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Optimal Dispatching Technology of Distributed Power Generation Based on Situation Awareness

Yu Xia*, Xinyuan Zhang, Haoran Ge, Shaofei Hao, Wenjing Zou

School of NARI Electric & Automation Engineering, Nanjing Normal University, Nanjing, China
*Corresponding author: 201846008@njnu.edu.cn

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Abstract The comprehensive utilization of distributed power sources can effectively reduce the consumption of fossil energy and reduce carbon emissions. Based on the situational awareness technology, this paper proposes a distributed power optimization dispatching technology, with the least carbon emission as the optimization goal and meeting the grid load demand as the constraint condition. First, in the situation awareness stage, collect information such as the operation status of the power grid; second, use the data collected by situation awareness to simulate the operation of the power grid in the situation understanding stage to achieve in-depth perception of the power grid; finally, consider the grid operating load in the situation guidance stage Demand adjustment and optimization strategy to realize flexible dispatch and control of the power grid in a favorable direction. This paper takes the IEEE 30-bus system as an example for simulation analysis, and the simulation results verify the effectiveness of the proposed method.

Keywords: *situation awareness, distributed power, optimal scheduling*

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1. Introduction

With the development of the power grid, distributed energy sources such as distributed power sources, energy storage power stations, and electric vehicles have been introduced into the power distribution system, and the cost of new energy generation has accelerated significantly. Starting from 2021, new energy power generation will enter a new stage of parity grid [1]. Today, when distributed energy is the new normal, traditional power system multi-objective dispatching technology can no longer meet the needs of modern smart grids. At the same time, the backward development of the power grid system will bring security risks to the operation of the entire power grid. Reasonable dispatching methods can Reduce power generation costs and reduce energy waste [2].

Distributed energy optimization scheduling problem is actually a high-dimensional, non-differentiable, discretized mathematical optimization problem [3]. Reference [4] combines the reactive power output of distributed power supply with traditional voltage regulation methods, and establishes a reactive power optimization multi-agent immune model, and uses multi-agent immune algorithms to achieve reactive power optimization. Reference [5] The minimum active power loss of the distribution network is the objective function to establish a reactive power optimization mathematical model, but the reactive power output of distributed power sources is not considered in the model. Reference [6] established a reactive power optimization mathematical model that takes the minimum active power loss of the distribution network as the objective function, and the voltage limit is used as the penalty item, and the optimization object is a small hydropower station. Reference [7] Aiming at the problem that intermittent wind power degrades the voltage control effect based on real-time reactive power optimization, a reactive power optimization control model is established based on the voltage limit probability

Based on the existing research, this paper proposes a distributed power optimization dispatching technology based on situational awareness. The goal of dispatching is to minimize carbon emissions while meeting the power demand of the load, and achieve the purpose of protecting the environment and saving energy. Situational awareness technology includes three parts: situational awareness, situational understanding, and situational guidance. In the situational awareness stage, the power generation of various power generation methods is explained, the objective function of the minimum carbon emission is established in the situational understanding stage, and the constraint conditions are established in the situational guidance stage. To ensure that power generation meets demand. On the basis of situational awareness, the IEEE30-bus system is used as an example to simulate. The simulation results show that the scheduling method proposed in this paper is effective.

1.1. Situation Awareness

Situation awareness is to rely on the system analysis and control requirements of the power grid to reasonably configure information detection technology to obtain power grid status data. The information obtained from situation awareness prepares for situation understanding and situation guidance [8].

The current distributed power sources mainly include hydropower, wind power, thermal power, etc. This article takes these three types of electric energy as the goal of situational awareness. During the operation of the power grid, not only the differences and complementarities of the three power generation methods must be considered, but also their randomness and uncertainty must be considered. The power of wind power generation system comes from natural wind, and its output power is related to wind speed. Therefore, wind power generation has certain randomness and uncertainty. The power system of hydropower plants is greatly affected by the season, so the output power of hydropower plants fluctuates greatly in the long-term planning. In addition, the power generation of hydropower stations is also affected by the weather, so its output has a certain degree of uncertainty.

The relationship between the wind speed and output power of a wind turbine can be expressed by the following approximate function [9]:

$$P(v)=\begin{cases}0 & v\le v_{ci}\\ a+bv & v_{ci}\le v\le v_r\\ P_r & v_{cr}\le v\le v_{co}\\ 0 & v\ge v_{co}\end{cases} \tag{1}$$

$$a=\frac{P_r\cdot v_{ci}}{v_{ci}-v_r}\qquad b=\frac{P_r}{v_r-v_{ci}}$$

In the formula, v_{ci} is the cut-in wind speed, v_{co} is the cut-off wind speed; v_r is the rated wind speed; P_r is the output power of the wind turbine at the rated wind speed.

