Research on the Impact of Industrial enterprises Participation in the Peak shaving Auxiliary Service Market on Carbon Dioxide Emission

--A case study in Liaoning province

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Abstract—With the advancement of the construction of new power systems, industrial enterprises participation in the peak shaving auxiliary service market is increasing. This paper proposes a model to estimate the impact of industrial enterprises participation in the peak shaving auxiliary service market on carbon dioxide emission, and designs a blockchain-based platform architecture to ensure the credibility of transaction of the aggregation trade. The simulation results indicate that most enterprises in the magnesia park use electricity during normal and valley hours. Transferring electricity consumption from peak hours to flat and low periods will reduce carbon dioxide emissions. Moreover, a blockchain-based aggregation platform architecture is an attractive measure too. Besides, the carbon dioxide emission factor of the power grid and the production proportion of primary energy show an opposite trend.

1. INTRODUCTION

To forge a grand blueprint for promoting China's climate and environmental governance and sustainable development, China proposed the goal of carbon peaking and carbon neutrality (“double carbon” goal) in September 2020. Electricity generation is a main source of carbon dioxide （CO_2） emission [1]. Analysis from the perspective of load side, adopting electricity consumption reduction measures or transferring to consume green power for high power consuming industries will be conducive to achieving the dual carbon target. Electricity consumption of industry was 5235.3 billion kWh in 2020, accounting for 67.4% of the total social electricity consumption, according to data released by the National Bureau of Statistics. Consequently, reducing the CO_2 emission of industrial enterprises will generate great significance to the “double carbon” goal.

Enterprises join in the electricity trading is an effective measure to minimize carbon emissions [2]. Some scholars have studied the synergistic mechanism between the electricity market and the carbon market. Literature [3] studied the interaction mechanism of various key factors among markets, and constructed the coupling effect analysis model of three market interactions, namely green card trading, carbon trading and electricity trading. Literature [4] designied a linkage mechanism between the electricity market and carbon market based on carbon emission factors on the electricity consumption side, which increased the willingness of electricity users to purchase low-carbon electricity. Literature [5] proposed an optimal decision-making model of electricity market subject considering carbon trading and CBAM, whose simulation results demonstrating that under the dual influence of carbon trading and carbon tariffs, users tend to trade with renewable energy source producers. To conclude, enterprise users are willing to trade with new energy power generation enterprises and consume more green electricity under the influence of carbon emission trading and carbon tariffs.

Besides, continuously promoting the substitution of electricity and implementing the substitution of electricity for coal and oil in the terminal energy consumption process is conducive to improving the level of clean and low-carbon terminal energy consumption, and promoting the consumption of clean energy[6]. Some studies have demonstrated that new energy generation connected to the grid would contribute to a reduction in carbon emissions from the power industry [7-10]. Along with the construction of a new type of power system, a large amount of distributed new energy connects to grid. Therefore, the CO_2 emission factor generated by the consumption of electricity also will decrease. At the same time, the CO_2 generated by the production of electricity in industrial parks will also decrease with the increasing of new energy connection into the power grid.

In conclusion, scholars have studied the synergistic mechanism between the electricity market and the carbon market, and the carbon emission factor of electricity vary along with the new energy generation. However, no one

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studies the impact of industrial enterprises participation in the peak shaving auxiliary service market on CO_2 emission.

Moreover, as the increasing openness of the electricity market and the access to a high proportion of distributed resources, trading entities are becoming increasingly diversified and decentralized. The need for transparency and credibility in transactions has been enhanced [11-14]. Literature [15] established a blockchain spot trading mechanism that considers both electric energy and carbon emissions trading, which simulation results shown that it can effectively improved the enthusiasm and trading efficiency of every trading entity participating in the power Spot market. Conclusion, the blockchain, utilized its transparent, reliable and other technical characteristics, is highly coupling with the business characteristics of decentralized power market, data security, privacy protection and other needs.

Consequently, this article will study the changes in CO_2 generated by the consumption of electricity in industrial parks after participating in the peak shaving auxiliary service market. At the same time, this article constructs a blockchain-based transaction model, providing a reliable environment for park enterprises to aggregate and participate in transactions, and then promoting the initiative of park enterprise aggregation.

2. METHODOLOGY

In the process of electricity production and consumption, there will be emissions of carbon dioxide[14]. In this paper, we take Guidelines for Accounting Greenhouse Gas Emissions from Chinese Magnesium Smelting Enterprises to estimate the CO2 emission.

