Solving Power System Economic Dispatch Problem Based on Genetic Algorithm

Yaming Ren

College of Mechanical and Control Engineering, Guilin University of Technology, Guilin, 541006, China.
Email: rym2002@163.com

Abstract. With the rapid development of the world economy, the demand for power load is also growing rapidly. The power system economic dispatch problem studied in this paper is to reduce the fuel cost of generator units on the premise of satisfying some series of constraints of power system. In this paper, genetic algorithm is adopted as the solution strategy for power system economic dispatch problem, and the penalty function is used to deal with the equality constraint condition in the power system economic dispatch problem. Finally, we use the genetic algorithm to solve the IEEE-9 notes power system economic dispatch problem and give the corresponding simulation results. The simulation results show that the genetic algorithm can solve the power system economic dispatch problem effectively.

1. Introduction

Electric power provides a strong guarantee for industrial stable production and plays an important role in promoting national economic development. Since the beginning of the 21st century, with the rapid growth of the world economy, the demand for electricity is also increasing. While meeting basic electricity needs, we also need to consider the economics of power system operation. Using the professional language in the field of power system is to minimize the fuel cost of generator units on the premise of satisfying some series of constraints of power system [1].

In this paper, we choose power system economic dispatch problem as our research object. The commonly used methods for this problem are mainly divided into two categories: iterative algorithm based on gradient information and intelligent algorithm. The iterative algorithm based on gradient information mainly includes interior point method [2] and quadratic programming, etc. The iterative algorithm based on gradient information converges quickly, but it is only suitable for solving convex optimization problems with unique extreme point. The advantage of intelligent algorithm is that it is simple to use and does not require the problem to have some special mathematical properties [3]. At the same time, the disadvantage of the intelligent algorithm is obvious: the accuracy of the results is not as good as the iterative algorithm based on gradient information. In terms of the solution in general engineering problems, we do not need to solve the exact optimal solution, only to require the solution to meet certain precision conditions. Therefore, this paper adopts the genetic algorithm theory to solve the power system economic dispatch problem.

The structure of this paper is organized as follows. In the second section, we introduce the mathematical model of the power system economic dispatch problem. In the third section, we introduce the genetic algorithm in detail and give the corresponding pseudo code. Finally, we take advantage of genetic algorithm to simulate.

2. The Mathematical Model of the Power System Economic Dispatch Problem

The aim of power system economic dispatch is to minimize the fuel cost of generator units under the constraints of various equations or inequalities. The mathematical model is expressed as follows [4, 5].

$$\begin{aligned} &\min F = \sum_{i=1}^{N} F(P_i) = \sum_{i=1}^{N} (a_i P_i^2 + b_i P_i + c_i) \\ &\text{s.t} \quad \sum_{i=1}^{N} P_i = P_D \\ &\qquad P_i^{\min} \le P_i \le P_i^{\max} \end{aligned} \tag{1}$$

Where the objective function is expressed as F; the fuel cost consumed by i-th unit is expressed by quadratic function, and the coefficient of quadratic function is expressed by a_i, b_i and c_i, what is more, the coefficients of a_i, b_i and c_i are given fixed values. The equality constraint indicates that the sum of active power emitted by all generators is numerically equal to the total load P_D of the power system. The inequality constraint condition represents the physical limit of the active power of generators, including the maximum active power limits $P_i^{\max}$ and the minimum active power limits $P_i^{\min}$ for the i-th generator.

3. Genetic Algorithm

Genetic algorithm is a parallel random search optimization method which simulates the genetic mechanism of nature and biological evolution. Genetic algorithm is proposed by professor Holland from the university of Michigan in 1962 firstly. Genetic algorithm introduces the biological evolution principle of survival of the fittest into the population. According to the principle of survival of the fittest, the operation of genetic algorithm includes population initialization, selection, crossover and mutation [6]. With the continuous evolution of the population, the fitness of the individual in the population is continuously improved until the evolution of the population meets certain conditions. In this section, we will introduce in detail on how to use genetic algorithm.

3.1. Population Initialization

The first thing we need to do when we use genetic algorithm is to generate the initial population of the problem. The common population coding methods of genetic algorithm include binary code, real code and reflected binary code. In this paper, the physical meanings of the variables we deal with are the active power output of the generator units. We further consider the description of variables in formula (1), which are continuous real numbers within a certain range. Therefore, we initialize variables in real code. We could write the initialization pseudo code as follow.

$$\text{Variables} = (\text{Ub}-\text{Lb})*\text{rand} + \text{Lb} \tag{2}$$

Where Ub represents the upper limit of the corresponding variable and Lb represents the lower limit of the corresponding variable; rand is a function in Matlab software and the function of rand returns a pseudorandom value drawn from the standard uniform distribution on the open interval (0, 1).

