ISSN 2616-7433 Vol. 2, Issue 13: 111-117, DOI: 10.25236/FSST.2020.021315

Enhanced quantum-behaved particle swarm optimization algorithm for power system dispatch problem

Gu Zheng, Yang Bo, Liu Songnan

State Grid Liaoning Electric Power CO, LTD. Power Electric Research Institute, Shenyang, Liaoning110015, China

ABSTRACT. *In this paper, a modified quantum-behaved particle swarm optimization (QPSO) method is proposed to solve the problem. The proposed method, denoted as RPQPSO, combines the QPSO algorithm with random perturbation operation to enhance the global search ability of the algorithm. The perturbation strategy adopts two methods to perturb each particle in the group according to the random probability at the late stage of evolution, so that the algorithm avoids falling into the local optimum. The simulation results show that the proposed RPQPSO method is able to obtain higher quality solutions in the ED problem than any other tested optimization algorithm.*

KEYWORDS: *Economic dispatch; constrained optimization; random perturbation; evolutionary computation; particle swarm optimization*

1. Introduction

From the perspective of mathematical modeling, the ED problem can be described as a quadratic programming problem with certain constraints. A variety of mathematical programming methods, such as lambda iteration method, gradient method, and dynamic programming, are often used to solve such problems. However, none of these traditional methods can get the optimal solution, because they all use local search techniques and usually fall into the local optimum. On the other hand, the ED problem has the characteristics of discreteness, high dimensionality, nonlinearity, and multiple constraints, which make the solution method of the ED problem have great limitations.

The literature proposed a genetic algorithm based on lambda to solve the ED problem. In large-scale systems, this method is faster and more robust than lambda iteration. The literature proposes a genetic algorithm and an improved genetic algorithm to solve the ED problem[1-3].

The result is better than the dynamic programming method. The literature uses an improved genetic algorithm with multiplier updating to solve the ED problem with valve point effect and multiple fuels. The literature proposes a PSO method to solve

ISSN 2616-7433 Vol. 2, Issue 13: 111-117, DOI: 10.25236/FSST.2020.021315

the ED problem of the power system. The results show that the PSO method can obtain a higher quality solution to the ED problem than the GA method. The literature uses a dynamic search space reduction strategy to accelerate the optimization process of the PSO method to solve the ED problem. The literature applies the QPSO algorithm to the solution of the ED problem, and obtains better results than PSO and other algorithms on 3 test sets. Although intelligent algorithms have made significant progress in solving ED problems, there are also problems such as premature convergence and insufficient group diversity. Compared with previous research, a QPSO with Random Perturbation (RPQPSO) based on QPSO is proposed, and the applicability of RPQPSO in solving ED problems is discussed. Compared with GA, PSO and QPSO, this method can find a better solution in the tested power system[4-5].

2. Mathematical model of economic dispatch

ED studies a problem of power resource optimization. Under the premise of ensuring that each unit in the system runs within its own physical characteristics and is safe and stable, the power output of each unit in the system is rationally allocated to reduce network losses, so that the entire system can meet production requirements. At the same time as life needs, the total fuel consumption is the least, and the total power generation cost of the system is the least. The ED problem requires comprehensive consideration of multiple equations and inequalities such as network loss, power balance constraints, unit power range, unit power forbidden area, etc[6].

Under the constraint of formula, the objective function (total cost of the system) is minimized.

$$\sum_{i=1}^{N_g} P_{Gi} = P_D + P_L$$

$$P_{Gi}^{\min} < P_{Gi} < P_{Gi}^{\max},\ i = 1,\ 2,\ \cdots,\ N_g$$

$$P_i^{\min} \leqslant P_i \leqslant P_{i,1}^{l}$$

$$P_{i,j-1}^{u} \leqslant P_i \leqslant P_{i,j}^{l},\ j = 2,\ 3,\ \cdots,\ n_i$$

$$P_{i,n}^{u} \leqslant P_i \leqslant P_i^{\max}$$

$P_i^{\min}$, $P_i^{\max}$ means the minimum and maximum output power of the i-th unit; $P_{i,j}^{l}, P_{i,j}^{u}$ means the minimum and maximum values of the j exclusion zone of the i unit.

