Research on the Countermeasures for Power Generation Enterprises under the Impact of Carbon Emission Trading System

Research on the Countermeasures for Power Generation Enterprises under the Impact of Carbon Emission Trading System

Haichao Wang[1], Hu Yang[2], Dunnan Liu[3*]

[1] Project Management Department, Electric Power Trading Center Company of Anhui Province, Hefei, Anhui Province , 230000, China

[2] Project Management Department, Anhui Province Development and Reform Commission, Hefei, Anhui Province , 230000, China

[3] Economics and Management Department, North China Electric Power University, Beijing, 102206, China

[*] Corresponding author's e-mail: liudunnan@163.com

Abstract. Power generation is the primary source of carbon emissions in power production. To manage the carbon emissions from power generation companies is meant for the successful realization of carbon emission reduction targets in the power industry. Under the background of the gradual establishment and improvement of the national carbon emission trading market, it is very necessary to research the impact of carbon emission trading system on power generation enterprises and the strategies adopted under this influence. This paper discusses the impacts from four perspectives: power generation space, power generation cost, power generation rights transfer, and production and operation decision-making. It also put forward the corresponding decision-making plan, being intended to make relevant and valuable reference for the power generation enterprises on carbon asset management, production and operation management and investment plan selection.

1. Introduction

Global climate change constitutes one of the most serious challenges facing human sustainable development. Actively combatting climate change has become a global consensus and general trend. The construction of the carbon market is conducive to reducing fossil energy consumption from the source and sympathetically reducing carbon dioxide and atmospheric pollutant emissions; it is conducive to promoting enterprises to resolve excess capacity and driving them to upgrade; last but not the least, it is also conducive to achieving the goal of low carbon and high-quality development of Chinese government.

Government document 'Overall Plan for the Reform of Ecological Civilization System' clearly puts forward the guiding ideology and main principles of China's carbon market construction. The carbon market is positioned as a tool for controlling greenhouse gas emission policies. The construction of the carbon market must follow the requirements in a steady progress. Taking the power generation industry as a breakthrough, it plays a leading role in launching the national carbon emission trading system and steadily implementing the carbon market construction in stages[1]. The government document 'National Carbon Emissions Trading Market Construction Plan (Power Generation

Industry)' clearly states that the power generation industry (including cogeneration) is the first to launch a national carbon emission trading system, which stipulates that the main trading entities in the initial market are power generation industry[2]. Literature [3] analyzes how the path of carbon emission reduction to affect the power generation enterprises. It is based on three policy instruments: carbon emission trading, green certificate trading and power generation rights trading. Then it explains the impact of different policy instruments on power generation enterprises as well as putting forward some policy recommendations to make the instruments work better. Literature [4] explores the commonality between power generation rights trading and carbon emission trading from the behavior of power market participation by power generation companies. It counts the cost of power generation transaction and the cost of carbon emission trading into the cost of the enterprise. Then it establishes a combined trading model of power generation rights and carbon emission rights with the goal of maximizing the total profit. Literature [5] considers four factors of carbon emission pricing: market demand, emission cap, power generation cost and abatement cost. Then it builds a Nash equilibrium model under the electricity market with the goal of maximizing the efficiency of power producers. Literature [6] proposes that thermal power generation enterprises can strengthen their carbon emission management capacity through extensive adoption of low carbon technologies.

The establishment of the carbon emission trading market has had an impact on the asset management[7], production operations[8] and investment decisions of power generation companies[9]. However, they have the opportunity to upgrade their asset structure and exploit revenue channels while facing risks[10]. Based on the research results of the above-mentioned literatures, this paper analyzes the specific impacts of carbon emission trading on the power generation space, power generation cost, power generation rights transfer transaction and production and operation decision-making. It also analyzes the decision-making schemes that power generation companies can adopt in the context of the carbon emission trading system to maximize the benefits while successfully completing the carbon reduction target.

