Forest Chemicals Revew
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2021 Page No. 1782-1793
Article History: Received: 12 May 2021 Revised: 25 June 2021 Accepted: 22 July 2021 Publication: 31 August 2021

The Irresistible Market Quota Model of New Energy Power Generation under the Goal of Carbon Peak and Carbon Neutralization

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Abstract:

With more and more attention to environmental protection, reducing carbon emissions is an issue that countries all over the world pay attention to. In order to achieve the goals of "carbon peak" and "carbon neutralization", it is an inevitable trend to vigorously develop new energy power generation. The power market of energy generation is special, and its bidding behavior will have an impact on the market clearing price, and then affect its own bidding strategy. Considering the influence of electricity sellers' bidding strategy on market clearing price and the uncertainty of clearing price itself, an irresistible power market model based on PQC is established by combining the distribution of market clearing price with price quota curve (PQC). The experiment and result analysis show that the method based on PQC can make e-sellers better adapt to the market and reasonably adjust the bidding strategy.

Keywords*: Carbon peak, Carbon neutralization, PQC, Electricity price, Irresistible market model.*

I. INTRODUCTION

More and more evidence and studies show that the global average temperature is rising faster since the industrial revolution, which will lead to global climate change and more frequent disastrous extreme weather. On December 12, 2015, the Paris agreement was adopted at the United Nations climate conference, Set a long-term goal: control the global average temperature rise above the pre industrialization level below 2 ℃, and strive to limit the temperature rise to 1.5 ℃ above the pre industrialization level[1]. And put forward the path of carbon peak and carbon neutralization: in order to achieve the long-term temperature goal, the parties aim to reach the global peak of greenhouse gas emissions as soon as possible and

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achieve the balance between anthropogenic emissions by sources and removal by sinks in the second half of this century. The Paris agreement has entered into force on November 4, 2016. At present, 190 parties around the world have ratified the Paris Agreement, It covers most countries and regions. By the end of the first quarter of 2021, 80 countries and regions have submitted updated national independent contribution goals to the United Nations[2]. In addition, according to the latest research report released by the United Nations Environment Programme, 127 countries and regions around the world have made commitments to achieve carbon neutrality by the middle of this century, Its carbon emissions account for 65% of the world's total carbon emissions by 2020[2]. The number of countries making carbon neutralization commitments is accelerating. It can be seen that the world has reached a broad consensus on strengthening the response to climate change, and carbon peaking and carbon neutralization are the main means to achieve this goal.

China's energy structure is dominated by thermal power generation, which is also the main source of China's carbon emissions. With the promotion of the concept of ecological and environmental protection and the vigorous development of science and technology, new energy power generation technology came into being, which has become an important measure to solve environmental problems in the world and an important topic for the development of China's power industry. The rapid development of new energy power generation is of great significance to China's economic transformation. Combined with the development situation of new energy power generation, China vigorously develops new energy and promotes the realization of low-carbon transformation. This paper analyzes the technical background of China's new energy power generation from the perspective of carbon peak and carbon neutralization, and puts forward an irresistible market quota model.

II. MANUSCRIPT PREPARATION

2.1 Double Carbon Targe

Carbon neutralization and carbon peaking are referred to as "double carbon goals".

Carbon neutralization means that enterprises, groups or individuals calculate the total amount of greenhouse gas emissions directly or indirectly generated within a certain period of time to offset their own carbon dioxide emissions through afforestation, energy conservation and emission reduction, so as to achieve "zero emission" of carbon dioxide. As a new form of environmental protection, it is adopted by more and more large-scale activities and conferences, which promotes green life and production and realizes the green development of

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the whole society[3]. On March 5, 2021, the work report of the Chinese government for 2021 pointed out that we should do a solid job in carbon peaking and carbon neutralization, formulate an action plan for carbon emission peaking by 2030, and optimize the industrial structure and energy structure.

Carbon peaking means that at a certain point in time, carbon dioxide emissions will no longer increase, reach the peak, and then gradually fall back. China promises that carbon dioxide emissions will not increase before 2030, and will slowly decrease after reaching the peak. The Chinese government promises that by 2030, greenhouse gas emissions from fossil energy combustion activities such as coal, oil and natural gas, industrial production processes and land-use change and forestry will no longer increase and reach a peak.

In 2017, the global average power carbon intensity was 450 (g / kWh). Among the 16 major countries below this average, Britain has the fastest decarbonization transition. The change trend is shown in Fig 1.

