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Steel Enterprise Energy Management System Based on Mitsubishi PLC

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Abstract: The iron and steel energy system has the nature of large scale and complex structure, which brings huge challenges to the management of the production process of enterprises. The traditional energy management system management mode is chaotic, the workload of management personnel is large, and the utilization rate of system resources is low, resulting in high cost of network construction of iron and steel enterprises. The main purpose of this paper is to analyze the application of Mitsubishi PLC in the energy management system of iron and steel enterprises. This paper mainly analyzes the problems existing in the energy management of iron and steel enterprises at this stage, puts forward the basic principles for the design of the energy management system, and uses the Mitsubishi brand PLC to carry out the system design. The research shows that in recent years, the blast furnace gas emission rate of the iron and steel enterprise has been continuously reduced from 8.12% in the first year to 0.31% in the fourth year. The effect of reducing blast furnace gas emission rate is obvious, not only fully utilizing gas resources, but also reducing pollution, and achieving good economic and social benefits.

1. Introduction

The iron and steel industry is one of the most representative industries in the world's industrialization process, and it is also an important industry for the growth of the national economy of all countries in the world. It is of great significance to the national defense and infrastructure construction. With the continuous development and extensive use of Internet technology and networking technology, the development of a software management system that integrates iron and steel enterprise management ideas and computer technology has become an inevitable requirement for the development of iron and steel enterprises [1-2].

In related research, Pal et al. developed intelligent energy management, which separately modeled the cost characteristics of interruptible loads and battery storage systems [3]. The proposed scheme can efficiently handle the energy demand of the VPP domain. Four different scenarios and different load conditions are considered to validate the concept of smart energy management. The experimental results show the profitability of each scenario. A simple home energy management using the two-phase simplex method (TPSM) was proposed by Singaravelan et al. [4]. Furthermore, a detailed survey of IoT-monitored smart energy home management models is presented. Considering different load scenarios, the proposed TPSM method is found to be simple, reliable and efficient.

This paper firstly analyzes the problems existing in the energy management of iron and steel enterprises at this stage, puts forward six basic principles for the design of energy management system, and roughly summarizes the three functions of PLC according to the usage situation. According to the system principles and functional requirements, this paper determines the hardware part , choose to use Mitsubishi brand PLC to design the energy management system of iron and steel enterprises, and finally carry out relevant experiments.

2. Design Research

2.1. Existing Problems

The problems existing in the energy management of iron and steel enterprises at this stage mainly include the following aspects:

(1) The level of informatization is low, the informatization management of energy has just started, and many aspects need to be improved and perfected;

(2) Most enterprise energy management systems have single functions, such as only simple data collection and centralized monitoring functions, weak energy management and optimization functions in line with enterprise characteristics, and are out of touch with the actual production process. This situation is common in small and medium-sized enterprises. This is especially obvious in the case of enterprises, which requires enterprises to optimize and upgrade according to their own characteristics and product process, and have certain requirements for human and material resources;

(3) The enterprise management system is not perfect. The enterprise energy center is a complex system involving the entire enterprise, which requires the coordination and cooperation of multiple departments. Only a matching management system can make the energy management system fully play its role;

(4) There is a deviation in the understanding of energy management by enterprises. In order to reduce costs, some enterprises inappropriately reduce the use of energy, resulting in a decline in product quality or output, while some enterprises only focus on reducing direct energy consumption, but Important content such as recycling of energy and control of energy production costs are ignored;

(5) Only focus on energy management at the technical level, but ignore the role of people. Appropriate employee management systems, incentive systems, training systems, etc. can make the energy management system play a better role;

(6) There is a lack of innovation in the enterprise. A good energy management system needs to be continuously updated and upgraded according to the development and actual changes of the enterprise, and the technical level can be continuously improved to obtain better benefits;

(7) The national energy management system and international energy management standards (such as the relevant International Electrotechnical Commission IEC standards) are not yet perfect.

