Research on Energy Consumption Benchmark Index System and Evaluation of Thermal Power Unit

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Abstract. With the acceleration of industrialization, urbanization and the continuous upgrading of consumption structure, China's energy demand has grown rigidly. The coal-based energy structure has caused China's economic development to face severe environmental pressures. Energy conservation and emission reduction in the power industry has become an inevitable development trend. In order to strengthen energy consumption management and control in the thermal power industry, improve energy efficiency, and comprehensively implement energy efficiency benchmarking, this paper establishes thermal energy plant energy consumption index system according to the characteristics of thermal power plant energy consumption, and uses multi-attribute decision-making methods to evaluate the index system for China's thermal power generation and provide theoretical guidance for energy transformation, energy conservation and emission reduction.

1. Introduction

The traditional thermal power generation is the most important source of energy consumption in the power industry. Therefore the environmental pressure is also the most serious. At the same time, thermal power generation takes the first place in China's total power generation. Considering that the new energy generation cannot comprehensively replace thermal power generation, the energy conservation and emission reduction of thermal power industry is of great significance.

Despite numerous contributions in the field of energy consumption evaluation of thermal power unit(eg. Naveen, 2011), thermal power unit energy consumption evaluation needs to comprehensively consider the effect of multiple factors, both to consider certain factors, also needs to consider many qualitative description of uncertainty in the process of energy management. There lacks of a comprehensive study on this aspect that is this study aims to fills.

2. Construction of energy consumption evaluation index system of thermal power unit

Energy consumption index of thermal power industry is involved in the whole process of thermal power. The energy consumption of each part of energy consumption index system is mainly composed of power supply standard coal consumption rate, power utilization rate, boiler energy consumption index, fuel oil, power generation, power supply, water rate integrated water rate, coefficient of equivalent available, SO_2 concentration, concentration of nitrogen emissions, carbon concentration, etc.

(1) Standard coal consumption rate of power supply, standard coal consumption per unit of power

supply to the power grid of thermal power plants are also core indexes of the energy consumption index system of thermal power units.

(2) The power consumption rate of power plants, the proportion of the power consumed by the auxiliary equipment of power plants in the total power generation, and the proportion directly affects the utility of energy consumption.

(3) Other indicators, such as combustion oil, water supply rate of power generation and sulfur dioxide emission concentration, also have an impact on the classification of energy consumption index system.

In this paper, the energy consumption of generator sets is divided into A, B, C and D levels, respectively representing the energy consumption of generator sets. Energy consumption A refers to the reduction of energy saving of generating sets. The drainage level is high, meeting the national advanced requirements; energy consumption B indicates that the energy saving level of generating sets is relatively high, which basically reaches the national energy consumption benchmark. There is a certain amount of energy saving Row of potential;Energy consumption of class C represents the energy saving index and reduction of generating set rank relatively poor, overall below the industry average, has the bigger energy conservation and emission reduction transformation potential;Energy consumption of D means that the energy saving and emission reduction of generating sets are in the industry

Backward state, needs to carry on energy conservation rectification.

Through practical analysis, the above indicators are all natural indicators, that is, the smaller the better.

3. Multi-attribute decision - making method for thermal power unit energy consumption evaluation

The multi-attribute decision making method is to collect all the alternative schemes by the decision maker. For each scheme, several attributes (each with different evaluation criteria) need to be comprehensively evaluated. The purpose of decision making is to find a solution that can make the decision maker feel the most satisfied from this set of alternatives, or to make a comprehensive evaluation ranking of this set of alternatives, and the ranking result can reflect the decision maker's intention.

Thermal power unit energy consumption evaluation need to comprehensively consider the effect of multiple factors, both to consider certain factors such as the performance of the equipment, also need to consider many qualitative description of uncertainty in the process of energy management, due to factors associated with more has the characteristics of uncertainty and fuzziness, as a result, with the aid of fuzzy theory and multiple attribute decision making method to evaluate thermal power unit energy consumption, through fuzzy membership of each index to determine the influence of the index weights, and through the decision rules for optimizing the value of the order.

3.1. Multiple attribute problem description

Assuming that m thermal power enterprises participate in the evaluation of thermal power unit energy consumption index, the set of thermal power enterprises is $x=\left\{x_1, x_2, \cdots x_m\right\}$, and the evaluation index set considered is $A=\left\{A_1, A_2 \cdots A_{10}\right\}$. The weight of each indicator is denoted as $W=\left\{w_1, w_2, \cdots w_n\right\}$, and $0 \leq w_j \leq 1$, $\sum_{j=1}^{n} w_j=1$, then after investigation, statistics and analysis, the initial decision matrix composed of the original data of the region to be evaluated under 10 evaluation indicators is recorded as:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1\times 10} \\ x_{12} & x_{22} & \cdots & x_{2\times 10} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{m\times 10} \end{bmatrix}$$

x_{ij} denotes the initial decision index value representing the j attribute of the i scheme .