2.1 CO_2 Emission Accounting Model

Owing to this article mainly studies the changes in CO_2 generated by the consumption of electricity during the magnesium smelting process. The CO_2 estimation model is as follows.

$$E_{\mathrm{electricity,i}} = AD_{\mathrm{electricity,i}} \times EF_{\mathrm{electricity,i}} \quad (1)$$

where $E_{\mathrm{electricity,i}}$ is the CO_2 emission generated by the consumption of electricity in year i (t); $AD_{\mathrm{electricity,i}}$ stands for the consumpiton of electricity in year i (MWh); $EF_{\mathrm{electricity,i}}$ represents the emission factors for electricity consumption in year i (t/MWh).

2.2 $EF_{electricity}$ estimation model

There is no specific data of $EF_{\mathrm{electricity}}$ in China directly. This paper will take the Emission Reduction Project China Regional Grid Baseline Emission Factors to estimate $EF_{\mathrm{electricity}}$.

$$EF_{\mathrm{electricity}} = \frac{1}{2} \times (EF_{grid,OM,i} + EF_{grid,BM,i}) \quad (2)$$

where $EF_{\mathrm{grid},OM,i}$ refers to marginal emission factor of electricity consumption in year i; $EF_{\mathrm{grid},BM,i}$ refers to capacity marginal emission factor. The two emission factors both estimated base the Power System Emission Factor Calculation Tool (Version 07.0). Moreover, in the "Annual Emission Reduction Project China Regional Grid Baseline Emission Factors", the grid baseline emission factors are uniformly divided into North China, Northeast China, East China, Central China, Northwest China, and Southern regional power grids. Tihs paper take Liaoning province as a case. Therefore, we take Northeast China grid baseline emission factors in the model.

2.3 Industrial Park Aggregation Participation in Electricity Market Model

Blockchain is a new technology that supports power peer-to-peer network transactions. By connecting government, power grid enterprises, regulatory authorities, financial institutions, new energy power producers, green energy service providers, and power users as nodes to the blockchain network, peer-to-peer transactions are achieved. Key technologies such as digital signatures, consensus mechanisms, smart contracts, and asymmetric encryption algorithms are used to ensure transaction security, data transparency, and financial reliability[16-17].

The scenario designed is for enterprises who are represented by aggregators to participate in the day-ahead electricity peak shaving auxiliary service market. Enterprises will log in to the blockchain-based power peak shaving auxiliary service platform (Figure 1). The entire process of power trading will be conducted on the blockchain platform, and blockchain will leverage its value in traceability, certificate storage, and tamper prevention. The application of smart contracts also enhances the credibility of aggregator decomposition benefits.

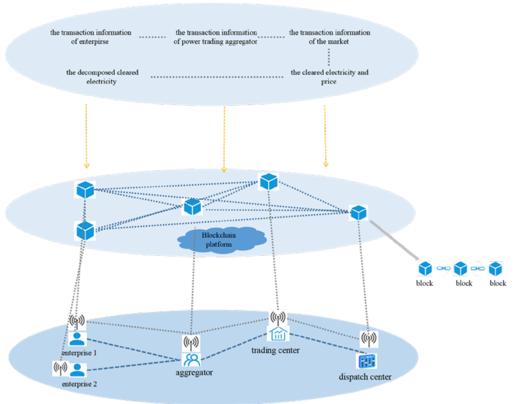

Figure1 The blockchain-based power peak shaving auxiliary service platform

The transaction process is dipicted in Figure 2. First, enterprises log in to the platform, then they can input adjustable capacity, the consumption of benchmark electricity, price etc. Information. Next, the aggregator will declare the aggregated resources to the power trading center, and then the dispatch center will calculate the clearing electricity and clearing pricies based on the declared data and the principles of power production safety boundaries. When the aggregator received the clearing data from the trading center, it will decomposes the total clearing electricity based on the proportion of declared electricity consumption to the total aggregation volume. Enterprises in the park will carry out production base on the winning electricity quantity and clearing price on the second day. Finally, the auxiliary service fees for power peak shaving will be given to aggregators followed a diurnal division and monthly settlement. Aggregator decomposes the total auxiliary service fees to the park enterprises followed the excitation mechanism.

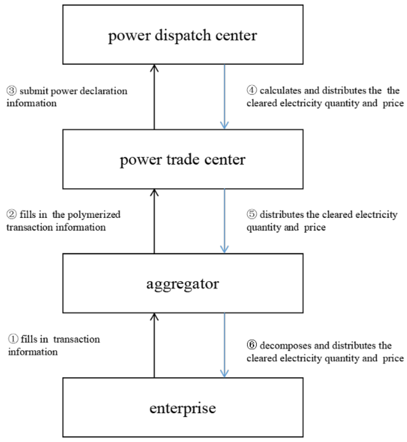

Figure2 The specific transaction process of the industrial park aggregation participation in the electricity market

2.4 Cleared electricity decomposition model

The industrial park enterprises aggregated together to parcitpate in the electricity market. The cleared electricity will be decomposed by the aggregator. The D.decomposition model is set as follows.

$$BV_i = BV_{\text{total}} \times \frac{DE_i}{\sum DE_i} \tag{3}$$

where BV_i refers to the bided volume of enterprise i; BV_{total} is the the total bided volume of the aggregator; DE_{i} refers to the declaration electricity of enterprise i.