In addition, the current application of energy management systems in my country is mainly concentrated in metallurgical enterprises such as iron and steel, and other high-energy-consuming industries (such as chemicals, automobiles, electric power, subways, buildings, etc.) Further strengthening [5-6].

2.2. Basic Principles of Energy Management System Design

In order to ensure the cost-effectiveness of the system, the design of the energy management system needs to follow certain principles:

(1) Feasibility

The so-called feasibility means that the design of the energy management system should be within the allowable range of the current technical conditions, equipment conditions, economic conditions, and human conditions [7-8].

(2) Advanced and practical

The so-called advanced nature means that under the premise of satisfying feasibility, some new technologies and new equipment with good prospects can be used in the design to make the system have strong vitality.

Practicality means that while considering the advanced nature of the system, we should not blindly pursue high-end grades. We should choose according to the actual situation of the enterprise and the system, pay attention to practical results and practical needs, and try to choose mature technologies and equipment to avoid inconvenience.

(3) Security and reliability

Security includes both hardware and software aspects. The safety of hardware refers to the selection of equipment that meets the safety requirements according to the actual working conditions, and the safety of equipment and personnel should be fully considered, and measures such as fire prevention, waterproofing, and leakage prevention should be taken; software safety refers to the selection of safety The security of data and software systems can be improved by means of highly reliable data transmission methods, setting up firewalls, and authority control.

Reliability refers to the ability of a system to operate stably, efficiently and continuously. The stability of the system can be improved by optimizing the system structure, selecting appropriate equipment, selecting standardized components as much as possible, and adopting redundant technology [9-10].

(4) Operability

The operability can also be called the friendliness of the system. Good system operability can enable users to use the functions provided by the energy management system faster and better, and make the energy management system function more fully.

(5) Standard

Standardization refers to the selection of standardized components and modules as much as possible, and the system structure design, equipment selection, network transmission, interfaces, etc. conform to relevant international standards, thereby improving the openness and stability of the system, and is conducive to data transmission and communication between systems.

(6) Scalability and easy maintenance

Scalability means that the expansion and extension of the system in the future should be fully considered in the design process of the energy management system, so that the system can be expanded conveniently and at low cost according to the development of the enterprise.

Ease of maintenance refers to the ability of a system to quickly eliminate faults and keep the system running well, which can be achieved by optimizing the system structure in the design and making the equipment meet the standard and open requirements [11-12].

2.3. Functions of PLC

It can be roughly classified into the following functions according to the usage.

(1) Basic functions

It includes functions and functions such as logic operation, timing, counting, data transfer comparison, bit processing, data processing, data table processing and high-speed processing of switch quantities. The input and output ports of PLC are not limited by the main unit, and the module can be expanded at its expansion interface, so that its basic functions can be enhanced. The basic functions of PLC are widely used, and the analysis and processing of data can be used to respond quickly. It is widely used in various petrochemical, elevator, machine tool, metallurgy, automobile manufacturing and other occasions [13-14].

(2) Special control function

The special control functions of PLC mainly include analog quantity control and positioning control. The analog quantity control of PLC is also called process control, and it is used in the occasions where physical quantities such as flow, pressure, temperature, etc. are required to be controlled. Similarly, if the digital quantity via PLC cannot be directly transmitted to the actuator, it must also pass through a circuit called a digital/analog converter, that is, a D/A converter. PLC manufacturers will produce A/D and D/A special function modules, which can realize analog control in combination with PLC units.

PLC positioning control is also called position control or fixed-point control, which means that when the PLC issues a control designation, the moving workpiece completes the designated displacement according to the designated speed and direction. The traditional positioning control is realized by using switches, and the upper limit switch is installed at the place where it needs to stop. Although this positioning control is simple, the accuracy and poor, the stop time and distance are determined by the inertia of the system. If the PLC is introduced as the positioning controller, the corresponding control program is written, and the relevant commands are issued according to the current value of the counting input to complete the corresponding actions, and the precise positioning control can be realized. The application of PLC positioning control is also quite extensive, such as the workbench of machine tools, the leveling of elevators, conveying machinery and various packaging machinery. PLC manufacturers will be equipped with production positioning function modules, which can realize positioning control together with PLC units [15-16].

