Research on the Game Model of Electricity Supply and Demand in Steel Enterprises Based on the Optimal Power Supply Efficiency

Bei Yu[a], Xin Li[b]*, Mingyu Yu[c], Hongliang Cui[d]

[a]15801648080@139.com, [b]xionggenxin111@163.com, [c]shiwenjuan_ph@163.com, [d]hongyang1922@163.com

State Grid Huitongjincai (Beijing) Information Technology CO., LTD (Beijing ,100089,China)

Abstract. As one of the important pillars of the national economy, the steel industry faces many challenges in terms of electricity supply and demand. In order to achieve the optimization of power supply efficiency, this paper establishes a power supply and demand game model for steel enterprises under the optimal power supply efficiency, conducts in-depth research and analysis of the supply and demand relationship, aiming to provide decision support and theoretical guidance for steel enterprises and power supply departments.

Keywords: power supply efficiency; Steel enterprises; Game model;Evaluation index system.

1 Introduction

The steel industry, as one of the important pillars of national economic development, plays a crucial role in the national economy and social development. However, due to the significant energy consumption required in the steel production process, the steel industry has also become one of the industries with high energy consumption. How to optimize power supply efficiency in the context of imbalanced power supply and demand has become a common challenge faced by steel enterprises and power supply departments.

Electricity is an indispensable energy source in the production process of steel enterprises. Insufficient power supply can have a serious impact on steel production, even leading to production line shutdowns, thereby affecting the operation of the entire industrial chain. Therefore, establishing a game model of electricity supply and demand in steel enterprises that can simulate the optimal power supply efficiency and conduct research and analysis on the supply-demand relationship has important theoretical and practical significance[1].

Firstly, establishing a power supply and demand game model for steel enterprises under the optimal power supply efficiency requires considering multiple factors. Among them, the electricity demand of steel enterprises is an important variable. In the process of steel production, the demand for electricity is influenced by factors such as production scale, production process, and equipment efficiency. By analyzing historical data and conducting on-site research, the trend of electricity demand changes in steel enterprises can be identified, and corresponding mathematical models can be established[2].

PMBDA 2023, December 15-17, Nanjing, People's Republic of China

DOI 10.4108/eai.15-12-2023.2345350

In addition, the power supply capacity of the power supply department is also one of the key factors affecting the supply-demand relationship. The power supply department needs to allocate power resources reasonably according to the national power planning and forecast demand, to ensure that the supply can meet the needs of steel enterprises. Therefore, when establishing the model, it is necessary to consider factors such as the operational strategy of the power supply department, the status and efficiency of power generation equipment, etc[3].

When establishing a game model of electricity supply and demand for steel enterprises under the optimal power supply efficiency, it is also necessary to consider the characteristics and operating mechanisms of the electricity market. The competitive environment, pricing mechanism, and balance between supply and demand in the electricity market are crucial for the establishment and analysis of models. By studying the operational laws of the electricity market, a more accurate characterization of the supply-demand relationship in the model can be achieved to optimize power supply efficiency in real situations.

By establishing a power supply and demand game model for steel enterprises under the optimal power supply efficiency, effective decision-making support can be provided for steel enterprises and power supply departments. The model can improve power supply efficiency, reduce energy waste, and reduce production costs by adjusting power supply strategies, optimizing supply-demand matching relationships, and other methods. At the same time, the model can also predict the trend of changes in supply and demand relationships, help steel companies and power supply departments formulate long-term plans, and prepare for resource allocation and adjustment in advance[4].

In addition, establishing a power supply and demand game model for steel enterprises under the optimal power supply efficiency can also provide reference for power planning departments. Through model analysis and prediction, the impact of the steel industry on electricity demand can be evaluated, and more scientific and reasonable electricity planning schemes can be formulated to ensure the stability and sustainability of national electricity supply.

In summary, establishing a power supply and demand game model for steel enterprises under the optimal power supply efficiency is of great significance for improving power supply efficiency, optimizing energy utilization, and promoting sustainable development of the steel industry. The establishment of this model requires comprehensive consideration of the electricity demand of steel enterprises, the power supply capacity of the power supply department, and the operating mechanism of the electricity market, in order to achieve the optimization of the supply and demand relationship. Through the application of this model, scientific decision-making support can be provided for steel enterprises, power supply departments, and power planning departments, promoting the coordinated development of the steel and power industries.

