Evaluation of The Production and Operation Benchmarking Management Effect of Natural Gas Thermal Power Plant Based on Fuzzy Comprehensive Evaluation

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Abstract: Under the trend of continuous development of natural gas industry, the demand for the management of natural gas thermal power plants is increasing, and more and more production and operation management methods are gradually emerging, which is very important for the evaluation of the effect of management methods. Based on this, this paper conducts a research on the evaluation of the management effect of natural gas power station production and operation benchmarking based on fuzzy comprehensive evaluation. By dividing the evaluation index of benchmarking management, the corresponding parameter factors are obtained. The paper established a benchmark management evaluation model for the production and operation of natural gas power stations, and collected data on generator set indicators. Then, the load factor, power supply coal consumption, power generation fuel consumption, nitrogen oxides and other key indicators of the generating units of natural gas power stations, are calculated and the benchmark value of benchmarking management is determined. Based on the fuzzy comprehensive evaluation method, the benchmarking score was calculated to achieve the goal of benchmarking management effect evaluation. Experiments show that this method can improve the overall evaluation value of natural gas power station, and has more advantages in the accuracy of evaluation result analysis and decision-making.

Keywords: **Fuzzy Comprehensive Evaluation; Natural Gas Thermal Power Plants; Production Operations; Benchmarking Management**

1. Introduction

Benchmarking management is an important part of enterprise management methods, which is widely used in various enterprises, which helps to promote the improvement of the overall management level of enterprises, strengthen the core competitiveness of enterprises, and consolidate the market value of enterprises [1]. The basic meaning of "benchmarking" in benchmarking management is "comparison", which compares, analyzes and judges enterprises by comparing their business performance, market competitiveness, and operational effects, so as to improve the deficiencies in the production and operation of enterprises [2]. In general, due to the different benchmarking objects, benchmarking management can be divided into two management types: external benchmarking and internal benchmarking [3]. Based on the nature of benchmarking management, it can be divided into three types: competitive benchmarking, general benchmarking, and industry benchmarking [4]. With the continuous development of energy technology, more and more power generation companies are facing increasing pressure in production and operation, especially natural gas thermal power plants [5]. Based on this, this paper uses a fuzzy comprehensive evaluation method to evaluate the effect of benchmarking management of production and operation of natural gas thermal power plants, in order to improve the level of energy conservation and emission reduction of thermal power enterprises and achieve the goal of reducing energy consumption and emissions [6].

2. Design of Evaluation Method for the Evaluation Effect of Benchmarking Management of Natural Gas Thermal Power Plants

2.1 Benchmarking Management Evaluation Index Division

According to the characteristics of the generating units of natural gas thermal power plants, the benchmarking management evaluation indexes were divided, and the corresponding parametric factors, technical factors, structural factors, and regional factors were obtained [7]. Due to the different manufacturers of the main engine and auxiliary engine of the gas unit, there are certain differences in the specific characteristics of the unit. Moreover, the parameter factors of the gas turbine have a large span, so the difference in installed capacity is significant. The technical factors of thermal power units should be considered, and the benchmarking method should be revised [8].

Based on structural factors, the benchmarking index of the production and operation of thermal power plants is divided. Among them, the first-level indicators are mainly safety indicators and production technology indicators, and all the other indicators that affect the first-level indicators are called second-level indicators. China's thermal power plants are adapted to local conditions, which leads to large differences in the operating conditions of power plant units, and the power generation cost of some units is relatively high, and the power generation cost index has a large correlation with regional factors.

Based on the influencing factors of the above-mentioned benchmarking indexes, a series of benchmarking indicators for the production and operation of thermal power plants are divided, and the capacity levels are divided into 200MW, 600MW, 300MW, 1000MW and 660MW level; The types of units are divided into water-cooled, air-cooled, heating, and condensing; The unit parameters are divided into subcritical, supercritical, and ultra-supercritical; The combustion mode is divided into pulverized coal furnace and circulating fluidized bed furnace.

2.2 Establishment of Benchmarking Management Evaluation Model

Combined with the coal consumption, power generation, load rate and power consumption rate of thermal power plants, the benchmarking management evaluation model of production and operation of thermal power plants was constructed. The model mainly includes three parts: the index name, the index level and the evaluation object. There are many index names in the model, which are comprehensively divided into safety, production, operation, and fuel indicators [9].

The "benchmarking" indicators in production and operation in the model include the advanced value of the thermal power plant, the historical optimal value of the unit, and the design value of the unit. Through the power generation of the gas turbine in the statistical period, the utilization hours of the generator set are obtained, which provides data support for the management evaluation model. Collect the fuel consumption of the gas turbine during operation, and obtain the optimal value of the gas turbine through the benchmark unit.