(3) Network communication function

PLC network communication includes communication between PLC units and between PLC units and other intelligent systems (such as PCs). Its purpose is to interconnect multiple PLC units or other intelligent systems. By agreeing on a common communication protocol or communication method, through the application of this technology, data exchange, transmission and communication between multiple intelligent systems can be realized. With the development of intelligence and the development of computer network technology in factories, a single PLC unit can no longer meet the needs of integration, so PLC manufacturers also have different network communication systems [17-18].

2.4. Algorithm Research

(1) Scheduling optimization

In the scheduling process, each device and information management tool has complexity and variety. In the actual strategy process, the effective management of allocation is generally based on the index number. Here we can use formula (1) to express:

$$I_k = \frac{C_k}{f_k}, k = 1,2,3,\ldots, n \tag{1}$$

Among them: Ck represents the overall storage capacity; fk is the frequency of access; Ik is the index number;

(2) Optimization goals

Here we assume that the project is designed with i columns and j layers, and random storage tests are used for storage in the actual use process. First, the allocation is optimized. The purpose of optimization is to make Ik obtain the minimum value. When Ik obtains the minimum value, it means that it is placed in the best position as much as possible:

$$\min Q = \sum_{n=1}^{i}\sum_{m=1}^{j} I_k nm \tag{2}$$

Where: Q: high frequency case; Ik: index number; n: column value; m: row value.

Our main purpose in the process of cargo optimization is to distribute objects with lower mass at higher heights. Then the second optimization objective can be defined as:

$$\min S = \sum_{m=j}^{i}\sum_{n=1}^{j} m_q (m-1) \tag{3}$$

Where: S: total position situation; mq: quality; i: column value; j: row value.

To simplify the motion process, the optimization time can be simplified as:

$$\min T = \sum_{j=1}^{i}\sum_{m=1}^{j} t_{nm} \tag{4}$$

Among them: T: overall running time situation; tnm: each time; i: column value; j: row value.

(3) Multi-objective genetic algorithm optimization

In the process of genetic algorithm optimization, the multi-objective optimization problem is transformed, otherwise it is difficult to obtain a set of reasonable spatial solutions by using genetic algorithm. Use weighted summation to convert mesh numbers into:

$$\min F(x) = \sum_{m=1}^{i} \omega_m f_m(x), x \in \Omega \tag{5}$$

where: F(x): the new objective function. fm(x): for the subset of each question. ωm: The weighted value of each sub-objective function.

In the actual use process, which part of the optimization content is emphasized, its weight can be increased, and the optimal solution of different functions can be obtained by assigning different weights. For constrained genetic algorithm, it can be optimized in the form of penalty function, so that in the process of genetic algorithm optimization, the evolution direction can be evolved toward the optimal target solution.

In the actual optimization process, the weighted value of ωm is mainly selected manually.

3. Experimental Study

3.1. Determination of Hardware Part

This design adopts Mitsubishi brand PLC. The advantage of Mitsubishi PLC is that programming is intuitive and easy to understand, and it is more convenient for operators to learn and use.

The Q series PLC is a large and medium-sized PLC series developed by Mitsubishi on the basis of the original A series PLC. The Q series PLC adopts a modular structure. The composition and scale of this series of products are very flexible, and can be matched with various high-performance modules according to the requirements of use. It has the characteristics of high I/O points, large program memory capacity, and 32M expansion memory. Q series PLC is very flexible to install, has superior equipment compatibility, and has stronger CC-LINK network function, which is very convenient to use. The Mitsubishi Q series has the world's leading performance level and can be used to realize various complex motion control and automatic production line control and other occasions.