In the model of this article, the future water distribution of hydropower stations can be approximately regarded as a normal distribution [10], and the future water distribution function of hydropower stations in each time period is shown in formula 2.

$$f(x_{w,t})=\frac{\exp[-(x_{w,t}-\mu_{w,t})^2/2\sigma_{w,t}^2]}{\sqrt{2\pi}\sigma_{w,t}} \tag{2}$$

In the formula, $x_{w,t}$ is the power generation of the hydropower unit at time t, $\sigma_{w,t}$ represents the future water standard deviation, and $\mu_{w,t}$ represents the future water average.

1.2. Situation Understanding

Situation understanding refers to the information obtained from situation awareness, analysis and judgment through situation assessment technology, to achieve in-depth perception of the power grid. The situation understanding stage in this article is mainly to simulate the distributed energy grid to realize the assessment of the current state of the grid, and the simulation results will be used as the basis for situation guidance.

The optimization goal of this article is mainly to reduce the system's environmental pollution. Since both hydropower and wind power use clean energy and do not pollute the environment, in the optimal dispatching of power systems containing distributed energy, the coal consumption of thermal power plants should be minimized and the system can be improved while meeting relevant constraints. Economical and environmentally friendly power generation.

This paper takes the minimum coal consumption from the start t_p to the end time t_e as the objective function, as shown in formula 3.

$$\min Y=\sum_{t\in[t_p,t_e]}\sum_{i=1}^{N_i} f(x_{i,t}) \tag{3}$$

In the formula, Y is the coal consumption; i is the number of the thermal power unit; N_i is the number of the thermal power unit; $x_{i,t}$ is the power generation of the thermal power unit at time t.

1.3. Situational Guidance

Situational guidance is based on situational awareness, analyzes the operating status of the power grid, and conducts reasonable and optimized dispatch of the power grid operation to realize the flexible dispatch and control of the power grid in a favorable direction.

In the scheduling period [t_p, t_e], through the coordinated deployment of systems containing multiple distributed energy sources, the situational guidance is optimized according to the model derived from the situational awareness, and the constraint function is obtained as shown in formula 4.

$$\sum_{w=1}^{N_w}x_{w,t}+\sum_{i=1}^{N_i}x_{i,t}+\sum_{h=1}^{N_h}x_{h,t}=X_{D,t} \tag{4}$$

In the formula, N_w is the number of hydropower generating units, N_i is the number of thermal power generating units, N_h is the number of wind generating units, $x_{h,t}$ are the power generation of the wind turbines at time t, and X is the system power demand at time t.

2. Distributed Power Supply Control Strategy Based on Situation Awareness

In the optimal dispatch of power grids with distributed power sources, situation awareness and situation understanding are used to provide corresponding decision-making information for grid operation, and situation guidance is used to optimize low-carbon and environmentally friendly operation of the grid, so that it can be flexibly dispatched to the grid in a favorable direction And control.

First, the situational awareness stage: obtain grid electrical information, distributed power sources, energy storage information, etc. through PMU, observability measurement, advanced measurement and other technologies.

Second, the situation understanding stage: using the distribution network state estimation technology with distributed power generation, the survivability analysis technology of the distribution system and the power supply capacity analysis technology of the distribution network system, etc., starting from t_p, the coal consumption of thermal power plants is the smallest Is the objective function, and the total power generation meets the demand as the constraint condition to simulate the grid operation.

Finally, in the situational facilitation stage, coordinated deployment of systems containing multiple distributed energy sources based on the results of situational awareness, and optimization of control models, so that the system can minimize carbon emissions while meeting electricity demand.

The flow chart of distributed power control algorithm based on situational awareness is shown in Figure 1.