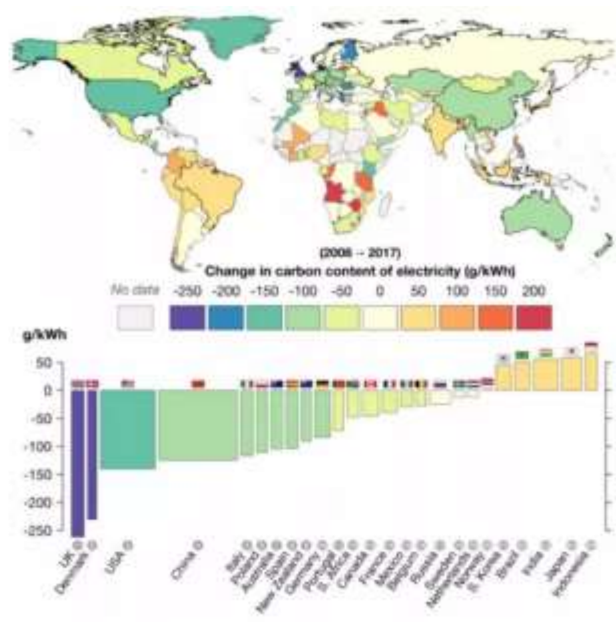

Fig 1: power carbon intensity of major countries in the world

To achieve the "double carbon goal", we should accelerate the adjustment and optimization of industrial structure and energy structure, promote the peak of coal consumption as soon as possible, vigorously develop new energy, accelerate the construction of a national energy use right and carbon emission trading market, and improve the dual control system of energy

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consumption.

2.2 Current Situation of New Energy Power Generation in China

New energy, also known as unconventional energy, refers to various forms of energy other than traditional energy, mainly based on solar energy, wind energy, hydro energy, geothermal energy, marine energy, biomass energy and nuclear fusion energy. Compared with traditional energy, new energy generally has the characteristics of less pollution and large reserves. China's new energy power generation started late, but it has developed rapidly. During the 13th Five Year Plan period, China's installed capacity of new energy increased by about 60 million KW per year, with a growth rate of 32%, making it the fastest growing country in the world. According to the data of China's national energy administration, in 2020, the national full caliber power generation equipment capacity was 220.58 million KW, a year-on-year increase of 9.5%[4]. Among them, the installed capacity of hydropower reached 370.16 million KW, a year-on-year increase of 3.4%; Thermal power was 1245.17 million KW, a year-on-year increase of 4.7%; Nuclear power was 49.89 million KW, a year-on-year increase of 2.4%; Wind power was 281.53 million KW, a year-on-year increase of 34.6%; Solar power generation was 253.43 million KW, a year-on-year increase of 24.1%. It can be seen that the installed capacity of new energy will grow more strongly in 2020, especially wind power and solar energy, which will grow rapidly, and the general trend of new energy power generation.

In the past 10 years, the global new power capacity has reached 1125 gigawatts. The global power cleanliness is shown in Fig 2.

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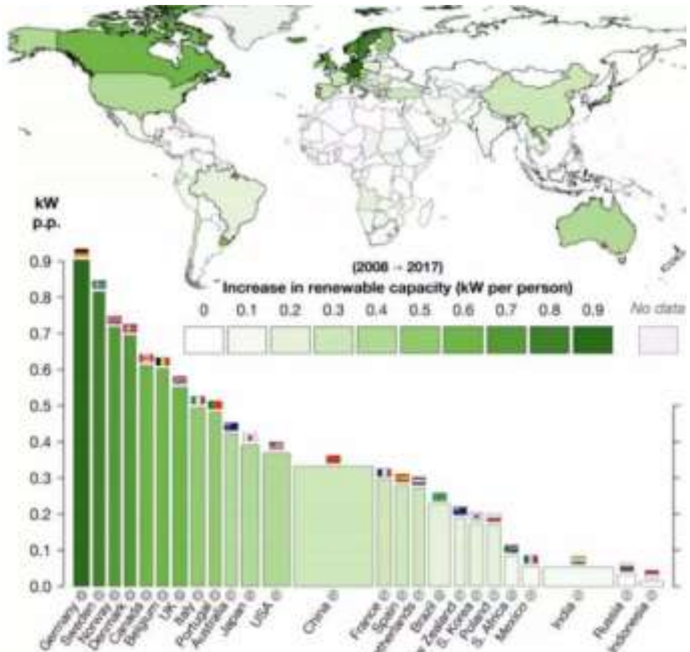