In the benchmarking management evaluation model, new gas turbines that have been in operation for less than one year and have an annual operating hour of less than 4500 hours are not involved in the evaluation of management effects. Through the statistical unit index data, the benchmarking management effect is evaluated.

2.3 Determination of Benchmarking Management

According to the actual situation and operating environment of the thermal power plant, the benchmark values of benchmarking management are determined by calculating the key indicators such as load factor, coal consumption for power supply, gas consumption for power generation, and nitrogen oxides of the thermal power plant [10].

The load factor of the gas unit of the thermal power plant refers to the ratio of the average load of power generation to the maximum load of power generation, and the calculation formula is:

$$\mu_p = P_t / P_{max} \times 100\% \tag{1}$$

where μ_p is the load factor of the generator set; P_t is the average load; P_{max} is for the maximum load. According to the degree of change, the economy of the operation of the generator set is evaluated. The closer the load factor of the gas turbine is to 1, the more stable the operation of the thermal power plant.

There is a certain correlation between the power supply gas volume of the thermal power plant and the power supply of the product, which can comprehensively reflect the gas consumption and electricity consumption rate of the thermal power plant, and is an important part of the evaluation

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index of the production and operation of the thermal power plant. The formula for calculating the gas consumption of the gas supply unit is as follows:

$$u_p = N/(Q - Q_g) \times 100\% \quad (2)$$

Where the u_p is the standard gas consumption of power supply when the gas turbine is running stably; N is the normal gas consumption under the power generation standard of thermal power plant; Q is the power generation of the coal-fired power plant; Q_g is the electricity consumption for thermal power plants. By calculating the gas consumption of the gas units of the thermal power plant, the change in the electricity consumption rate is judged.

The calculation of power generation consumption is mainly related to the gas pipeline flow, and the specific usage of power generation consumption is obtained by collecting the gas pipeline flow of thermal power plants. In order to control the emission of nitrogen oxides from thermal power plants, it is necessary to improve emission reduction efforts and reduce the emission concentration of nitrogen oxides from generating units in an all-round way to control it below 100mg/m^3.

2.4 Calculation of Benchmarking Score based on Fuzzy Comprehensive Evaluation

In this paper, the production and operation data of thermal power plants are collected in advance by means of fuzzy comprehensive evaluation, and the benchmarking management learning samples are obtained, and the sample set is trained. After the training, the weights of various indicators of benchmarking management are used as feature parameters, and the above-mentioned benchmarking management evaluation model is input to obtain the nonlinear mapping characteristics of the evaluation data, and finally an objective evaluation is given.

In this paper, the design value of the 660MW gas turbine of the thermal power plant is used as the benchmark value, and the total score of the benchmark score of the gas turbine is calculated, and the calculation formula is as follows

$$S = \sum_{i=1}^{4} S_1 \times x_1 \times 100\% \quad (3)$$

where S is the total score; S_1 is the score for absolute benchmarking; x_1 is the absolute benchmarking scoring coefficient; S_2 is the score points for historical benchmarking; x_2 is the historical benchmarking scoring factor; S_3 is the score points for regional benchmarking; x_3 is the scoring coefficients for regional benchmarking; S_4 is the benchmark score for the design parameters of the 660MW unit; x_4 is the benchmark scoring coefficient for the design parameters of the unit. The total benchmark score of the production and operation of the generator set of the thermal power plant was obtained by calculation, and the individual index score of the completion status was used to obtain the operating exposure rate of the unit. The exposure rate is calculated as:

$$Ep = H/(H + R) \times 100\% \quad (4)$$

where H is the operating hour of the generator set; R is the standby hours for the generator set to run. The operating exposure rate of the generator set is equivalent to obtain the best result in the correction value, which is used as the same capacity level for the production and operation of the gas power plant. Based on the fuzzy comprehensive evaluation method, the equivalent usable utilization hour index score of the same type of generator set is calculated, and the calculation formula is as follows

$$G = m_1/m_2 \times w_1 \times 100\% \quad (5)$$

where G is the equivalent usable utilization hour index score of the generator set; w_1 is the advanced value of the relative value of the hour is used for the generator set; m_1 is the utilization hours for the generator set completion value; m_2 is the average utilization hour of the thermal power plant. Considering the difference between the unit index evaluation and the benchmark unit, the weighted average calculation of the comprehensive score of the benchmark management of the production and operation of the thermal power plant is carried out

$$S_a = \sum_{i=1}^{n} \left(S_i \times \frac{x_i}{\sum_{i=1}^{n} x_i}\right) \quad (6)$$

where S_a is the total score of the benchmark management evaluation of the production and operation of the thermal power plant; n is the number of 660MW generating units participating in the benchmark management for thermal power plants; S_i is the ith score of the first 660MW generating unit of the thermal power plant in the benchmarking management of this series of units; x_i is the i th on-grid electricity of the first 660MW generating unit of the thermal power plant.

