Research Article

Power System Reactive Power Optimization Sensor Dispatching Digital Grid Based on Improved Cuckoo Algorithm

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In order to ensure the economic, safe, and stable operation of the power grid in the power system, the author proposes a power system reactive power optimization sensor dispatching digital grid based on an improved cuckoo algorithm. Use this improved cuckoo algorithm to optimize the solution, optimal dispatch model of power system considering economy and environmental protection. The main improvement strategies are as follows: on the basis of the original algorithm, the exchange operator in the particle swarm algorithm is introduced, promoting communication between bird’s nests; at the same time, two fixed parameters of probability and step size will be found and set to dynamic quantity to improve the convergence speed of the algorithm; in the process of updating the location of the bird’s nest, use nondominant sorting and calculation of crowding distance to maintain the archives; after generating the optimal solution, use the satisfaction evaluation theory of fuzzy mathematics to obtain the optimal solution. The result said that the cost of power generation and pollutant emissions is USD 125.1 million/h and 0.3361 t/h, respectively. Compared with the optimization results of the other three traditional algorithms, power generation costs and pollutant emissions reduced. The algorithm shows that the improved algorithm has better optimization speed and accuracy, and at the same time, it can effectively improve the global convergence, to ensure the diversity of Pareto’s noninferior solutions.

1. Introduction

In recent years, with the rapid development of social economy, people’s quality of life has gradually improved, in order to meet the needs of urban and rural residents’ domestic and industrial electricity; the scale of the power grid is becoming larger and more complex; whether the power system can operate stably will be directly affected by the quality of the voltage; therefore, the power quality and economic stability of the power system are becoming more and more important [1]. Optimization has power loss and voltage stability indicators, and voltage deviation can ensure voltage quality and improve the efficiency of grid operation. Therefore, how to make the power system network operate more economically, stably, and safety has become one of the most concerned topics of the researchers in the field of electric power research [2, 3]. Cuckoo search algorithm is a swarm intelligence optimization algorithm; it is also a new type of metaheuristic search algorithm. The idea is mainly based on two strategies: Cuckoo’s nest parasitic and Levi flight mechanism. By means of random walk, search for an optimal bird nest to hatch your own bird eggs; in this way, an efficient optimization mode can be achieved. The CS algorithm has good early search ability, but it has poor late search ability, low search accuracy, and slow convergence speed, so it needs to be improved in the multiobjective optimization.

In the process of transmitting power in the power system, which will transmit active power, reactive power is also transmitted. Active power is the power consumed by the load in the power grid system, and its change has little effect on voltage. Reactive power is generated by the energy exchange between the power system network and the load; in order to ensure the normal operation of the load, the power grid must provide a certain amount of reactive power to the load. The reasonable distribution of reactive power is the prerequisite for the safe, stable, and economic operation of the power system [4]. If the reactive power in the system is too low, the operating voltage of the load will decrease,
and the load will not work normally, seriously affecting the normal life of users, for example, some large-scale power outages; it is because the system voltage is running below the critical voltage and there is a big fluctuation, making the system out of synchronization causing voltage collapse; if the reactive power in the system is too high, it will cause the voltage of the system to increase, the bus voltage in the substation runs above the upper limit, and then endanger the grid system and damage related power equipment; it will also affect the safety of users’ electricity use [5, 6]. Therefore, reactive power optimization sensor dispatch is an important way to improve power quality and ensure the safe and stable operation of the power grid. Figure 1 is the reactive power optimization sensor dispatch diagram of the power system.

2. Literature Review

At present, many scholars have conducted research on the optimal dispatch of power systems; however, the current algorithms have certain obvious flaws; for example, the calculation speed is slow, and the calculation accuracy is relatively fuzzy. Jiang et al. proposed traditional optimization methods represented by simplified gradient method, Newton method, interior point method, and decoupling method, used to solve the problem; however, the simplified gradient method will have a sawtooth phenomenon and poor convergence, and the amount of calculation is large and time-consuming [7]. Vasin et al. believe that the basic idea of cuckoo search (CS) is to first initialize the positions of N bird’s nests in space and then determine the fitness value of each bird’s nest [8]. Wang et al. used reactive power control methods to adjust the reactive power flow distribution of the system, depending on the focus of optimization; from the perspectives of economy, stability, and safety, it can achieve the predetermined goals such as the smallest system active power loss, the best system static voltage stability, and the smallest node voltage deviation from the rated value; at the same time, the power system meets the constraints of various operating conditions [9]. P. Kumar et al. proposed an economic dispatch model including voltage and operating constraints, this model is based on mathematical theory, the derivation process is very strict, and it is called the optimal power flow (OPF) problem of the power system [10]. In order to overcome the shortcomings of traditional particle swarm optimization that are easy to fall into local optima, the result proves that the proposed improvement method is in the quality of the optimal solution and the speed of the solution, and the experimental success rate is better than traditional methods [16].