3. DATA SOURCE

We assume that enterprises will reduce their electricity consumption during peak hours (thermal power), transferring it to the low valley or flat hours. In the peak hours, the electricity is supplied by thermal power plants. In this paper, the $EF_{electrcity}$ in the peak hours is selected as the capacity marginal emission factor (EF_{OM}）.

Except for the peak periods, the $EF_{electricity}$ will be calculated by Formula 1. $EF_{grid,OM}$ and $EF_{grid,BM}$ in the Northeast, according to the emission reduction project China's regional grid baseline emission factors are shown in TABLE 1.

Table 1 China Regional Gridi Baseline Emission Factors

Year	**Grid name**	**EFgrid,OM Simple,y (tCO_2/MWh)**	**EFgrid,BM,y (tCO_2/MWh)**
2016	Northeast Regional Power Grid	1.1171	0.4425
2017		1.1082	0.331
2018		1.0925	0.2631
2019		1.0826	0.2399

a. Data sources：Annual Emission Reduction Project China Regional Grid Baseline Emission Factors

Data on the proportion of primary electricity and other energy production is from the Statistical Yearbook of Liaoning Province(TABLE 2). Data on electricity consumption of industrial enterprises is simulated according to a magnesite industrial park in Liaoning Province. We surveyed 18 enterprises as a sample to analyze.

Table 2 The Proportion Of Primary Energy Production In Total Energy Production

Year	The proportion of Primary energy in total energy
2016	21.1
2017	24.3
2018	29.9
2019	31.5
2020	33.0
2021	39.8

4. RESULTS ANALYSIS

4.1 The analysis of electricity counsumption

Taking the production and electricity consumption of a magnesite industrial park enterprises in Liaoning Province as an example, the consumption of electritiy of the enterprises is pictured in Figure 3. In order to maintain the safe and stable operation of the power grid, enterprises are encouraged to use electricity during low periods, and electricity prices have been set. The lowest price during low periods and the highest price during peak periods are set. As depicted in Figure3, due to differences in electricity costs, most enterprises in the magnesia park used electricity during normal and valley hours. On the basis of the sample, electricity consumption in peak hours accounted for about 7.08% in 2019.

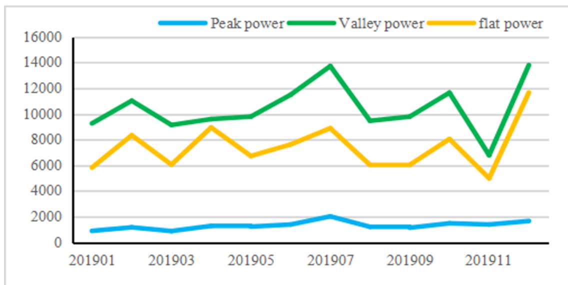

Figure 3 The simulated electricity consumpiton of industrial park enterprises in Liaoning Province in 2019

4.2 The reduction of CO2 counsumption

Referring to the sample data , the CO_2 emission factor of the electricity consumption in peak hours was 1.0826 in 2019. By calculation based the Formula 1, the emission of CO_2 generated by the sample enterprises was 163290.93 t CO_2, during the electricity consumption peak hours.

Assuming that from 2016 to 2019, the peak electricity consumption of enterprises in the park is 15083.22MWh. From Figure 4, it can be seen that as the carbon emission factor of the power grid decreases, the carbon dioxide emissions of the park also decrease.

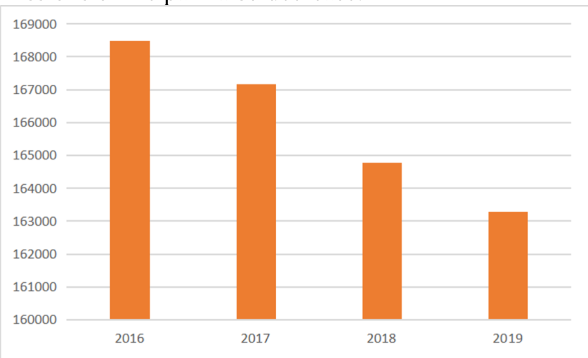

Figure 4 The trends in carbon dioxide emissions in parks during 2016 -2019

Through participating in the peak shaving auxiliary service market, after the aggregation of enterprises in the park, the electricity consumption of enterprises during peak hours can be transferred to normal or valley hours. Through participating in the peak shaving auxiliary service market, according to Formula 1 and Formula 2, the CO_2 emission generated by electricity consumpiton would be 99737.79t in 2019. The reduction of CO_2 reaches 63553.14 t . Per enterprise average decrease about 3530.73 t CO_2.