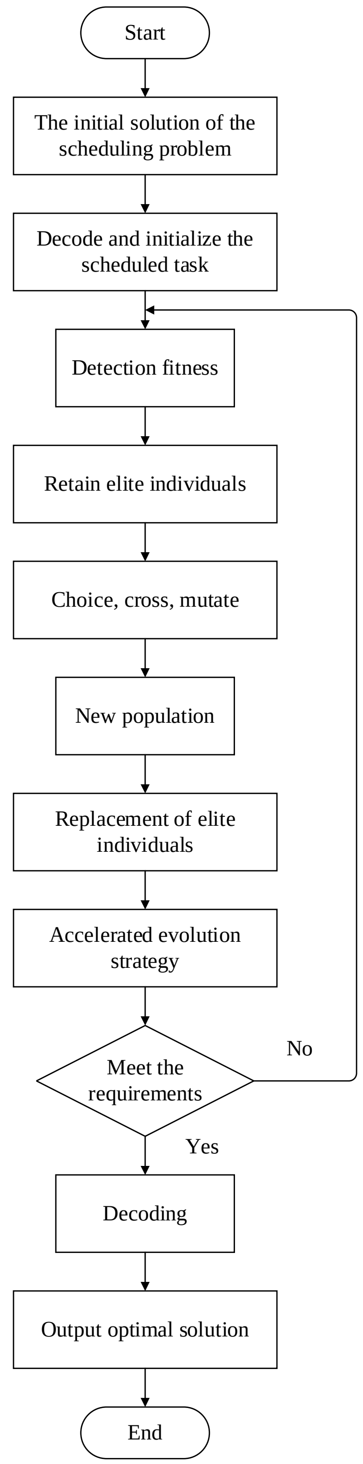

Figure 1. Algorithm flowchart

3. Simulation Analysis

This calculation example uses the IEEE30-node system, which includes 6 thermal power units, one wind power station, and two hydropower stations. The system wiring diagram is shown in Figure 2. Considering the access of a large-scale wind farm at node 8, this example expands the line transmission capacity of branch 10 in the IEEE 30-node system by five times, and the line transmission capacity of branch 40 by twice the original. At the same time, it is assumed that all nodes in the improved system contain elastic loads, and the elastic loads account for 10% of the total load of the nodes.

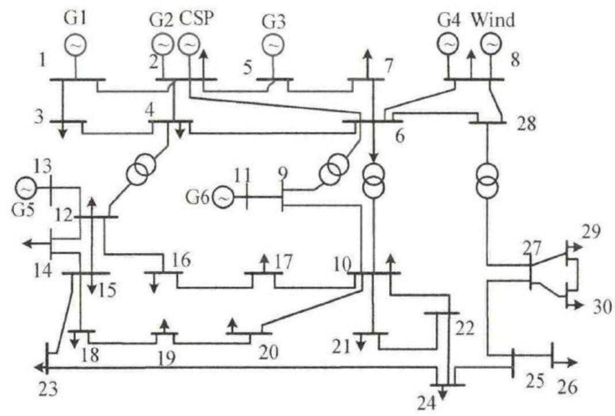

Figure 2. IEEE30 node wiring diagram

Typical daily load data is shown in Figure 3. The maximum load is 1096kW, which appears at 3 o'clock in the afternoon; the minimum load is 646kW, which appears at 2 o'clock in the morning.

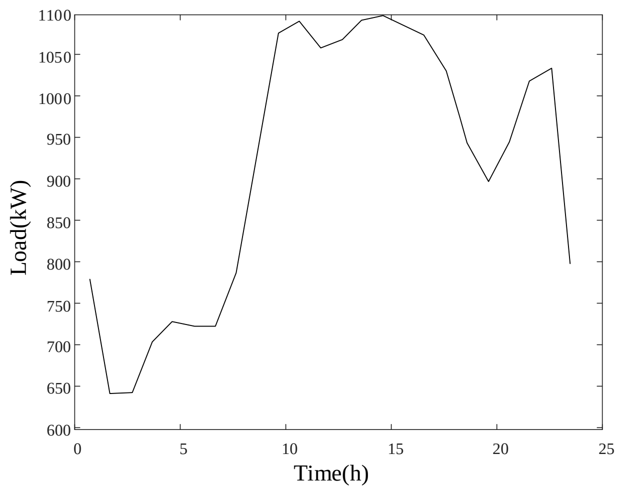

Figure 3. Typical Daily Load Data

According to formula 2, the specific future water data of the hydropower station is shown in Table 1.

Use Weibull distribution to predict wind power generation, as shown in Figure 4. Weibull distribution is a line type that expresses the distribution of wind speed. It is a single-modal, two-parameter distribution function cluster. k and c and are two parameters of the Weibull distribution, k is called the shape parameter, and c is called the scale parameter. The larger the k, the smaller the range of annual average wind speed change.

Table 1. Font Sizes for Papers

month	Hydropower station 1 m^3/s	Hydropower station 2 m^3/s
1	5.925	43.386
2	5.021	33.152
3	6.023	24.240
4	7.998	40.986
5	21.389	130.002
6	48.059	358.239
7	58.799	388.800
8	28.988	269.760
9	31.567	200.010
10	21.848	171.570
11	12.558	74.278
12	7.045	36.220

Calculate the Weibull distribution parameters for each height of the wind tower according to the calculation method in the "National Wind Energy Resources Evaluation Regulations". The Weibull parameters of the 10m high wind tower are k=2.13, c=4.78 m/s; the 30m high wind tower Weibull Parameters k=2.24, c=5.94 m/s; 50m high wind tower Weibull parameters k=2.24, c=6.46 m/s; 70m high wind tower Weibull parameters k=2.27, c=6.82 m/s.

