OPTIMAL CAPACITY PLANNING FOR HEAT STORAGE IN THERMAL POWER PLANT TO ACCOMMODATE WIND POWER

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***Abstract*—With the large-scale development of wind power in heating district of North China, the wind curtailment problem is getting more and more serious due to the insufficient peaking capacity of a high proportion of CHP units, especially in winter, to meet the heat load, the CHP units can't improve enough space for wind power. So the large amount of wind power is abandoned. Firstly, the new operation model of CHP units is proposed by equivalent heat drop theory, and the installation of heat storage in thermal power plant is put forward to increase the acceptance capacity of wind power. Then the model of cooperation game based on the Shapley value and its solution are introduced, according to this, the bilevel programming model of heat storage capacity is constructed. At last, the numerical example shows the validity of the planning model of heat storage capacity is verified.**

***Index Terms*--Wind curtailment, Peaking capacity, Coorperation game, Bilevel programming, Heat storage**

I. INTRODUCTION

In recent ten years, China's wind power industry has developed rapidly, and the total installed capacity reached 33.6%, ranking first in the world. Although the short-term development has formed a certain scale of installed wind power, the long-term problem of mechanism, grid-connection and abandoned wind power rationing is still serious. In Jilin, Heilongjiang, Xinjiang, Gansu and Inner Mongolia in 2015, the rate of wind power curtailment was up to 32%, 21%, 32%, 39% and 18%[1] respectively. The main reason is in winter, the CHP units' peak regulation capability is limited in order to meet the heat load, thus it can cause lots of abandoned wind power. So far, the problem of wind power accommodation in "sanbei" area is an important obstacle to restrict the development of new energy sources.

Nowadays, in Europea , using the transmission channel to carry out the wind power from surplus area to realize accommodating[2]. In German, based on the real-time electricity price spot market varies throughout a single day and non-controllable and partially unpredictable of wind power, an approach is presented in [3] where a battery energy storage system (BESS) is used to make wind power plants scheduled.

But the current research in this field is planning[5] and dispatching[4,6,7],the benefits distribution studies during accommodating are less. In [8], a trading mechanism of wind fire alternative was proposed. On the basis of their respective prospects for peak trading and earnings confidence and expectations, the thermal power plant and wind farm distributed the cost. Game theory, as an important method to solve economic problem, is widely used in electricity market reform. In game theory, the cooperation game is effectively applied to the optimal acceptance system of wind power[9] which is aimed to realize a win-win alliance. And in [10], the total peak regulation cost of the northwest power grid hydropower unit was calculated, and paid by coal-fired power units. Using the method of "core" and Shapely values to distribute the cost between the hydroelectric units, the results show the method of distributing the profits is rationality.

According to the above analysis, in this paper, the heat storage is equipped in the thermal power plant to provide peak regulation service. The new operation model is established by equivalent heat drop theory. Bases on the model, the principle of accommodating wind power by heat storage can be analyzed, and the Sharpley value of the cooperation game theory is used to solve the problem of the distribution of the profit after the increase of the total income of the alliance. After that, the bilevel programming model of heat storage capacity is proposed, aiming at providing the technical support for improving the wind power accommodation in "sanbei" region.

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II. TRADING MECHANISM OF WIND-THERMAL POWER PLANT TO ACCOMMODATE WIND POWER

A. Mathematical model of combined heat and power (CHP) units

In order to improve the peak load regulating capacity, we firstly analyze the relationship between the heat and the power of the CHP units and establish a mathematical model of thermoelectric relationship.

In the case of the constant heat power output and steam parameters, the electric power output of units can be calculated by the equivalent heat drop theory. As shown in (1) and (2):

$$P_{te} = \frac{G_0 H_0 - G_{CN} H_{CN}}{3600} \tag{1}$$

$$P_{th} = \frac{G_{CN} H_{CN}}{3600} \tag{2}$$

Where the H_0 and H_{cn} represent main steam equivalent heat drop and heating extraction equivalent heat drop respectively, calculated by the operation parameters of the steam turbine; G_0 and G_{cn} are main steam flow and heating extraction flow.