3.2. Selection

Selection means to choose individuals from the old population under certain rules. Individuals with the optimal fitness function have the highest probability of passing on genetic information to the next generation. In this paper, we use roulette to select individuals. In the roulette method, the probability of an individual being selected is positively correlated with its fitness. In other words, the greater the fitness function, the greater the probability of being selected. This is in conflict with the goal of our power system economic dispatch problem, our goal is to minimize the objective function. Considering the objective function of power system economic dispatch problem is positive in the range of variable feasible region, we do the inverse of the objective function: the new objective function is equal to the inverse of the original objective function. The smaller the value of the original objective function is, the larger the value of the newly generated objective function will be and the greater the probability of

Journal of Physics: Conference Series **1575** (2020) 012048 doi:10.1088/1742-6596/1575/1/012048

selection will be. The corresponding pseudo code for selected operation is shown in Table 1. The function of rand returns a pseudorandom value drawn from the standard uniform distribution on the open interval (0, 1). The function of sum returns sum along different dimensions of an array.

Table 1. The pseudo code for roulette selection

```
Input: fitness; population size(sizepop)
Output: the selected individual j
Fitness = 1./ fitness;
Sumfitness = sum(fitness);
sumf= fitness./sumfitness;
temporary variable1 = 0;
cumulative probability = [];
for i=1: sizepop
        temporary variable1 = temporary variable1 + sumf(i);
        cumulative probability = [ cumulative probability, temporary variable1];
end
for i=1: sizepop
        temporary variable2 = rand;
        for j=1: sizepop
            if temporary variable2 < cumulative probability[j]
               the j-th individual is the selected individual;
               break;
            end
         end
end
```

3.3. Crossover

The crossover operation simulates the phenomenon of reproduction in the process of biological evolution by the exchange and combination of two chromosomes to produce new individuals. We use random selection to choose the individuals. The corresponding pseudo code for crossover operation is shown in Table 2. The function of ceil(A) rounds the elements of A to the nearest integers greater than or equal to A. The function of rand returns a pseudorandom value drawn from the standard uniform distribution on the open interval (0, 1).

Table 2. The pseudo code for crossover

```
Input: probability of crossover (pcorss); population size(sizepop)
Output: the newly formed individual
pick = rand;
index1 = ceil(pick.*sizepop);
pick = rand;
index2 = ceil(pick.*sizepop);
pick = rand;
If pick < pcorss
       index1 individual= index1 individual * rand + index2 individual *(1- rand);
       index2 individual = index2 individual * rand + index1 individual *(1- rand);
else ;
end
```

3.4. Mutation

The mutation operation is used to simulate the genetic mutation caused by various accidental factors in the natural genetic environment, which randomly changes the genes with a small probability. Mutation operations increase the diversity of the population. Therefore, we can say that the mutation operation is helpful for the genetic algorithm to jump out of the local optimum and get the global optimal value more easily and the corresponding pseudo code for the mutation operation is shown in Table 3. The function of rand returns a pseudorandom value drawn from the standard uniform distribution on the open interval (0, 1).

Table 3. The pseudo code for Mutation

```
Input: probability of Mutation (pmutation); population size(sizepop)
Output: the newly formed individuals
pick1 = rand;
if pick1 < pmutation
Pick2 = rand;
if Pick2 > 0.5
        individual = individual - rand*( individual - lower limit of individual);
end
if Pick2 < 0.5
        individual = individual + rand*( upper limit of individual -  individual);
end
```

4. Simulated Analysis

4.1. Simulation Example

In this paper, we employ IEEE-9 notes system as simulation example. IEEE-9 notes system contains three generators and the information of generators is shown in Table 4. The total system load is 315MW.

Table 4. The data of Generators

Generator	Pmax(MW)	Pmin(MW)	*a*	*b*	*c*
1	10	250	0.11	5	150
2	10	300	0.085	1.2	600
3	10	270	0.1225	1	335

4.2. The Establishment of the Objective Function

According to the description of genetic algorithm, we find that genetic algorithm can effectively control variables within the upper and lower limits. However, the problems dealt with by genetic algorithm are unconstrained optimization problem and the power system economic dispatch problem involves an equality constraint. We introduce the concept of penalty function to deal with the equality constraints, and then formula (1) can be rewritten as follow.

$$\begin{aligned} &\min F = \sum_{i=1}^{N}(a_i P_i^2 + b_i P_i + c_i) + t\left|\sum_{i=1}^{N} P_i - P_D\right| \\ &\text{s.t} \quad P_i^{\min} \le P_i \le P_i^{\max} \end{aligned} \tag{3}$$

Where t is the penalty coefficient.

