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Energy Conservation (EC) and Emission Reduction (ER) Technology Based on Genetic Algorithm (GA)

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Abstract: The equipment manufacturing industry is the basic industry for the development of the national economy and an important strategic industry that promotes the transformation of the national energy structure to green and clean energy. As my country accelerates the adjustment of the energy structure, liberalizes and absorbs private capital into the market, the development of the equipment manufacturing industry will be further deepened, refined, and specialized, and the technology and methods of energy saving and ER in the equipment manufacturing process will be studied, so as to achieve "clean energy and clean manufacturing". ", will become an important part of the applied science of environmental engineering. The main purpose of this paper is to conduct research on energy saving and ER technology based on GA. This paper evaluates and analyzes the collected electricity consumption throughout the year. The experiment shows that the annual average electricity consumption of the main workshops is nearly 12000MkW. According to the 80/20 principle, it can be concluded that the total electricity consumption of the first five items accounts for 89.78% of the total electricity consumption. (Other items, hydraulic press, heating furnace, air compressor system, lighting system), which belong to the key energy-consuming equipment of this workshop.

1. Introduction

In recent years, my country has been adopting administrative measures to promote building EC and ER, and has achieved certain results. However, administrative measures often focus on short-term benefits, and long-term sustainability is not strong, which can only achieve the effect of treating the symptoms rather than the root causes. Market-oriented adjustment methods are more effective choices in energy-saving and emission-reduction policy plans. In the context of the construction of carbon market trading system, the "building carbon emission trading" system established on the basis of property rights theory and Coase theorem is to deal with climate change.

It is an inevitable choice to change and realize the development of low-carbon buildings [1-2].

In a related study, Rehman et al. based energy usage scheduling and management under electric utilities and renewable energy [3]. Efficient integration of renewable energy (RES) and battery storage systems (BSS) has been proposed to address energy management issues, lower billing costs, peak-to-average ratios (PARs), and carbon emissions. Through the proposed electricity scheduling method and integrating the low-cost RES, the reduction of the user's electricity bill is achieved.

Ammar studies the effects of using ER strategies for container ships from an environmental and economic perspective [4], focusing on improving the Energy Efficiency Design Index (EEDI). As case studies, A19 and A7 class container ships were investigated. Three different options were considered, including natural gas, processing equipment and vessel deceleration. The A19 achieves the lowest annual emission rate per cargo shipped.

Pashchenko et al. considered waste heat thermochemical recovery (TCR) using steam and combustion products for natural gas reforming [5]. The use of TCR has significantly improved the efficiency of industrial furnaces - it has been observed that TCR is able to reduce fuel consumption by almost 25%. In addition, improving energy efficiency has a beneficial impact on the environment as it reduces greenhouse gas emissions.

In this paper, based on GA, the research on energy saving and ER technology is carried out. Aiming at the path of energy saving and ER in the thermal coal supply chain, this paper considers the mining, transportation and power generation processes in the supply chain, subdivides the thermal coal supply chain system into mining links, transportation links and power generation links, and analyzes the energy consumption of each link in the chain. , carbon emission and energy saving and ER paths, dynamically simulate the energy saving and ER effects of different paths, propose corresponding energy saving and ER measures, and then optimize the entire system. Research on energy-saving and emission-reduction technology investment decision-making issues, put forward specific technology investment plans and quantitatively analyze the energy-saving and ER effects of each plan. The research results are correct and convincing.

2. Design and Research

2.1. Advantages of the Market Mechanism

Although planning control policies may be effective in controlling the level of EC and ER in buildings, they may lead to high additional government enforcement costs and inefficient resource allocation. Through direct control, enterprises must meet a certain level of building EC and ER standards, and the government must obtain complex technical information, spend a lot of human and material capital to collect information, and establish a supervision and management mechanism. On the other hand, in order to achieve goals, enterprises must use various resources to rationalize costs in the implementation process. However, uniform EC and ER standards cannot actually guarantee that enterprises of different scales, regions, and properties can achieve optimal performance. The allocation of resources will eventually lead to rising costs and low efficiency of resource allocation.