The relationship of G_0 and G_{cn} can be described by the experiment data as (3):

$$G_0 = \mathrm{f}(\mathrm{G_{CN}}) = \begin{cases} G_{0\max} = 1025 \\ G_{0\min} = 469.086 + 0.301 G_{CN} + 0.001 G_{CN}^2 \\ (0 < G_{CN} < 400\,\mathrm{t/h}) \end{cases} \tag{3}$$

Combining (1), (2) and (3), the range of electric power output adjustment of CHP unit is shown in Fig.1 when its heat power output is constant:

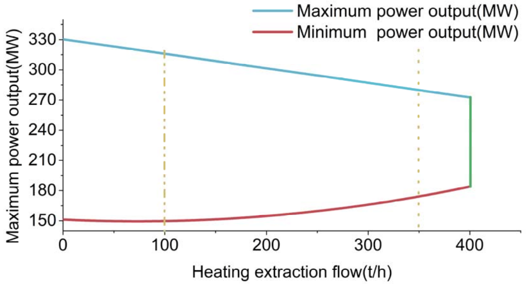

Figure 1. The operating curve of CHP unit

B. Principle of wind power curtailment by thermal power plant with heat storage

The heat storage is built in the thermal power plant, and placed between hot-water export and running piping of users. when heat is storing, the hot water from the thermal power plant is added directly to the heat storage; and when heat is supplying, the hot water can be delivered to users by running piping. The heat power balance between heat storage, thermal power plant and heat load is shown in (4):

$$\sum_{i=1}^{M} P_{th,i}^{t} + P_{sh,i}^{t} = P_{LH}^{t} \tag{4}$$

Where $P^t_{th,i}$ is the heat power output of *i*th CHP unit at *t*th time period; $P^t_{sh,i}$ is the heat power output of *i*th heat storage at *t*th time period; P^t_{LH} is the basic heat load of system during time period t. The heat storage is supplying heat if the $P^t_{sh,i}$ is a positive, and is absorbing heat when $P^t_{sh,i}$ is a negative.

Equation (5) represent the state constraint of the heat storage:

$$S^N = S^0 \tag{5}$$

Where S^0 is the capacity at the beginning of the day and S^N is at the end of day. Only the two equal can guarantee the heat storage to run normally the next day.

Equation (6) describes the relationship between the status of the heat storage and the power:

$$\Delta t \left(P_{SH}^{t} - K_{loss} S^{t} \right) = S^{t+1} - S^{t} \tag{6}$$

Where K_{loss} is the coefficient of heat leakage, and the leakage of heat loss power is proportion to the heat storage power, which is $K_{loss}S^t$. S^t is the heat storage power at the *t*th.

Equation (7) is the power limit of the heat storage:

$$0 \le P_{SH}^{t} \le P_{SH}^{\max} \tag{7}$$

Where $P^{\max}_{SH}$ is the maximum power of the heat storage.

Fig.2 describes the effect of the heat storage on electric power output of the thermal power plant. The electric power of the thermal power plant with heat storage varies with the power of the heat storage. The green shaded region is the peak regulation space by adjusting the power of heat storage. And the peak regulation space is the increasing space for wind power penetration.

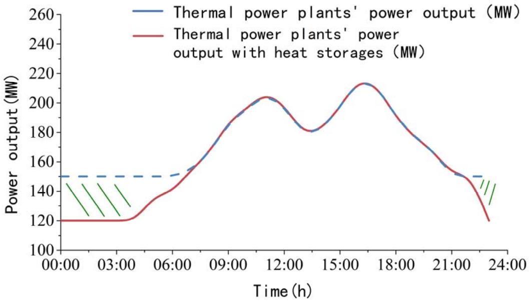

Figure 2. Changes of electric power in thermal power plant

C. Trading mechanism between the wind farm and the thermal power plant

After installing the heat storage, the relationship between main body of power system is shown in Fig.3. The cost of the heat storages' construction and maintenance in thermal power plant is wholly borne by itself. However to maintain the profit of the thermal power plant, it can sell the peak regulation power to wind farm to get some compensate.

