# Research on Power Network Unit Commitment Optimization Based on Hybrid Intelligent Algorithm

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## Abstract

With the development of the market-oriented reform of the power industry, the task of unit combination optimization cannot be delayed. The unit combination problem is a large-scale, non-convex, discrete, nonlinear optimization problem. There are differences in the search mechanism and scope of each algorithm based on cluster intelligence, and the optimization effect of a single algorithm is not ideal, so think about two or more intelligent algorithms. In combination, the genetic particle swarm optimization algorithm is used to optimize the unit combination. The genetic algorithm is used to solve the unit combination. Then the particle swarm optimization algorithm is used to solve the load economic allocation and improve the optimization performance. Finally, the feasibility and effectiveness of the hybrid algorithm are verified by experimental analysis.

## Keywords

unit combination,genetic algorithm,particle swarm optimization algorithm,load economic distribution.

## 1. Introduction

In the early and long period of the unit combination, the minimum total operating cost target during the dispatch period; in the context of the market reform of the power industry, the optimization goal is to minimize the cost of purchasing electricity, maximize the total social income, and minimize emissions; When the combination problem is to estimate various requirements such as economy, network security and emissions, a multi-objective model emerges. The unit combination optimization problem includes two basic aspects, one is the unit combination, and the other is the unit load economic allocation [1]. The unit combination determines the operation mode of the unit at each time during the planning period under the constraints of the rotating reserve constraint and the minimum opening and closing time; the objective of the unit load economic allocation is to allocate the system load demand at each moment of the operation unit and minimize the system. Consumption [2]. Both the genetic algorithm [3] and the particle swarm optimization algorithm [4] belong to the bionic algorithm. The genetic algorithm is robust, and although the global optimal solution can be found with high probability, there is no way to guarantee [5]. The particle swarm optimization algorithm can be used to solve a large number of nonlinear, non-differential, non-convex, high-dimensional complex optimization problems. The particle swarm optimization technique produces high quality solutions that can be completed in a short computation time and have more stable convergence characteristics than other random search methods. However, its shortcoming is that it is easy to fall into local minimum points, and the search accuracy is not high [6]. On the basis of studying the basic principles of genetic algorithm and particle swarm optimization algorithm, the global optimization ability of genetic algorithm and the local optimization ability of particle swarm optimization algorithm are studied. The genetic particle swarm optimization algorithm is used to optimize unit combination, which can better solve the constraint. The problem is to avoid the use of hard constraints.

The optimization of the unit combination state is completed by the binary coding genetic algorithm. When setting the mutation operator, the energy-saving scheduling principle is fully embodied, that is, the unit is opened as much as possible, and the small unit is opened. On the basis of genetic algorithm optimization, the unit combination is obtained, and the particle swarm algorithm is used to realize the economic load distribution between the starting units.

## 2. Mathematical model of unit combination

### 2.1 Objective function

Unit combination optimization [7] is to rationally arrange the start and stop plan of the unit to minimize the total power generation cost of the system. The total power generation cost includes unit power consumption and unit start-up consumption. Therefore, the objective function of unit combination optimization is: $\min F = \sum_{t=1}^{T}\sum_{i=1}^{N}\left(F_{it}\left(P_{it}\right)+S_{it}\left(1-u_{it-1}\right)\right)\cdot u_{it}$ (1) where $u_{it}$ only accepts 0 and 1 values. $u_{it}=1$ indicates boot, $u_{it}=0$ indicates shutdown. $P_{it}$ is the active power of the unit i during the t period. $F_{it}\left(P_{it}\right)$ is the operating consumption of unit i, $F_{it}\left(P_{it}\right)=a_i+b_iP_{it}+c_iP_{it}^2$, $a_i$ , $b_i$, $c_i$ are operating characteristic parameters. $S_{it}$ is the starting consumption of the unit i during the t period, It is determined by $S_{it}=S_{0i}+S_{1t}\left(1-e^{\left(-T_{it}^{OEF/\tau_i}\right)}\right)$, $S_{0i}$ represents the start-up consumption of the turbine, generally a constant, $S_{1t}$ represents the start-up consumption of the boiler when it is started from a fully cooled state, and $\tau_i$ is the boiler cooling time constant.

### 2.2 Restrictions

(1). Power balance constraints

$\sum_{i=1}^{N}\left(P_{it}\right)\cdot u_{it}-P_{Dt}-P_L=0$ (2) where $P_L$ is the system loss of the t period.

(2). Unit technology output constraints

$P_i^{\min}\le P_{it}\le P_i^{\max}$ (3) $P_i^{\min}$ is the minimum output of the unit, and $P_i^{\max}$ is the maximum output of the unit.

(3). Rotation reserve constraint

$\sum_{i-1}^{N}\left(P_i^{\max}\right)\cdot u_{it}\ge P_{Dt}+P_{Rt}$ (4), $P_{Rt}$ is the rotating standby power.