Based on this research, the author proposes a power system reactive power sensor optimized dispatching digital grid based on an improved cuckoo algorithm; among them, the introduction of exchange operators, dynamic discovery probability, and dynamic step size can reduce the number of iterations of the algorithm in the optimization process, and secondly, on the basis of improving the optimization speed, the position of the bird’s nest is sorted and maintained nondominantly; it can improve the optimization efficiency and accuracy of the algorithm during operation, and the superiority of the improved algorithm is verified.

3. Research Methods

3.1. Improved Cuckoo Algorithm

3.1.1. Cuckoo Algorithm. The cuckoo algorithm combines the common cuckoo propagation mechanism and the levy search method. The algorithm’s search ability was better at the beginning, but over time, the shortcomings of its search ability are gradually exposed; at the same time, the problems also include low search accuracy and slow speed; it is necessary to improve when solving multiobjective problems [17].

For a d-dimensional optimization problem, d variables are required as shown in

\[ x = [x_1, x_2, \ldots, x_d]. \]

The position update formula based on Levi flying is as shown in

\[ x_i^{(t+1)} = x_i^t + \alpha \odot L(\lambda), \quad i = (1, 2, \ldots, n), \]

\[ L(\lambda) \sim \mathcal{U}(1, \lambda), \quad 1 < \lambda \leq 3, \]

where \( x_i^{(t+1)} \) is the position of the bird’s nest after the update, \( x_i^t \) is the current location of the bird’s nest, \( \alpha \) is the step size, \( L(\lambda) \) is the data search path, and \( \mathcal{U} \) is the standard normal variable [18, 19].
3.1.2. Improved Cuckoo Algorithm. CS algorithm is a new research hotspot in the field of intelligent group algorithm, its unique Levi flight characteristics have good global optimization capabilities, and it has been widely used in the engineering of actual optimization problems. The author introduced the basic update process of the CS algorithm and improved it from three different angles; an improved CS algorithm with faster convergence speed and higher

Figure 1: Reactive power optimization sensor dispatch diagram of power system.

Figure 2: Changes in power generation costs.
search accuracy is proposed; in addition, the traditional penalty function method for processing constraints is combined with the improved CS algorithm.

3.1.3. Principles of Quantum Computing. Qubit is the smallest unit in quantum computing. \( |\psi_i\rangle = \alpha_i |0\rangle + \beta_i |1\rangle \) can be expressed as
\[
\begin{bmatrix}
\alpha_i \\
\beta_i
\end{bmatrix},
\]
where \( \alpha_i = \cos \theta_i \) and \( |\alpha_i|^2 + |\beta_i|^2 = 1 \), \( |\alpha_i|^2 \) are the probability of a qubit taking 0 and \( |\beta_i|^2 \) is the probability of a qubit taking 1. Randomly generate a random number \( r \) between \( (0, 1) \). If \( r > |\alpha_i|^2 \), then this qubit takes 1; otherwise, it takes 0, and \( \theta_i \) is the angle corresponding to the qubit. It is as shown in
\[
q = \begin{bmatrix}
\alpha_1 & \alpha_2 & \cdots & \alpha_n \\
\beta_1 & \beta_2 & \cdots & \beta_n
\end{bmatrix}.
\]

The qubit string represents an individual in the

![Figure 3: Changes in pollution emissions.](image3.png)

![Figure 4: NSGA optimal frontier.](image4.png)
population. Suppose the value range of the $i$th dimension of the individual is $[U_{i}^{\text{min}}, U_{i}^{\text{max}}]$, the binary string corresponding to the $i$th dimension is $b_n b_{n-1} \cdots b_2 b_1$, and then, the value $x_i$ of the $i$th dimension is shown in

$$x_i = U_{i}^{\text{min}} + \left( \sum_{j=1}^{n} b_j 2^{i-j} \right) \frac{U_{i}^{\text{max}} - U_{i}^{\text{min}}}{2^n - 1}. \quad (5)$$

After the decimal conversion of each dimension, the corresponding individual $X = (x_1, x_2, \cdots, x_D)$ can be obtained.

### 3.2. Power System Reactive Power Optimization Sensor Dispatch Model and Algorithm Optimization

#### 3.2.1. Optimal Scheduling Model.

The sensor is a detection device that can feel the measured information and can transform the felt information into an electrical signal or other required forms of information output according to a certain law, so as to meet the requirements of the transmission, processing, storage, display, recording, and control of the information.

(1) The economic dispatch target is shown in

$$\min f_1 = \sum_{j=1}^{N} (a_i + b_i P_j + c_i P_j^2), \quad (6)$$
where \( N \) is the number of thermal power units; \( a_i, b_i, \) and \( c_i \) are the power generation cost coefficients of the unit; \( P_i \) is the output of the unit; and \( f_1 \) is the objective function of economic dispatch.

