Research on Power Purchase Optimization Strategy Under Power Carbon Coordinated Transaction Mode

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Abstract. With the development of carbon trading pilot work in various regions, as a major carbon emitter, the power industry bears the brunt. Carbon emission will become a factor that power enterprises do not ignore enough and have an impact on the power purchase of the power grid. Based on the way of objective function constraints, this paper studies the optimization strategy of power purchase decision-making of power grid enterprises under the transaction mode of power carbon coordination, so as to minimize the cost of low-carbon, energy saving and environmental protection of units and promote the process of carbon emission reduction.

Keywords: Electricity carbon coordination · Power purchase optimization · Objective function constraint method

1 Introduction

The greenhouse effect has become a common concern of mankind. The "low-carbon economy" has begun to become a very important branch of the new normal. Carrying out carbon emission trading is an important way to solve global warming [1]. As the world's largest CO2 emitter, China has solemnly committed to "carbon peak" in 2030 and "carbon neutralization" in 2060, which is a great challenge for China. Actively participating in carbon emission trading and actively developing clean energy are important means to achieve this goal. The Third Plenary Session of the 18th CPC Central Committee proposed to implement the carbon emission trading system [2]. The construction of the national carbon trading market has been included in the task of the central reform leading group. The construction of China's carbon market has accelerated. The carbon markets of seven provinces and cities such as Beijing and Shanghai have been launched, and the national carbon market will be established in 2021.

From the perspective of China's energy consumption and emission structure, the current energy consumption and CO2 emission mainly come from the power industry,

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which is bound to become the main force of low-carbon energy conservation and emission reduction [3, 4]. In 2015, several opinions of the CPC Central Committee and the State Council on further deepening the reform of power system (ZF [2015] No. 9) once again sounded the horn of power market reform, which will have a positive impact on promoting distributed power generation and clean energy access, which also coincides with the original intention of carbon emission trading. Therefore, it is a major issue for enterprises in the power industry to orderly promote the coordinated trading of electricity and carbon in the power industry and improve the level of low-carbon, energy conservation and emission reduction in the power industry [5].

With the improvement of electricity carbon resource marketization, carbon price and electricity price affect each other. Under the condition of electricity marketization, electricity price is the basic factor affecting the change of carbon price, and the electricity price will also fluctuate with carbon price [6]. From the experience of EU, there is a direct positive correlation between EU natural gas price, crude oil price and electricity price and EUA price. The change of carbon price will also affect the electricity price. For example, in the second stage of the European Union, the electricity price in northern Europe will rise by 0.74 euros for every Euro increase in EUA price. The European electricity market is relatively mature, and the carbon market is mainly included in the power generation enterprises. The power generation enterprises can transfer part or all of the carbon price to the end consumers, which will have an impact on the end power consumption behavior, but the premise is that the quota cannot be issued excessively. Therefore, the implementation of carbon trading policy should allow the price of electricity to rise and avoid the impact on power investment, so as to ensure power supply [7].

Once the user's selling price is approved, the selling price on the demand side will not change with the change of power supply type. Therefore, the optimization analysis mainly focuses on the analysis of the market structure and market operation on the generation (purchase) side. On the premise of considering low-carbon, energy conservation and environmental protection, the environmental cost of power needs to be considered for the power purchase decision of power grid companies. Therefore, this paper constructs an objective function constraint model to optimize the power purchase decision [8].

2 Optimization of Power Purchase Based on Objective Function Constraint Method

The power purchase of provincial power grid mainly includes low-carbon power (such as hydropower, wind power, photovoltaic, etc.) and thermal power.

Under the electricity carbon coordinated transaction mode, the objective function constraint method is used to optimize the sequencing of generator units in the province to achieve the purpose of power purchase optimization. The idea is to minimize the environmental cost on the premise of considering low-carbon, energy saving and environmental protection [9].

The cost of low-carbon power generation mainly comes from investment cost and daily labor and maintenance cost. Low carbon power basically has no low-carbon cost, and there is no need for later low-carbon treatment [10, 11]. However, due to the small proportion of low-carbon power, the optimal power purchase of provincial power grid companies is the optimal sequencing of thermal power units in the province. The optimization model of local thermal power units is as follows.

The objective function is low carbon, energy saving and environmental protection with the lowest cost, as shown in formula (1).

$$MinC_{\text{local}} = \sum_{i=1}^{n} \left(e_{CO_2i} + e_{SO_2i} + e_{NO_xi} + e_{PMi} + e_{\text{sewage}i} + e_{\text{water}i} + e_{\text{coal}i}\right) \times Q_i \quad (1)$$

Clocal refers to the cost of low-carbon, energy saving and environmental protection of local units, n refers to the total number of units, and e_{CO2_i} refers to the emission equivalent of each pollutant, Q_i is the generating capacity of the unit.