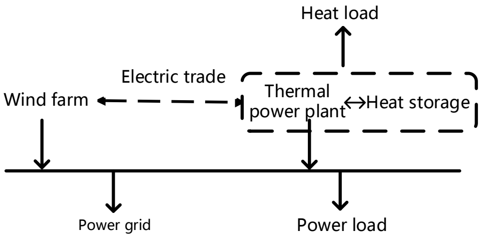

Figure 3. the relationship between main body of power system

III. HEAT STORAGE CAPACITY PLANNING MODEL AND SOLUTION BASED ON SHARPLEY VALUE

A. Game model and solution of Shapley value

① Game players: This game is a two-party game composed of the thermal power plant and wind farm, represented by T and W respectively.

②The strategy of players

When the thermal power plant and wind farm are gaming, the strategy set can be choosen is {cooperation, noncooperation}, as shown in Tab. Ⅰ.

TABLE Ⅰ. Game strategy of the Thermal Power Plant and Wind Farm

Wind Farm Thermal Power Plant	Cooperation	Non-cooperation
Cooperation	(More profits，More profits)	(0，0)
Non-cooperation	(0，0)	(Less profits，Less profits)

③The profits of players

The annual profits of the thermal power plant and the wind farm are the difference between annual earnings and costs. The total profits of the alliance is v, and when the thermal power plant and wind farm cooperate, their annual profits are v_{CT} and v_{CW} respectively, while non-cooperation are v_T and v_W.

Based on the strategy of cooperative game, the total profit of alliance must be greater than the sum of their respective profits when they are non-cooperative, that is $v \geq v_T + v_W$, otherwise they have no motivation to cooperate. And their respective profits when cooperation should satisfy the equation: $v_{CT} + v_{CW} = v$.

The annual income of the thermal power plant when it is non-cooperative includes: G_{hh} is the annual income of selling heat and G_{he} is selling electric. The annual cost mainly includes: the equivalent annual value of fixed cost for investing in building the heat storage is C_{stofix}; the annual operation cost is G_{hc}; the annual emission cost is C_{he}.

The annual profit of the thermal power plant when it is non-cooperative is:

$$v_T = G_{he} + G_{hh} - C_{stofix} - C_{hc} - C_{he} \tag{8}$$

The annual profit of the thermal power plant when cooperation increases the income of annual peak compensation I_{hsub}:

$$v_{CT} = G_{he} + G_{hh} + I_{hsub} - C_{stofix} - C_{hc} - C_{he} \tag{9}$$

The annual income of the wind farm when it is non-cooperative includes: G_{we} is the annual income of selling wind power; G_{wsub} is the annual policy subsidy income. The annual cost mainly includes: C_{wprot} is the annual maintenance cost.The annual profit of the wind farm when it is non-cooperative is:

$$v_W = G_{wsub} + G_{we} - C_{wprot} \tag{10}$$

The annual profit of the wind farm when cooperation deducts the annual peak compensation of thermal power plant I_{hsub}:

$$v_{CW} = G_{wsub} + G_{we} - C_{wprot} - I_{hsub} \tag{11}$$

④The scheme of profit distribution based on Shapley value

In seeking solutions of cooperative game, the em$_{pt}$y set and infinite solutions of "core" lead to a fatal defect, while the Shapley value, as "one point solution", can provide the solution reasonably. So we can use the Shapley value to distribute the profits of alliance between wind farm and thermal power plant.

The Shapley value is the arithmetic mean of margin contribution, which is relating to the sequence of alliances. For the player in a certain position, the margin contribution is the difference between the profits he formed after joining the alliance and the profits before him joining.