GA is one of the most popular evolutionary algorithms that imitate the natural selection process. It is a population-based heuristic algorithm that generates optimal solutions to optimization problems through multiple iterations. The steps of genetic

ISSN 2616-7433 Vol. 2, Issue 13: 111-117, DOI: 10.25236/FSST.2020.021315

algorithm include initial population generation, fitness function estimation, iteration process and termination condition checking. PSO is an evolutionary calculation method based on swarm intelligence, which is inspired by biological behaviors, such as fish flocking and bird gathering. In the particle swarm optimization system, each particle corresponding to a biological individual is a candidate solution for the current problem. The particles in the population fly around in the multi-dimensional search space, searching for optimal or suboptimal solutions through competition and cooperation between them. Experiments have proved that the PSO algorithm has comparable performance to the GA algorithm.

The disadvantage of the PSO algorithm is that it is not a global optimization algorithm, and it is easy to fall into premature convergence in the later stage, which has limitations. In order to better solve this problem, Sun Jun et al. proposed in 2004 the concept of quantum behavioral particle swarm optimization algorithm is called QPSO algorithm. In the QPSO algorithm, the search space and solution space of the problem are two different spaces. The search space of a single particle in each iteration is the entire feasible solution space of the problem. The experimental results show that QPSO is in several the benchmark function is better than the standard PSO.

In the iterative process of the QPSO algorithm, the evolution of each particle depends on two main factors: ①pi,j(t), the optimal position of the particle itself and the optimal position of the entire particle swarm are standardized and randomly; ② mbestj(t) － xi,j(t), the global average optimal position of the particle and the particle[7-9].

The difference between the child’s previous experience. By sharing group information, the algorithm continuously corrects the gap between the previous experience of particles and the advantage information, thereby forming a continuously optimized search mechanism to find the optimal solution. In the QPSO algorithm, when the particles continue to evolve, all particles tend to be concentrated in a specific position, or it can be a few specific positions, the group diversity is inevitably reduced, and the algorithm is easy to fall into a local optimal solution. Improved quantum particle swarm algorithm RPQPSO is based on the QPSO evolution model and introduces a random perturbation strategy. In the later stage of evolution, each particle in the swarm is perturbed according to the random probability p. This strategy helps to increase the diversity of the population and avoid the algorithm falling into the local optimum. This article uses two strategies to perturb each particle. In the first strategy, the particle can adjust its behavior according to the difference between its own optimal position and the optimal position of the entire particle swarm, that is, the perturbation step is set to gbestj(t)-pbesti, j(t). In the second strategy, inspired by the random walk strategy in the bat algorithm, an optimal solution is randomly selected from the current optimal solution, and the optimal solution is used as the step size to update the particle position. This has been proved The method can effectively jump out of the local optimal solution and obtain the global optimal solution. Based on the idea ofthis algorithm, the perturbation step size can be set to the average optimal position best to update the particle position. Based on the above two strategies, the particles are updated iteratively according to the

ISSN 2616-7433 Vol. 2, Issue 13: 111-117, DOI: 10.25236/FSST.2020.021315

following equation during random disturbance.

3. Performance test of RPQPSO algorithm

A set of standard test functions F={f1 (x), f2 (x) ,..., f5(x)} are used to test the RPQPSO algorithm to verify the performance of the algorithm. The performance of RPQPSO algorithm is compared with GA algorithm, PSO algorithm and QPSO algorithm. The software and hardware operating environment of all algorithms are consistent: Matlab 7.0, Windows XP; Inter Core I3; 4G RAM. For each standard test function, each optimization method performs 2 sets of experiments under the same calculation scale (set to 20 000): In one set, the number of particles is m = 100, and the maximum number of iterations MAXITER = 200; in the other set, the particles The number m = 20, the maximum number of iterations MAXITER = 1 000. For each standard test function, each optimization method performs 100 independent runs using the given m and MAXITER. The parameter settings of each method are: For the GA algorithm, the crossover probability pc and the mutation probability pm are set to 0.25 and 0.1 respectively; for the PSO algorithm, w linearly decreases from 0.9 to 0.4 according to the number of evolutions, and Set c1 = c2; For the QPSO algorithm, α1 and α2 are set to 1.0 and 0.5, which means that α decreases linearly from 1.0 to 0.5; for the RPQPSO algorithm, the disturbance probability p is set to 0. 6. The value of parameter α is the same as the value in the QPSO algorithm. Each test function runs independently 50 times, and after 50 experiments, the optimal value, average optimal value and standard deviation of each test function are obtained.