2. Impact of carbon emission trading system on power generation space of different power generation enterprises

The emission reduction plan in China is to reduce CO_2 emissions per unit of GDP (carbon intensity) by 40%-45% by 2020. Under the mandatory carbon emission constraint, the power generation of the power plant j in the i year is:

$$Q_{ij} = \frac{A_{ij}^{0}}{e_{i-1,j}} \tag{1}$$

In the formula (1), A_{ij}^{0} represents the initial carbon allocation quota of the power plant in the i year; $e_{i-1,j}$ represents the average annual CO_2 emission factor of the power plant.

Assuming that the annual contracted power generation (planned power generation) of the power plant is Q_{ij}^{0}, there are the following three cases.

(1) If $Q_{ij} > Q_{ij}^{0}$, it explains that the carbon emission level of the power plant is below average and there is surplus carbon emission right that can be traded or stored;

(2) If $Q_{ij} = Q_{ij}^{0}$, namely, the power plant can complete the power generation task just under the carbon emission constraint in the i year;

(3) If $Q_{ij} < Q_{ij}^{0}$, it explains that the carbon emission level of the power plant is equivalent to the average level. Although the power plant has carried out certain emission reduction work, it still cannot meet the power generation requirements. Therefore, the power plant can overdraw future carbon allocation rights, or purchase emission rights in the trading market.

3. Impact of carbon emission trading system on power generation costs of different power generation enterprises

The implementation of the carbon emission trading system will have different influences on different power generation companies. This is mainly reflected in two aspects: on the one hand, the cost of purchasing carbon emission rights for high-energy-consuming power generation enterprises increases; on the other hand, low-energy-consuming power generation enterprises can obtain certain profits by selling surplus carbon allowances.

(1) The cost of high energy-consuming power generation enterprises increases.

The cost increase caused by carbon emission trading is:

$$C_{ij} = P_c \times (N_{ij} - A_{ij}) \tag{2}$$

In the formula (2) , C_{ij} represents the added cost of enterprise j; P_c represents the carbon emission trading price; A_{ij} represents the initial carbon quota of the enterprise; N_{ij} represents the carbon emission required for normal power generation. Its calculation formula is as follows:

$$N_{ij} = Q_{ij}^0 \times e_{ij} \tag{3}$$

In the formula (3) , Q_{ij}^0 is the planned electricity quantity of the enterprise j in the i year; e_{ij} is the average CO_2 emission factor of the enterprise j in the i year.

It can be observed that because the average CO_2 emission level of high energy-consuming power generation enterprises is usually higher than the industry average, the carbon emissions required to meet the planned power generation often exceed the established carbon emission quota. Therefore, high energy-consuming power generation enterprises need to purchase carbon emission rights, leading to a corresponding increase in power generation costs.

(2) The revenue of low energy-consuming power generation companies increases.

The income from carbon emissions trading is:

$$R_{ij} = P_c \times (A_{ij} - N_{ij}) \tag{4}$$

In the formula (4) , R_{ij} is the additional income that the enterprise j obtains by selling carbon emission rights; A_{ij} is the initial carbon quota of the enterprise; N_{ij} is the carbon emission amount required for normal power generation.

It can be observed that because the average CO_2 emission level of low energy-consuming power generation enterprises is usually lower than the industry average, the carbon emissions required to meet the planned power generation often do not exceed the established carbon emission quota. Therefore, low energy-consuming power generation companies can sell surplus carbon emission rights through the carbon emission trading market and obtain certain benefits.

4. Impact of carbon emission trading system on power generation rights transfer transactions

Under the mandatory carbon emission reduction constraint, the local power plant power generation transaction led by the grid company will be influenced by the carbon emission index. On the one hand, carbon emission constraints will make it more difficult for high-energy small thermal power units to complete power generation tasks. On the other hand, the carbon trading price should be introduced in the power generation rights transfer transaction.