There are two distribution schemes for the profits of wind farm and thermal power plant when cooperation:

$$\sigma(1) = (v_T, v - v_T)$$
$$\sigma(2) = (v - v_W, v_W)$$

(1) $v_{CT} = v_T$，$v_{CW} = v - v_T$,

When the thermal power plant is the first participant, its margin contribution is the profit of the thermal power plant when it is non-cooperative; As the second participant, the margin contribute of the wind farm is greater than the profits when it is non-cooperative.

(2) $v_{CT} = v - v_W$，$v_{CW} = v_W$

To sum up, according to this scheme of profit distribution, the latter in an alliance always gets more profits. So, we can calculate the arithmetic mean of a player's profits in all sequencing. That's the Shapley value.

Formula for calculating Shapley value is:

$$X_i = \sum_{S \subset Z, i \in S} W(|S|)(v(S) - v(S \setminus i))$$
$$W(|S|) = \frac{(N - |S|)!(|S| - 1)!}{N!} \tag{12}$$

Where S are subsets contained i; Z is a set of N members; |S| is the number of S; v(S) is the total profits of alliances contained i; v(S\i) is the total profits of alliances except i; W(|S|) is average contribution factor.

According to the above, the formula for calculating Shapley value to distribute the profits in this paper is:

$$(v_{CT},v_{CW})=(\frac{v(\mathrm{T})+v(W,\mathrm{T})-v(W)}{2},\frac{v(\mathrm{T},\mathrm{W})-v(\mathrm{T})+v(W)}{2}) \tag{13}$$

B. The bilevel programming model of heat storage capacity based on Shapley value

The capacity of the heat storage not only affects the ability of the system to accommodate wind power, but the construction cost of the thermal power plant. When the capacity increases to a certain extent, the continuous time will reach the limit. Continuing to increase the heat storage capacity will not accommodate the wind power, but only to add to the thermal power plant construction cost. So the capacity of the heat storage has an optimal value, which is S_{hsub}.

1) Upper level planning model

The objective of the upper level is the maximum of the alliance total profits,.

The total profit of the alliance can be calculated by (14):

$$\begin{aligned}\max\quad \mathrm{v}&=\mathrm{v}_{\mathrm{CT}}+\mathrm{v}_{\mathrm{CW}}\\&=(\mathrm{G}_{\mathrm{hh}}+\mathrm{G}_{\mathrm{he}}+\mathrm{I}_{\mathrm{hsub}}-\mathrm{C}_{\mathrm{stofix}}-\mathrm{C}_{\mathrm{hc}}-\mathrm{C}_{\mathrm{he}})+(\mathrm{G}_{\mathrm{we}}+\mathrm{G}_{\mathrm{sub}}-\mathrm{C}_{\mathrm{wprot}}-\mathrm{I}_{\mathrm{hsub}})\end{aligned} \tag{14}$$

The calculation formula for each part of the cost is as follows:

The cost of the thermal power plant:

a. The annual income of selling electric:

$$G_{he}=\sum_{i=1}^{M}\sum_{t=1}^{n_s}P_{te,i}^{t}\times\Delta t\times p_t \tag{15}$$

Where $P^t_{te,i}$ is the electric power output of ith CHP unit at tth time period; p_t is benchmark price of the thermal power plant; Δt is the dispatch period; n_s is the number of the dispatch period; M is the number of thermal power plants.

b. The annual income of selling heat:

$$G_{hh}=\sum_{i=1}^{M}\sum_{t=1}^{n_s}P_{th,i}^{t}\times\Delta t\times p_h \tag{16}$$

Where $P^t_{th,i}$ is the heat power output of the ith CHP unit at *t*th time period.

c. The equivalent annual value of fixed cost for investing in building the heat storage included the investment and maintenance cost:

$$\mathrm{C}_{\mathrm{stofix}}=\mathrm{C}_{\mathrm{heatbud}}(\frac{\mathrm{i_c}(1+\mathrm{i_c})^{\mathrm{N_s}}}{(1+\mathrm{i_c})^{\mathrm{N_s}}-1}+\mathrm{N_s}\,\varepsilon_{\mathrm{s}}) \tag{17}$$