Experimental results show that the standard deviation of the RPQPSO algorithm is optimal for all test functions, which shows that the stability of the RPQPSO algorithm is the best. Therefore, the RPQPSO algorithm has achieved the best results on the 3 indicators of the 5 test functions, obtained the highest average accuracy, and is the most stable. Use the five standard benchmark functions in Table 1 to study the influence of the disturbance rate p on the overall performance of the algorithm, and find that the value of p is 0.4 to 0.8, which is suitable for most test situations.

4. RPQPSO algorithm solves ED problem

The power generation of each unit is defined as a certain coordinate component of a particle, so that the power generation of all units in the entire system constitutes a particle coordinate position. Each particle in the particle swarm represents a candidate solution to the ED problem. For example, if there are Ng units (the number of units), then the i-th particle Pgi can be defined as:

$$P_{gi} = [P_i, 1, P_i, 2, \ldots, P_{i,j}, \ldots, P_i, N_g], i = 1, 2, \ldots, m$$

Where: m is the number of particles; j is the unit number; Pi, j is the power output of the i-th particle in the j-th unit.

In order to evaluate the performance of the proposed RPQPSO algorithm in solving ED problems, the RPQPSO algorithm was compared with three existing

ISSN 2616-7433 Vol. 2, Issue 13: 111-117, DOI: 10.25236/FSST.2020.021315

intelligent algorithms: GA algorithm, PSO algorithm and QPSO algorithm. The experimental hardware and software configurations are as the previous RPQPSO algorithm. As described in the performance test.

According to the parameter settings and calculation scales of all methods described in the performance test of the RPQPSO algorithm above, the two penalty coefficients in the objective function are set as: penalty coefficient K1 = 100×t, t is the generated number; penalty coefficient K2 is one Very large number, set to 1000000.

The minimum cost unit dispatching scheme for all generating units: best fuel cost, best average cost, best maximum cost and lowest standard deviation. This shows that RPQPSO has achieved the best performance on this ED problem, and the lowest standard difference means that RPQPSO has the best robustness as showed in fig 1.