By introducing a market mechanism, the unit building energy consumption can be positioned as the cost value of the market, and then transformed into different market means, such as carbon tax, carbon emission trading, etc., to encourage enterprises to use low-emission production processes or technological innovations. An ideal enterprise will choose and decide how to reduce its building carbon emissions to a level equal to the carbon trading price or carbon tax rate based on the principle of profit maximization, so as to minimize the total cost of building EC and ER in society and achieve control. Optimization of building carbon emissions [6]. The market mechanism has three advantages over planning:

(1) After the cost value of building carbon emission and energy consumption is set, the building energy consumption cost caused by the enterprise to the environment is included in the production decision, and the enterprise can choose advanced construction technology, energy saving and ER means and green technology to achieve lower building carbon emissions.

(2) The market mechanism can make the production of enterprises flexible, and promote the innovative and open utilization of advanced green building technology and building carbon emission technology, as well as a high-efficiency management system [7-8].

(3) The cost of government supervision in the market is much lower than that of planned policies.

Scholars at home and abroad have done a lot of research on the use of market mechanisms such as carbon tax and carbon emission rights trading to analyze carbon emission control. Huge role, the huge role that various environmental policy tools have on enterprises' ER costs, the role of ER technology incentives produced by various environmental policy tools, the impact on economic development, and the role of ER effects. For specific analysis, the specific research content can refer to the literature review section of the paper.

In general, the existing literature mainly focuses on the macro level, and the research on the mechanism and effect of carbon tax and carbon emission trading is mostly isolated, for example, it only focuses on a single impact on ER costs, and lacks systematic research. Compared with a single effect study, the implementation of carbon tax and carbon emission trading will have many impacts on enterprises in terms of total control, ER cost, technological innovation, ER effect, etc. It is necessary to study it in a unified framework model [9-10].

2.2. The Current Research is Insufficient

The current research mainly has the following shortcomings:

(1) There is a lack of targeted research on industry carbon emissions trading. Since the carbon emission trading system itself is a market-based policy tool in the exploratory stage for China, and from the perspective of property rights, the distribution of carbon emission rights from a regional perspective is relatively easy to achieve. There are few in-depth studies [11-12].

(2) There are few studies on building carbon emissions and the influencing factors of building carbon emission rights. In view of the complex measurement of building carbon emissions, the related research on building carbon emissions should consider more energy-saving and ER measures at the technical level such as heat transfer coefficient and energy consumption, and explore the literature results of building carbon ER from the perspective of market and mechanism. At the same time, there are fewer research results on the influencing factors of building carbon emission rights, and the setting of influencing factors in the existing results is relatively rough, which cannot effectively reflect the multi-faceted effects of building carbon emission rights.

(3) Lack of support from effective research methods. As mentioned above, the measurement of building carbon emission rights is relatively complex, so the existing research results lack sufficient method support, and are mostly elaborated from the perspective of theory and literature analysis [13-14].

2.3. Advantages of GAs

Due to the special search method and principle of the GA, the GA has the following advantages compared with other optimization algorithms:

(1) The GA performs a global search, so the optimization results are more reliable and stable. Through multiple experiments and comparisons, it is found that the results of each optimization can be basically consistent.

(2) The optimization speed of the GA is faster. The GA can quickly search the space with higher fitness value, so the optimization speed is faster.

(3) GA only needs one search information for fitness value. The operation is simple and the search results can be obtained faster [15-16].

2.4. Algorithm Research

The optimization objective of WPTNs in this paper is the transmission path, which is related to the scale of WPTNs nodes, the distribution of nodes, and the power storage status of nodes. Therefore, it is necessary to adjust and improve the cellular GA according to the particularity of the problem in this paper. It enables the algorithm to quickly find the optimal path, adjust and improve from aspects [17-18].

