Research Article

Research on Coordinated Scheduling Strategy of Heat Storage Thermoelectric Units Based on Wind Power Data Acquisition System Using Edge Computing

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Cogeneration units use heat and electricity as the main operation mode in the heating season. It suffers the lack of peak shaving ability, resulting in intense wind curtailment. This study presents a coordinated scheduling strategy of heat storage thermoelectric units considering the uncertainty of wind power. The developed method performs a wind power data measurement and process system based on edge computing and deep learning to acquire operation data quickly and independently and adopts a wind power prediction method based on interval scenario. Furthermore, the coordinated control model of the thermal storage unit is established after the analysis of the characteristics of coordinated scheduling strategy of heat storage thermoelectric units based on wind heat complementation, and then the improved particle swarm optimization (PSO) is adopted to the solving process. The proposed method is verified by applying it to two typical thermal power units.

1. Introduction

In recent years, the installed capacity and scale of wind power installed in China have been increasing, and there has been a serious phenomenon of wind abandonment. According to the latest information released by the national energy administration, in 2017, China's wind abandonment mainly concentrated in the northeast, northwest, and North China, among which Gansu, Xinjiang, Jilin, and Inner Mongolia were the most serious provinces, with wind abandonment rates of 43%, 38%, 30%, and 21%. One of the main reasons for this phenomenon is that the heating demand of the thermal power unit in winter leads to a sharp decline in the peak shaving ability of the system [1, 2]. Due to the climate of the heating season in the north of China, the main power supply is the cogeneration unit, which lacks the capacity of peak load regulation. In order to respond to the demand of the heating load in the heating period, the thermal power unit adopts the mechanism of "power by heat," and generating output and heating output have a

coupling relationship. With the increase of the minimum generating capacity, the contradiction of the lack of peak shaving ability of the system is intensified. This problem is also one of the important directions in the related research process of energy management system, by the establishment of layered distributed management system to collect and manage the data of power production, energy storage, and energy consumption and with the means of energy monitoring, energy statistics, and conversion efficiency analysis used in the system to distribute properly the energy facilities allocation and control functions which can significantly increase the utilization efficiency of the facilities and energy and reduce costs.

In order to improve the scale of wind power input network, energy storage technology has attracted extensive attention in recent years due to its excellent wind power complementarity. However, except for the mature pumped storage power stations, almost all other energy storage methods are faced with problems such as scale difficult to meet the requirements of modern power system and life,

cost, and efficiency. In order to expand the feasible area of wind power operation and solve the contradiction between wind power and heating units, a joint scheduling model of cogeneration unit with heat storage and electric heating system is established in [3], which shows that some heat storage devices with large capacity can effectively improve the flexibility of system scheduling and increase the wind power consumption. Literature [4] puts forward the concept of electricity-heat combined system, which goes beyond the scope of traditional power system, makes full use of the complementarity between power system and thermal system, and improves the ability of optimal allocation of resources in a broader space and time scope. Cogeneration units are of great importance for solving the energy crisis [5], but their thermoelectric coupling relationship is in contradiction with the new energy grid connection. Literature [6] uses heat storage devices to break the thermoelectric coupling relationship of “fixing electricity by heat” and analyzes the effects generated by different installation locations of heat storage devices. Literature [4] summarizes a scheduling model of comprehensive utilization of wind power consumption of heat storage device and electric boiler based on the thermoelectric decoupling characteristics of heat storage device and electric heating characteristics of electric boiler and compares the economic situation of different scheduling methods. In [7], under the influence of uncertain factors of wind power, the scheduling model of joint operation of the wind farm and cogeneration unit with heat storage is established. Considering the interaction between the online revenue and penalty cost under uncertain factors, the dual operation scheduling strategy is formulated with the goal of the highest final revenue. Under the condition of the German spot market, the efficiency of thermal power unit greatly improved by increasing cogeneration and heat storage device with the appropriate capacity. Scholars first analyzed the principle of peak shaving and valley filling of heat storage device to improve the peak shaving capacity, established a joint scheduling model of wind power, thermal power, and heat storage device, and tested the economy of wind power and heat storage device with the coal consumption rate as the index. At the same time, considering the uncertainty of wind power and the heat release characteristics of a heat storage device, a bilinear model scheduling method proposed solving the combined scheduling problem of electric heating [8–11].