Where $C_{heatbud}$ is the total construction costs of thermal power plant; $C_{heatbud}N_s\varepsilon_s$ the total maintenance costs; $\varepsilon_s$is the ratio of construction costs to maintenance costs; N_s is the service life of the heat storge; i_c is the discount rate.

$$C_{heatbud,i}=S_{hsub}\times pc_{hsub}\times M \tag{18}$$

Where pc_{sub} is the unit cost of the heat storage.

d. The annual operation cost:

$$C_{hc}=\sum_{i=1}^{M}\sum_{t=1}^{n_s}F_i^t\times p_c \tag{19}$$

Where F^t_i the cost of conventional coal-fired in the ith thermal power plant at tth time period; pc is the price of unit coal.

e. The annual emission cost[11] is

$$\Delta C_{he}=\sum_{x\in\{so2,co2,y\}}(\frac{\Delta E_{mx}}{\sigma_x}\times p_x) \tag{20}$$

The current emissions from coal-fired power plants are mainly sulfur dioxide, nitric oxide and smoke.

$$\Delta E_{mso_2}=\sum_{i=1}^{M}\sum_{t=1}^{n_s}(F_{t,i}^{'}-F_{t,i})\times G_{so2} \tag{21}$$

$$\Delta E_{mno_x}=\sum_{i=1}^{M}\sum_{t=1}^{n_s}(F_{t,i}^{'}-F_{t,i})\times G_{no_x} \tag{22}$$

$$\Delta E_{my}=\sum_{i=1}^{M}\sum_{t=1}^{n_s}(F_{t,i}^{'}-F_{t,i})\times G_y \tag{23}$$

Where ΔE_{mso2}, ΔE_{mnox}, ΔE_{my} are the emission changes of SO2, NOX and smoke; G_{so2}, G_{nox}, G_y are the emission index of SO2, NOX and smoke; p_x is unit equivalent of unit emission price, shown in Tab. Ⅱ.

TABLE Ⅱ. Equivalent value of atmospheric pollutants

Pollution	Equivalent value σx
SO2	0.95
NOx	0.95
Smoke	2.18

The cost of the wind farm:

f. The annual income of selling wind power:

$$G_{we}=\sum_{t=1}^{n_s}P_{wpra}^{t}\times\Delta t\times p_w \tag{24}$$

Where P_{twpra} is the wind power output at *t*th time period; p_w is benchmark price of wind power.

g. The changes of annual maintenance cost for wind farm:

$$\Delta C_{wprot}=\sum_{t=1}^{n_s}P_{wpra}^{t}\times\Delta t\times p_{wprot} \tag{25}$$

Where p_{wprot} is the management and maintance cost of wind power, generally it's 0.05 yuan/kwh.

h. The annual peak compensation of thermal power plant is I_{hsub}.

I_{hsub} should be included in the annual profits of the thermal power plants and deducted from the wind farm when they are cooperating.

$$I_{hsub}=C_h \times p_{hsub} \tag{26}$$

$$C_h=\sum_{i=1}^{M}\sum_{t=1}^{n_s}P_{te,i}^{t}-\sum_{i=1}^{M}\sum_{t=1}^{n_s}P_{te,i}^{t'} \tag{27}$$

Where C_h is the the peak regulation power of the thermal power plant for accommodating wind power; $P^t_{te,i}$ is the electric power dispatch result of thermal power plant with heat storage; $P^t_{te,i}$ is without heat storage; p_{hsub} is the compensate price for peak load regulation.

Constraints:

a. The capacity limit of heat storage:

$$S_{hsub}^{\min} \le S_{hsub} \le S_{hsub}^{\max} \tag{28}$$

Where S^{max}_{hsub}, S^{min}_{hsub} represent the maximum and minimum heat storage capacity respectively.

b. The limit of compensation price for peak load regulation

$$p_{hsub}^{\min} \le p_{hsub} \le p_{hsub}^{\max} \tag{29}$$

Where p^{max}_{hsub}, p^{min}_{hsub} are the maximum and minimum price.