(1) Fitness function

For WPTNs in the active injection mode, the energy demand node sends a request, the power injection node receives the request, and a transmission link is established between the power injection node and the energy demand node. In order to improve and reduce the power loss, the optimization goal is the path with the highest transmission efficiency between the power injection node and the receiving node. In order to make the algorithm obtain the minimum fitness function value in the operation process, the path transmission loss rate f(R) is used as the fitness. function:

$$\eta(R) = e_{S_1,S_D}(R) = \prod_{i=1}^{D-1} e_{S_i,S_{i+1}}, S_i \in R, S_i \in S \tag{1}$$

$$f(R) = 1 - \eta(R) \tag{2}$$

For passively injected WPTNs, link optimization has two performance indicators, Powertransfer and Powerloss. The dimensions of these two performance indicators are the same. Therefore, the fitness function is set as:

$$\begin{aligned} f(R) &= w \cdot \frac{p_{need}}{Power_{transfer}} \cdot Power_{loss} + (1-w) \cdot total(Power(S_i)), S_i \in R \\ w &= \begin{cases} 1 & Power_{transfer} \geq p_{need} \\ 0 & Power_{transfer} < p_{need} \end{cases} \end{aligned} \tag{3}$$

Since there are constraints g1 in the objective function expressions of active injection and passive injection of WPTNs in equations 3.1 and 3.5, which makes the expression more complicated, a penalty function mechanism is introduced here to remove the constraint:

$$\psi(g,\theta) = \theta \cdot \sum [\max\{0, g\}]^2 \tag{4}$$

Here θ is set to a large positive number, and g represents the constraint equation. Converted to an unconstrained optimization problem:

$$\Theta = f(R) + \psi(g,\theta) \tag{5}$$

Based on the above equation, the power transmission link is the optimal solution when the fitness function value is the smallest, which means that the transmission efficiency between the power injection node and the energy demand node is the highest in the WPTNs with active injection, and the transmission chain in the WPTNs with passive injection is the highest. In the case of meeting the energy demand, the energy loss in the transmission process is minimal.

3. Experimental Research on

3.1. Analysis of Energy Saving and ER System in Thermal Coal Supply Chain

3.1.1. Overall Framework

This paper starts from the system elements such as economy, energy and environment, and combines the characteristics of low-carbon economy and green supply chain to build a thermal coal supply chain system. The system can be divided into mining subsystem, transportation subsystem and power generation subsystem. The three subsystems are interconnected, and factors such as thermal coal volume, energy consumption, CO2 emissions, revenue, and cost within the subsystems interact to form a complex thermal coal supply chain system.

Due to the systematic and nonlinear characteristics of the thermal coal supply chain energy saving and ER system, by analyzing the interaction relationship between the internal factors of the thermal coal supply chain system, constructing a causal relationship diagram and then constructing a model flow diagram, the thermal coal can be better simulated. Supply chain energy saving and ER system, select the optimal plan to promote the coordinated development of electricity, environment and energy in the thermal coal supply chain.

The overall framework is as follows:

(1) According to the relationship between the thermal coal supply chain and the economy, energy and environment, determine the boundary of the system, and put forward the basic assumptions of the system.

(2) Analyze the interaction between factors such as coal volume, revenue, cost, energy consumption, and carbon emissions within the system, and build a causal relationship model;

(3) According to the causal loop diagram, construct the basic flow diagram of the dynamic model of the energy-saving and emission-reduction system of the thermal coal supply chain;

(4) Determine the variables and related parameters in the system, use mathematical expressions to determine the relationship between the variables, and enter the formula in the simulation software;

(5) By adjusting the main parameters in the model, set different scenarios to simulate the energy-saving and emission-reduction system of the thermal coal supply chain, and propose corresponding energy-saving and emission-reduction countermeasures according to the simulation results.

3.1.2. System Boundaries and Basic Assumptions

The thermal coal supply chain studied in this paper refers to the process in which upstream enterprises transfer coal through multiple processes such as mining, washing, transportation and consumption, from coal suppliers to power plants to complete consumption activities according to the power generation needs of downstream enterprises. sum. Among them, upstream enterprises refer to coal mining enterprises, and downstream enterprises refer to power generation enterprises that use thermal coal as the main energy source. The thermal coal supply chain includes multiple processes such as coal mining, washing, transportation and consumption, and there are energy consumption and CO2 emissions in each process. The energy saving and ER system of the thermal coal supply chain mainly considers the economic benefits, energy consumption and CO2 emissions generated by thermal coal in the supply chain transmission process, that is, to study the relationship between the thermal coal supply chain and the economy, energy and the environment. The energy-saving and emission-reduction system of thermal coal supply chain is a complex system, in which there are many factors affecting energy consumption and CO2 emission. Therefore, this paper only considers the main factors affecting EC and ER in the thermal coal supply chain. In this paper, the overall boundary of the thermal coal supply chain is taken as the outer boundary, and the supply chain enterprises are taken as the internal boundary to divide the energy-saving and ER system boundary of the thermal coal supply chain. The system structure is shown in Figure 1.