Through the above research, it can be found that the thermal storage device can decouple the thermal electric characteristics of the thermal power unit. Through the reasonable distribution of the electrical power and thermal power of the unit, the peak shaving ability of the system can improve, the generation of new energy such as wind power can connect to the grid, the consumption space can improve, and the operation cost can reduce. For the seasonal uncertain factors of wind power, a wind turbine data measurement and process system based on edge computing and deep learning is adopted to control each WT in real time, quickly, and independently, and a scheme to improve the capacity of peak load regulation of thermal storage unit based on the coordinated scheduling of wind and heat is

proposed. This paper mainly introduces the basic principle of the heat storage scheme and then analyzes the external characteristics of the thermal operation of the thermal storage unit. The coordinated scheduling strategy of heat storage thermoelectric units based on wind/heat complementary power system is proposed, and the coordinated control model of thermal storage unit is set up. Finally, the coordinated scheduling strategy is applied to typical thermal power units, and the improved particle swarm optimization (PSO) is used to solve and verify the effectiveness of the strategy.

2. Wind Turbine Measurement and Control System Based on Edge Computing and Deep Learning

2.1. Edge Computing. Along with the appearance of the ubiquitous power Internet of things, the Internet of everything era is coming [12–14]. The increasing amount of data generated by distribution network edge devices (such as large-scale DG and FL), at the same time, puts forward higher requirements for network communication bandwidth, data processing timeliness, data privacy, and so on, which cannot be effectively addressed by the centralized cloud computing model of traditional distribution network EMS. In this context, edge computing has received extensive attention from scholars at home and abroad. The basic idea is to carry out computing tasks at the data source side near the edge of the network, so as to reduce communication delay, reduce communication bandwidth requirements, relieve the computing pressure of the cloud master station, and realize data privacy protection of the edge nodes [15, 16].

2.2. Wind Turbine Measurement and Control System. A wind turbine measurement and control system based on edge computing and deep learning is adopted. The system includes the master server, the terminal sensor, the terminal controller, the terminal server, and WT master controller installed on the wind turbine. The terminal sensor is placed at the location of the parts to be monitored on the wind turbine. The structure diagram of the method is illustrated in Figure 1.

The terminal controller is connected to the terminal sensor and the terminal server. The terminal controller is stored with a deep learning model. The terminal controller is used to obtain the collected data of the terminal sensor, conduct edge computing and processing of the collected data through the deep learning model, store the processing results in the terminal server, and generate WT control instructions [17]. The terminal server is connected to the master server, which is used to obtain processing results through the terminal server and issue the deep learning model to the terminal controller. WT master connection terminal controller or the terminal server gets the WT control instructions and controls the WT according to the instructions. The data acquisition and control system can control each WT in real time, quickly, and independently, and wind turbine control is more efficient and intelligent. The implementation process is shown in Algorithm 1.

FIGURE 1: The structure diagram of wind turbine measurement and control system.

3. Coordinated Scheduling Model of Heat Storage Thermoelectric Units Based on Wind/Heat Complementary Power System

3.1. Electrothermal Characteristics of Heat Storage Thermoelectric Units. Poor regulation ability of the power system in the northern region during the heating period is largely due to the operation of the heating unit following the “heat to power” mode. Although the heat and electric load of the extraction unit change in a specified range, the power generation is greatly affected by the heat supply. With the increase of the heat supply, the adjustable range of the power generation becomes increasingly smaller. In the heating period, the heating task of a thermal power plant is very large, so the actual power adjustment range is very small [18,19]. The characteristic curve of thermoelectric unit is shown in Figure 2.