2) *Lower level planning model*

According to the The actual operation mode of electric power company, the heat storage in the power grid should be centralized dispatching [3]. The dispatching centre outputs the thermal output curve of heat storage, the electric and thermal output curve of thermoelectric units, according to the forecast electricity, heat load. And according to wind power forecast output data and wind power network space, the wind farm output curve. By scheduling simulation The power and thermal output of each unit and the heat storage tank are obtained.

C. *The solution of heat storage capacity planning model*

Analyzing the heat storage capacity planning model, to the upper level model, the heat storage capacity in a certain range is discretized at a certain step, and every capacity value is transmitted to the lower level model. In the lower level planning model, the power output of the thermal power plant and wind farm are solved by using the YALMIP toolbox in MATLAB. The objective of the upper level can be calculated with the result of the lower level. The heat storage capacity can ensure a maximum alliance benefit is the result.

The flow chart of the bilevel programming model of heat storage capacity based on Shapley value is shown in Fig.4.

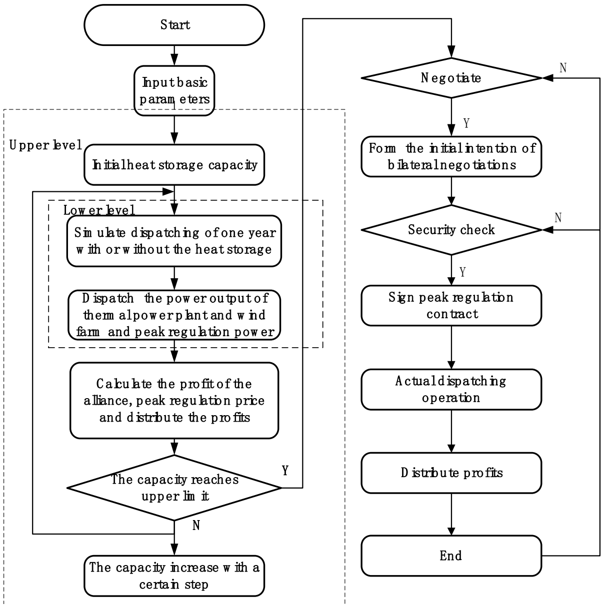

Figure 4. Flow chart of heat storage capacity planning

a. Initial the heat storage capacity. The heat storage is installed by integer capacity, and the capacity bound is ensured according to the geographical conditions. Therefore the heat storage capacity in a certain range is discretized at a certain step, and proposes the bilevel programming model to plan the capacity of heat storage.

b. The objective of the upper level planning model is to maximize the profits of the alliance, and transmit the capacity to the lower level model; In the lower level planning model, the objective is to minimize the wind power curtailments. In the case of heat storage and no heat storage, the power output can be simulated, then transmit the simulation result to the upper level.

c. Calculate the annual profit of the thermal power plant and wind farm according to (6)-(8).

d. Based on the lower level results, the total profit of the alliance is calculated under different heat storage capacity. With the game model of Shapley value, the alliance profit can be reallocated, thus the compensate price for peak load regulation to thermal power plant is calculated.

e. Repeat a-e steps until the heat capacity reaches the upper limit.

f. The thermal power plant and wind farm negotiate according to planning results, to ensure the peak regulation period, peak regulation capacity and the purchasing price of peak regulation capacity. The initial intention of bilateral negotiations is formed.

g. If the negotiation is successful, the initial intention of bilateral negotiations is handed power dispatch department to check. If not, the transaction will be ended.

h. If the check passes, the satisfaction of both parties sign bilateral trade contracts.If not, the transaction will be ended.

i. The power system dispatching is running in accordance with the contract requirements. According to the contract, the electricity price clears daily and the settlement was settled at the end of the year.

