Research on alternative electricity calculation method of alternative transaction between new energy and captive power plant

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Abstract. In view of the rapid development of new energy sources, a new peak load regulation alternative transaction between new generation enterprise and the coal-fired power plant was used in the Jibei area. Based on the analysis of the existing calculation methods of substitute transaction, new alternative trading calculation method was proposed. In this method, the actual power plant output and the dispatching order was considered. In order to make the power plant follow the dispatch order and make the substitute transaction can be better for the new energy consumption, the power output of captive power plant is punished according to the dispatching order. At last, an example verifies the feasibility of this method.

1. Introduction

With the rapid and large-scale development of new energy in west of China, the lack of new energy power consumption and transportation, and the shortage of grid peak load regulation ability have become increasingly serious, leading to severe wind and photovoltaic discard [1]. At the present stage, the potential and effect of providing ancillary services such as deep peak load are limited by means of planning means and scheduling instructions. It is urgent to establish a new market-oriented auxiliary power service mechanism.

At present, the power grid adopts a variety of means to ensure the power generation of new energy. The new idea of peak load regulation capacity responsibility is put forward by document [2]. A compensation mechanism of peak load regulation capacity is set up with the concept of equivalent available load rate to achieve paid peak adjustment. The solution of peak regulation service trading platform is set up by document [3]. Wind power gets Internet space by buying unconventional peak load regulation service to thermal power. Document [4] analyses peak regulation trading behavior between thermal power plants and new energy plants. The literature [5-8] analyses the structure of power grid, and proposes a series of questions such as new energy peak regulation consumption and so on.

2. Existing calculation methods of alternative electricity

2.1. Alternative trading principle
From the point of peak regulation of power grid, the fundamental cause of wind and photovoltaic discarding which new energy produced is that the conventional generator cannot reduce its power to accept wind power during the low load period. That is to say, the peak load regulation capacity of the system is not enough. The mechanism is illustrated in Figure 1.

During the actual dispatching and operation process, when the output of wind power exceeds wind power space which power grid accept, the excess part needs to be removed to ensure the real-time balance of power supply and demand, resulting in the wind abandonment of wind power, as shown in the shadow part of Figure 1.

Under the condition that the heating and peak regulation of the power grid are very difficult, captive power plant takes part in peak load regulation on the premise of the constant power load. When new energy output increases, captive power plant needs to reduce power output. The operation mechanism is shown in figure 2. When the result that minimum output of conventional units plus output is greater than system load, it is necessary to reduce generator output of captive power plant. The excess power can be consumed in captive power plant, as shown in the shaded parts.

2.2. model of alternative transaction
It is assumed that the power generation cost of the generator is quadratic curve, and the cost is:

\[ C_i(P_i) = a_iP_i^2 + b_iP_i + C_i \]  

(1)

Assuming that the demand for the power plant is \( P_x \), \( P_x \) can be considered as a constant and can be obtained according to the actual production plan. The actual profit of captive power plant:

\[ \pi = (a_iP_x^2 + b_iP_x + C_i) - (aP^2 + bP + C) - \lambda(P - P_f) \]  

(2)

When \( \pi_i = 0 \), that is, the profit is 0, the generator executes the alternative transaction according to power.
In general, when the pricing is considered, the upper and lower limits of the unit need to be between the two solutions of the formula (3), that is,
\[
\frac{\lambda - b \pm \sqrt{\lambda b - 4 \lambda (\lambda - b) P_s - a P_s^2}}{2 a_i} < P_{\text{max}} < \frac{\lambda - b + \sqrt{\lambda b - 4 \lambda (\lambda - b) P_s - a P_s^2}}{2 a_i}
\]

\[P_i = \frac{\lambda - b \pm \sqrt{\lambda b - 4 \lambda (\lambda - b) P_s - a P_s^2}}{2 a_i} \]

2.3. Calculation of Alternative Power

At present, the replacement price between new energy and captive power plant in Jibei is a consideration of many factors and ensures that new energy enterprises and captive power plants can make profits. The calculation formula of its alternative power is as follows:

\[P_t = P_o - P_n - P_s\]

where:
- \(P_t\): captive power plants alternative power.
- \(P_o\): captive power plants off-grid power.
- \(P_n\): captive power plants non-stop power.
- \(P_s\): captive power plants stock power.

Electricity formula of the existing alternative trading can be seen that the electricity from alternative trading is mainly related to the generating capacity of the unit and the load demand of captive enterprise. When the load is constant, replace the power is only related with the output power, when the output capacity of the unit is large, replace the power when the unit output is less; hours, instead of more power.

2.4. Problem and Mechanism

According to the current power calculation method of alternative transaction, the alternative power of captive power plant is only related to off-grid power and non-stop power. When the off-grid price is less than the power generation cost, captive power plant is willing to buy electricity from the power grid without considering the source of the power purchase of new or conventional energy.

According to the formula (2), the profit curve of captive power plant is shown in the following diagram:

\[\frac{\partial \pi}{\partial P_i} = 0\]

According to the actual profit, when \(\frac{\lambda - b}{2 a_i}\), that is, the unit has the greatest benefit.
According to the current calculation method of alternative electricity, captive power plant is willing to generate electricity according to the most profitable way, rather than considering the actual dispatching order. In this way, the actual alternative transaction cannot operate optimally.

In the calculation, it is impossible to distinguish off-grid power from new or conventional energy. The result is that the unit output of captive power plant is only handled according to its own advantages, and is not carried out entirely in accordance with the instructions of the scheduling.