There are the following constraints, Generation constraints:

$$\sum_{i=1}^{n} Q_i = Q_{all} \quad (2)$$

Installed capacity constraints:

$$0 \le Q_i \le Q_{ci}, i = 1, 2, 3, \cdots, n \quad (3)$$

Pollutant emission constraints:

$$\sum_{i=1}^{n} e_{CO_2i} \times Q_i \le W_{CO_2}$$

$$\sum_{i=1}^{n} e_{SO_2i} \times Q_i \le W_{SO_2}$$

$$\sum_{i=1}^{n} e_{NO_xi} \times Q_i \le W_{NO_x}$$

$$\sum_{i=1}^{n} e_{PMi} \times Q_i \le W_{PM}$$

$$\sum_{i=1}^{n} e_{\text{sewage}i} \times Q_i \le W_{\text{sewage}} \quad (4)$$

Among the above constraints, it is the total power generation demand in the calculation period, the maximum installed capacity of the current unit, and the equivalent is the pollutant emission index limit in the calculation period.

3 Case Analysis

(1) Generation constraints.

According to the predicted value of local power consumption - external power consumption - hydropower, the demand of local power consumption for local thermal power generation is 5100000 MWh. In order to meet the local power demand, the total amount of local power generation is required to be no less than this demand.

(2) Monthly installed capacity constraint of power plant.

The data in Table 1 is the maximum power generation of each power plant after deducting the auxiliary power consumption.

(3) Pollutant emission constraints.

According to the requirements of the environmental protection department, it is required to control the pollutant emission of power generation enterprises. According to whether its own emissions meet the emission limit constraints, if they exceed the standard, it is necessary to purchase the indicators of the exceeding part from other power plants with remaining indicators. If there are still remaining indicators, it can

Table 1. Power generation constraints of each power plant (MWh)

number	Power plant	Power supply quota constraint
1	1	627810
2	2	618101
3	3	389940
4	4	394476
5	5	340831
6	6	390217
7	7	216187
8	8	212228
9	9	164836
10	10	168358
11	11	548679
12	12	534481
13	13	603474
14	14	627931
15	15	171562
16	16	147879
17	17	202665
18	18	183790
19	19	315102

Table 2. Table of pollutant emission limits in August(t)

CO_2	SO_2	NOx	Solid particulate matter	sewage
3545666	1701	8025	641	3542889

conduct economic transactions with the exceeding power plants. Table 2 shows the emission limits of pollution control pollutants of a power grid in a month.

Based on the above constraints, the provincial power grid has the lowest cost of low-carbon, energy saving and environmental protection of units in the province under the comprehensive optimal allocation of resources considering low-carbon, energy saving and environmental protection. This example only calculates the cost of low-carbon, energy saving and environmental protection. The calculation results through linear programming are shown in Table 3.

The planned power generation results of the above units meet the constraints, and the pollutants discharged are also within the constraints, as shown in table 4.

Table 3. Calculation results

number	Power plant	Restricted power supply quota (MWh)	Generating capacity (MWh)
1	1	627810	627810
2	2	618101	618101
3	3	389940	389940
4	4	394476	394476
5	5	340831	340831
6	6	390217	390217
7	7	216187	216187
8	8	212228	212228
9	9	164836	164836
10	10	168358	168358
11	11	548679	0
12	12	534481	30509
13	13	603474	603474
14	14	627931	627931
15	15	171562	0
16	16	147879	0
17	17	202665	0
18	18	183790	0
19	19	315102	315102

Table 4. Pollutant emission

CO2Emissions(t)	SO2Emissions(t)	NOxEmissions(t)	Solidparticle emission(t)	Sewage discharge(t)
2697653.223	1471.772123	6780.525022	542.676345	4780834.55

It can be seen from Table 4 that there is a surplus in pollutant emissions, and the region can sell this part of pollutant emission rights to obtain more benefits.

According to the generation ranking of local units, the calculation result of the lowest environmental cost is 0.31 yuan / kWh. The result shows that the provincial unit generation dispatching scheme with the goal of the lowest environmental cost can reduce the environmental cost of 0.07 yuan / kWh and increase the low-carbon benefit of 0.07 yuan per unit of electricity.

4 Conclusion

With the continuous acceleration of China's urbanization process and the continuous increase of greenhouse gas emissions, the power industry, as a major polluter, must do a good job in energy conservation and emission reduction to contribute to climate change and energy security. Under the constraint of mandatory carbon emissions, the total carbon emissions of power plants are constrained, so the total power generation is also constrained, and the power consumption of the whole society will not change significantly due to the limitation of total carbon emissions. Therefore, the power purchase of power grid needs to consider the comprehensive and optimal allocation of resources with low-carbon, energy saving and environmental protection, so as to minimize the cost of low-carbon, energy saving and environmental protection.

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