Study on a Real Time Scheduling Optimization Model for Multi-source Heterogeneous Distribution Network

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Abstract: Real-time scheduling for distributed power consumption can be heterogeneous distribution network problems, in this paper, an optimization model based on real-time scheduling based on the day before the scheduling model, the power supply capacity of the model based on load forecasting to make full use of distributed power and energy storage equipment, reduces in the peak period of the main power supply rely on, and the imperialist competitive algorithm based on the optimization model was solved. Through the simulation test, the power supply capacity of the real-time scheduling model can effectively utilize the distributed power and energy storage devices to reduce the peak power grid based on the running cost of distribution network is reduced by 2.59%.

1. Introduction

With the development of power generation technologies such as photovoltaic and wind power, the number and capacity of distributed energy connected to the distribution network are rapidly increasing. This makes the network structure of the distribution network complicated to change, and is no longer just a matter of power distribution. Actively dissipate distributed energy with intermittent power supply, and effectively dispatch distributed power and energy storage equipment in the power grid\cite{1}. Therefore, the traditional real-time scheduling model is more and more difficult to deal with the development of multi-source heterogeneous distribution networks and urgently needs to be optimized.

In order to fully optimize and coordinate the dispatching management and efficient use of distributed energy, scheduling for multi-source heterogeneous distribution networks is generally scheduled from both the current and real-time levels\cite{2,3}. At the day-to-day scheduling level, the scheduling model uses load forecasting and information delivery data in the load area as the basis. Global scheduling algorithms are used to derive global scheduling strategies to aggregate, distribute, and control global information and real-time effective information \cite{4}. At the local level, the real-time status of distributed energy in grid-connected networks is mainly adjusted, and the scheduling strategy is adjusted in real time so that the power generation of distributed energy can be optimally absorbed \cite{5,6}.

Literature \cite{7} proposed a load forecasting scheme for distribution network power supply capacity. Based on the real-time special detection of distributed energy supply capability, this scheme accurately predicts the growth rate of load, combines the repeated power flow method to construct an expected change curve for the power supply capacity of the distribution network, and optimizes the dispatch for the possible local power supply limitations. The literature \cite{8} takes the real-time electricity price as the
scheduling goal, and based on the information exchange of the main network, proposes an optimization algorithm to autonomously schedule the distributed power source and energy storage equipment, and realize the efficient use of electric energy of the distribution network. Literature [9] proposes the scheduling based on multiple autonomous regions and consensus algorithms for the disadvantages of traditional scheduling algorithms such as low efficiency, poor adaptability, and difficulty in improving distributed power utilization efficiency in multi-source heterogeneous distribution networks. The strategy improves the operation speed of the ground algorithm and reduces the amount of system communication data, and it responds well to changes in the structure of the distribution network. In [10], more and more inter-regional power support will occur in the automatic power generation control (AGC) process caused by grid-connected intermittent energy sources, and the problem will be modeled and solved by differential game theory. Make the game reach the non-cooperative feedback Nash equilibrium point. The simulation on the two-region AGC model proves that the proposed coordinated control strategy can be guaranteed to be executed voluntarily and faithfully by each region, because the change of strategy alone will lead to the decline of revenue in each region. In [11], aiming at the randomness and low prediction accuracy of wind power, a coordinated economic dispatching strategy for power systems with large-scale wind power is proposed, and a coordinated economic dispatch model for wind power systems based on chance constrained programming is established.

The above literature has proposed a variety of strategies for global-level scheduling optimization for multi-source heterogeneous distribution networks, but there are few analytical studies for real-time scheduling. Based on load forecasting and power supply capacity analysis of distributed power supply, this paper constructs a multi-source heterogeneous distribution network real-time scheduling optimization model, solves the real-time scheduling optimization model through an improved competition algorithm, and finally optimizes the application of real-time scheduling through simulation experiments. The simulation of the model and the improved competitive algorithm is validated.