According to the above working condition diagram, there is a linear relationship between the generating power range of the heating unit and the change of the thermal power, which is expressed by the following formula [20]:

$$\begin{aligned} P_{ti}^{e, \max} &= P_{ti0}^{e, \max} - K_1 P_{ti}^{h, \max}, \\ P_{ti}^{e, \min} &= \begin{cases} P_{ti0}^{e, \min} - K_2 P_{ti}^{h, \max}, \\ P_{ti0}^{e, \min} - K_2 P_{ti}^{h, \max} + K_3 (P_j^{h, \max} - P_{ti}^{h, \max}), \end{cases} \end{aligned} \quad (1)$$

where $P_{ti}^{e, \max}$ and $P_{ti}^{e, \min}$ are the minimum and maximum values of generating power when the heating power of the unit is $P_{ti}^{h, \max}$ at time t . $P_{ti0}^{e, \min}$ and $P_{ti0}^{e, \max}$ are the minimum and maximum values of generating power when the unit is in condensate mode. $P_{ti}^{h, \max}$ is a certain heating power of the unit. K_1 , K_2 , and K_3 are coefficients.

The following formula is the energy relationship between the input and output of the extraction heating unit:

$$Q_{\text{coal}} = \frac{P_E (1 + \varepsilon_1)}{\lambda_{\text{coal}}}, \quad (2)$$

where Q_{coal} is the energy of coal, P_E is the generating power, ε_1 is the thermal power ratio, and λ_{coal} is the unit efficiency.

Through the analysis of the extraction type heating unit, it can be seen that the thermal power unit can automatically respond to the change of heating load, so the controllable thermal power unit can be used to make up for the uncontrollable wind power, form a complementary operation mode, and realize the stable heating of the user end. The necessity of decoupling the mode of “power by heat” to improve the peak load regulation ability of the system is explained.

3.2. Wind Power Prediction considering Uncertainty. The uncertainty of wind power is directly reflected in the large prediction error of wind power. Due to the characteristics of wind energy, such as randomness, volatility, intermittence, and poor controllability and the limitations of existing wind power prediction methods, wind power prediction error is inevitable. Taking the day ahead forecast as an example, the average absolute error of the wind power forecasting software actually put into commercial operation in the global scope is about 14%–20%, which will have a significant impact on the optimization results of the power flow analysis, unit combination, economic scheduling, and other issues considering wind power access.

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} \cdot e^{-(x-\mu)^2/2\sigma^2}. \quad (3)$$

3.3. Objective Function. At present, China has started to implement energy-saving power generation scheduling. The most common scheduling mode is the lowest operating cost and the lowest coal consumption of the system. Therefore, the objective function is the minimum cost, that is, the smallest coal consumption of the system. The short-term operational cost of the heat storage device is very small, so it is unnecessary to consider when modeling. For conventional thermal power units, the coal consumption C_c can be expressed as the secondary form of power generation:

$$C_c(i, t) = a_i \cdot (P_{el,i,j}^s)^2 + b_i \cdot P_{el,i,j}^s + c_i, \quad (4)$$

where a_i , b_i , and c_i are the coal consumption coefficients of unit i and the generating power of unit i at time 1.

The relationship between the coal consumption C_e of the extraction unit and the thermal power and electric power of the unit is as follows:

FIGURE 2: Characteristic curve of thermoelectric units.

$$C_e(i, t) = A_i \cdot (P_{el,i,j})^2 + B_i \cdot P_{el,i,j} + C_i, \quad (5)$$

where A_i , B_i , and C_i are coal consumption coefficients of thermal power unit.

Based on the cost function forms of the above two types of units, the following objective functions can be established:

$$\min C(i, t) = \left\{ \sum_{t=1}^T \left[\sum_{i \in G_c} C_c(i, t) + \sum_{j \in G_e} C_e(j, t) \right] \right\}, \quad (6)$$

where T is the total number of periods; G_c is the set of conventional thermal power units; G_e is the set of cogeneration units.