IV. CASE SIMULATION

A. Typical systems and parameters

To verify the validity of this model in the paper, we take the simplified power grid power supply structure of Heilongjiang province as an example. Detailed parameters of the thermal power plant unit are shown in the literature[3]. Different from literature[3], in this example, All the thermal power plants are installed heat storage tank, whose charge and discharge heat is 60W. The estimated useful life of heat storage tank is 20 years, and maintenance costs account for 0.5% of the total investment. The emission changes of SO2, NOX and smoke are 2.7kg/t、9.08kg/t and1.2kg/t. Considering the proper growth of load, the changes of annual load and wind farm output are based on the actual data of a regional power grid in Heilongjiang. Predicted power curve is shown in Fig.5. Electricity price and cost per unit price are referred to the actual situation of Heilongjiang province, which is shown in Tab.Ⅲ.The heating period is assumed of 260 days.

TABLE Ⅲ. Electricity price and cost per unit price

	price	unit
Heat storage tank unit cost	2600	Yuan/ m^3
Coal	600	Yuan/t
Wind farm electricity price	0.54	Yuan/kWh
Thermal plant electricity price	0.3864	Yuan/kWh
Wind farm maintenance cost	0.05	Yuan/kWh
Unit equivalent pollutant price	1.2	Yuan/ equivalent

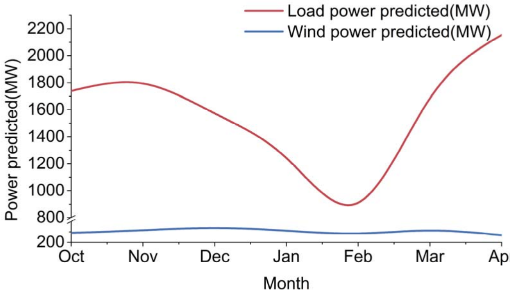

Figure 5. Predicted power curve

B. Analyses of heat storage capacity planning

According to the actual situation, the capacity of heat storage tank should be set at 300-400MW. When we take grid optimization method, we can select some discrete points by taking 5MW as a step to calculate the cost-effectiveness of wind farm and thermal plant in this situation. Through simulation calculations, we can get the results of heat storage capacity planning, which is shown in Fig.6.When capacity is 350MW, thermal power plants and wind farms achieve maximum benefits, which are 520,891,000 Yuan and 884,189,700 Yuan respectively. Corresponding compensate price for peak load regulation is 0. 3624 yuan/kWh.

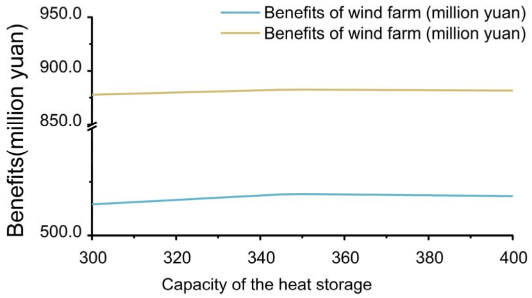

Figure 6. Benefits of Wind Farms and Thermal Power Plants at Different Capacity

As is shown in Fig.6, the annual profit is increased firstly and then decreased with the increase of the capacity of the heat storage tank. And Fig.7 represents the benefits of wind farms and thermal power plants at different capacity. If the capacity is bigger, the continuous time of storing and releasing heat is increasing. After 350MW, the capacity is sufficient to ensure continuous heating time, and the increase of capacity is only to increase the fixed cost of the heat storage tank, resulting in annual profits decline. Therefore, the electricity price increases faster.

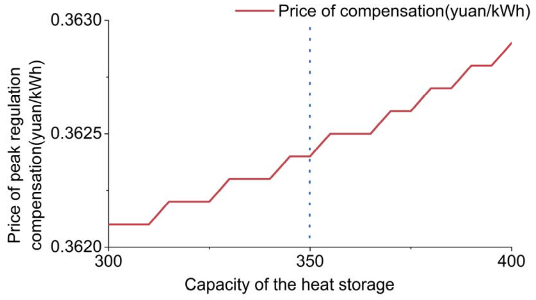

Figure 7. Peak Regulation Electricity Price at Different Capacity

C. Optimal capacity of heat storage tank under different installed capacity of wind power

In order to further verify the effectiveness of the optimization model of heat storage capacity, the rated installed capacity of the wind farm connected to the grid is changed in the simulation example. When the rated installed capacity of wind farm changes from 300MW to 400MW, the variation of the optimal heat storage capacity, the annual profits of wind farm and thermal power plant and peak load regulation compensation electricity price are shown in the figures below.