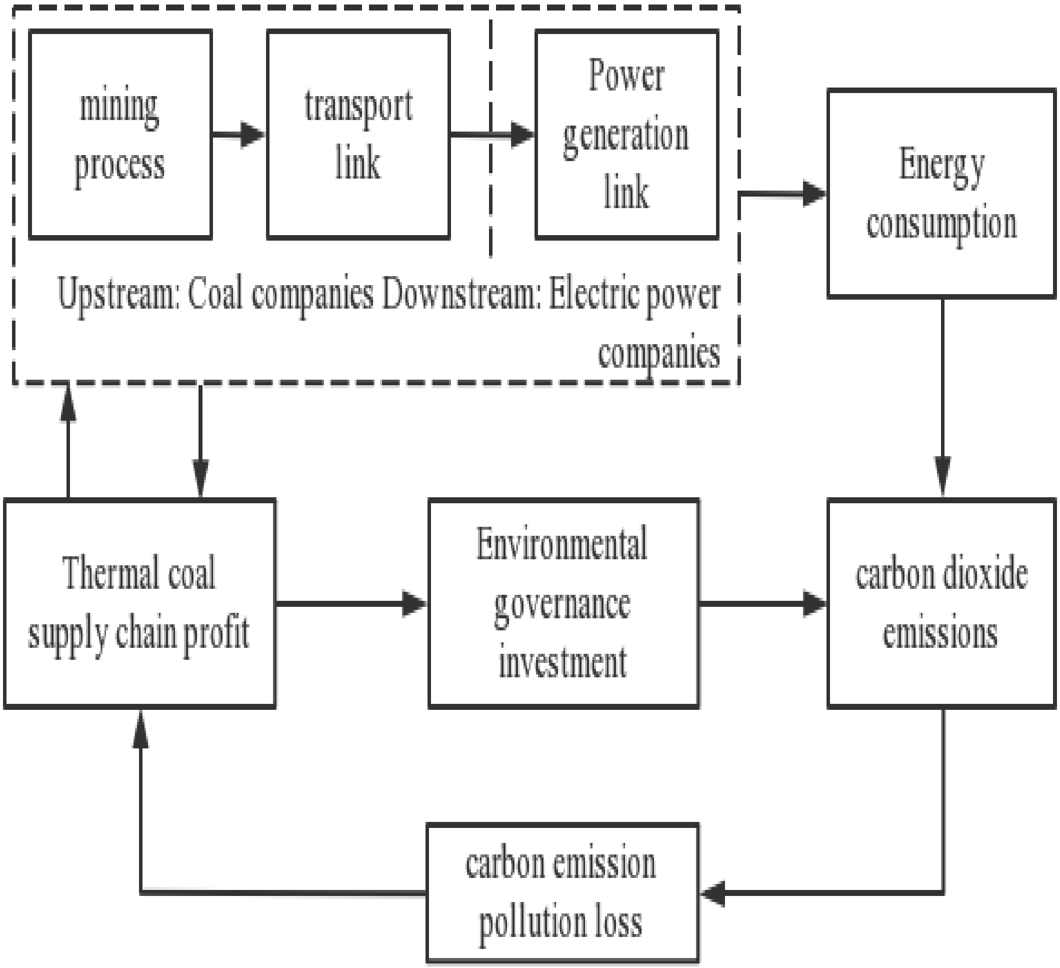

Figure 1. Structure block diagram of energy saving and ER system in thermal coal supply chain

3.2. Basic Operation of GA

In order to quickly understand and be familiar with the bionic principle of GA, the genetic terminology and the meaning of the algorithm in the GA are summarized, and the following comparison table is formed:

Table 1. Comparison table of genetic nouns and algorithm meanings in GA

Algorithm meaning	Genetics noun	Significance
Model feasible solution	Individual (chromosome)	Composed of gene strings
A set of feasible solutions	Population	Population size
Initial solution	Initialize the population	Individuals created by natural selection
Cross	Gene binding	Chromosome segregation, duplication and crossover
Mutations	Gene mutation	There is a certain chance of producing good genes
Choose	Survival of the fittest	Eliminate bad offspring with standard rules
Encoding (initialization)	Phenotype is internalized into genotype	Start to evolve
Decoding	External characteristics of genotype	End of evolution

Through the above concepts, the basic principles of the GA have been clearly explained. Next, these concepts are connected in series to introduce the execution process of the GA.

Start the GA preparation process:

Step1 randomly generates a feasible solution, that is, the first generation of chromosomes.

Step 2 Use the fitness function to calculate the degree of fitness respectively, and calculate the probability of selection.

Formally enter the "evolution" process:

Step3 generates N-M chromosomes through "crossover";

Step 4 Then perform a "mutation" operation on the N-M chromosomes generated after crossover;

Step5 Then use the "replication" method to generate M chromosomes;

So far, N chromosomes have been generated, and then the fitness of N chromosomes and the probability of being selected next time are calculated respectively. This is an evolutionary process, followed by a new round of evolution. Select the number of iterations according to preset parameters until a satisfactory result is obtained.

(1) Select operation

Following the laws of genetic evolution in nature, according to selection criteria or rules, relatively good individuals are selected from the parent generation as part of the offspring. The purpose is to allow the good traits to be passed on to the offspring and prevent the loss of genetic faults. There are three main categories of selection ideas: proportional selection, sorting selection, and competitive selection.

(that is, the larger the probability value, the easier it is to be inherited to the next generation) and has nothing to do with other factors (coding, chromosome form, etc.). The implementation process is as follows: divide the disc into different sectors, determine the size of the central angle of the sector according to the proportion of the individual fitness value, and then start to rotate the turntable randomly, and the selected individuals will be inherited into the next generation. The number of rotations leads to different uses: if it is rotated twice, it is used to participate in the next step - genetic crossover; if the number of rotations is equal to the number of individuals in the population, it is used to replicate the population.

(2) Cross operation

Each iteration of the GA will generate N chromosomes, and each iteration in the algorithm is called an "evolution", which is a unique operation step of the GA. The newly generated chromosomes in each evolution are obtained through crossover operations. If the crossover operation is required to judge the crossover probability, it can be analogous to mating in genetics. The crossover process needs to find two chromosomes (individuals) from the chromosomes of the previous generation, both of which are called parent chromosomes. This new chromosome contains a certain number of genes from both fathers at the same time.

Crossover is the process of random crossover of two chromosomes. The purpose of this operation is to generate new individuals and search efficiently in the gene fragment area, taking into account the possibility of preventing crossover from damaging excellent genes and chromosomes. The crossover is based on the number of individual gene strings constituting the individual, and the length of the exchange and the insertion position are randomly selected to carry out genetic crossover to obtain two offspring individuals.

(3) Mutation operation

Crossover can ensure that good genes are left after each evolution, but it is only a selection of family chromosomes, the existing gene information is fixed, but their combination order is exchanged. This ensures that after N times of evolution, the optimization result is closer to the peak value (the local optimum may not be the global optimum). In order to break through this limitation and approach the global optimum solution, mutation operators need to be introduced to perform mutation operations. Variation can be understood as a genetic mutation that occurs during the evolution of an individual organism, and there is a certain probability that new good genes will be generated to obtain powerful performance. Mutation can repair and supplement the gene fragments in the evolution operation, ensure the diversity of the solution space, and help to make the current solution jump out of the local for global search. Crossover and mutation complement each other, and loop iteration ensures the global search capability of the GA.

The mutation operation can be understood as: when we generate a new chromosome through crossover, we need to randomly select several genes on the new chromosome, and then randomly modify the value of the gene or replace it with other alleles, so as to introduce the existing chromosomes. New genes have been added to improve the diversity of chromosomes, so that the population evolves in the direction of diversification.