The coordinated control model considering environment includes the cost of conventional thermal power generating units, cogeneration unit, operation maintenance of wind power generation, coal desulfurization denitration processing, emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and the emission required for joining account [21, 22].

Assume that f is the environmental cost; then, the objective function is as follows:

$$f = C_1(P_{it}) + C_2(P_{e,it}) + C_3(P_{w,it}) + C_4(A_S, A_N) + C_5(L_S, L_N), \quad (7)$$

where C_1 is the generation cost of conventional thermal power units; C_2 represents the generation cost of cogeneration units; C_3 is the operation and maintenance cost of wind turbines; C_4 is the removal and treatment cost of SO_2 and NO_x ; C_5 is the pollutant emission penalty cost for the escape of SO_2 and NO_x ; P_{it} is the generation power of conventional thermal power unit at time; $P_{e,it}$ is the generation power of the cogeneration unit at any time; $P_{w,it}$ is the generating power of wind turbine at the moment; A_S and A_N , respectively, represent the mass of SO_2 and NO_x generated in the process of power generation; L_S and L_N , respectively, represent the mass of SO_2 and NO_x that have escaped [23].

3.4. Constraints

3.4.1. Power Balance Constraints.

$$\sum_{i \in N} P_{el,i,t}^s + P_{w,t}^s = P_{D,el,t} + \rho \cdot \sum_{k=1}^M |h_{k,t}|, \quad (8)$$

where N is the collection of thermal power units in the area, $N = G_c + G_b + G_e$. The coefficient $P_{sw,t}$ is the wind power of the wind farm connected to the grid at time t in scenario S . $P_{D,el,t}$ is the electrical load of the system at time t . ρ is the power consumption when the electric pump stores unit heat. $h_{k,t}$ is the heat storage and release power of the heat storage tank at time t .

3.4.2. Heating Constraint.

$$\sum_{i \in G_c^k \cup G_b^k} P_{h,j,t} + h_{k,t} \geq P_{D,h,j,t}, \quad (9)$$

where $k = 1, \dots, M$, M is the total number of heating zones; $P_{D,h,j,t}$ is the total heat load of the k zone thermal power plant at time t ; G_a and G_b are the collection of extraction type and backpressure type units of the k zone, respectively.

3.4.3. Start-Stop Output Constraint of Unit. When a generator set changes from a stagnant state to an operating state or is about to change from an operating state to a stagnant state, the minimum output of the generator set shall be maintained stable.

$$\begin{aligned} u_{i(t-1)} &= 0, u_i = 1, \\ u_i &= 1, u_{i(t+1)} = 0, \\ P_{it} &= P_{i \min}. \end{aligned} \quad (10)$$

3.4.4. Constraints on the Upper and Lower Limits of Unit Climbing Speed.

$$D_i T_1 \leq P_i^t - P_i^{t-1} \leq U_i T_1, \quad (11)$$

where D_i and U_i are the upper and lower limits of unit climbing speed.

3.4.5. Wind Power Output Constraint.

$$P_{w,t}^s \leq P_{w,fore,t}^s, \quad (12)$$

where $P_{w,fore,t}^s$ is the predicted wind power of the wind farm at time t .

3.4.6. Operation Restriction of Heat Storage Device.

$$h_{k,c \max} \leq h_{k,t} \leq h_{k,f \max}, \quad (13)$$

$$h_{k,t} = (1 - \lambda) \cdot S_{h,k,t-1} - S_{h,k,t}, \quad (14)$$

in which formula (13) is the heat storage and release capacity of heat storage device and $h_{k,cmax}$ and $h_{k,fmax}$ are the maximum heat storage and release power of the heat storage device. $h_{k,t}$ is calculated by formula (14); $S_{h,k,t}$ is the heat storage capacity of k zone heat storage device at time t . λ is the heat loss rate of the heat storage tank in a single period.