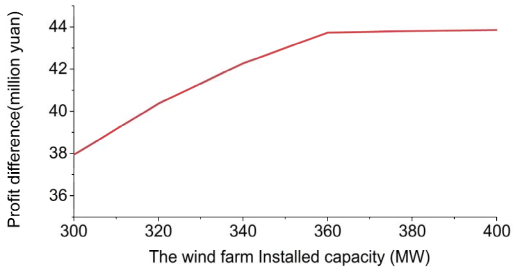

Figure 8. Optimal Capacity of Heat Storage Tank under Different Installed Capacity of Wind Farm

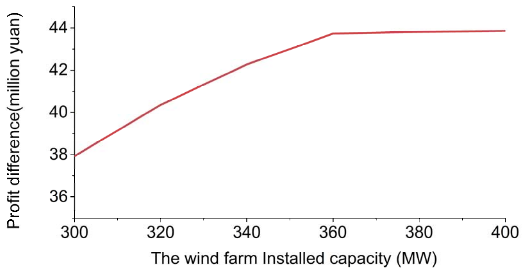

Figure 9. Difference in Profit Margins under Different Wind Farm Installed Capacity

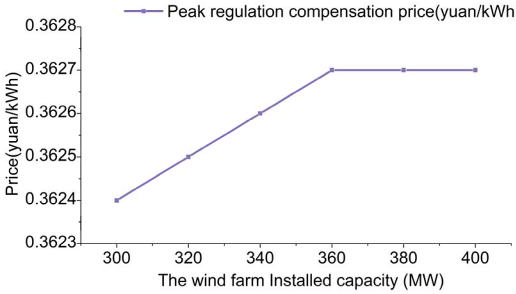

Figure 10. Peak Load Regulation Compensation Electricity Price under Installed Capacity of Different Wind Farms

As shown in Fig.8, with the increase of the rated installed capacity of the wind farm, the optimal capacity of the heat storage tank increases first and then tends to be stable. When the rated installed capacity of wind farm reaches 360MW, the optimal installed capacity will not continue to increase .

As shown in Fig.9, with the increase of the installed capacity of the wind power, the optimal capacity of the heat storage tank increases, which leads to an increase in the total profit of the wind heat alliance. After the game is allocated, the wind farm and thermal power plant will also increase their profits, thus making the annual profit difference increases.

As shown in Fig.10, the change of the rated installed capacity of the wind farm and the optimal capacity of the heat storage tank will affect the peak load regulation compensation electricity price.

As a result, when the installed capacity of the wind farm is increased to a certain extent, new heat storage tank must be set in thermal power plant side to continue to accommodate wind power.

V. CONCLUSION

This paper establishes a planning model of heat storage capacity to improve the capability of accommodating wind power. Based on the electricity market of Heilongjiang and national policy, the bilateral bargaining mechanism between wind farm and thermal power plant is constructed, and the benefits are distributed by Shapley value game model, in order to ensure the thermal power plant to provide peak regulation space and not to damage its benefit. Case studies show that the optimal capacity of heat storage can be calculated by the planning model, when the installed capacity of wind power is a constant. Furthermore, the simulation analysis is done when the installed capacity of the wind power is changed. The result can be concluded: With the increase of wind power installed capacity, the best heat storage capacity will also increase. But when the capacity is to a certain extent, the effect of heat storage to accommodate wind power tends to be gentle. So increasing the thermoelectric units with heat storage can be taken into account to increase the wind power accommodation.

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