2 A Game Model of Electricity Supply and Demand in Steel Enterprises under the Optimal Power Supply Efficiency

2.1 Establish an evaluation index system for power supply efficiency

In modern society, the stability and efficiency of electricity supply are crucial for a country's economic development. It is necessary to establish an evaluation index system for power supply efficiency in order to ensure the reliability and efficiency of the power supply system.

The evaluation index system for power supply efficiency should be determined separately from the power supply side and the demand side to comprehensively evaluate the quality of power supply efficiency. Firstly, from the perspective of the power supply side, power supply capacity is an important evaluation indicator. Power supply capacity refers to the ability of the power supply system to stably provide sufficient electricity while meeting user needs. A system with strong power supply capability can respond to emergencies and peak demand, ensuring the reliability and stability of power supply[5].

Establishing an evaluation index system for power supply efficiency is not a simple task, and it is necessary to consider the interrelationships and trade-offs between various factors. There is a certain contradiction and balance between indicators such as power supply capacity, electricity efficiency, and electricity prices. For example, improving power supply capacity may increase the investment cost of the power supply system, leading to an increase in electricity prices. Therefore, when establishing an evaluation index system, it is necessary to comprehensively consider the weights of each indicator to ensure the objectivity and accuracy of the evaluation results.

In addition, establishing a power supply efficiency evaluation index system is not a one-time task and requires continuous updates and improvements. With the development of technology and changes in society, the requirements for power supply systems are also constantly changing. Therefore, the evaluation index system needs to be adjusted at any time to adapt to new needs and challenges[6].

In short, establishing a power supply efficiency evaluation index system is an important measure to ensure the stable, reliable, and efficient operation of the power supply system. By determining evaluation indicators from the power supply side and demand side respectively, it is possible to comprehensively evaluate the quality of power supply efficiency and provide scientific basis for improving and optimizing the power supply system. At the same time, it is necessary to fully consider the balance between various indicators to ensure the objectivity and accuracy of the evaluation results. By continuously updating and improving the evaluation index system, it can adapt to new needs and challenges, and promote the sustainable development of the power supply system.

2.2 Establishing a Game Model of Supply and Demand Relationship

Establish a game model of supply and demand relationship through the comprehensive application of power supply efficiency evaluation indicators. This model takes into account factors such as the electricity demand, power supply capacity, and electricity price of steel enterprises, and considers the goal of maximizing the interests of both supply and demand parties, thus forming a game model of the supply-demand relationship[7]. On the basis of

considering the evaluation indicators of power supply efficiency, we will establish a game model of the supply-demand relationship to achieve the goal of maximizing the interests of both parties. Based on the characteristics of different loads, search for relevant factors related to different load types (such as production/maintenance plans and historical loads), use feature selection techniques to select the most effective key factors, and form a multi model fusion power load forecasting system. On this basis, corresponding prediction models are obtained based on sample data. The power load forecasting system of a certain steel enterprise is shown in Figure 1.

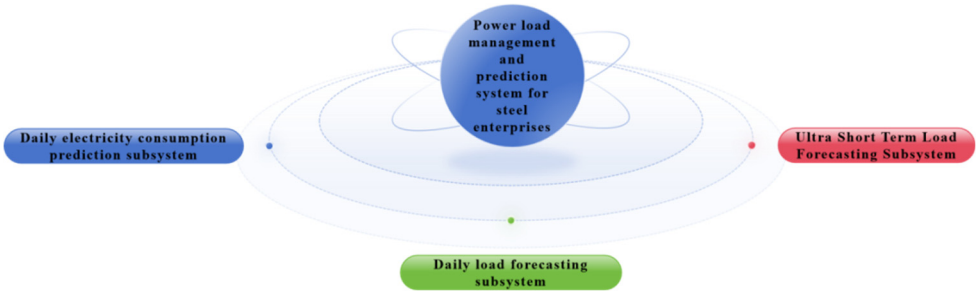

Fig. 1 Overall structure diagram of load management and prediction system for a certain steel enterprise.