3.2. Mitsubishi L Series

The selection of PLC models should satisfy the system functions to the greatest extent, and the main factors should be attributed to the following aspects:

First: PLC software and hardware are in place, and the structure is reasonable. In the design process, the number of PLC input and output points and the difficulty of maintenance after the equipment is damaged should be comprehensively considered according to the process requirements and environmental conditions, and the PLC equipment suitable for the storage structure should be selected. Class structure, integrated structure is cheap, but the number of I/O points is fixed, and it is difficult to expand according to project requirements; separate PLC can expand the number of I/O points by adding function modules according to project requirements, but for small projects, the price again too high. In the design process, PLC equipment should be flexibly selected according to project requirements.

Second: The PLC equipment function is required to meet the performance requirements. According to the actual requirements, the control methods such as transistors or relays can be selected. According to the actual control requirements, different grades of PLC equipment can be selected, and the PLC equipment will not be overly dependent on the actual work process.

Third: The PLC equipment is required to have environmental adaptability. In the selection process, the controller must have a certain understanding of the PLC control method and process, and can carry out reasonable engineering design and hardware selection of PLC products through the control process. In the process of selection, you can choose whether the PLC equipment needs to meet specific requirements, such as explosion-proof, moisture-proof, required I/O points, etc., according to the characteristics of the project. The required input and output interfaces, according to the control requirements, reasonably estimate the number of I/O points and the approximate required capacity of the memory; the functions required in the PLC operation process; after understanding the characteristics of the interface, choose a PLC with the highest cost performance as this time. The main controller of the project. The commonly used Mitsubishi Q series and L series PLCs have very high cost performance and stability to meet our needs.

Fourth: Reasonable proportioning program capacity. In the process of I/O port point ratio, the I/O points should be calculated according to the actual usage. After the calculation is completed, a margin of 20% should be left. The main purpose of the existence of the margin is to In order to facilitate the project expansion later. Due to the fixed size of the running memory of the existing PLC structure, the PLC ladder diagram program we wrote requires that the actual operation is smaller than the actual memory of the PLC. For this reason, in the process of selecting the size of PLC running memory, it is necessary to estimate the capacity according to the selection. In the current method framework, storage capacity is mainly used to replace user capacity, and there is no fixed formula for storage capacity selection and calculation. However, considering the margin problem in the actual use process, it should be increased by 25~30% on this basis.

3.3. PLC Programming

GXWorks2 is a new generation PLC software of Mitsubishi Electric. Its software interface is simple and easy to operate. It is a programming tool specially developed for the design, debugging and maintenance of Mitsubishi PLC system. While maintaining a simplified interface as much as possible, it also has rich functions of setting, running and debugging, and supports multiple programming languages. It is a production tool that is widely used in English in industry.

The design of the Mitsubishi PLC ladder diagram should follow the following design principles:

(1) The Mitsubishi PLC ladder diagram should comply with the principle of sequential execution, from left to right, from top to bottom.

(2) Mitsubishi PLC coil output is a necessary condition for the program to be output after logic execution, and it cannot be output without a coil. Since they cannot be directly connected to each other, when the design necessity of the control system program cannot avoid direct connection, in order to achieve functional requirements, internal special relays are used to solve the problem.

(3) Each logic line of the Mitsubishi PLC ladder diagram always starts from the left bus bar, and through the connection of various contacts, the logic line ends at the coil or the right bus bar. There must be contact between the left bus and coil, and there must be no contact between the right bus and coil.

(4) The same coil of Mitsubishi PLC, as a necessary condition for logic output, is generally only allowed to be used once. In some cases, it will be reused twice, and this double-coil repeated use is called double-coil output. For this kind of design usage, the PLC programming rules of some manufacturers will consider this a design error and it is forbidden to apply. The PLC programming rules of some manufacturers will regard the previous output as invalid, and only consider the last one as a valid output.