2. Real-time Scheduling Optimization Model

2.1 Real-time Schedule Model

Before the date of dispatch is the basis for real-time scheduling, providing basic constraints for real-time scheduling. Multi-source heterogeneous distribution network dispatch system block diagram shown in Figure 1.

Figure 1. Multi-source heterogeneous distribution network scheduling system structure.

The purpose of the day-to-day scheduling is to construct a scheduling model based on load forecasting, forecasting the intermittent power supply capacity of distributed power supplies, and detection of energy storage data, and to optimize the operation of the distributed power supply to
achieve the lowest system operating cost. The ideal power supply quality. The operating costs of the distribution system include the cost of the distributed power supply, the main network purchase cost, the line loss cost, and the energy storage cost [12].

The model of the day-to-day schedule is shown in Equation 1.

$$\min (P_{\text{cost}}) = \sum_{t=1}^{T} \left[ \sum_{i=1}^{N} c_i(t) (P_{\text{in}}^t - \Delta) + \sum_{j=1}^{M} c_j(t) (P_{\text{out}}^t - \Delta) \right]$$

$$+ \sum_{t=1}^{T} \left[ \sum_{i=1}^{N} \Delta C_{\text{ess}}(t) (P_{\text{in}}^t - \Delta) + \sum_{i=1}^{N} c_i(t) P_{\text{in}}^t \right]$$

(1)

Among them, $c_i(t)$ represents the power purchase cost of I on the t time point, and $c_j(t)$ represents the operating cost of the distributed generation unit j at the t point of time, $\Delta C_{\text{ess}}(t)$ indicating the difference between the charge and discharge costs of the energy storage equipment at the t time point. N is the total number of feeders in the distribution network area, and M is the total number of distributed power sources in the distribution network area. $P_{\text{in}}^t$ instantaneous power of the distributed power J at the time point of the T is expressed as the consumption power of the line I on the t point of time, $P_{\text{out}}^t$ indicating the charge and discharge power of the energy storage device K at the time point of t. $\Delta P_{\text{line}}^t$ represents the line loss value at t time point, and its formula is shown in formula 2.

$$\Delta P_{\text{line}}^t = \frac{\delta_i(t)}{\delta_i(t) - 1} P_{\text{in}}^t$$

(2)

Type 2, $\delta_i(t)$ indicates the comprehensive line loss value of the distribution network on the t time point, and the unit is kW.

From Formula 1, it can be seen that the goal of the current scheduling is to minimize the operating costs of the distribution network. When the running cost of distributed power supply is lower than the cost of main power purchase, it is necessary to make full use of the power provided by distributed power supply. When the operating cost of distributed power supply is higher than the cost of main power purchase, the operation of distributed power supply must be reduced. The energy storage unit in the distribution network can temporarily store electrical energy in the event of a power outage, reducing the cost of electricity purchase during peak periods.

2.2 Real-time scheduling optimization model

Real-time scheduling is the real-time adjustment of the daily scheduling. Its main purposes are: 1. Based on the monitoring of the real-time running status of the distributed power supply, according to the current scheduling strategy, the power supply of the distributed power supply is adjusted; 2. The real-time operation of the energy storage unit is performed. State monitoring, based on the current scheduling strategy, switches the charge and discharge status of the energy storage unit in real time and adjusts the charge and discharge power. The data base for real-time scheduling is the prediction of load changes in the short term and the real-time status of distributed power and energy storage units within the distribution network [13].

$$\min (P_{\text{cost}}) = \sum_{t=1}^{T} \left[ \frac{\sum_{i=1}^{N} P_{\text{in}}^t (I(t)) + \sum_{j=1}^{M} P_{\text{out}}^t (J(t)) + \sum_{k=1}^{O} P_{\text{ess}}^t (K(t))}{\delta_i(t)} \right]$$

(3)

Type 3, $P_{\text{in}}^t$ the power function of the Chinese controlled distributed power supply, $P_{\text{out}}^t$ is the power function of the photovoltaic power supply. $P_{\text{ess}}^t$ is the power function of the wind power supply. I, J and o are the total number of various types of distributed power supply in the distribution network.