When the dispatching order does not agree with the actual power generation, the profit difference is as follows:

\[
\Delta \pi_i = (a_i P_x^2 + b_i P_x + C_i) - (a_i P_a^2 + b_i P_a + C_i) - \lambda (P_{\text{max}} - P_a) \\
-[(a_i P_x^2 + b_i P_x + C_i) - (a_i P_d^2 + b_i P_d + C_i) - \lambda (P_{\text{max}} - P_d)]
\]

\[
= a_i P_x^2 + b_i P_d - a_i P_a^2 - b_i P_a + \lambda P_a - \lambda P_d
\]

\[
= a_i (P_x^2 - P_a^2) + (b_i - \lambda) (P_d - P_a)
\]

(4)

When \(\Delta \pi_i > 0\), The unit is not willing to generate power according to the command.

As a result, alternative electricity is due to the generation of new energy substitution or the increase of conventional energy output. Because the source of electricity is hard to distinguish, we can consider the dispatching order method.

3. Alternative transaction calculation with instructions

In order to make the calculation of the alternative electricity more accurate and make the captive power plant be willing to carry out generating power according to the dispatching order, the following measures are put forward.

1. The calculation of alternative electricity only considers the amount of electricity executed according to the scheduling instruction.

2. The electric power that does not execute part according to the dispatch instruction is settled in accordance with the current electricity price

3. When the actual output is less than the dispatching order, the settlement is calculated according to the actual off-grid electricity.

According to the above methods, when \(P_{\text{dispatch}} > P_{\text{actual}}\), the profit of the power plant is

\[
\pi_i = (a_i P_x^2 + b_i P_x + C_i) - (a_i P_a^2 + b_i P_a + C_i) - \lambda (P_{\text{max}} - P_a)
\]

Profit according to the instruction:

\[
\pi_i = (a_i P_x^2 + b_i P_x + C_i) - (a_i P_a^2 + b_i P_a + C_i) - \lambda (P_{\text{max}} - P_a)
\]

margin:

\[
\Delta \pi_i = (a_i P_x^2 + b_i P_x + C_i) - (a_i P_a^2 + b_i P_a + C_i) - \lambda (P_{\text{max}} - P_a)
\]

\[
-[(a_i P_x^2 + b_i P_x + C_i) - (a_i P_d^2 + b_i P_d + C_i) - \lambda (P_{\text{max}} - P_d)]
\]

\[
= a_i (P_x^2 - P_a^2) + (b_i - \lambda) (P_d - P_a)
\]

(5)

\[
\pi_i = (a_i P_x^2 + b_i P_x + C_i) - (a_i P_a^2 + b_i P_a + C_i) - \lambda (P_{\text{max}} - P_a) - \lambda (P_{\text{min}} - P_a)
\]

margin:

\[
\Delta \pi_i = (a_i P_x^2 + b_i P_x + C_i) - (a_i P_a^2 + b_i P_a + C_i) - \lambda (P_{\text{max}} - P_a)
\]

\[
-[(a_i P_x^2 + b_i P_x + C_i) - (a_i P_d^2 + b_i P_d + C_i) - \lambda (P_{\text{max}} - P_d)]
\]

\[
= a_i (P_x^2 - P_a^2) + (b_i - \lambda) (P_d - P_a)
\]

(6)

When \(\Delta \pi_i > 0\), The unit is unwilling to generate electricity in accordance with the instructions.

When \(\Delta \pi_i < 0\), the result is just reversed. the power of the power grid under the power plant is really generated by new energy.

By comparing the formula (4) and the formula (7), we find that according to the original calculation method, the profit margin of the unit is not larger than the new calculation method. According to the new calculation method, the difference is not smaller according to the scheduling
instruction. The unit has more power to generate electricity according to the actual dispatching instruction.

4. example analysis
In this paper, an example of a unit in a captive power plant in Jibei is given. The unit parameters are shown in Table 1. In order to explain the problem, make the following assumptions: The load required by the unit is a fixed value of 150MW. The settlement price of alternative electricity is 400 yuan/MW.h, and non-alternative power's is 600 yuan/MW.h.

Tab.1 The parameters of the generator

| generator | ai | bi | ci | Pmin/MW | Pmax/MW |
|-----------|----|----|----|---------|---------|
| 1         | 1.5| 200| 1000| 15      | 200     |

It can be seen from the diagram 4 that there is a difference between the dispatching order and the actual output.

Fig.4 Unit output

It can be seen from the figure 5 that the profit of the generator sets with different calculation methods is very different. The original method has the highest actual profit, and is the least profitable according to the new method. The corresponding period profit curve is shown in the following diagram.

Fig.5 chart of Unit profit

From the above, we can clearly see that if the new method is implemented, the profits of captive power plants will be greatly reduced. So captive power plants are more willing to make generators'
output according to the dispatching order, so as to ensure the complete implementation of the alternative transactions.

5. Conclusion
In order to solve power generation problems of new energy, the alternative trading between new energy and captive power plant is put forward. Through the analysis of the existing alternative trading rules, we find that the alternative electricity of captive power plant is considered as coming from the new energy consumptive power, no consideration is given to the deviation from the captive power plant's failure to follow the dispatch instruction. Based on the analysis of the principles and defects of the traditional calculation method of substitution power, this paper adds the consideration that the power supply of the captive power plant is not processed according to the dispatching instructions. In this new method, captive power plant is more willing to contribute according to the dispatching instruction, and alternative trading makes the actual consumption of new energy more accurate. This method is beneficial to the smooth progress of alternative transaction.

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