(4). Minimum downtime

$T_{it}^{ON}>MUT_i;T_{it}^{OFF}>MDT_i$ (5), $MUT_i$, $MDT_i$ they are the minimum continuous running time and minimum continuous downtime of the equipment [8]. According to formula (1), the unit start-stop plan is the first to solve the unit combination problem. This is an integer programming problem. It can search for the feasible solution and output level of all units in a specific time period through a binary algorithm. At the same time, the planning unit must rotate the standby demand and independent constraints for a given period of time to meet the balance of the system.

## 3. Hybrid Genetic Particle Swarm Optimization Algorithm for Unit Commitment Optimization

### 3.1 Genetic algorithm and its improvement

Genetic algorithm is a numerical optimization algorithm that simulates the natural selection of organisms and the genetic mechanism of populations. It selects, crosses, and mutates according to the objective function. After repeated iterations, it gradually approaches the global optimal solution. The first step in solving a problem through genetic algorithms is to determine the coding scheme, and the nature of the problem and the genetic operators of the design greatly influence the choice of coding scheme. The combinatorial optimization problems all have different degrees of constraints. Therefore, in the specific implementation process of solving the combinatorial optimization problem algorithm, the main work is to design the genetic operator and select the coding scheme [9].

There are various constraints in the combinatorial optimization problem, so the feasible solutions must meet certain conditions. Individuals with traditional genetic operators such as crossover and mutation may no longer be feasible solutions. Moreover, due to various restrictions, crossover operators are easy to fall into. The local optimal solution in the solution process [10]. Although genetic algorithm is one of the best methods for solving combinatorial optimization, if only a single genetic algorithm is used for encoding, the constraints in the optimization problem cannot be fully expressed, and it is easy to prematurely converge and cannot guarantee convergence to the optimal solution. Therefore, the genetic algorithm should be improved.

The unit combination problem usually uses the 0-1 binary code to indicate the start and stop status of the unit. 0 in the matrix indicates the interruption of the unit, and 1 indicates the operation status [11]. The start and stop states of the crew during the entire dispatch cycle can be represented by a string containing 0 or 1. The dimension of each particle represents the optimal combination of N units in the scheduling period T period, and the state space of each particle is N*T.

By studying the characteristics of roulette, it is decided to adopt PK method and optimal retention strategy method, arbitrarily select two individuals in the father, compare their fitness values, select individuals with smaller fitness values, and the best individuals directly enter Child generation. Then cross in two steps, row crossing and column crossing [12]. After the column crosses, check whether the formula (4) is satisfied. If it is not satisfied, the operation is re-executed; after the line crossover, it is checked whether the formula (5) is satisfied, and if it is not satisfied, the crossover is cancelled.

In order to shorten the calculation time of the optimal solution and reflect the principle of energy-saving scheduling, this paper uses a two-step mutation operation [13]. Firstly, according to the principle of opening up large units as much as possible, the whole-day variation operation of the unit is given, and a certain probability p of the large unit is given. If the probability requirement is met, the closed state of the unit is turned off to start, and then the small unit is turned off in turn. If one is closed, check if the formula (4) is satisfied. If not, cancel the previous step and terminate the all-day mutation operation. Then enter the single point mutation operation to check whether the formula (4) (5) is satisfied during the compilation process.

### 3.2 Economic load distribution

The selection operation in the genetic algorithm requires the adaptation value of each individual [14], and the unit combination is obtained by the genetic algorithm, and then the power generation cost is calculated according to the load economic distribution result. $x, v = \left(p_{\min} + a\left(p_{\max} - p_{\min}\right)\right)u$ (6)

$p_{\max}$ and $p_{\min}$ are the upper and lower limits of the unit output; $a$ is the random number between (0,1), and $u$ is the unit status.

In the particle swarm algorithm, the velocity and position of the particle are initialized according to equation (6), and the particle velocity is updated according to equation (7). $v_{ij}(n) = w v_{ij}(n) + c_1 r_{1,i}(n)\left[p_{ij}(n) - x_{ij}(n)\right] + c_2 r_{2,i}(n)\left[p_j(n) - x_{ij}(n)\right]$ (7) $v_{ij}(n)$ is the velocity of the jth dimension of the particle i in the nth particle swarm; $c_1, c_2$ is the acceleration rate; $r_{1,i}(n)$, $r_{2,i}(n)$ is the random number on (0, 1); $p_{ij}(n)$ is the pole of the particle i in the nth particle swarm The value is in the j-dimensional position; $x_{ij}(n)$ is the position of the j-th dimension of the particle i in the n-th particle group; $p_j(n)$ is the position of the extremum of the n-th particle group in the j-dimensional; w is the inertia weight, $w = w_{\max} - \left(w_{\max} - w_{\min}\right) \times Iter / MaxIter$ (8), $w_{\max} = 0.9$, $w_{\min} = 0.4$, $Iter$ is the current number of iterations, and $MaxIter$ is the maximum number of iterations.

Get the updated particle velocity and update the particle position according to equation (9). $x_{ij}(n)=x_{ij}(n)+v_{ij}(n)$ (9) If $x_{ij}(n)$ is greater than $p_{\max}$ after the location is updated, then $x_{ij}(n)=p_{\max}$, $x_{ij}(n)$ is less than $p_{\max}$ and then $x_{ij}(n)=p_{\min}$. After obtaining the particle position, the objective function value is calculated, and the extreme position of the particle group and the extreme position of the particle are updated [15].