3.4.7. Capacity Constraints for Heat Storage.

$$S_{h,k,0} = S_{h,k,T}, \quad (15)$$

where $S_{h,k,max}$ is the heat storage capacity of the heat storage device. In the model, it is assumed that the heat storage capacity $S_{h,k,t}$ of the heat storage device at the end of the cycle is equal to its initial heat storage capacity $S_{h,k,0}$.

3.4.8. System Rotation Standby Constraint.

$$\begin{aligned} U_{SR} &= \sum_{i=1}^N \min(P_{i,max} - P_i(t), P_{ui})^3 P_{sr}, \\ U_{DR} &= \sum_{i=1}^N \min(P_i(t) - P_{i,min}, P_{di})^3 P_{sr}, \end{aligned} \quad (16)$$

where U_{SR} and U_{DR} are the sum of the positive and negative rotating spare capacity provided by each thermal power and thermoelectric unit, respectively. P_{sr} is the amount of rotation reserve set.

3.5. Solution Method. In this paper, the improved PSO algorithm is used to improve the learning factors, combined with the prior method. For a certain time, if the output value of a unit exceeds the maximum value of the output range of the unit, the output value of the unit in that period is the maximum value of the unit output. If the output value of the unit is from zero to the minimum value of the output range of the unit, the output value of the unit in this period shall be zero or the minimum value of the unit output. If the output value of the unit is lower than zero at this time, it will be zero. After the output of each unit is set in this way, if all start-up units have reached the upper limit of output or the allowable value limit of climbing rate, all start-up units have reached the lower limit of output or the allowable value limit of downward climbing rate, unable to meet the requirements of rotating reserve and additional equality constraints. Then run or shut down the selected unit in turning. Then, the above operations are conducted at all times to achieve the correction of each particle position, to ensure that the solution obtained in each iteration of the particle swarm is feasible. The specific solution steps are as follows (Algorithm 2).

The flowchart of the overall scheme is shown in Figure 3.

4. Example Analysis

4.1. Experimental Description. The example study is divided into four parts, part A is the introduction to the experimental

environment, part B is based on interval scene, and two contrast tests were conducted in parts C and D, respectively.

In part C, the specific data of two cogeneration units are shown in the literature [15], the basic parameters of four conventional thermal power units are shown in Table 1, and the predicted power curve of a wind farm is shown in Figure 4 to verify the effectiveness and feasibility of the proposed model. One day is divided into 24 scheduling periods, and a swarm optimization algorithm is used to solve the model to determine the joint output scheduling of cogeneration unit with heat storage.

To make a comparison, the configuration, parameters, and load of the units are consistent with those in the previous part D cogeneration units; 4 conventional thermal power units and 1 wind farm are also selected to verify the effectiveness and feasibility of the proposed model. In the simulation analysis, the operation and maintenance cost of the wind farm in the selection area in this paper is 110 yuan/MW·h, and the cost of desulfurization and denitrification treatment unit for SO_2 and NO_x per kilogram is 3 yuan/kg and 15 yuan/kg, respectively. The generator unit uses coal burning at a price of 520 yuan per ton, and the mass of SO_2 and NO_x released by coal burning per ton is 8 kg and 7 kg, respectively. According to the reference, the treatment efficiency of the desulfurization and denitrification unit is set as 80%, and a penalty fee of 0.65 yuan is imposed per kilogram of SO_2 and NO_x . One day is divided into 24 scheduling periods, and the swarm optimization algorithm is used to solve the model to determine the joint output scheduling of cogeneration unit with heat storage and wind power considering the environmental cost.