4.3. Simulation Result

In this paper, we set the maximum number of iterations as 100, population size as 100, crossover probability as 0.7, mutation probability as 0.03 and the penalty coefficient t as 100. The curve of the objective function changing with the number of iterations is shown in Figure 1 and the curve of the violation of the equality constraint condition with the number of iterations is shown in Figure 2. The optimal results of the IEEE-9 notes system are shown in Table 5.

Table 5. Simulation results

P1(MW)	P2(MW)	P3(MW)	Total cost($/hr)
81.2579	131.7491	101.9957	5146.4

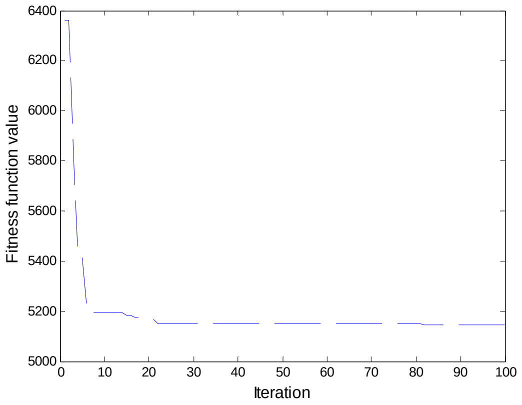

Figure 1. The objective function curve

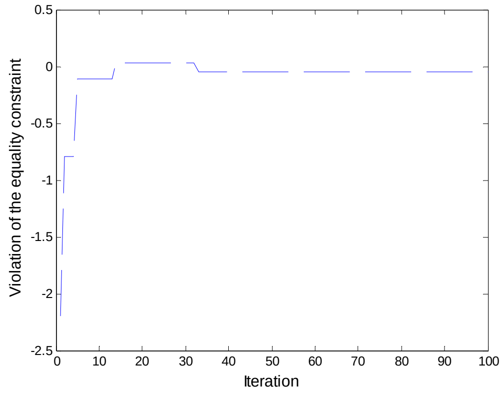

Figure 2. The equality constraint condition curve

5. Conclusion

In this paper, we first introduced the mathematical model of power system economic dispatch problem. After that, we introduced the origin of genetic algorithm and detailed the operation of genetic algorithm. Finally, in the section four, we adopt the method of penalty function to deal with the equality constraints and give the curve of the objective function changing with the number of iterations and the curve of the equality constraint condition changing with the number of iterations. The simulation results show that the genetic algorithm can solve the power system economic dispatch problem effectively.

6. Acknowledgments

The author is supported by Foundation of Guilin University of Technology (GLUTQD2018001).

7. References

[1] DAWN S, TIWARI P K, GOSWAMI A K. Efficient approach for establishing the economic and operating reliability via optimal coordination of wind–PSH–solar-storage hybrid plant in highly uncertain double auction competitive power market[J]. IET Renewable Power Generation, 2018,12(10): 1189-1202.

[2] XIE L, CHIANG H. Weighted Multiple Predictor-corrector Interior Point Method for Optimal Power Flow[J]. Electric Power Components and Systems, 2011,39(2): 99-112.

[3] LI R, PENG Y, SHI H, et al. First-order Difference Bare Bones Particle Swarm Optimizer[J]. IEEE Access, 2019,7: 132473-132491.

[4] TANG Y, LUO C, YANG J, et al. A chance constrained optimal reserve scheduling approach for economic dispatch considering wind penetration[J]. IEEE/CAA Journal of Automatica Sinica, 2017,4(2): 186-194.

[5] REN Y, FEI S, WEI H. The self-adaptive alternating direction method for the multiarea economic dispatch problem[J]. Turkish Journal of Electrical Engineering & Computer Sciences, 2016,24: 4611-4622.

[6] MOEINI-AGHTAIE M, DEHGHANIAN P, FOTUHI-FIRUZABAD M, et al. Multiagent Genetic Algorithm: An Online Probabilistic View on Economic Dispatch of Energy Hubs Constrained by Wind Availability[J]. IEEE Transactions on Sustainable Energy, 2014,5(2): 699-708.