4. Experimental Analysis

4.1. Main Energy Consumption Process and Pollution Discharge

An important feature of the turbine manufacturing process is that it covers the main processes in the mechanical manufacturing process, such as cutting, grinding, welding, machining, etc. Analysis of the entire process flow shows that the direct energy and resource consumption of the turbine production mainly includes electricity, steam, gasoline/diesel, and cylinder gas, etc., and the pollution emissions are mainly welding fumes, oil-containing hazardous waste, waste packaging materials, etc.; combined with the manufacture of a certain turbine By analyzing the company's financial data and energy consumption data, it can be concluded that the main energy consumption of the company's production/lighting is electric energy; electric welding, as the process with the largest number of workers and the longest working time, also has the most significant emission pollution of welding fumes.

Then, the collected annual electricity consumption is evaluated and analyzed as shown in Table 2.

Table 2. Average annual electricity consumption of a factory

Workshop	Energy used	Proportion
Total	11675	100%
Other	6501	55.68%
Hydraulic press	2092	17.92%
Heating furnace	861	7.37%
Air compressor system	557	4.77%
Lighting system	471	4.03%
Sandblasting room	443	3.79%
Other equipment	323	2.77%
Stand up car	271	2.32%
Spray booth	156	1.34%

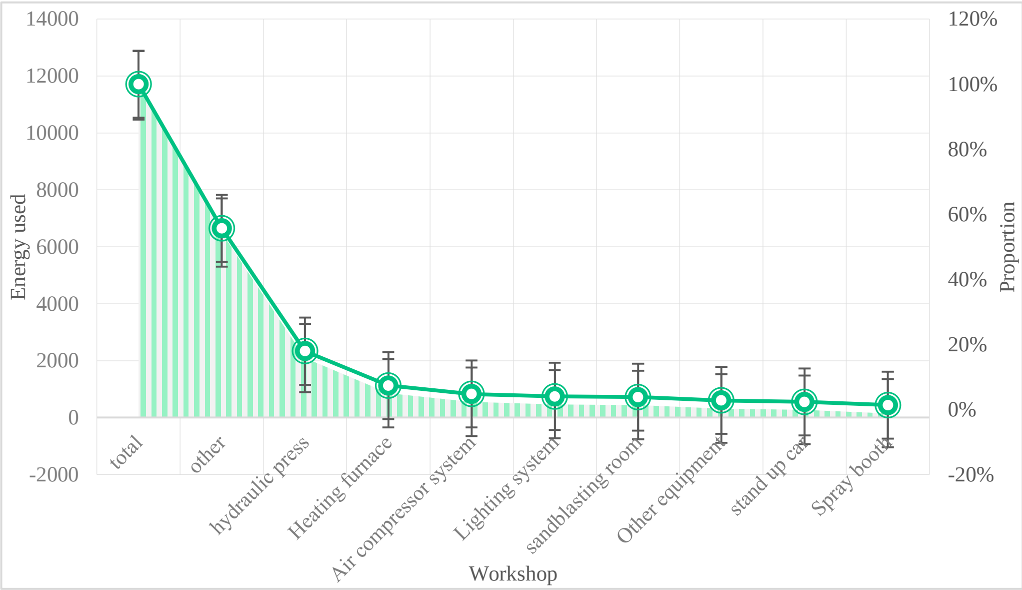

Figure 2. Analysis of the average annual electricity consumption of a plant

As can be seen from the above figure, the average annual power consumption of the workshop is nearly 12,000MkW. According to the 80/20 principle, it can be concluded that the total power consumption of the first five items accounts for 89.78% of the total (other items, hydraulic presses, heating furnaces, and air compressors). system, lighting system), which belong to the key energy-consuming equipment of the workshop.

Further analysis shows that the "Other" item includes electric welding machines, heating cabinets, driving, workshop offices and other power-consuming equipment. Due to the large number, there are nearly 70 electric welding machines, nearly 40 heating cabinets, and Most of them are mobile devices. At present, the measurement has not been effectively and accurately covered and cannot be further subdivided. Hydraulic presses and heating furnaces belong to a single large-scale equipment. Considering that they are mature processes, the energy saving potential is limited.