As electricity consumers, the electricity demand of steel enterprises directly determines the game results of the supply-demand relationship. We will consider factors such as the production scale of steel enterprises and the energy consumption characteristics of electrical equipment, quantify the electricity demand, and use it as an important parameter in the game model.

The power supply capacity is the core indicator of the power supply system, which reflects the carrying capacity and guarantee capacity of the power supply system. We will comprehensively consider factors such as power generation capacity and transmission and distribution capacity of the power supply system, and match them with the electricity demand of steel enterprises to determine the power supply capacity parameters in the supply and demand game model.

Electricity price is one of the important factors in the game model of supply and demand relationship, which directly affects the distribution of interests between the supply and demand sides and the balance of the electricity market. We will determine a reasonable electricity pricing mechanism by comprehensively considering factors such as power supply costs and supply and demand conditions in the electricity market, in order to achieve stability in the supply and demand relationship and maximize the interests of both parties[8].

2.3 Game strategy for determining supply and demand relationship

By solving the game model of supply and demand relationship, determine the optimal strategy for both parties. Under the optimal power supply efficiency, steel enterprises can optimize their electricity consumption plans, adjust their electricity equipment, etc. to reduce electricity demand; The power supply department can optimize power supply plans and improve power supply capacity to meet the needs of steel enterprises.

In order to further optimize the supply and demand relationship game model, we can consider the following aspects:

In addition to factors such as power supply efficiency evaluation indicators, electricity demand, power supply capacity, and electricity prices, we can also consider other factors that affect the supply-demand relationship, such as policy environment and market competition. By comprehensively considering these factors, we can analyze the game results of the supply and demand relationship more comprehensively and propose corresponding optimization strategies.

In the game model of supply and demand relationship, both parties pursue the maximization of their own interests, so corresponding game strategies need to be determined. We can use game theory methods to analyze the strategic choices and income distribution between supply and demand sides, in order to achieve equilibrium and stability in the supply and demand relationship.

3 Case analysis

Firstly, through data analysis, steel companies have optimized their electricity consumption plans. After precise data collection and analysis, the enterprise has determined the peak and valley periods of electricity consumption and formulated a reasonable electricity consumption plan. By allocating electricity usage time reasonably, steel companies can reduce electricity demand during the production process, thereby reducing the pressure on the power supply department.

In addition, steel companies have further improved power supply efficiency through equipment adjustments. Enterprises have improved the operational efficiency of equipment and reduced energy waste through equipment maintenance and optimization. For example, companies have made technological improvements to high energy consuming equipment, reducing their energy consumption levels and thus reducing their demand for electricity. This not only reduces the burden on the power supply department, but also reduces the production costs of enterprises and improves the competitiveness of steel enterprises. Consider two asymmetric game populations, with power generation companies and provincial power companies representing two different types of populations in the game. Each population has strategies s 1 and s 2 to choose from, and is randomly paired for the game as shown in Table 1.

Table 1 2×2Asymmetric Game Benefits.

	Provincial power company S1	Provincial power company S2
Power generation manufacturers S1	a11,b11	a12,b12
Power generation manufacturers S2	a21,b21	a22,b22

The proportions of individual selection strategies s1 for power producers and provincial power companies are p and q, respectively, resulting in the following game replication dynamic system:

$$\begin{cases} dp/dt = p(1-p)[a_1 - (a_1 + a_2)q] \\ dq/dt = q(1-q)[b_1 - (b_1 + b_2)p] \end{cases} \quad (1)$$

In the formula: a1=a12- a22, a2=a21- a11; b1=b21-b22, b2=b12- b11

There are multiple equilibrium points in the evolutionary game model, but the equilibrium point may not necessarily be the development point of market stability strategy, and stability analysis needs to be conducted on the equilibrium point.

If the right end of equation (1) is zero, the five local equilibrium points of the above system can be obtained as follows:

(0,0),(0,1),(1,0),(1,1),$(\tilde{p}, \tilde{q})$ where $\tilde{p}$ = a1/ (a1+ a2),q= b1/ (b1+ b2).