Fig 2: clean power situation of major countries in the world

III. IRRESISTIBLE MARKET QUOTA MODEL

3.1 Electricity price model based on PQC

In the traditional market quota model, aiming at the impact of the bidding of market members on the clearing price, it is divided into price takers and price makers. Small companies have a small market share and their bidding behavior has little impact on the clearing price, so they are often regarded as price recipients; Large companies have a large market share and their bidding behavior has a great impact on the clearing price. They are called price setters. Theoretically, there is no absolute limit between price receiver and price maker. Any market participant will affect the clearing price, but to different degrees[5]. In application, when the impact of bidding on clearing price (i.e. price recipient) is not considered, the typical method is bidding optimization based on the predicted market price. Robust optimization is generally used to model the bidding behavior of power producers and users.

In this paper, an irresistible electricity selling market model is proposed by combining clearing price distribution with market clearing price distribution and price quota curve (PQC).

PQC is the relationship curve between the bid winning power of power market participants in the market and the market clearing price, including power generation side PQC and power

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purchase side PQC. The E-seller belongs to the power purchaser in the market, so the PQC on the de power purchaser side is an increasing (non decreasing) curve, which remains unchanged in other situations in the market。

The more electricity suppliers win the bid, the more total power purchase demand in the market, the more fierce competition on the power purchase side, and the market clearing price shows an upward trend. This paper only considers the unilateral delivery of the generation side market. Easy, taking the minimum power purchase cost as the objective function. The objective function of power dispatching is as Formula (1):

$$q_A = \sum_{i=1}^{T}\sum_{i=1}^{N} q_{i,t} \times \lambda_e \tag{1}$$

The curve is divided into section k, q_A is the specific electricity value of section k, λ_e is the electricity price of segment k that is, the corresponding electricity quantity is between $q_{i,t}$. The power spot market generally adopts the power economic dispatching model[6].

The unified price clearing mechanism MCP (market clearing price) is adopted for clearing in the power spot market. Unified price clearing means that under certain constraints, the units are cleared in the order of quotation from low to high. The quotation of the last unit meeting the balance of load supply and demand is the clearing price of the whole market. The last unit traded is also called marginal unit. The unified clearing mechanism is shown in Fig 3.

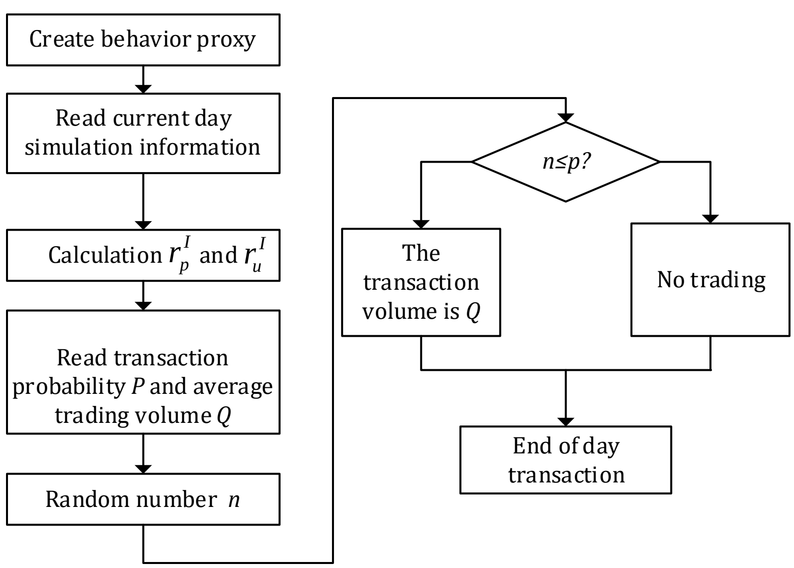

Fig 3: electricity price clearing flow chart

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3.2 Irresistible market model

The calculation of expected profit of electricity sellers is a piecewise integral process, including profit function and electricity price distribution function. The specific segments are determined by the bidding of electricity sellers. Due to the complexity of distribution function, it is difficult to solve the optimal bidding strategy directly by formula. However, a known bidding strategy can directly calculate the expected profit. Therefore, a certain bidding strategy space can be preset to calculate the expected profit corresponding to all bidding strategies and select the maximum value[7]. This method will lead to a lot of calculation and occupy a huge space. In order to solve this problem, we can use the irresistible market model[8].