After the final evaluation, it is believed that the air compressor system and the lighting system have the feasibility of improving energy consumption, and the energy saving potential is large.

4.2. Calculation Result of Target Weight Coefficient

According to the Pareto optimal solution set of the two optimized target efficacy factors, the distance method is used to obtain the weights corresponding to the closest solutions to the two target ideal points. The results are shown in Table 3.

Table 3. Weights of two targets under different market conditions

Market	GD	GG	DD	DG
Operating cost weight factor	0.72	0.49	0.53	0.44
Carbon emission right coefficient	0.28	0.51	0.47	0.56

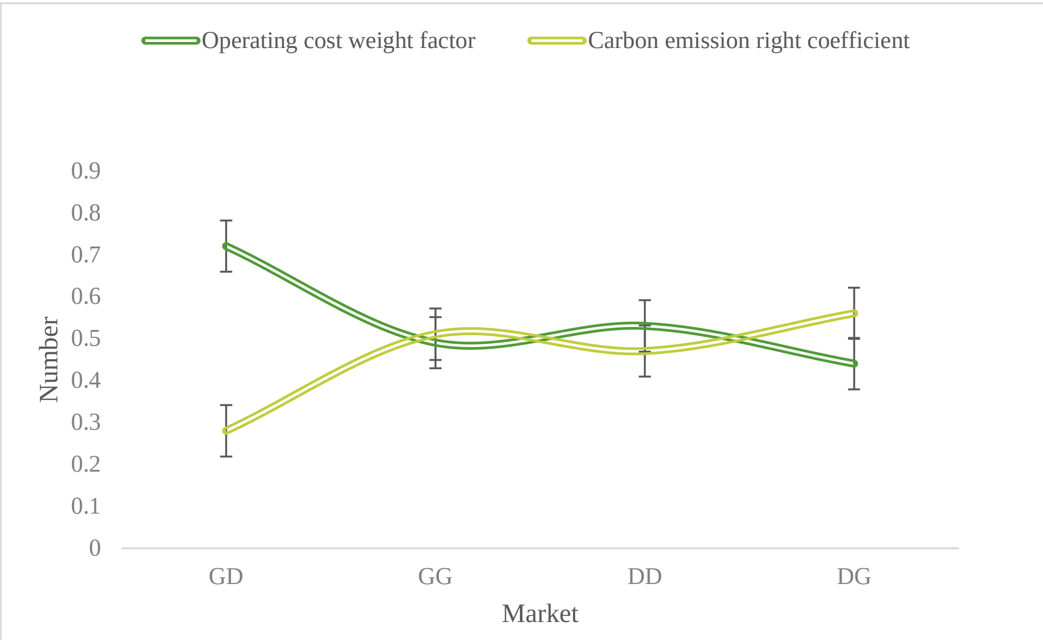

Figure 3. Weight coefficient analysis of two targets under different market conditions

The weight coefficients of the two objectives are calculated by the distance method. The importance of the two objectives in the speed optimization is different under different market conditions. Through the two cases of "GD" and "GG", it is found that when the rental price is constant and the fuel cost increases, the importance of carbon emissions increases significantly. The impact of carbon emissions on both goals increases, so the importance of the carbon emissions goal increases. Through the two market conditions of "GD" and "DD", it is found that when the fuel price remains unchanged and the rent increases, the proportion of operating costs in the optimization of the speed increases significantly. In multi-objective speed optimization, it is very important to choose the ideal weight, and the weight calculated by the distance method is more reasonable than the weight given randomly or based on experience.

5. Conclusion

In the context of global warming, all countries are speeding up the adjustment of energy structure, setting targets to significantly reduce carbon emissions, and taking the road of sustainable development. At the same time, my country also promises to voluntarily reduce carbon emissions. While the state is increasing and deepening legislative support for policies, research on the application of energy-saving and emission-reduction measures at the technical level has also become more important. In the national environment of EC and ER, it is of great practical significance to reduce production costs, live in harmony with the environment, and effectively enhance the competitiveness of enterprises. At the same time, enterprises are constantly looking for energy-saving and emission-reduction measures that are suitable for the current situation of the enterprise, are effective, have a short recovery period and are highly operable.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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