4.2. Wind Power Prediction Based on Interval Scene. The test results show that the expected value of the predicted relative error $\mu_f = 0.0203$, and the standard deviation of the predicted relative error $\sigma_f = 0.0667$. Through the calculation of probability distribution, the prediction error is mainly distributed between 16% and 22%, reaching 99.52%. It is discredited in steps of 0.02, the curve with the largest probability of occurrence is called 1.0 curve, and the curves on both sides are called 1.02, 1.04, ..., 0.98, 0.96, ... For the statistical wind power data of a wind farm in 2018 during the heating period, see Figure 5 and Table 2.

According to the distribution characteristics of wind power prediction error and considering the obvious seasonal difference of wind power, the discretization interval of wind power prediction can be simplified as a curve with I number, corresponding to a scene with I number. Each curve with I number corresponds to an empirical probability value f_i , where $I = 1, 2, \dots, I_{max}$ (upper limit to the lower limit in order), indicating the probability of its possible occurrence, and the sum of all f_i is 1.

4.3. Coordinated Scheduling of Heat Storage Thermoelectric Units. For the coordinated scheduling of heat storage thermoelectric units, through the proposed solution, it is found that the lowest comprehensive cost is 495600 yuan/d,

FIGURE 3: The flowchart of the overall scheme.

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(1) Initialization
(2) for  $WT_i = 1$ 
(3) Send model  $DL_i$  to terminal controller  $C_t$ .
(4) end for  $WT_i = n$ 
(5) End of Initialization
(6) repeat
(7)   for  $S_t = 1$ 
(8)     collects monitoring data
(9)     Send data to  $C_t$ .
(10)    edge calculation
(11)    Results compiled and stored
(12)  end for  $S_t = m$ 
(13)    Send control instructions
(14)    for  $WT_i = 1$ 
(15)      obtains the control instructions
(16)      transmits the processing results
(17)    end for  $WT_i = n$ 
(18) until achieve control effect
  
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ALGORITHM 1: Wind turbine measurement and control system.

and the power output scheduling of each unit within the scheduling day is shown in Figure 6. It can be seen from Figure 6 that the sum of electric output and thermal output of the unit at each time under this dispatching mode is equal to the electric load and thermal load, to meet the balance of heat, power supply, and demand. In the peak period of the heat load (1–7 h; 21–24 h), the electric load is in the low period, and there is an obvious contradiction between power on and heat demand. Because the fuel cost of cogeneration unit is significantly lower than that of thermal power unit and its thermal output and electrical output have certain coupling characteristics, in the peak period of electrical load, in order to reduce the output of thermal power unit, it is necessary to increase the electrical output of cogeneration

unit. The heat storage device releases heat during the peak period of the electric load, to reduce the thermal output of the cogeneration unit, then achieves the purpose of increasing its electricity output, and achieves the goal of reducing the comprehensive operation cost.

From the curve in Figure 7, it can be seen that the period of no downregulation capacity of thermal power generation mostly occurs in the period of low-level operation of the power grid and almost coincides with the period of heat storage input at night. When the period of no downregulation capacity coincides with the period of heat storage input, it is less than the period of no downregulation capacity or heat storage input. It shows that when the power grid is in a low period and the thermal power has no

FIGURE 4: Prediction curve of thermal load, electric load, and wind power output.

FIGURE 5: Statistical wind power in heating period.

downregulation capability, there is no need to put heat storage into operation. Although this rarely happens, one explanation is that the wind power output is in the process of decreasing.

4.4. Coordinated Scheduling of Heat Storage Thermoelectric Units considering Environmental Costs. After calculation, the total cost of the coordinated control model considering environmental costs is 576,000 yuan per day, including 104,000 yuan for the operation of the

desulfurization and denitrification device and 0.14 million yuan for the penalty charged for the gas escaping SO_2 and NO_x . Figure 8 shows the electric load and output curves of the thermal storage unit, and Figure 9 shows the wind power consumption of different models. Table 3 is the comparison of wind power consumption between different models.

Figure 9 shows the main running time of wind power is 8~16 h; by the time, the internal heat load is in a low state, and the wind power is in its peak, wind curtailment still exists subject to the operational cost of wind power.