The comprehensive score of the benchmarking management of the production and operation of the thermal power plant is obtained through calculation: 5 points will be deducted if the operation effect of the generator set is lower than the design value; If the temperature of the main steam on the side of the machine deviates from the design value, 3 points will be deducted; If the high input rate of the unit exceeds 95.55%, 3 points will be added; If the total pass rate of the unit's soda quality exceeds 98.55%, 5 points will be added; If the accuracy of relay protection action exceeds 98.55%, 2 points will be added; If the heat consumption rate and steam consumption rate of the generator set steam turbine are lower than the design value, 3 points will be added; If the error between the hot gas temperature and the design value on the machine side is less than 0.55%, 3 points will be added.

The corresponding results are obtained through calculation, and compared with the standard to achieve the evaluation of the benchmark management effect.

3. Validation Experiments

In order to verify the practical application effect of the evaluation method of benchmarking management effect of production and operation of thermal power plant based on fuzzy comprehensive evaluation designed in this paper, thermal power plant A was taken as the experimental object to dynamically evaluate the energy conservation and emission reduction effect of benchmarking management of production and operation of thermal power plant. The data of the dynamic correlation index of energy conservation and emission reduction of 660MW generating units of the thermal power plant from May 2022 to December 2023 is obtained, as shown in Table 1.

Table 1. Dynamic Correlation Index Data of Energy Conservation and Emission Reduction of Thermal Power Plant A

Structure	Correlation metrics	Indicator coefficients
Energy-saving subsystem	Air intake	0.613
	Gas heat	-0.322
	Power consumption	-0.913
	Internet power	0.513
	Water consumption rate	-0.453
Emission reduction subsystem	Comprehensive utilization of solid waste	0.132
	Sulfur dioxide emissions per unit of electricity generated	-0.287
	Nitrogen oxide emissions per unit of electricity generated	-0.964
	Soot emissions per unit of electricity generated	-0.801

Combined with the calculation formula and standard value of thermal power plant revenue, the correlation between the influencing factors of energy conservation and emission reduction and income is obtained. Combined with the test method of the residual of the evolution equation of benchmarking management, the mean value of the residual value of benchmarking management of generator sets is 0 and the variance is 1, and the fitting effect is analyzed. Comparative experiments were carried out with the production and operation indicators as the goal.

The proposed method based on fuzzy comprehensive evaluation is set up as the experimental group, and the traditional method based on grey correlation method is set up as the control group. The original index data of the two effect evaluation methods were benchmarked, and the index statistics of 660MW generating units of thermal power plants of different models, operation modes and layout modes were used as information entropy, and all 660MW generating units in the thermal power plant were labeled and marked as No. 1~6 respectively, and the changes in the evaluation values of the production and operation indicators of the two effect evaluation methods were obtained, as shown in Table 2. In different series of thermal power plants, the evaluation value of the production and operation index of the benchmarking management effect evaluation method of thermal power plant based on fuzzy comprehensive evaluation designed in this paper always shows an upward trend. The changes in the evaluation value of the traditional effect evaluation method are relatively unstable, and there is a certain downward trend. The overall evaluation value of the paper design method is higher than that of the traditional method, which can improve the dimension of the effect evaluation index to a certain extent, and has more advantages in the accuracy of evaluation result analysis and decision-making.

Table 2. Comparison of the Evaluation Values of Production and Operation Indicators of the Two Effect Evaluation Methods

Gas turbines	Control group	Experimental group
1	0.48	0.51
2	0.51	0.82
3	0.32	1.22
4	0.78	1.70
5	0.61	1.82
6	0.98	2.48

4. Concluding Remarks

In summary, on the basis of the evaluation of the benchmarking management effect of traditional thermal power plants, combined with the fuzzy comprehensive evaluation method, the energy consumption of thermal power plants can be effectively reduced and the stable development of energy conservation and emission reduction can be promoted. In view of various indicators in the overall operation and management of thermal power plants, it is of great significance to the operation of generator sets and the management of equipment to achieve effective benchmarking management.

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