Research on Intensive Power Resource Regulation Algorithm

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Abstract. The paper takes the economic load distribution of the power system as the objective function, and establishes a mathematical model with economy, environmental protection, and reliability as system variables. It adopts the hierarchical thinking of control theory, uses multi-particle swarm multi-level optimization algorithm, and combines power distribution the characteristics of the network take the optimal value of each subsystem as the individual optimal value of the current particle, and perform the second particle swarm optimization to increase the probability of effective solution generation in the iterative process. Using multi-particle swarm hierarchical distributed algorithm, effectively improve the optimization accuracy of the objective function, the convergence speed and the number of times of convergence to the global solution. This paper focuses on power system optimal dispatch, fully considers the relationship between each system, and uses particle swarm optimization algorithm to obtain the optimal allocation of power resources. At the end of this paper, two typical IEEE power distribution networks are simulated and calculated. The calculation results show the superiority of the algorithm in calculation accuracy and convergence speed.

Keywords: Intensive, power resource allocation, optimal dispatching, example group algorithm.

1. Introduction

Because it is difficult to solve the optimization problem of hydrothermal power system, its solution method is the key. The study of its calculation method has always been sought by scholars. So far, methods such as dynamic programming, decomposition and coordination, and network flow have been developed. With the rapid development of intelligent population algorithms, neural networks, leapfrog algorithms, genetic algorithms, ant colony algorithms, particle swarm algorithms, etc. It has also been widely used in power system optimization dispatching. The dynamic programming method is an effective method for solving the optimization problems of complex systems. Its core is to transform the multi-stage decision-making process into a series of single-stage problems, and then solve them one by one. From continuous systems to discrete systems, from single-objective systems to multi-objective systems, the dynamic programming method can be solved theoretically. However, because the dynamic programming method has to store the state generated at each stage of the system in the analysis process when the dynamic programming method is used to analyse the calculation system, its space complexity...
is very high, and the computer memory requirement is also relatively high, especially when it solves multi-objective systems. The problem of insufficient memory for dynamic programming becomes more apparent [1]. In order to solve this problem, scholars have proposed many improvement methods for dynamic programming.

Based on this research background, the paper analyses the optimal dispatching of multi-voltage power grids, and studies the output of each generator, the nature of the energy consumption of the generators, the hydrological conditions in the area where the cascade hydropower stations are located, and the influence of dispatch commands on the optimal dispatch of the power grid. It puts forward and focuses on the analysis of the restrictions and correlations between the various voltage levels in the multi-voltage level power grid. It is proposed to divide the multi-voltage power grid into regions according to different voltage levels, distribute the unfavourable effects on the optimal dispatch of the power system that originally belonged to the network as a whole to each region, and solve them in small regions by themselves to minimize the impact on the overall power network. And take it as an objective function to participate in the optimal dispatch of the power system.

2. Particle Swarm Algorithm

Xuhui Shi proposed an improved particle swarm algorithm with inertial weight. Figure 1 is a flowchart of the basic PSO algorithm. The evolution process is:

\[ v_g(t+1) = wv_g(t) + c_1r_1(t)(p_g(t) - x_g(t)) \]  

\[ x_g(t+1) = v_g(t+1) \]

Figure 1. Flow chart of the basic PSO algorithm

3. Improved particle swarm algorithm

3.1. Adjust the inertia weight

Control the global and local optimization capabilities of the PSO algorithm of its value adjustable agent. If the value of \( w \) is larger, the global optimization ability is strong, but the local optimization ability is weak [2]. On the contrary, the local optimization ability is enhanced, while the global optimization ability is weakened. The literature proposes an adaptively adjusted linearly decreasing weight strategy, which linearly reduces the value of \( w \) as iteratively proceeds, namely [3]:
\( w(t) = \left(\frac{w_{\text{ini}} - w_{\text{end}}}{T_{\text{max}}}\right) \ast (T_{\text{max}} - t) + w_{\text{end}} \)  \( (3) \)

3.2. Introducing shrinkage factor

\[ v_{id} = \chi [v_{id} + c_1 r_1 (p_{id} - x_{id}) + c_2 r_2 (p_{gd} - x_{id})] \]  \( (4) \)

Among them, the shrinkage factor

\[ \chi = \frac{2}{2 - \varphi - \sqrt{\varphi^2 - 4\varphi}}, \quad \varphi = c_1 + c_2, \quad \varphi > 4 \]  \( (5) \)

Experimental results show that compared with the particle swarm optimization algorithm using inertia weight, the particle swarm optimization algorithm using shrinkage factor has a faster convergence speed. In fact, as long as the factors are selected appropriately, the particle swarm optimization algorithm with shrinkage factor can be regarded as a special case of the PSO algorithm.

3.3. Simplified particle swarm optimization algorithm (sPSO) with extreme perturbation

After adding the extreme perturbation operator to sPSO equation (1), the form is

\[ x_{id}(t + 1) = \omega x_{id}(t) \]  \( (6) \)

The algorithm corresponding to formula (6) is a simplified particle swarm optimization algorithm with extreme perturbation. The value of T0 and Tg determines the length of the delay for the extreme perturbation operator to take effect, and the value range is 3-8. When T0, When Tg is equal to the number of evolutionary generations, formula (6) degenerates into formula (1). Therefore, sPSO is the promotion of PSO, and PSO is a special case of sPSO.