(5) The number of series and parallel contacts in the Mitsubishi PLC ladder diagram is not limited.

(6) Two or more Mitsubishi PLC coils can be output in parallel.

3.4. Structure of Energy Management System

The energy system of iron and steel enterprises can be divided into subsystems such as electricity, power, and waterways according to different energy media. Each subsystem collects various measurement data and equipment parameters through its own on-site control system, and the data is stored and transmitted to the network and other supporting systems. The energy management system performs display and management. Through the analysis and decision-making of the energy management system, the set parameters are transmitted to the field equipment through the network, so as to realize the remote monitoring and control of the energy equipment. The overall structure of a typical energy management system in an iron and steel enterprise is shown in Figure 1.

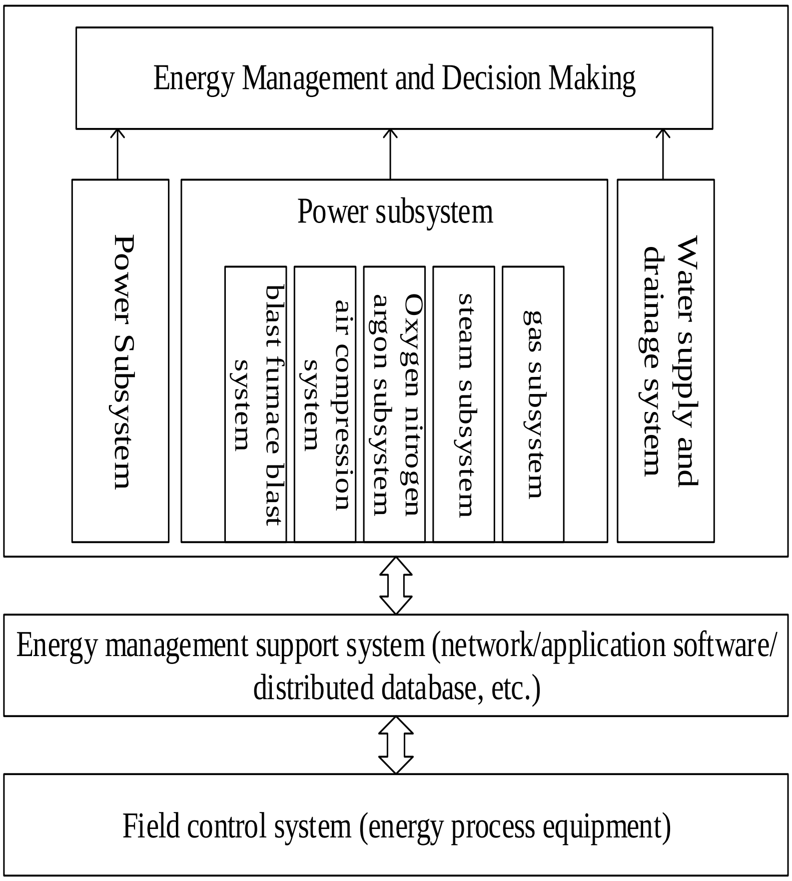

Figure 1. Overall structure of the energy management system

4. Experiment Analysis

After the system was launched, the "four remote" functions of the power system were improved, the centralized monitoring and enhanced management of the energy system were realized, and the remote data collection and centralized management of the energy system were realized. Optimal energy supply and demand balance and scheduling, especially rational use of gas and steam, timely guidance for each process, and maximize the comprehensive utilization of energy.

4.1. Reduce Blast Furnace Gas Emission

Table 1 is the data of the blast furnace gas emission rate of the iron and steel enterprise in recent years.