The model formula is as follows (2):

$$f_{\mathrm{PQC}}(\lambda_{\mathrm{c}})=\begin{cases}\dfrac{f_0}{p_{\mathrm{sum}}} & \lambda_{\mathrm{c}} > \lambda_{\mathrm{b,1}} \\ \dfrac{f_1}{p_{\mathrm{sum}}} & \lambda_{\mathrm{b,2}} < \lambda_{\mathrm{c}},, \lambda_{\mathrm{b,1}} \\ \dfrac{f_2}{p_{\mathrm{sum}}} & \lambda_{\mathrm{b,3}} < \lambda_{\mathrm{c}},, \lambda_{\mathrm{b,2}} \\ \dfrac{f_3}{p_{\mathrm{sum}}} & \lambda_{\mathrm{c}},, \lambda_{\mathrm{b,3}} \end{cases} \tag{2}$$

f_{PQC} is the market price model after normalization, and f_{i} is the location parameter.

The purpose of the irresistible market model is to quantitatively describe the market power in the power market and study various factors affecting the market power. The corresponding model in the case of multi leaders closer to the power market is deduced, and the analytical solution of the equilibrium point is obtained, focusing on the analysis of production cost, power demand elasticity in the market The number of power companies as leaders in the market and the impact of capacity constraints on market power.

IV. SIMULATION AND ANALYSIS

4.1 Model Data

The carbon market simulation is based on the dynamic simulation platform of large energy system. The simulation time is 180 days and the performance time is 365 days. According to the unit carbon emission rate, the actual generator unit structure of the power system in a province of China in 2021 is aggregated into 13 categories, corresponding to 13 generator

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manufacturers, and one manufacturer corresponds to one unit, representing 5 types of coal-fired units, 4 types of gas-fired units and 4 types of renewable energy units respectively. At the same time, 100 carbon traders are set up to represent other types of emission control enterprises[8].

The power market adopts the day-to-day centralized matching and unified clearing transaction mode, and generators quote according to their unit marginal generation cost in the power market. The simulation data are set based on the power system planning data of a province in China in 2021. The daily power consumption curve of the system is calculated according to the actual daily power consumption curve of the system in 2020 and the given growth rate. The available power generation is the sum of the daily maximum power generation of all coal-fired gas units plus the daily actual output of renewable energy units, as shown in Fig 4.

Fig 4: system daily load and available power generation curve

The power market adopts the day-to-day centralized matching and unified clearing transaction mode, and generators quote according to their unit marginal generation cost in the power market. The simulation data are set based on the power system planning data of a province in China in 2021. The daily power consumption curve of the system is calculated according to the actual daily power consumption curve of the system in 2020 and the given growth rate. The available power generation is the sum of the daily maximum power generation of all coal-fired gas units plus the daily actual output of renewable energy units, as shown in Fig 4.

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4.2 Results and Analysis

The quota allocation scheme adopts the key emission units of power generation industry in 2019 (including self emission) issued by the Ministry of ecological environment of the people's Republic of China. Allocation scheme II in the implementation scheme for allocation of carbon dioxide emission quota of standby power plant and cogeneration). That is, ordinary coal-fired units take 300MW as the dividing line, plus three quota allocation benchmarks for gas-fired units[9]. The quota allocation amount is the base line corresponding to the unit multiplied by the generating capacity and relevant correction coefficient. Among them, the reference value of 300MW and above coal-fired units is 0.989 tCO_2 / MWh, the reference value of below 300MW is 1.063 tCO_2 / MWh, and the reference value of gas-fired units is 0.382 tCO_2 / MWh[10].

Under the benchmark scenario, the power generation cost curve of coal-fired power producers after participating in the carbon market is shown in Figure 5. The carbon market quota price is positively correlated with the power generation cost of power producers. This also shows that the change of quota price may affect the clearing order of different units. For example, the power generation cost of low emission rate units with high investment cost will decrease with the increase of quota price, so they will be cleared first in the market environment, and the units with high emission rate will be eliminated due to the continuous increase of power generation cost, so as to make the whole power industry achieve the purpose of emission control and emission reduction.