(2) the scheduling model of energy storage unit
The expected goal of the scheduling model of the energy storage unit is to minimize the operating cost of the full energy storage unit.

\[
\min(P_{ESS}) = \left| \sum_{t=1}^{n} \Delta C_{ess}(t) P_{t}^{e}(t) \Delta t - \sum_{t=1}^{n} \sum_{i=1}^{k} \Delta C_{ev}(t) P_{t}^{w}(t) \Delta t \right|
\]  

(4)

The instantaneous operating cost of the energy storage terminal in the 4 Chinese daily scheduling model, \( \sum_{t=1}^{n} \sum_{i=1}^{k} \Delta C_{ev}(t) P_{t}^{w}(t) \Delta t \) is the instantaneous running cost of the storage terminal after real-time adjustment.

The real-time adjustment of the distributed power supply and energy storage unit needs to meet some basic preconditions.

First of all, the real-time adjustment of the energy storage unit requires the following conditions.

- \( \min(P_{a}(t)) \leq P_{a}^{*}(t) \leq \max(P_{a}(t)) \)
- \( 0 \leq P_{charge}^{*} \leq P_{charge} \)
- \( 0 \leq P_{discharge}^{*} \leq P_{discharge} \)

Second, the real-time adjustment of distributed power supply needs to meet the following conditions.

- \( \min(P_{i}) \leq P_{i}^{w} \leq \max(P_{i}) \)
- \( \min(P_{i}^{s}) \leq P_{i}^{s} \leq \max(P_{i}^{s}) \)

The instantaneous total load and instantaneous power supply are equal in the multi-source heterogeneous distribution network, and the expression is as follows.

\[
P_{i}^{l}(t) + P_{i}^{w}(t) + P_{i}^{s}(t) + P_{ESS}^{*}(t) = \tilde{P}(t)
\]  

(7)

3. Solution of the Model

3.1 Empire competition algorithm

Imperial Competition algorithm is a group-inspired optimization algorithm has good convergence speed and has outstanding advantages for low dimensional target optimization [14]. But the Imperial competition algorithm in the operation of the lack of effective information interaction between the Empire, the Imperial forces did not fully consider in the iterative process, but the weakest colony to the strongest empire, resulting in the algorithm easily fall into the local optimal [15]. In this paper, the evolutionary coefficients are introduced to improve the effectiveness of the algorithm in the low dimensional target function. The specific evolutionary steps are as follows.

First, each colony was mutated in the form of 8.

\[
CO = CO_{1} + \lambda(CO_{2} + CO_{3})
\]  

(8)

Among them, the 3 random colonies, \( \lambda \) is the coefficient of variation.

Second, cross-operate each target according to type 9.

\[
T_{i} = \begin{cases} 
CO & \text{rand} < \mu \\
CO_{i} & \text{rand} \geq \mu
\end{cases}
\]  

(9)

These are the cross coefficients, Rand is the random factor, and Rand's range of values is [0,1].

Finally, according to the greedy strategy, the colony was updated, that is, when the new colonies
were more powerful than the old colonies, the Old colony's position was updated.

3.2 The solution process based on imperial competition algorithm

The process of solving the real-time scheduling model using the imperial competition algorithm is as follows.

(1) Initialization of national, national cost function, Empire, assimilation coefficient, colony coefficient and other related parameters.