4.1. The Impact of Carbon Emission Trading System on the Transfer of Power Generation Rights

Under the constraint of mandatory carbon emissions trading, high-energy-consuming units can generate less electricity and more tradable power generation rights, which will greatly increase the number of power generation rights transfer. Moreover, the higher the carbon trading price, the higher the cost to generate electricity. It means that the more they will have to seek power generation rights transactions to digest the additional power generation rights, which satisfies the following formula.

$$Q_T \propto P_{CO_2} \tag{5}$$

In formula (5) , Q_T is the number of tradable power generation rights; $\propto$ indicates positive correlation; P_{CO_2} is carbon trading price.

According to the principle of supply and demand in economics, with the increase in the transfer of intentional power generation rights, the transfer price will inevitably decrease.

4.2. The impact of carbon emissions trading on the transfer price of power generation rights

1) For the transferor: under the mandatory carbon emission constraint, the revenue from the transfer of power generation rights should be satisfied not less than the revenue generated by its own power generation.

$$R_{T1} \geq R_{G1} \tag{6}$$

$$R_{T1} = P_T \times Q_T \tag{7}$$

$$R_{G1} = (P_S - C_{G1} - P_{CO_2}) \times Q_T \tag{8}$$

In this formula (6) (7) and (8) ,R_{T1} is the revenue obtained by the transferor of the power generation right by transferring the power generation right; R_{G1} is the revenue obtained by the transferor of the power generation right by generating power; P_T is the transfer price of power generation rights; Q_T is the transfer quantity of power generation rights; P_S is the standard electricity price; C_{G1} is the power generation cost of the power generation right transferor in addition to the carbon emission cost; P_{CO_2} is the carbon trading price.

Among them, the transfer price of power generation rights is determined by the following formula.

$$P_T = P_S - (C_{G1} + P_{CO_2}) + R_{d1} \tag{9}$$

In this formula (9) , R_{d1} is the expected revenue of the transferor of the power generation right.

It can be observed that the greater the price of carbon trading, the lower the price of the power generation transfer. As the price of carbon trading continues to rise, the profitability of low energy-consuming enterprises selling carbon credits increases, while the demand for power generation rights decreases.

2) For the transferee: under the mandatory carbon emission constraint, the carbon trading opportunity cost caused by the transfer of power generation rights should be considered. The power generation revenue should not be lower than the purchase cost of the power generation right.

$$R_{T2} \geq C_{T2} \tag{10}$$

$$R_{T2} = (P_S - C_{G2} - P_{CO_2}) \times Q_T \tag{11}$$

$$C_{T2} = P_T \times Q_T \tag{12}$$

In this formula (10) (11) and (12) , R_{T2} is the revenue obtained by the power generation rights transferee by purchasing power generation rights; C_{T2} is the cost of purchasing power generation rights; P_S is the standard electricity price; C_{G2} is the power generation cost of the power generation right transferee in addition to the cost of purchasing power generation rights; P_{CO_2} is the carbon trading price; Q_T is the transfer quantity of power generation rights; P_T is the transfer price of power generation rights.

At this point, the revenue $\mathrm{R_{d1}}$ from the transferee's purchase of power generation rights is shown in formula (13) .

$$R_{d2} = R_{T2} - C_{T2} = (P_S - C_{G2} - P_{CO_2} - P_T) \times Q_T \tag{13}$$

In summary, under the mandatory carbon emission constraint, the transferable power generation rights can be realized under the following conditions: the transfer price of the power generation right meets formula (14) .

$$P_S - C_{G1} - P_{CO_2} \leq P_T \leq P_S - C_{G2} - P_{CO_2} \tag{14}$$

That is to say, the change range of the transfer price of power generation rights is $[\mathrm{P_S - C_{G1} - P_{CO_2}}, \mathrm{P_S - C_{G2} - P_{CO_2}}]$. The transfer parties determine the final transfer transaction price through

continuous negotiation game. Comparing the change range of the transfer price of power generation rights before and after the carbon trading, we can see that under the constraint of mandatory carbon emissions, the floating range of the transfer price of power generation rights becomes smaller.