The decision objective is to quantitatively evaluate the energy consumption of thermal power units in the enterprise to be evaluated according to the existing initial decision matrix $X = (x_{ij})_{m\times 10}$.

3.2. *Decision-making method*

Starting from the initial decision matrix $X = (x_{ij})_{m\times 10}$, the specific decision-making process is as follows:

（1）The normalization processing of decision index，As the quantitative index belongs to the cost-type attribute, also known as negative attribute, it refers to the attribute with smaller attribute value and larger membership degree. In other words, the smaller attribute value is, the better.

$$y_{ij} = x_j^{\min} / x_{ij} \quad (1)，\text{ and } x_j^{\min} = \min\{x_{1j}, x_{2j}, \cdots, x_{mj}\}$$

（2）The ranking method of energy consumption level of thermal power unit based on grey relational analysis. Grey relational degree evaluation is a multivariate statistical analysis method, which uses the grey relational degree to describe the strength, size and order of the relations between schemes based on the sample data of each factor (attribute). If the change situation between the sample data is basically consistent, the correlation degree is large. The reverse is smaller. The core of grey relational degree evaluation method is to calculate the correlation coefficient, and the essence of the calculation of correlation coefficient is a standard method to determine the quantitative index by using ideal sample (scheme).

The reference sample (ideal scheme) has been determined before, and the normalized decision matrix is obtained:

$$Y = (y_{ij})_{m\times 10} = \begin{bmatrix} y_{01} & y_{02} & \cdots & y_{0\times 10} \\ y_{11} & y_{12} & \cdots & y_{1\times 10} \\ y_{21} & y_{22} & \cdots & y_{2\times 10} \\ \vdots & \vdots & \cdots & \vdots \\ y_{m1} & y_{m2} & \cdots & y_{m\times 10} \end{bmatrix}$$

and $y_{0j} = \min\{y_{1j}, y_{2j}, \cdots, y_{mj}\}$， $j = 1,2,\cdots,10$

The correlation coefficient between the j index of the i scheme and the reference sample (ideal scheme) is：

$$r_{ij} = \frac{\min_i \min_j \left| y_{ij} - y_{0j} \right| + \rho \max_i \max_j \left| y_{ij} - y_{0j} \right|}{\left| y_{ij} - y_{0j} \right| + \rho \max_i \max_j \left| y_{ij} - y_{0j} \right|}$$

and , ρ is the resolution coefficient, which is evaluated in [0,1] and usually takes 0.5. The small value of ρ can improve the significance of the difference between the correlation coefficients and the ability to distinguish the evaluation results. This is also a significant feature of the grey correlation evaluation method.

The weight vector of the index is $W = \{w_1, w_2, \cdots w_n\}$, The correlation between the evaluated scheme and the reference sample (ideal scheme) is:

$$R_i = \sum_{j=1}^{n} w_j r_{ij}, \quad i = 1,2,\cdots,m$$

The assessed schemes were ranked according to the degree of correlation. The correlation degree of the evaluated scheme and the reference sample is ranked from large to small. The higher the correlation degree is, the closer the evaluated scheme is to the reference sample, and the better the evaluated scheme is.

4. Conclusion

This article selects power supply standard coal consumption rate, power utilization rate, boiler energy consumption index, fuel oil, power generation, power supply, water rate integrated water rate, coefficient of equivalent available, SO_2 concentration, concentration of nitrogen emissions, carbon concentration index, scientifically and systematically covers the process of thermal power generating units energy consumption and pollution, etc., to reasonably evaluate the condition of coal-fired power plant energy conservation and emissions reduction.

When the multi-attribute decision-making method is used to evaluate the energy saving and emission reduction status of generating units, the classical domain scope is scientifically and rationally divided, and the correlation value calculated according to the classical domain scope can scientifically reflect the classification of generating units. In addition, the grey relational analysis can be used to analyze the energy saving and emission reduction status of generating sets to a certain level according to the value of the relational degree, and the evaluation status of generating sets can be obtained to make the evaluation results more specific, providing a new idea for exploring the energy saving and emission reduction potential of generating sets.

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