Table 1. Enterprise blast furnace gas emission rate table

1	2	3	4
8.12%	6.86%	0.34%	0.31%

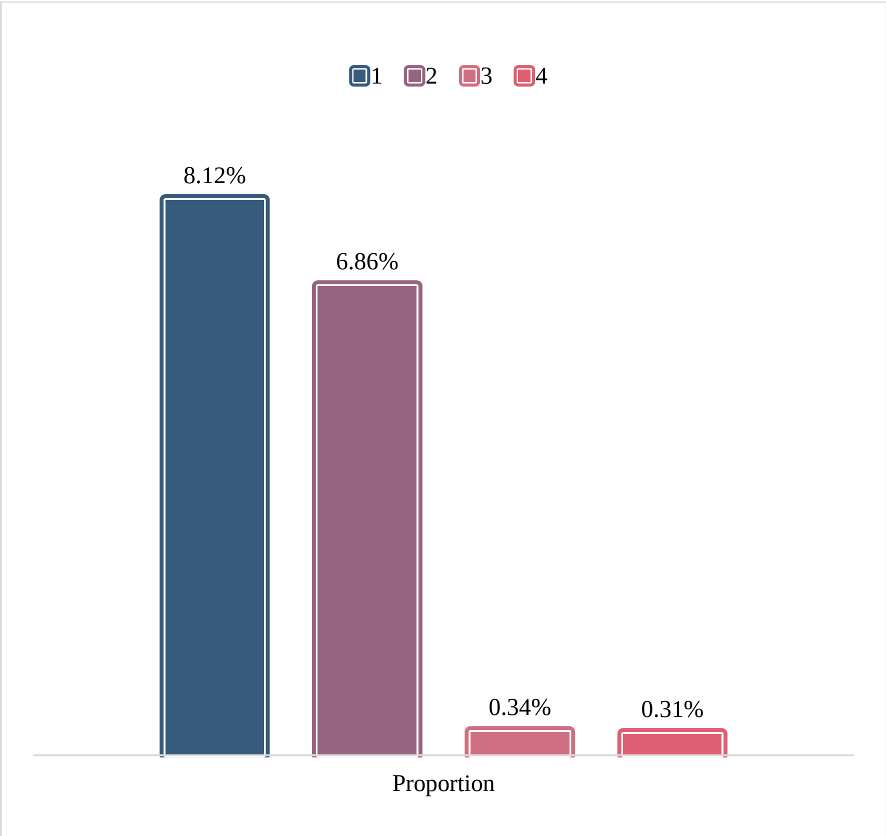

Figure 2. Analysis chart of blast furnace gas emission rate of enterprises

Analysis of the above figure shows that in recent years, the blast furnace gas emission rate of the iron and steel enterprise has been continuously reduced from 8.12% in the first year to 0.31% in the fourth year, which proves that the system can realize online real-time monitoring and adjustment of gas users, and adjust the gas to the maximum extent. Balance, the effect of reducing the blast furnace gas emission rate is obvious, not only fully utilizing the gas resources, but also reducing the environmental pollution caused by the gas emission, and achieving good economic and social benefits.

4.2 Reduce The Loss of Coke Oven Gas

Table 2 is the coke oven gas loss rate table of the iron and steel enterprise in recent years.

Table 2. Enterprise coke oven gas loss rate table

	Coke oven gas loss rate	Coke oven gas emission rate
1	1.87%	0.82%
2	5.25%	0.79%
3	3.89%	0.37%
4	3.73%	0.52%