(2) The environmental scheduling goal is shown in

\[
\min f_2 = \sum_{i=1}^{N} E(P_i)
\]

\[
E(P_i) = [10^{-2} (a_i + b_i P_i + c_i P_i^2) + \zeta_i \exp (P_i)].
\]

In the formula, \( a_i, b_i, \gamma_i, \) and \( \zeta_i \) are the pollutant emission coefficients and \( f_2 \) is the objective function of environmental scheduling.

Combining the two objective functions and scheduling constraints solved in the article, integrate to get a multiobjective optimization scheduling model, as shown in

\[
\begin{align*}
\min Y(x) &= \min [f_1(P_i) f_2(P_i)] \\
s.t.\ &h(P_i) = 0 \\
&g(P_i) \geq 0,
\end{align*}
\]

where \( h(P_i) \) and \( g(P_i) \) are the equality and inequality constraints of the scheduling model, respectively, and \( Y(x) \) is the integrated objective function [20].

4. Results Discussion

Choose a 30-node system of IEEE6 units. Use different algorithms to analyze and compare models, calculate with a cycle of 24 h, and refer to the parameters of unit operation, emission coefficient and line power loss, the upper and lower limits of G1-G6 output, and the system demand load (see [21, 22]). Keep the parameter conditions constant, respectively, and adopt Multiscale Oriented Patches (MOPOS) algorithm, Nondominated Sorting Genetic Algorithm (NSGA), and Multiobjective Cuckoo Algorithm, and its improved algorithm further analyzes the above calculation examples; suppose that the population size is \( N = 200 \) and the maximum number of iterations is \( T = 600 \), the threshold for performing communication is 0.6, and the iterative process is shown in Figures 2 and 3.

From the iterative curves of Figures 2 and 3, it can be seen that, compared with other algorithms, the improved cuckoo algorithm, the number of iterations has been greatly reduced; the key is because of the introduction of AC operators, dynamic parameters, and non-controlling sorting; this leads to changes in the search efficiency and convergence speed of the algorithm. After the iteration is completed, through NSGA, MOPOS algorithm, Multiobjective Cuckoo Algorithm, the optimal Pareto boundary obtained is shown in Figures 4–7. Table 1 shows the results of unit output and objective function after optimizing the scheduling model through different algorithms, where \( P_{Gi}(i = 1 \sim 3) \) is the unit output. As can be seen from Figures 4–7, when the demand load of the regional power grid is determined, the power generation cost is inversely proportional to the

\[
\begin{array}{cccccc}
\text{Project} & \text{PG1 (MW/h)} & \text{PG2 (MW/h)} & \text{PG3 (MW/h)} & \text{F1 (ten thousand dollars/h)} & \text{F2 (t/h)} \\
\hline
\text{NSGA} & 76.141 & 124.647 & 24.261 & 1.262 & 0.3402 \\
\text{MOPOS} & 75.261 & 121.412 & 26.741 & 1.260 & 0.3384 \\
\text{MOCS} & 69.127 & 128.155 & 27.161 & 1.252 & 0.3374 \\
\text{Improve algorithm} & 73.131 & 126.552 & 25.352 & 1.251 & 0.3361 \\
\end{array}
\]
pollutant emissions, and there are checks and balances between the two. After comparison, it can be seen that the first three algorithms did not search for the optimal Pareto peak; the slope of the optimal Pareto peak obtained in the early stage of Figures 4 to 5 is too large. And the later algorithm is too small, the slope in the middle section of Figure 6 fluctuates to a certain extent, and the later algorithm is intermittent; the improved algorithm can get the smooth and integral optimal Pareto front [23].

As can be seen from Table 1, the power generation cost and pollutant emission of this algorithm are 125.1 million USD/h and 0.3361 t/h, respectively.

5. Conclusion
The author proposes a power system reactive power optimization sensor dispatching digital grid based on improved cuckoo algorithm; using the improved cuckoo algorithm, simultaneously optimize the two targets of power generation cost and pollutant emission. Compared with traditional optimization algorithms, improve the cuckoo algorithm by referring to different algorithms, making the improved algorithm have better stability and convergence; it makes up for the shortcomings of the original algorithm of poor optimization ability, low accuracy, and easy trapping in local optimality. For multiobjective optimization scheduling problems, simulation results show that the proposed algorithm can find the optimal Pareto front and the compromise solution quickly; at the same time, the multitarget requirements of power generation costs and lower pollutant emissions are achieved. Many of the problems in science and engineering practice can be attributed to optimization problems. Compared with ACO, PSO development with more perfect bionic intelligent algorithm and CS algorithm application research in power system, biomedicine, fuzzy control, finance, electronic, and electromagnetic fields are less; how to find the CS algorithm and its derived algorithm and the actual problem, combining the CS algorithm with practical problems, will effectively promote the rapid development of CS algorithm.

Data Availability
The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest
The author declares no conflicts of interest.

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