(2) Encode the power of distributed power supply. When the total quantity of distributed power supply in distribution network is \( a \), the power supply code of power is as shown in (10).

\[
\hat{P}_{DG} = \begin{bmatrix}
P_{DG,1}^1 & P_{DG,2}^1 & \cdots & P_{DG,1}^B \\
P_{DG,2}^1 & P_{DG,2}^2 & \cdots & P_{DG,2}^B \\
\vdots & \vdots & \ddots & \vdots \\
P_{DG,a}^1 & P_{DG,a}^2 & \cdots & P_{DG,a}^B
\end{bmatrix} = \begin{bmatrix} P_{DG} \end{bmatrix}
\]

\( P_{DG} \) represents the instantaneous power of a distributed power in the B of distribution area. Similarly, it is possible to deduce the coding of the power supply of the C energy storage units in the distribution area B and the power supply \( P_{ESS} = [P_{ESS}]_B \), coding of the main network \( P_{ESS} = [P_{ESS}]_A \). Therefore, the coding of individuals in A countries can be deduced from the above variables \( N = [P_{DG}, P_{ESS}, P_{ESS}] \).

(3) Using the competition algorithm to optimize the solution of the model, the solution process is shown in Figure 2.

![Figure 2. Optimization solution process based on imperial competition algorithm.](image-url)

4. Simulation Verification

Based on the standard IEEE33 node distribution system, this paper constructs a multi-source heterogeneous distribution system, as shown in Figure 3.
Figure 3. structure diagram of multi-source heterogeneous distribution network

Figure 3 Sets the various types of distributed power and energy storage units to 17 for the larger load nodes, and the configuration of the power and energy storage units is shown in table 1.

Table 1. Distributed power supply parameter configuration table

| No. | Node number | Energy type     | Installed capacity |
|-----|-------------|----------------|-------------------|
| 1   | A6          | Energy storage  | 250KW•h           |
| 2   | A8          | Wind power      | 500KW             |
| 3   | A9          | Photovoltaic    | 300KW             |
| 4   | A10         | Fuel oil        | 300KW             |
| 5   | A12         | Energy storage  | 250KW•h           |
| 6   | A13         | Fuel oil        | 300KW             |
| 7   | A16         | Energy storage  | 250KW•h           |
| 8   | A17         | Photovoltaic    | 260KW             |
| 9   | A18         | Wind power      | 500KW             |
| 10  | A21         | Photovoltaic    | 300KW             |
| 11  | A23         | Wind power      | 500KW             |
| 12  | A25         | Energy storage  | 250KW•h           |
| 13  | A26         | Energy storage  | 250KW•h           |
| 14  | A28         | Wind power      | 500KW             |
| 15  | A30         | Fuel oil        | 300KW             |
| 16  | A31         | Photovoltaic    | 300KW             |
| 17  | A32         | Energy storage  | 250KW•h           |

The sales price curve for the main network is shown in Figure 4. It can be seen that during the peak of electricity price, it is necessary to improve the power supply of distributed power supply to reduce the dependence on the main network. During the trough of electricity price, it is necessary to charge the energy storage unit with the main network power supply. Assuming that the fuel generation cost is 0.45 yuan/(kw h), the load of the multi-source heterogeneous distribution network and the power supply of the distributed power supply are forecasted as shown in Figure 5.

Figure 4. graph of electricity price of main network.
Figure 5. Distribution network load and distributed power supply power forecast

The Imperial competition algorithm's parameters are shown in Table 2.

Table 2. The parameter configuration of the Imperial competition algorithm

| Reference type                  | Value |
|---------------------------------|-------|
| Maximum number of iterations    | 200   |
| Number of countries             | 100   |
| Number of empire                | 5     |
| Assimilation coefficient        | 2     |
| Offset coefficient              | \(\pi/4\) |
| Colonial coefficient            | 0.1   |
| Coefficient of variation        | 0.6   |
| Cross coefficient               | 0.9   |

The simulation test platform is configured for the Intel Xeon e5-2600 v2, 8GB DDR3 RAM, and the Windows 10 flagship system, using MATLAB to run the program to solve the scheduling model.