Whether the above equilibrium point is ESS (Evolutionary stable strategy) needs to be determined by examining the Jacobian matrix J of the above system, i.e

$$J = \begin{bmatrix} (1-2p)[a_1 + a_2]q - p(1-p)(a_1 + a_2) \\ -q(1-q)(b_1 + b_2) \quad (1-2p)[b_1 - (b_1 + b_2 p)] \end{bmatrix} \quad (2)$$

The discriminant criteria are: If the determinant of the matrix corresponding to the equilibrium point is greater than zero and the trace is less than zero, then it is ESS;

If the trace is equal to zero, it is the saddle point.

Using stability analysis methods, four local equilibrium points were obtained, where (p, q)=(-0 282 6, -0.131 4),

Not in line with reality, therefore it is discarded. The results are shown in Table 2.

Table 2 Evolutionary Stability Analysis of Equilibrium Point.

Equilibrium point	Determinant of J (symbol)	J's trace (symbol)	Result
P=0, q=0	-18400 × 36800 (-)	18 400 (+)	Unstable fixed point
P=0, q=1	23600× 36 800(+)	-60 400 (-)	ESS
P=1, q=0	18400×42000(+)	60 400 (+)	Unstable fixed point
P=1, q=1	-42000 × 23600 (-)	-19 400 (-)	Unstable fixed point

It can be seen that only one of the four local equilibrium points in the system is stable, which is the Evolutionary Stability Strategy (ESS), where p=0 and q=1 are the market evolutionary stability strategy points. At this time, the power generation company reports a low price and the provincial power company reports a high price. In addition, the other three equilibrium points of the system are all unstable points. Through data analysis and model solving, the results show that under the optimal power supply efficiency, steel enterprises and power supply departments can achieve a mutually beneficial situation through game strategies. Specifically, steel companies have reduced the demand for electricity and alleviated the pressure on the power supply department by optimizing electricity consumption plans and adjusting equipment. The power supply department has met the needs of steel enterprises by improving power supply capacity and adjusting electricity prices reasonably[9].

Suppose that in a certain period of power market transactions, A total of 5 power generation enterprises participate in the competition, the competitors of power generation enterprises A are power generation enterprises B, C, D, E, and each power generation enterprise has only one unit, and all are coal-fired thermal power units, to participate in the competition with its maximum power supply. The electricity market takes the form of spot trading, and all the on-grid electricity is settled according to the market clearing price. Suppose the power demand Q = 900 MWh. The cost function of the power generation enterprise A is $C(P_i) = 0.158P_i^2 + 116.7P_i + 19770$ .The maximum power supply of power generation enterprise A is 300 MWh, and the calculated unit cost is 230 YUAN / MWh. Without knowing the bidding information of other enterprises, the standard coal consumption rate information of their power generation is collected, as shown in Table 3,figure 2.

Table 3 Unit parameters.

Power generation enterprise (generating unit)	Maximum power supplyPi/MWh	Standard coal consumption rate of power generation / (g / KWH)
B	200	313.6
C	330	313.3
D	170	316.5
E	150	316.6

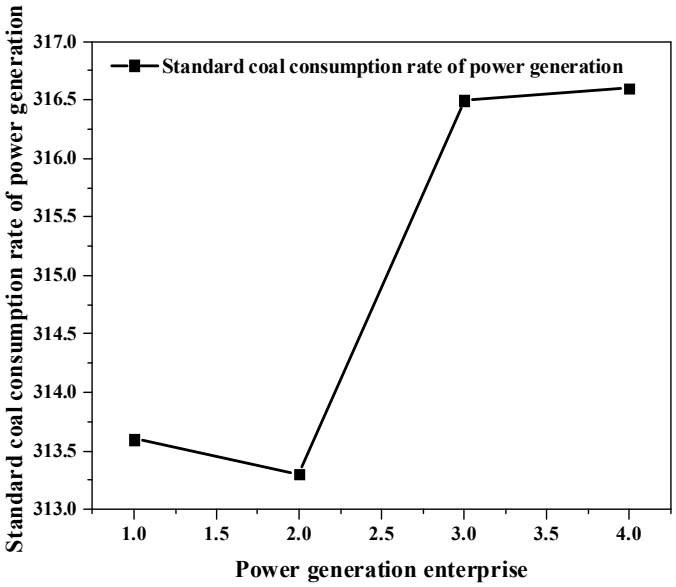

Fig 2 Standard coal consumption rate of power generation.