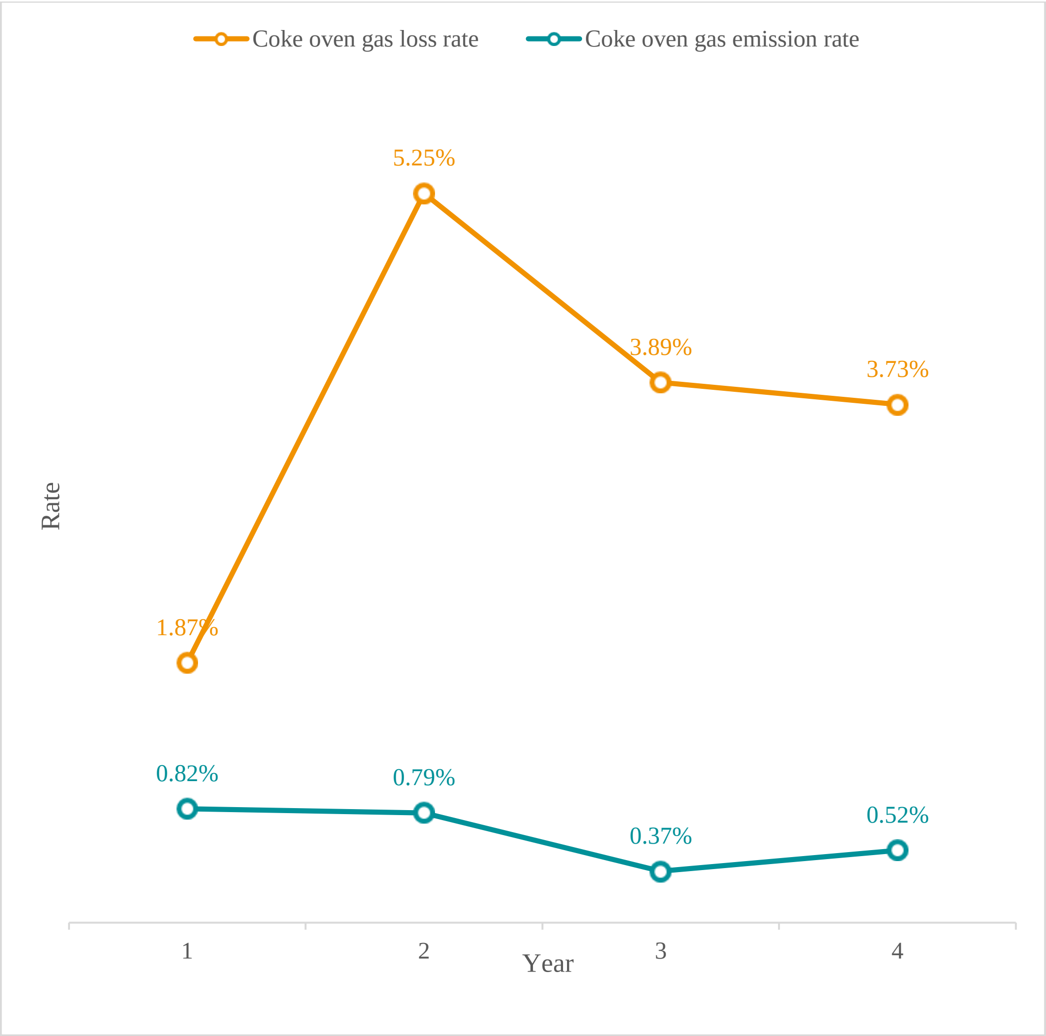

Figure 3. Analysis of the loss rate of coke oven gas in the enterprise

In the above figure, the loss rate of coke oven gas in the first year is an estimated value, and the high emission rate of coke oven gas in the fourth year is due to the overhaul of the power plant boiler and the technical transformation of the hot rolling mill. The analysis found that the loss rate of coke oven gas was effectively reduced, the gas utilization efficiency was improved, and the economic benefit was increased by means of monitoring and adjustment.

5. Conclusion

With the continuous development and extensive use of Internet technology and networking technology, the development of a software management system that integrates iron and steel enterprise management ideas and computer technology has become an inevitable requirement for the development of iron and steel enterprises. In order to manage the permissions of different system users to access and operate the resources of the iron and steel enterprise, and to ensure the safety of the production of the iron and steel enterprise and the reliability of the system operation, it is necessary to carry out effective authority control management user-friendly operation.

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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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