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(1) Initialization
(2) Parameters setting: particle number  $n_p$ , iteration number  $g_{\max}$ , constraints: cons.
(3) Initialize the position  $p_i$  and speed  $s_i$ 
(4) End of Initialization
(5) repeat
(6) optimal value calculation  $f_g$ 
(7) for  $g = 1$ 
(8)   for each  $n_i$ 
(9)     update the  $p_i, s_i$ 
(10)   end for all particle updated
(11)   new particles judgment
(12)   if particles  $\in$  cons
(13)     next step
(14)   if particles  $\notin$  cons
(15)     particles correction and judgment
(16)   if particles  $\notin$  cons
(17)     replace the last particle value
(18)     determine the optimal output value  $f_g$ 
(19)  $g = g + 1$ 
(20) until  $g = g_{\max}$ 

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ALGORITHM 2: Improved particle swarm optimization (PSO).

FIGURE 6: Generating power dispatching value of unit.

FIGURE 7: Equivalent heat-load curve of heat storage device of cogeneration unit.

FIGURE 8: Electric load and output curve of thermal storage unit.

FIGURE 9: Wind power consumption of different models.

TABLE 1: Parameters of the conventional thermal power unit.

Thermal power unit	Upper limit of output	Lower limit of output	Unit climbing rate	Fuel cost factor		
	$P_{\max}$ (MW)	$P_{\min}$ (MW)	r_{ui} (MW/h)	a_l (yuan/MW ²)	b_l (yuan/MW)	c_l (yuan)
1	50	25	25	0.011	18.84	11.50
2	35	10	18	0.070	25.97	32.87
3	30	10	15	0.030	38.02	18.11
4	40	12	20	0.010	13.01	7.07

In the traditional coordinated control model without environmental costs, the daily cost of power generation is 471,000 yuan, and the wind power consumption is 21.9% of the predicted value, while in the coordinated control model considering the environment and wind power operation and maintenance, the daily cost of power generation is 576,000 yuan, and the wind power consumption is 30.7% of the predicted value. Obviously, in

the coordinated control model that takes into account environment and wind power operation and maintenance, wind power operation and maintenance costs and pollution control costs will increase the power generation cost to a certain extent, but the emission of pollution gases will significantly change, among which SO₂ emission will be reduced by 5.8 t and NO_x emission will be reduced by 5.2 t.

TABLE 2: Distribution of wind power in heating period.

Scene I	Empirical probability value f_i
Early stage	0.21
Middle stage	0.47
Last stage	0.32

TABLE 3: Environmental cost on wind power consumption and pollution emission.

Environmental costs	Power generation cost/ten thousand yuan	Wind power consumption (%)	SO ₂ pollution (t)	NO _x pollution (t)
Considering	57.6	30.7	1.4	1.1
Not considering	47.1	21.9	7.2	6.3

5. Conclusions

In view of the problem that a large number of winds are abandoned due to the lack of peak load regulation capacity caused by the operation of cogeneration unit with heat as power, this paper proposes a research on coordinated scheduling strategy of heat storage thermoelectric units based on wind power data acquisition system using edge computing. A wind power data measurement and process system based on edge computing and deep learning is introduced, and a wind power prediction method based on interval scenario is adopted to process the uncertainty of wind power. Finally, the coordinated scheduling strategy of thermal power units is applied to typical thermal power units, and the swarm optimization is used to verify the effectiveness of the strategy. By reasonably dispatching conventional thermal power units, cogeneration units, and wind power, the comprehensive operation cost can significantly reduce, the consumption of wind power can increase, and the output of thermal power units and cogeneration units can reduce, to achieve the goal of energy conservation and emission reduction.

Data Availability

The data used to support the findings of this study are currently under embargo while the research findings are commercialized. Requests for data, 12 months after publication of this article, will be considered by the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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