to step 3.

8) Output global extreme value point and optimal individual value.

3. TEST RESULTS

The section gives two examples of the method, and theresults of the reconfiguration.

Figure 1show a typical distribution network with 69 buses. The total power loss is shown in Figure 2 which is the results of loss calculation using the method presented in this paper based on the geometric network distribution model. Through the results, we can easily find the weak location of DN which is used for decision supporting and next switch change states for next reconfiguration.Figure 3 shows a typical three-power distribution system structure with 3 contact breakers. Using the algorithm mentioned above Table 1 shows the results of the power loss calculation and distribution network reconfiguration.

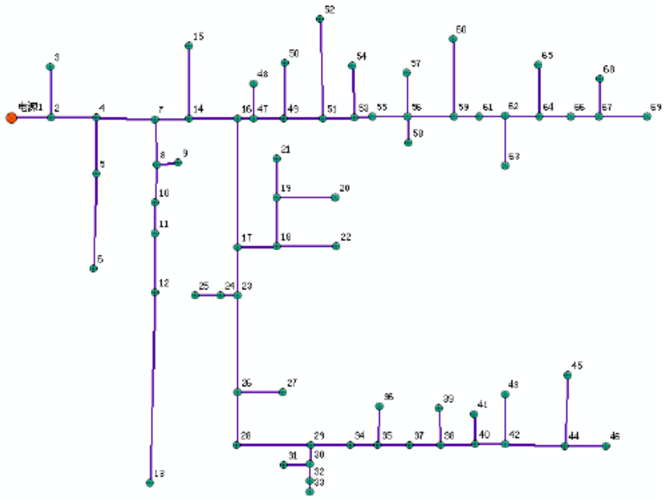

Figure1. IEEE 69 bus sample system

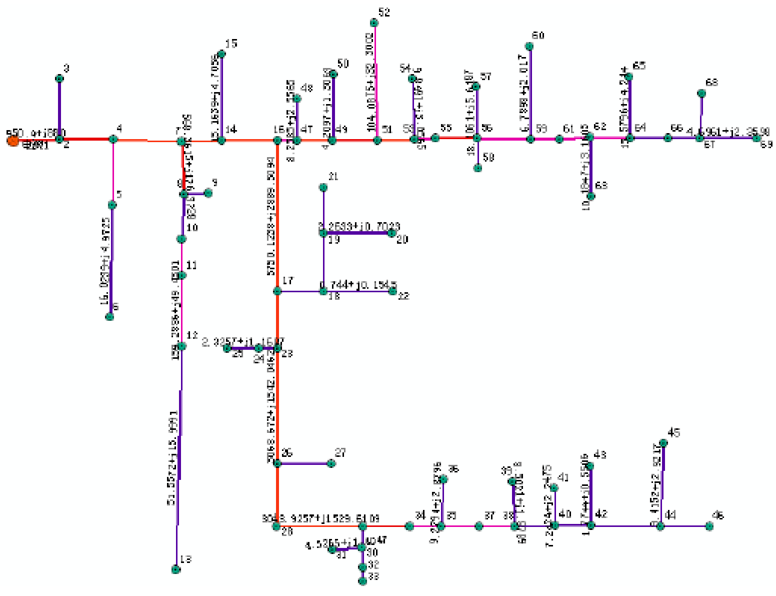

Figure 2. Results of power loss calculation on GIS for IEEE 69 bussample system

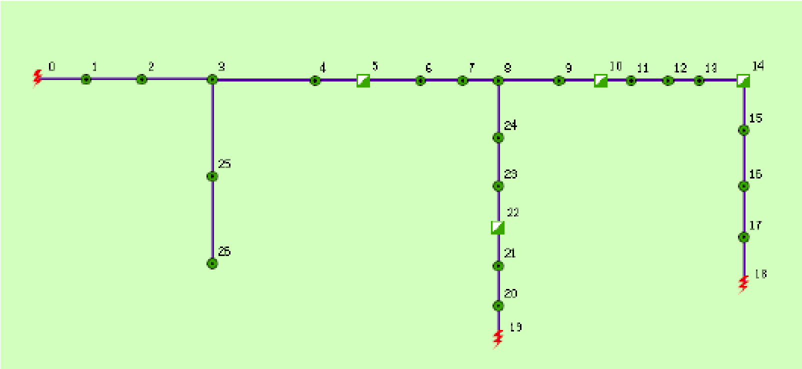

Figure3. A typical three-power distribution system structure

Table 1 Line loss calculation results for switch combinationSwitch combinationsLine losses （KVA）

Switch5	14closed	Switch10	22opened	62.6
Switch5	22closed	Switch10	14opened	98.23
Switch14	22closed	Switch5	10opened	101.85
Switch5	10closed	Switch14	22opened	47.61
Switch10	22closed	Switch5	14opened	63.03

4. Conclusions

This paper proposes an improve firefly algorithm, the redesign of the individual location update in the algorithm, and introduced a Levy flight to increase the population search domain. The improve firefly algorithm is applied to solve distribution network reconfiguration, the performance has been improved obviously, the improvement is more obvious. Experiments show that: the algorithm is feasible and effective for solving distribution network reconfiguration.

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