In summary, the genetic particle swarm hybrid algorithm firstly generates the unit population of the unit in the genetic algorithm, and then passes the unit combination solution to the particle swarm algorithm, initializes the particle state according to formula (6), and sorts according to the energy consumption level of the unit. Avoid using the penalty function to get the unit output, update the extreme position of the particle and the global extremum position, update the particle velocity and position according to equations (7) and (9), and iterate repeatedly to perform the selection, crossover and mutation operations, and Terminate when the algorithm termination condition is met.

## 4. Experimental design and results analysis

### 4.1 Experimental design

By setting the all-day mutation operator in the genetic algorithm, it is possible to open larger units and reduce small units to achieve energy-saving scheduling. In the particle swarm optimization algorithm, self-use inertia weights are set to improve convergence performance. These two steps enable the algorithm to improve the optimization ability to prevent the load economic allocation from falling into local optimum. When the particle swarm optimization algorithm performs load economy allocation, according to the energy-saving scheduling sorting rule, the use of penalty function is avoided in the load balance constraint, and the energy-saving principle can be reflected.

In the simulation experiment, the parameters are as follows: the number of population individuals in the genetic algorithm is 40, the crossover operator is 0.6, the number of iterations is 51, the all-day compile operator is 0.6, and the single-point mutation operator is 0.5; in the particle swarm optimization algorithm The number of particles is 20, the number of iterations is 51, the inertia weight is obtained by equation (8), and the acceleration rate is 2.04.

### 4.2 Experimental results and analysis

Combining the genetic algorithm mentioned in this paper with the particle swarm mixing algorithm, the unit combination is optimized within 10 hours of the 10-machine system. After 40 calculations, the fuel consumption is obtained by the fuel consumption, as shown in Figure 1 below.

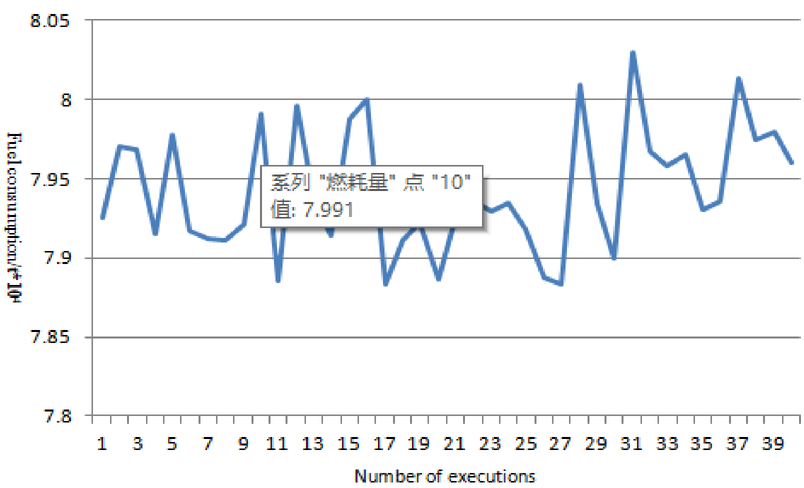


Fig. 1 Fuel consumption result map

As can be seen from the above figure, the maximum fuel consumption is 80278.27t, which is the worst result. The relative best result is 78852.82t. There is a deviation of 1.8% between the two results, and the deviation can be seen at 1. % times reached 74.32%. The new algorithm obtained by the above-mentioned genetic algorithm and particle swarm optimization algorithm has a good search ability.

Then compare the genetic algorithm, particle swarm optimization algorithm, fuel consumption of the hybrid algorithm, and get Table 1. It is easy to see from the data in the table that the fuel consumption of the hybrid algorithm is smaller than that of the genetic algorithm and the particle swarm optimization algorithm. It can be seen that the hybrid algorithm can get good results. The validity of this hybrid algorithm was verified.

Table 1 Fuel consumption comparison chart

| algorithm | Genetic algorithm | Particle swarm optimization | Hybrid algorithm |
|---|---|---|---|
| Fuel consumption / t * $10^4$ | 7.9876 | 7.8852 | 7.8852 |

In the following list, Table 2 shows the obtained unit state coding matrix.

Table 2 Unit status coding matrix

| Time slot | Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 | Unit 6 | Unit 7 | Unit 8 | Unit 9 | Unit 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 2 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 3 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| 4 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| 5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 7 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 9 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 10 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 11 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 12 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 13 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 14 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 15 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| 16 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| 17 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 18 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 19 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 |
| 20 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 21 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 22 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| 23 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| 24 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |

## 5. Conclusion

By setting the all-day mutation operator in the genetic algorithm, it is possible to open larger units and reduce small units to achieve energy-saving scheduling. In the particle swarm optimization algorithm, self-use inertia weights are set to improve convergence performance. These two steps enable the algorithm to improve the optimization ability to prevent the load economic allocation from falling into local optimum. When the particle swarm optimization algorithm performs load economy allocation, according to the energy-saving scheduling sorting rule, the use of penalty function is avoided in the load balance constraint, and the energy-saving principle can be reflected.

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