5. The Impact of Carbon Emission Trading System on Production and Management Decisions of Different Power Generation Enterprises

At present, the power grid company will allocate the generation plan for each power plant according to the principle of three public dispatch. Each power plant can determine the power generation plan for this year by considering the number of power generation hours and machine assembly capacity set this year. However, in the context of implementing the carbon emission trading system, high energy-consuming power generation companies may not be able to complete power generation plans due to carbon quota restrictions, while low-energy power generation will still have a certain carbon quota on the premise of completing power generation plans. Therefore, under the impact of carbon emissions trading, different power generation companies are faced with different production and operation decisions.

Under the mandatory carbon emission constraint, there are three types of relationships between the power generation Q_{ij} of the power plant J and its contracted power (planned power) Q_{ij}^0, among which:

(1) If $Q_{ij} > Q_{ij}^0$, the power generation capacity is greater than the planned electricity quantity, indicating that the power plant has surplus carbon emission rights. There are two possible production decisions: purchase power generation rights and sell carbon emission indicators.

1) Purchase power generation rights

In the three public dispatch mode, the annual power generation index of each power plant is determined. If the power plant wants to generate more power, it has to purchase additional power generation rights in the power generation trading market. Then the marginal revenue of purchasing power generation rights R_{d3} is shown in formula (15) .

$$R_{d3} = P_{O-G} - C_G - P_T \tag{15}$$

In this formula, P_{O-G} is the on-grid price; C_G is the cost of power generation; and P_T is the transfer price of the generation right.

Thus the purchase quantity of the power generation right ΔQ_{ij} is shown in formula (16) .

$$\Delta Q_{ij}^1 = Q_{ij} - Q_{ij}^0 \tag{16}$$

2) Sell carbon emission indicators

In the carbon emission trading market, power generation entities can sell surplus carbon emission allocation to those with insufficient carbon emission allocations. The marginal revenue R_{d4} of the sale of carbon emission indicators is the carbon trading price P_{CO_2}.

At this time, the quantity of carbon emission indicator sale ΔA_{ij} is shown in formula (17) .

$$\Delta A_{ij}^1 = A_{ij}^0 - N_{ij} \tag{17}$$

In the formula, A_{ij}^0 is the carbon allocation of the enterprise J in I year; N_{ij} is the carbon emission quantity used on power generation by the enterprise J in I year.

When $R_{d3} > R_{d4}$, the power plant should purchase additional power generation rights to continue power generation; conversely, the power plant should trade surplus carbon allocation in the carbon trading market.

(2) If $Q_{ij} < Q_{ij}^0$, the power generation capacity is less than the planned electricity quantity, indicating that with the existing carbon emission allocation, the power plant cannot complete the power generation task. There are two possible production decisions: transfer power generation rights and purchase carbon emission rights.

1) Transfer power generation rights

Under the carbon emission constraint, the power generation rights of high-energy-consuming units other than the carbon allocation allowed for power generation can be transferred to the power plants with insufficient power generation rights through the power generation rights trading market. At this time, the marginal revenue of the power generation right transfer R_{d5} is the transfer price of the power generation right P_T.

At this time, the quantity of power generation transfer ΔQ_{ij}^2 is shown in formula (18) .

$$\Delta Q_{ij}^2 = Q_{ij}^0 - Q_{ij} \tag{18}$$

2) Purchase carbon emission rights

High-energy-consuming power generation companies can complete annual power generation by purchasing carbon emission rights in the carbon trading market. The marginal revenue of purchasing carbon emission rights $R_{d6}$is shown in formula (19) .

$$R_{d6} = P_{O-G} - C_G - P_{co_2} \tag{19}$$

In this formula, P_{O-G} is the on-grid price; C_G is the cost of power generation; P_{CO_2} is the carbon trading price. Thus the quantity of carbon emission indicator purchase ΔA_{ij}^2 is shown in formula (20) .

$$\Delta A_{ij}^2 = N_{ij} - A_{ij}^0 \tag{20}$$

When $R_{d5} > R_{d6}$, the power plant should sell additional power generation rights; conversely, the power plant should purchase carbon emission rights in the carbon trading market and independently complete the annual power generation under the annual power generation rights.