The optimization results of real-time scheduling are shown in Figure 6. According to the current unit operation, combined with the real-time scheduling objective function, the weighted total value of the current system load is 90.646 MW, and the system load is reduced by 0.584 MW compared with the previous dispatch result of 91.23 MW. The real-time scheduling result significantly reduces the peak-to-valley difference of the all-day scheduling, and the system load curve is smoother. In addition, the intermittent distributed energy output is 15.55 MW, compared with the 14.95 MW of the previous dispatch result, the intermittent distributed energy utilization rate is increased by 3.98%; the gas turbine output is 21.51 MW, compared with the 21.34 MW of the previous dispatch result, the gas turbine output increased by 0.8%; the output of the energy storage battery was 2.491 MW, compared with 2.205 MW of the previous dispatch result, the output of the energy storage battery increased by 12.97%; the output of the main network was 53.50 MW, compared with 54.85 MW of the previous dispatch result. Net output decreased by 2.46%. It can be seen from the figure that the utilization rate of distributed energy has been greatly improved during the peak period of electricity price, in which the effective utilization rate of energy storage equipment is maximized, and it can ensure effective charging during the valley period, and participate in system cutting during peak hours. Peak effect; during the valley period, the increase of wind power and photovoltaic output greatly reduced the output of the main network, thus reducing the cost of power purchase. The real-time scheduling cost of the system is 45,876.25 yuan, which is a direct economic benefit of 2.56% compared with the previous scheduled operating cost of 470,836.64 yuan. From the above results, it can be concluded that the system optimization strategy can get the next day system operation strategy. The real-time optimization scheduling can further rationally arrange the distributed energy output according to the current unit operation, which can effectively improve the distributed energy utilization rate and reduce the system operation cost. Improve economic efficiency.
In order to verify the efficiency of the proposed algorithm in the scheduling optimization problem of distributed energy systems, common ICA, genetic algorithm (GA) and particle swarm optimization (PSO) algorithm are selected as the comparison algorithm. The simulation calculation results are shown in Table 3.

![Figure 6. Real-time scheduling optimization results](image)

Table 3 Calculative results

| Algorithm      | Number of iterations (real time) | Real-time scheduling of global optimal values/yuan | Real-time scheduling average optimal value/yuan |
|----------------|----------------------------------|-----------------------------------------------|-----------------------------------------------|
| This article algorithm | 35                              | 45876.25                                     | 46237.14                                     |
| ICA            | 59                              | 47866.63                                     | 48161.10                                     |
| GA             | 57                              | 46444.96                                     | 47000.46                                     |
| PSO            | 54                              | 46454.28                                     | 46996.00                                     |

As shown in Table 3, in the real-time scheduling optimization calculation, the algorithm calculates the optimal value of the system as 45876.25 yuan when the number of iterations is 35. Compared with the other three algorithms, the iteration times of the algorithm are smaller than the common ICA, GA and PSO algorithms, and the optimal values of the algorithm are smaller than the optimal values obtained by the common ICA, GA and PSO algorithms, indicating that the algorithm is distributed energy scheduling. In the application, the solution ability and algorithm adaptability are better, and it can converge quickly in a short time. By improving the optimization method, the algorithm's optimization ability and convergence ability are improved. In addition, compared with the common GA and PSO algorithms, DE-ICA can quickly converge in a short time, so that the optimal value of the algorithm can be obtained. The calculation results fully demonstrate the effectiveness and superiority of the algorithm in the distributed energy system scheduling optimization problem under the active distribution network.

5. Conclusion
Real-time scheduling optimization for multi-source heterogeneous distribution networks The efficiency of distribution network operation can be improved by effective elimination and efficient utilization of distributed energy sources. In this paper, based on the in-depth study of the dispatching model of distribution network, a real-time scheduling optimization model of multi-source heterogeneous distribution network is constructed, and the optimization of the model is solved by the improved Imperial competition algorithm, finally, through the verification of simulation test, the operation cost of distribution network can be reduced by 2.59.
6. References

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