In order to achieve a game strategy with optimal power supply efficiency, steel enterprises and power supply departments need to strengthen cooperation and communication. Steel enterprises should actively communicate with the power supply department and provide

timely electricity consumption plans and demand forecasting data, so that the power supply department can arrange power supply based on actual demand. At the same time, the power supply department should also actively communicate with steel companies to understand their electricity needs and adjust electricity prices reasonably based on power supply capacity to achieve a balance between supply and demand.

In addition, while coordinating the interests of both parties, the government should also strengthen its regulatory and guiding role. The government can formulate relevant policies to encourage steel enterprises to implement energy-saving and emission reduction measures, while supporting the power supply department to improve power supply capacity and improve power quality. In addition, the government can establish a sound market mechanism to promote competition in the electricity market, improve power supply efficiency and lower electricity prices, promote industrial upgrading and sustainable economic development.

In summary, through data analysis and model solving, steel companies have chosen the game strategy under the optimal power supply efficiency. By optimizing electricity consumption plans and adjusting equipment, they have reduced electricity demand; The power supply department has increased its power supply capacity and reasonably adjusted electricity prices to meet the needs of steel enterprises. The implementation of this game strategy requires the joint efforts of enterprises, power supply departments, and the government to strengthen cooperation and communication, achieve supply-demand balance, and promote the healthy development of the steel industry[10].

4 Conclusion

This article conducts in-depth research and analysis on the supply-demand relationship of steel enterprises based on a game model of electricity supply and demand under the optimal power supply efficiency. The research results indicate that under the optimal power supply efficiency, steel enterprises and power supply departments can achieve coordination and balance of supply and demand through optimization strategies. Future research can further improve the model, consider more factors and constraints, propose more accurate and practical decision-making methods, and promote the sustainable development of the steel industry.

References

[1]Ye, C. , & Wu, L. . (2022). Research on the policy synergy of supply-side and demand-side environmental policies: an analysis based on green value chain of manufacturing enterprises. Environmental Science and Pollution Research,85(31), 29.

[2]Su, Q. , Wang, H. , Shi, X. , Li, G. , & Sun, K. . (2022). Research on energy supply and demand forecast and carbon neutralization path based on grey-monarch butterfly optimization model. Journal of Physics: Conference Series, 2247(1), 012008.

[3]Jamil, F. , Iqbal, N. , Imran, Ahmad, S. , & Kim, D. H. . (2021). Peer-to-peer energy trading mechanism based on blockchain and machine learning for sustainable electrical power supply in smart grid. IEEE Access, PP(99), 1-1.

[4]Yu, S. , & Hou, Q. . (2021). Supply chain investment in carbon emission-reducing technology based on stochasticity and low-carbon preferences. Complexity,65(7),85-89.

[5]Hu, Z. , & He, D. . (2022). Operation scheduling optimization of gas–steam–power conversion systems in iron and steel enterprises. Applied Thermal Engineering, 206(7), 118121.
[6]Wang, Z. , Lin, W. , Wang, W. , Wang, Z. , Li, J. , & Xu, J. , et al. (2021). Research on performance optimization and mechanism of electrochemical water softening applied by pulse power supply. Water Science and Technology,85(7/9), 84.
[7]Mabugu, T. , & Inglesi-Lotz, R. . (2022). The effect of mismatched supply and demand of electricity on economic growth in south africa. Energy sources, Part B. Economics, planning, and policy,45(7),65-69.
[8]Song, T. , Zhang, Q. , Ran, J. , & Ran, W. . (2021). Research on supplier collaboration of daily consumer goods under uncertainty of supply and demand. Sustainability, 13(7),25-29.
[9]He, J. , & Zheng, T. . (2022). Research on the model of industrial interconnection intelligent manufacturing supply and demand network and its robustness. Discrete Dynamics in Nature and Society, 432(7),52-56.
[10]Cheng, Z. , Zeng, W. , Shu, Z. , Liao, W. , & Lin, Y. . (2021). Grid-connected micro-grid power supply and distribution transformer capacity optimization system design in the electricity sales environment. Journal of Physics: Conference Series, 1852(2), 022050.