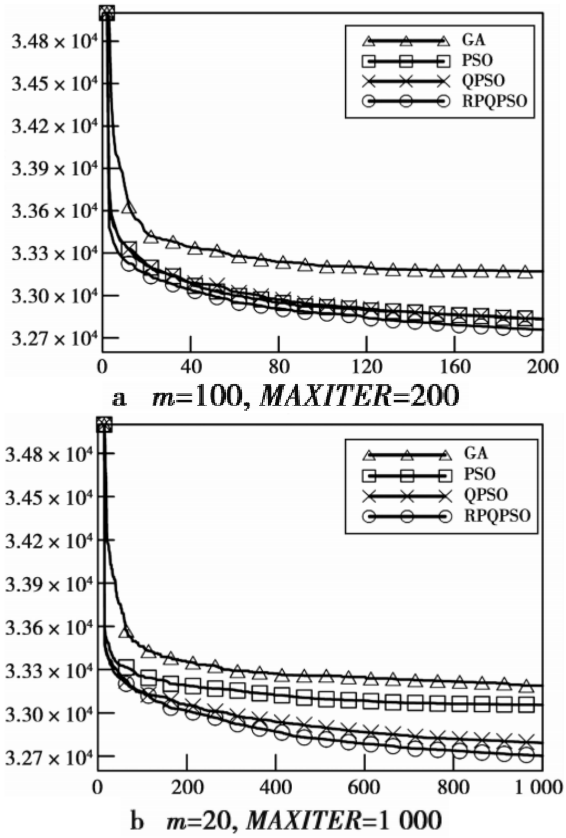

Fig.1. 15-Unit convergence of the system algorithm

ISSN 2616-7433 Vol. 2, Issue 13: 111-117, DOI: 10.25236/FSST.2020.021315

The proposed RPQPSO algorithm is applied to the ED problem of a typical power system, and the performance is compared with GA, PSO and QPSO algorithms. Experimental results show that the performance of GA algorithm and PSO algorithm is significantly lower than other test algorithms. GA algorithm is easy to converge prematurely, and the search efficiency is low in the later stage of evolution. PSO algorithm has strong search ability in the early stage of evolution, but it is easy to converge to the local optimal solution prematurely. The performance of QPSO algorithm is better than the above two algorithms. Pass in

The random perturbation strategy is introduced into QPSO, and the RPQPSO algorithm is superior to the QPSO algorithm in terms of solution quality, convergence and robustness. For the same power system, two sets of different scale tests were carried out. Comparing the results of the two sets of experiments, it is found that under the same number of iterations, the number of particles

Larger (m = 100, MAXITER = 200) experimental results are better, because the population diversity is relatively high. Therefore, combining the QPSO algorithm with a random perturbation strategy is of great significance for enhancing the global search ability and avoiding the algorithm from falling into the local optimal solution.

5. Conclusion

The economic dispatch of power systems is a basic problem in the optimal dispatch of power systems. The study of this problem is of great significance for reducing power generation costs and energy consumption in the construction of new urbanization. In this paper, the problem is mathematically modeled, taking into account many nonlinear characteristics of the generator, such as unit power forbidden zone, power balance and non-smooth cost function, etc., and an improved QPSO algorithm combining two random disturbance strategies is proposed. RPQPSO to solve the ED problem. Experimental results show that the RPQPSO algorithm is better than GA, PSO and QPSO in terms of high-quality solutions, robustness and good convergence. Based on these results, the RPQPSO algorithm provides an alternative method for solving the ED problem.

References

[1] Present Practices in the Economic Opera tion of Power Systems ［J］ IEEE Transactions on Power Apparatus ＆ Systems,1971,PAS-90(4) : 1768-1775.
[2] A Hybrid EP and SQP for Dynamic Economic Dispatch with Nonsmooth Fuel Cost Function［J］. IEEE Transactions on Power Systems,2002,17(2) : 411-416.
[3] A particle swarm optimization for economic dispatch with nonsmooth cost functions ［J］.IEEE Transactions on Power Systems,2005,20(1) : 34-42.
[4] Large-scale economic dispatch by genetic algorithm ［J］.IEEE Transactions on Power Systems,1995,10(4) : 1919-1926.
[5] Improved Genetic Algorithm for Power Economic Dispatch of Units With

ISSN 2616-7433 Vol. 2, Issue 13: 111-117, DOI: 10.25236/FSST.2020.021315

Valve-Point Effects and Multiple Fuels［J］.IEEE Transactions on Power Systems,2005,20(4) : 1690-1699.
[6]Particle swarm optimization to solving the economic dispatch considering the generator constraints［J］. IEEE Trans Power Syst 2003,18(3) : 1187-1195.
[7]Particle swarm approach based on quantum mechanics and harmonic oscillator potential well for economic load dispatch with valvepoint effects［J］.Energy Conversion ＆ Management,2008,49(11) : 3080-3085.
[8] A particle swarm optimization for economic dispatch with nonsmooth cost functions［J］.IEEE Trans Power Syst 2005,20(1) : 34-41.
[9] WANG D J,SUN J,XU W B. Quantum-behaved Particle Swarm Optimization for Security Constrained Economic Dispatch［C］/ /The fifth International Conference on Distributed Computing and Applications for business engineering and sciences. China,Hangzhou: Journal of Algorithms ＆ Computational Technology,2006: 42-46.