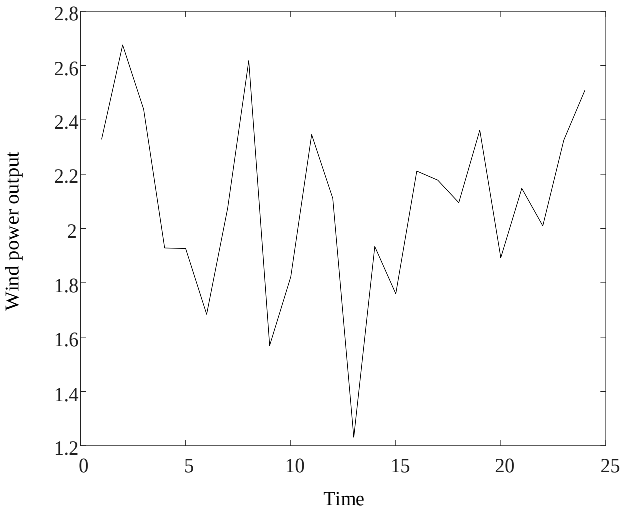

Figure 4. Wind power output forecast

In order to reduce the random influence in the simulation, we will perform multiple simulations and take the average of all the final results calculated by the simulation to obtain a more accurate value in order to eliminate the simulation error. Finally, by programming MATLAB, using the parameter settings given in the previous article, we carried out a simulation. After the simulation, all the results were calculated and sorted out. We got the following results, as shown in Table 2.

Table 2. Optimization Results

	Method of this article	Traditional method
Coal consumption /t	878596.88	886593.45
Wind power generation /MWh	675286.15	672589.65
Hydroelectric power generation /MWh	1246248.56	1225485.12
Thermal power generation /MWh	2713073.49	2748853.55
Time consuming /s	61.0	1793

It can be seen from Table 2 that compared with the traditional algorithm, the algorithm based on situational awareness used in this paper consumes less time than the traditional algorithm. In addition, the algorithm in this paper consumes less coal, which is more in line with the goal of low carbon and environmental protection.

Figure 5 is the convergence curve. It can be seen from Figure 5 that after about 20 iterations, the curve begins to stabilize. It can be seen that the intelligent optimization algorithm based on situational awareness not only converges quickly, but also can find higher-quality optimization solutions.

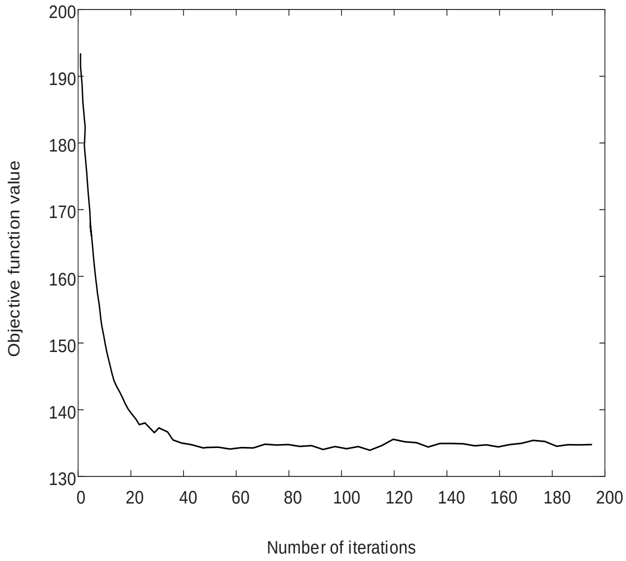

Figure 5. Convergence curve

4. Conclusions

The situational awareness-based distributed power optimization dispatching technology proposed in this article uses situational awareness technology, through situational awareness, situational understanding and situational guidance, to conduct real-time assessment of the grid operation situation, and optimize dispatch based on the assessment results. The calculation example shows that the principle is simple, the calculation speed is fast and the accuracy is high, which not only meets the load demand, but also reduces carbon emissions.

This paper only studies the optimal dispatch based on situational awareness technology, and does not consider the support time of the load power supply guarantee and the study of the recovery strategy after the grid failure, which is also the research direction of the next stage.

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