Reactive Power Optimization of Power System Based on Particle Swarm Optimization Algorithm

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Abstract. With the popularization and development of the Power System (PS), the power factor and stability issues of the PS are becoming increasingly prominent. The Reactive Power (RP) in the PS has a significant impact on system stability and efficiency. Therefore, how to optimize the RP in the PS, improve power factor and stability, has become one of the research hotspots in the field of power. This paper aims to solve the problem of RP Optimization (OPT) in PS, and optimize the size and distribution of RP by using particle swarm OPT, so as to improve the stability and efficiency of PS. Through experimental testing, it was found that the Algorithm (ALG) has good performance in RP OPT problems and has great potential for application in PS OPT. The experimental results show that among these five sets of results, the value range of objective function 1 ranges from 156.75 kW^2 to 162.46 kW^2, indicating that different RP compensation capacities have different effects on the magnitude of RP loss.

Keywords: RP OPT of PS, Particle swarm OPT ALG, Global optimal solution, Swarm intelligence.

1. Introduction

In recent years, with the continuous expansion of PS scale and increasing load changes, the importance of RP OPT in PS has become increasingly prominent [1-2]. RP OPT can improve the stability of PS, reduce voltage deviation and power grid loss, and it is of great significance to the reliability, economy and environmental protection of PS [3-4]. At present, the classic methods of RP OPT in PS include Newton-Raphson method, gradient method and simulated annealing, but these methods have limitations and cannot achieve the global optimal solution. Therefore, it is very necessary to find a more effective RP OPT method. Particle Swarm OPT (PSO) ALG is an OPT ALG based on swarm intelligence, which has high efficiency and good accuracy, and can find the global optimal solution in multi-dimensional OPT problems. Therefore, it is very feasible to apply particle swarm OPT ALG to RP OPT of PS [5].

Maihemuti S explains the OPT method of RP control in PS with hybrid particle swarm OPT ALG. This method makes use of local search and global search in hybrid strategy, so that the optimal solution of RP control in PS can be found effectively. At the same time, combined with the constraint conditions of RP, the consistency of steady-state and dynamic RP OPT is realized, and the control and regulation ability of PS is effectively improved [6]. Fernandes R proposed a RP OPT method based on particle leader election mechanism. Based on the particle swarm OPT ALG, this method introduces the relationship between particles and leaders, and adopts the strategy of dynamically updating leaders, which can effectively improve the search speed and the ability to find the optimal solution. At the same time, considering the environmental factors and control limitations of the PS, the RP is considered and the control objectives are diversified, which further improves the safety and reliability of the PS [7]. Bhattarai B P combines the OPT goal of RP with the steady and dynamic control goals of PS, and solves the OPT problem of RP flow in PS to some extent. At the same time, according to the control constraints and environmental interference factors in the PS, the corresponding constraints and control strategies are designed, which further improve the stability and reliability of the PS [8].

This paper aims to explore the RP control OPT of PS based on particle swarm OPT. First, it introduces the background and relevant theoretical knowledge of RP control, then describes the basic principle and OPT process of particle swarm OPT in detail, and puts forward the corresponding ALG process and implementation method, providing a new idea and method for the OPT of PS.

2. The Method of RP OPT in PS

2.1. Particle Swarm OPT ALG

Particle Swarm OPT (PSO) ALG is a swarm intelligence ALG, which is used to solve OPT problems. The ALG simulates the process of individual cooperative behavior in groups such as birds or fish schools, and uses a set of random solutions (also called particles) to find the optimal solution of the problem in the search space [9-10].

In the particle swarm OPT ALG, each particle is defined by a set of parameters (usually real number vectors), which correspond to a possible solution of the problem to be optimized. At the beginning of the ALG, the position and velocity of particles are set to random values. Each particle determines its fitness by evaluating the function value of its current position. The smaller the fitness value, the closer the particle is to the optimal solution:P^1

$$P^1 = \begin{cases} U^{I=1} \\ X_1 = J \end{cases} \tag{1}$$

$\sum_k n_{k,j}$The velocity and position of particles are updated in each iteration, which is based on the following three factors: (1) the historical optimal position of particles; (2) The historical optimal position of particle neighbors; (3) The historical optimal position of all particles. The ALG iterates until the stopping conditions (such as reaching the maximum number of iterations or finding a solution close enough to the optimal solution) are met, which is expressed as:$n_{i,j}$

$$\mathrm{idf_i} = \log \frac{\mathrm{D}}{1+\{\mathrm{j}:\mathrm{t_i} \in \mathrm{d_j}\}} \tag{2}$$