4.3 The benefit of the reduction of CO_2

This article takes the transaction price of the national carbon market to estimate the income of carbon assets for emission reduction. Assuming that the price of CO_2 is 56 yuan/t. Throug participating in the peak shaving auxiliary service market, the benefits will achieve 355.90 ten thousand yuan, in the scenario of transferring all peak electricity consumption to normal and valley periods. At the same time, this income can serve as an additional fee to incentivize enterprises to participate in the peak shaving auxiliary service market, providing another welfare to support enterprises join in the aggregation transactions.

4.4 Analysis of the interests of different types of enterprises

This paper simulated three types of enterprises (TABLE 3) participating in aggregation transactions. As shown in TABLE 2, the number of enterprises is 11, whose peak power consumption proportion is below 3%. However, the peak electricity consumption is mainly generated by 3 enterprises, whose consumption accounts for total peak electricity consumption up to 73.52%.

Table 3 The Simulated Three Types Of Enterprise

enterprise type	the Proportion of peak power consumption	Enterprise amount
type1	<3%	11
type2	3%-7%	4
type3	>7%	3

Therefore, for enterprises that produce during peak hours, the carbon reduction benefits obtained by aggregating and participating in the electricity peak shaving auxiliary service market can be shared to them, which would result in an motivation effects. Besides, a blockchain-based aggregation platform architecture has been designed to ensure the credibility of transaction data, further attracting enterprises to participate in the peak shaving auxiliary service market. This approach will be beneficial for reducing CO_2 emissions.

4.5 Analysis of the carbon dioxide emission factors

According to formula 2, the carbon dioxide emission factor of electricity during the flat valley period can be calculated, indicating a downward trend (Figure 5). Moreover, the carbon dioxide emission factor of the power grid and the production proportion of Primary energy show an opposite trend(Figure 5).

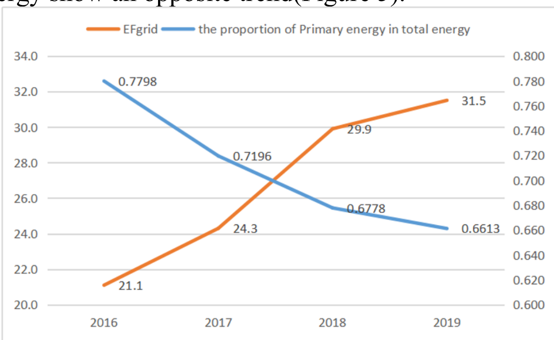

Figure 5 The trends of EFgrid and the proportion of Primary energy in total energy during 2016 -2019

By applying the function of Excel table, a regression model is established. The results (Figure 6) show that the goodness of fit between the grid carbon emission factor and the proportion of Primary energy production is as high as 95.63%. Moreover, the regression equation was used to estimate the carbon emission factors of the power grid in 2020 and 2021, which were 0.6413 and 0.5684, respectively. The research results of reference 18 are consistent with this article, which states that increasing the supply of new energy power generation could decrease the carbon dioxide emissions of park enterprises.

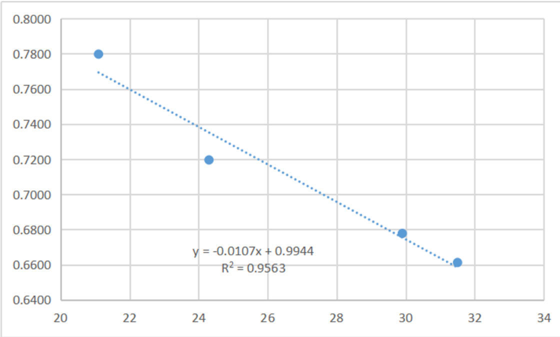

Figure 6 The fitting results of grid carbon emission factors and the proportion of Primary energy production.

5. Conclusions

This paper proposes a new method to achieving CO_2 emission reduction, which is industrial enterprises through participation in the peak shaving auxiliary service market. Besides, we estimated the carbon reduction effect of transferring peak hours electricity consumption to normal and valley periods. To ensure the credibility of transactions of the aggregation trade, a blockchain-based platform architecture also is designed. In the future, we will study the dividend transmission mechanism of the carbon market, and will propose suggestions to relevant regulatory authorities.

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