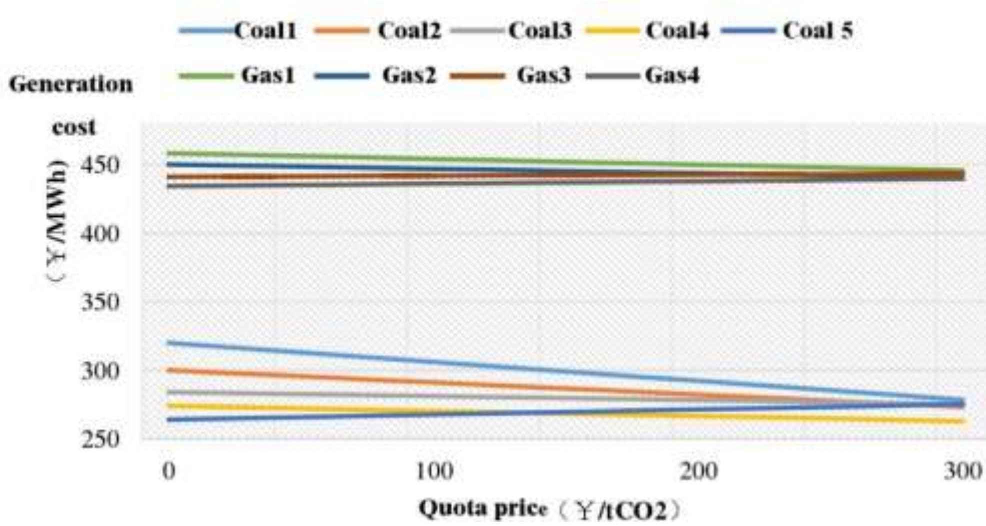

Fig 5: relationship between electricity price and energy

In this example, since the carbon price limit is set at 102 ¥ / T, it can be seen from Fig 5.

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That after the quota price changes, the power generation cost of the generator will change accordingly. Although the power generation cost has changed, due to the existence of market price limit (the quota ceiling price set in this example is 102 ¥ / T,), the changed power generation cost is not enough to change the clearing order of the generator set, so the carbon dioxide emission of the whole system has not changed. Compared with the example results in Chapter 3, due to the setting of quota price limit in the current market, the quota price can not play a good emission reduction effect, but will only change the power generation cost of power producers. At present, the national carbon market is in the initial stage of construction and the market is still in the stage of exploration and development. It is not suitable to set too high carbon price. With the development and improvement of the carbon market, the price of the carbon market can be gradually increased and maintained within a stable range, so as to achieve the purpose of using the market mechanism to promote energy conservation and emission reduction and low-carbon transformation of the power industry, so as to indirectly improve the overall social welfare.

TABLE I. Carbon Market Simulation Data

No	Declared power /(GW·h)				offer /(CNY·(KW·h)-1)			Expected profit / 10000 CNY	Total clearing price /(CNY·(KW·h) -1)
	S1	S2	S3	Total	S1	S2	S3		
1	—	—	—	98	0.382	0.385	0.385	430	0.360
2	32	—	—	87	0.386	0.367	0.367	471	0.350
3	—	—	—	98	0.387	0.387	0.385	325	0.330
4	30	—	—	89	0.385	0.372	0.376	336	0.360

Table I. shows the impact of force majeure model and electricity price on the bidding strategy of electricity sellers.

When considering PQC, the change of clearing price distribution will have an impact on the bidding strategy of electricity sellers. With the increase of parameters, the quotation of electricity sellers in paragraphs 2 and 3 will increase, and the total declared electricity will increase. That is, with the increase of the distribution range of electricity price, in order to obtain sufficient profits, the bidding strategy of electricity sellers changes from winning low clearing price to increasing declared electricity, so as to reduce the impact of market changes.The model data and electricity price simulation results in Section 3.1 are shown in Table 1. "-" in the table indicates that the data does not reach the convergence state.

V. CONCLUSION

The irresistible power market model proposed in this paper not only solves the problem of not considering the impact of its own bidding when predicting the distribution of clearing price, but also overcomes the lack of uncertainty of clearing price. The model is applicable to the members who have influence on the price in the centralized bidding market with unified clearing. The actual economic environment is extremely complex, especially there are still very complex uncertainties and evolving game behavior. The model proposed in this paper is the best within a certain boundary. Through software simulation and practical application, the irresistible power market model proposed in this paper has good performance, and its results have obvious reference value. Under the objectives of carbon neutralization and carbon peak, it can optimize the new energy power market.

ACKNOWLEDGEMENTS

This research was supported by the National Natural Science Foundation of China (No.51367015, No.51667018) and Joint fund project of Natural Science Foundation of Xinjiang Uygur Autonomous Region (No.2021D01C044).

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