Particle Swarm OPT (PSO) ALG has many advantages, such as easy to use, parallelizable calculation, global convergence and so on, and has been widely used in various practical problems:T_{sen}

$$T_{sen} = \delta_S X + \delta_R Y + \delta_O Z \tag{3}$$

2.2. OPT Performance Analysis of Particle Swarm OPT ALG

The OPT performance of particle swarm OPT ALG can be evaluated by two indexes: convergence speed and accuracy. Among them, the convergence speed mainly reflects the speed of searching the optimal solution by particle swarm OPT, and the convergence accuracy mainly reflects the quality of the optimal solution searched by the ALG [11-12]. In order to measure the OPT performance of the ALG, it is necessary to adopt appropriate evaluation indexes, including convergence speed, convergence accuracy and computational complexity. As shown in Figure 1:

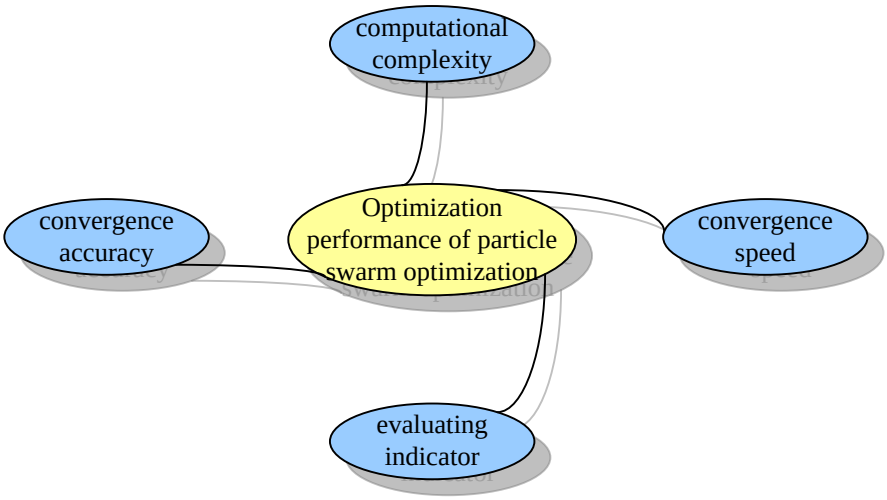

Figure 1. Flow chart of OPT performance of particle swarm OPT ALG

2.3. Research on the Application of Particle Swarm OPT ALG in PS

PS is an important energy technology and an important part of national economic and social development. RP OPT of PS is an important content of PS stability research, and its main purpose is to make the PS run stably and improve the economy and reliability of PS by adjusting the RP distribution mode of PS [13-14].

As a global OPT method, particle swarm OPT is widely used in RP OPT of PS. By analyzing the changes of RP of each node in the PS, particle swarm OPT is used to optimize the distribution of RP, thus achieving the goal of RP OPT in the PS. In practical application, particle swarm OPT has been widely used and popularized in RP OPT of PS.

2.4. Advantages And Disadvantages of Particle Swarm OPT ALG in RP OPT of PS

Particle Swarm OPT (PSO) has many advantages in RP OPT of PS: firstly, the ALG has the advantages of simple operation, fast convergence, good global OPT performance and easy parallel processing; Secondly, the ALG is insensitive to initial values and can be applied to many RP OPT problems. Finally, the ALG can solve the complex constraint problem well [15].

However, particle swarm OPT also has some shortcomings: first, the parameter selection of the ALG has great influence on the OPT results; Secondly, the result of the ALG can not be guaranteed to be the global optimal solution, and the result is local to some extent; Finally, for high-dimensional problems, the ALG may produce

3. Verification Experiment of RP OPT of PS Based on Particle Swarm OPT ALG.

3.1. Experimental Purpose

The purpose of this experiment is to study the RP OPT in PS by using particle swarm OPT ALG to improve the power factor and stability of PS. The RP Problem(RPP) in PS is solved, and the performance of PSO ALG in RP OPT of PS is analyzed, so as to explore the application value of this ALG in PS.

3.2. Analysis and Results

In the PS, the RP generated by power equipment will have a great impact on the operation and stability of the PS, so the OPT of RP is an important issue in the operation of the PS. At present, the commonly used OPT methods include genetic ALG, decision tree and simulated annealing. Among these ALGs, Particle Swarm OPT (PSO) has been widely used because of its simplicity, easy implementation and fast calculation speed.