4. Optimization model based on multi-objective power system

4.1. Objective function

Minimizing the total fuel consumption (or total cost) of the entire system for power generation. The total fuel cost of power generation is the most important economic indicator of power plant production, which can be expressed by the second-order polynomial of the generator's active power output:

\[ F_{gi} = \sum_{i=1}^{n} \left( a_i + b_i + c_i P_{gi}^2 \right) \]  \( (7) \)

\( a_i, b_i \) and \( c_i \) respectively represent the constant term, the first-order coefficient and the second-order coefficient of the consumption characteristics of the \( i \) generator set. The valve point effect is not considered here. The emission of nitrogen oxides is expressed by the sum of the second-order polynomial and the exponential equation produced by each generator:

\[ E_{i} = \sum_{i=1}^{N} E(P) = \sum_{i=1}^{N} \left( a_i + \beta_i P_i + \gamma_i P_i^2 \right) + \zeta \exp(f, P) \]  \( (8) \)

Among them, \( \alpha, \beta, \gamma, \zeta \) and \( f \) respectively represent the coefficients of the emission characteristic equation of generator set \( i \).

4.2. Constraints

(1) Power stability constraint: This is an equation constraint. The total output of the system generator must meet the sum of the total system load and the transmission line loss:

\[ \sum_{i=1}^{N} P_{gi} - P_{D} - P_{\text{LOSS}} = 0 \]  \( (9) \)
\[ P_i = \sum_{j=1}^{N} \sum_{j=1}^{N} P_{Bj} + \sum_{j=1}^{N} B_{Pj} + B_{i0} \]  

(10)

(2) Unit generating capacity constraint: This is an inequality constraint. The generator output power must be within the scope of the stable operation requirements of the system [4]:

\[ P_{\text{min}} \leq P_i \leq P_{\text{max}} \]  

(11)

The mathematical model is established according to the selection of the objective function and constraints [5].

\[
\min \{ F_{G}, F_{G'} \} \\
\text{s.t.} \begin{cases} 
  h(x) = 0 \\
  g(x) \leq 0 
\end{cases} 
\]  

(12) (13)

In the above formula, g and h are respectively the inequality and equality constraints mentioned in the previous section.

4.3. Multi-objective particle swarm algorithm solves power system economic problems

In order to improve the convergence speed of PSO, Shi and Eberhart proposed the inertia weight (ω) method in 1998. ω is a scale factor related to the previous speed. When it is larger, the particle swarm tends to search globally [6]. As the number of iterations increases, ω gradually decreases, which promotes the rapid local search of the particle swarm. The calculation formula is defined as follows:

\[
\omega = \omega_{\text{max}} \frac{\omega_{\text{max}} - \omega_{\text{min}}}{T_{\text{max}}} t 
\]  

(14)

In the formula: \( \omega_{\text{min}} \) and \( \omega_{\text{max}} \) are the minimum and maximum values of inertia weight respectively; \( t \) is the current iteration number, and \( T_{\text{max}} \) is the maximum iteration number. The method of using the linear change of acceleration factor to improve has been applied in the test function simulation of multi-objective particle swarm algorithm [7]. The appropriate parameter settings have been repeatedly tested and it is found that when \( c1 \) and \( c2 \) change linearly between 0.5-2.5, it is better for the value of w to change linearly between 0.4-0.9. The optimized power system simulation diagram is shown below.

![Figure 2. Optimized power system dispatch simulation based on particle swarm optimization](image)
5. Algorithm analysis

In order to illustrate the effectiveness of using the model and method proposed in this paper to solve the unit problem, this paper takes the IEEE-30 node system as an example, and uses MATLAB7.0 programming to verify the above model and method [8]. Table 1 shows the economic parameters and output limits of various conventional generators participating in the optimization in the calculation example system. The total system load $P=283.40$MW undertaken by the generators.

Table 1. Generator economic parameters and output limits

| unit | $a_i$  | $b_i$  | $c_i$  | $P_{gi,\text{max}}$ | $P_{gi,\text{min}}$ | $Q_{gi,\text{max}}$ | $Q_{gi,\text{min}}$ |
|------|--------|--------|--------|--------------------|--------------------|--------------------|--------------------|
| 1    | 0.0048 | 7.7700 | 78.000 | 200                | 50                 | 150                | -20                |
| 2    | 0.0068 | 8.2519 | 53.150 | 80                 | 20                 | 60                 | -20                |
| 3    | 0.0093 | 8.9728 | 41.680 | 50                 | 15                 | 63                 | -15                |
| 4    | 0.0109 | 9.5690 | 21.797 | 35                 | 10                 | 50                 | -15                |
| 5    | 0.0125 | 9.5290 | 21.150 | 30                 | 10                 | 40                 | -10                |
| 6    | 0.0111 | 9.5290 | 32.490 | 40                 | 12                 | 45                 | -15                |

This text uses PSO algorithm and GA algorithm in the literature to operate 10 times respectively, the comparison of PSO and GA optimization result is shown in Table 2. The non-inferior solution set obtained by simulation is shown in Figure 3 and Figure 4.

Table 2. Comparison of PSO and GA optimization results

| method | Max   | Minimum | average value |
|--------|-------|---------|---------------|
| PSO    | 2828.45 | 2828.38 | 2828.45       |
| GA     | 2828.46 | 2828.44 | 2828.45       |

Figure 3. Multi-objective particle swarm algorithm without improvement
6. Conclusion

As an important task in power optimization dispatching, power system unit load optimization has a decisive impact on the reliability, economy and safety of the future power grid. Scientific planning of the power system is one of the hotspots of current power development research. In this paper, the improved particle swarm algorithm is applied to the optimal dispatching of units in power system planning, and the environmental parameters are considered in it. The proposed method can be used as a method for optimal dispatching of power units in the future.

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