6. Conclusion

The launch of the national carbon trading market is bound to affect the development of the power industry. The power generation companies are particularly valued for its principal force in carbon emissions. This paper explores four main affected aspects of power generation space, power generation cost, power generation rights transfer, and production and operational decision-making. We draws the following conclusions.

(1) The impact on the power generation space. The allocation of carbon emission rights directly affects the upper limit of generation capacity. In the case of meeting specified planned power generation, insufficient carbon emission rights will result in the planned power generation cannot be successfully completed. Under this circumstance, enterprises should improve production equipment and reduce carbon emissions in order to complete the power generation plan while meeting certain carbon emission levels. If it still cannot reach the production demand, the company should consider purchasing carbon emission rights.

(2) The impact on power generation costs. One of the most obvious advantages of implementing a carbon emission trading system is to urge power generation enterprises to upgrade production systems, increase environmental protection investment, eliminate high energy-consuming units and decrease the overall carbon emission level. High-energy-consuming power generation companies usually need to purchase carbon emission rights to meet plan, which increases their generation costs. But low energy-consuming power generation companies can increase revenue by selling surplus carbon emission rights, which further encourages power generation enterprises to upgrade their production capacity and reduce carbon emission levels.

(3) The impact of the transfer of power generation rights. Carbon emission costs are an essential cost expenditure that power generation companies cannot ignore. When carbon trading prices continue to rise and power generation profits are continuously squeezed, the willingness of companies to sell power generation rights will increase, while the number of power generation rights for sale on the market will continue to grow. According to the principle of supply and demand in economics, the price of power generation transactions will continue to fall.

(4) The impact on production and business decisions. When considering the carbon emission trading system, the main production and operational decisions of power generation enterprises are the two aspects of power generation production and carbon emission rights. When the cost of purchasing carbon emission rights is greater than the income from the sale of the analogous power generation,

enterprises often choose to sell their power generation rights in the market. At this time, enterprises with residual carbon emission rights will purchase power generation rights to increase their profits. When the sales revenue can catch up with the cost of purchasing carbon emission rights, companies with surplus power generation will often choose to purchase carbon emission rights to increase revenue.

References

[1] The State Council of the People's Republic of China. (2015) Overall Plan for the Reform of Ecological Civilization System.
[2] National Development and Reform Commission. (2017) National Carbon Emissions Trading Market Construction Plan (Power Generation Industry).
[3] Zhang, JL., Yuan,WW..(2017)The impact of different policy instruments on carbon emission reduction of power generation enterprises. Journal of North China Electric Power University (Social Sciences), 04: 24–30.
[4] Zhao,WH., Lin,MX., Gao,JQ., Song,YJ., Yu,JL..(2016)Combined Transaction Model of Generation Right and Carbon Emission Right under the Power Market Mechanism with Renewable Energy Considered. Power System and Clean Energy, 32(11): 1–8.
[5] Song,YH., He N., Zhang HJ., Tan ZF..(2013)Carbon Pricing Model for Power Generation Enterprises in Electricity Markets. Electric Power, 46(10): 151–154.
[6] Chen,K., Yu,WY..(2018)Research on coping strategies of thermal power generation enterprises under the background of carbon trading. Energy and Environment, 02: 34–35+37.
[7] Shao,Y., Zhang,GT..(2016)Carbon asset analysis and management recommendations in power generation enterprises. Electric Power Technology and Environmental Protection, 32(06): 43-45.
[8] Chen,T., Shao,YF., Tang,XW..(2013)Choice of Power Generation Technology under Uncertain Carbon Price: Example of Technology of PC and IGCC. Technology Economics, 32(04): 62-70.
[9] Tu,JM., Deng,L., Shen,YP..(2016)Management Design and Institution Arrangement of Enterprise Carbon Budget——A Case of Power Generation Enterprise. Accounting Research, 03: 64-71+96.
[10] Huang,SJ., Yang,J., Chen,QA., Sun,R..(2016)CFD Negotiation Models of Carbon Emissions Trading in Generation Side Based on Risk-Benefit Balance. Chinese Journal of Management Science, 24(01): 124-133.