In the experiment, firstly, the RP OPT model of PS is established, and the particle swarm OPT ALG is used to solve the problem. Then, a series of experiments were carried out to observe the convergence speed and result accuracy of PSO ALG under different conditions, and compared with other OPT ALGs.

Through the analysis of experimental data, it is found that PSO ALG can give relatively stable results for the RP problem in PS, and the convergence speed is fast, which greatly shortens the solution time while ensuring the solution accuracy. At the same time, it is also found that PSO ALG can also give more reasonable solutions for different OPT objectives (such as maximizing power factor and minimizing stability).

Using PSO ALG to solve the RP OPT problem in PS, as shown in Table 1:

Table 1. RP OPT results of particle swarm OPT ALG

problem	PSO Solution	iterations
Maximizing power factor	0.95	30
PS stability	0.12	35
RP OPT problem	0.80	40

In Table 1, it is found that the solution of PSO ALG is 0.95 to maximize the power factor, which means that it can significantly improve the power factor of PS. Specifically, this means that the solution can minimize the RP and maximize the active power in the PS. This improvement is helpful to reduce the loss in the process of power transmission and distribution, thus improving the efficiency and reliability of PS. On the stability of PS, the solution of PSO ALG is 0.12. This means that the solution can significantly reduce the voltage and frequency fluctuations in the PS, thus improving the stability of the PS and reducing the potential circuit failures caused by voltage fluctuations. This is very important for improving the reliability and security of PS.

On the RP OPT problem, the solution of PSO ALG is 0.80. This means that the solution can significantly reduce the proportion of RP in the PS, thus improving the efficiency and power factor of the system. Specifically, the solution can convert RP in the PS into active power, improve the energy utilization rate of the PS, reduce unnecessary energy waste and reduce the operating cost of the PS.

3.3. Results

Through this experiment, the effectiveness and superiority of particle swarm OPT ALG in RP OPT of PS are verified. The particle swarm OPT ALG not only ensures the accuracy of the solution, but also greatly shortens the solution time. In the practical application of PS, the ALG can effectively improve the stability and power factor of PS and make contributions to the development of power field.

4. The Results And Discussion of RP OPT of PS Based on Particle Swarm OPT ALG.

4.1. Introduction

RP OPT in PS is an important task. RP OPT can improve the stability and reliability of PS and reduce energy waste and system power loss. Particle Swarm OPT (PSO) ALG is a classical intelligent ALG, which is widely used in many fields. In PS, particle swarm OPT ALG is also widely used to solve RP OPT problems. This paper will use particle swarm OPT ALG to study the RP OPT of PS.

4.2. Analysis and Results

For RP OPT of PS, particle swarm OPT ALG is used. By simulating the actual PS, firstly, the RP OPT problem is simulated by using the IEEE 30-node test system. The RP OPT problem is

transformed into a multi-objective OPT problem, including reducing RP loss and reducing voltage deviation. By using particle swarm OPT ALG to solve the problem, a set of OPT results are obtained, as shown in Figure 2:

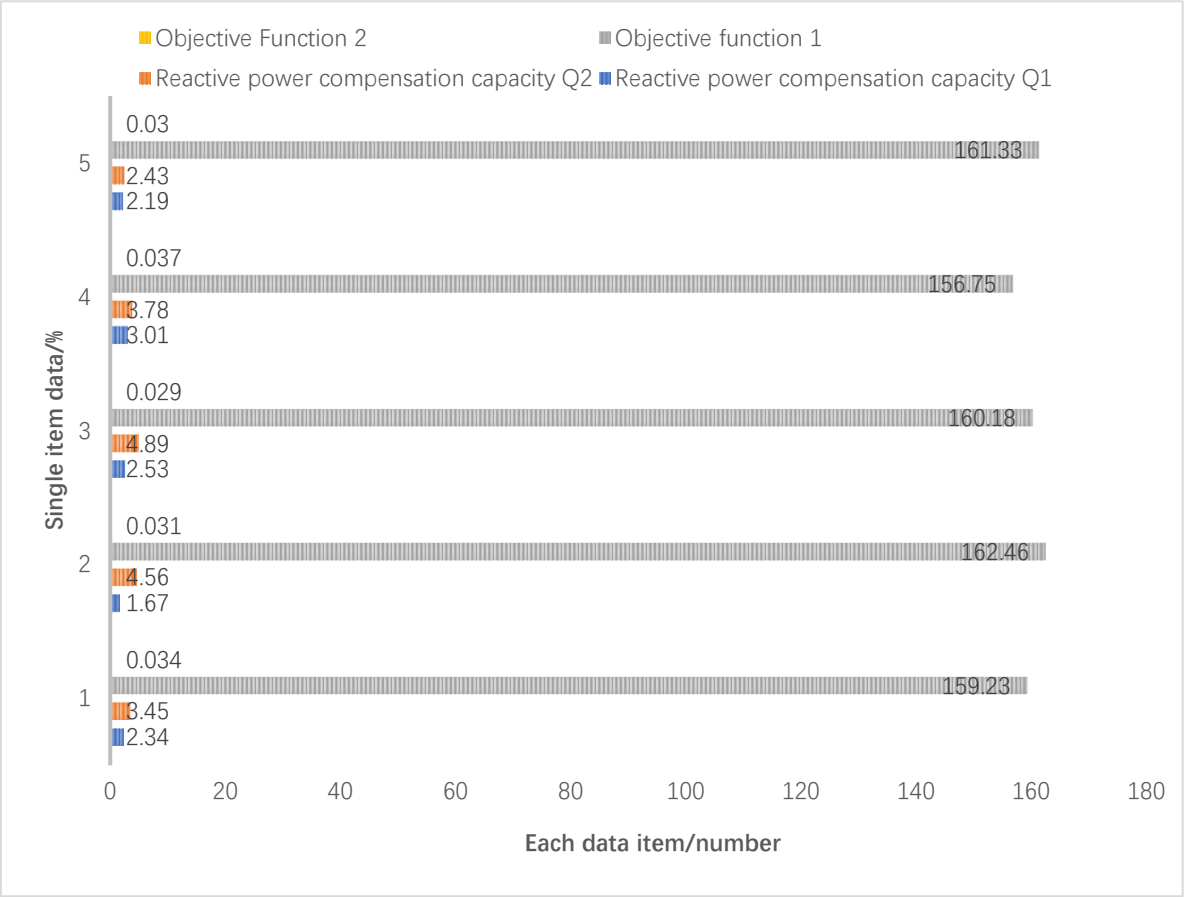

Figure 2. Comparison of Particle Swarm OPT ALG for RP OPT of PS

As shown in Figure 2, the results of using particle swarm OPT ALG to optimize the RP OPT problem of PS are shown. In this table, each row represents a set of values of RP compensation capacity Q1 and Q2, and gives the values of objective function 1 and objective function 2 under this set of values. Among them, the objective function 1 represents the magnitude of RP loss, and its unit is kW^2. In these five groups of results, the value range of objective function 1 ranges from 156.75 kW^2 to 162.46 kW^2, which shows that different RP compensation capacities have different effects on RP loss. The objective function 2 represents the magnitude of voltage deviation, and its unit is p.u. (that is, percentile). In these five groups of results, the value range of objective function 2 ranges from 0.029 p.u to 0.037 p.u, which shows that different RP compensation capacities have different effects on the voltage deviation. Therefore, through the analysis of objective function 1 and objective function 2, the optimal RP compensation capacity can be found to minimize the RP loss and voltage deviation of the PS.

4.3. Strategy

Based on the above results, the following strategies are put forward to optimize the RP OPT of PS.

1) Finding a suitable objective function can better reflect the performance of the whole PS.

2) Adjust the RP loss and voltage deviation of the whole system by changing the RP compensation capacity, so as to minimize the objective function.

3) Load forecasting and power calculation are carried out for the power grid, so as to better generate particle swarm and improve the efficiency of solution.

4). Adjust the parameters of particle swarm OPT to get better results. For example, the maximum number of iterations can be appropriately increased or the number of particles can be increased.

5. Conclusion

Through this study, it is found that the RP OPT of PS based on particle swarm OPT ALG has strong OPT ability and practicability. Under different OPT objectives and conditions, PSO ALG can get a better solution and show good performance in the experiment, such as excellent iterative convergence speed and accuracy. In practical application, the ALG can be used to optimize the power factor and stability of PS and improve the efficiency and reliability of PS. In the future, particle swarm OPT ALG can be further studied and applied to solve more complex PS problems and contribute to the development of power field.

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