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Research Article

Trend Analysis and Comprehensive Evaluation of Green Production Principal Component of Thermal Power Unit Based on ANP-MEEM Model

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Low-emission environmental protection concept once it replaced the low-carbon energy transformation concept, to a certain extent, disrupted the core direction of energy transformation. This paper takes the green development of electric power as the research direction, the thermal power unit is the green source control point of electricity, and the green production of the thermal power unit is the research target; based on the actual research data and the actual data, the comprehensive evaluation of the green production of a thermal power generating unit in a city is carried out by means of ANP, matter-element extension model, and principal component analysis. This paper not only reflects the quantification of green benefits in each year, but also achieves the comparison of green achievements and the analysis of increasing losses in the data years. Furthermore, the indexes of annual increase and loss of the index system are analyzed and filtered. The indexes of strong contribution index and short board of barrel are found out, and the dimension reduction management of green production of thermal power unit is realized.

1. Introduction

As the source control point, the green production of thermal power unit is an important factor to promote the green development of power; the high energy consumption and heavy pollution of the thermal power generating units especially have become an important factor restricting the healthy development of energy-saving emission reduction in the power industry [1]. At present, China's thermal power installed capacity growth rate is lower than the total installed capacity of power generation growth, but still showed a slow growth trend; thermal power units in the future for a long period of time will still occupy an important position in China's power production [2]. The development of green production of thermal power units will directly affect the pace of social transformation to low carbon and high efficiency [3]. Therefore, the implementation of green production of thermal power units is in line with the inevitable trend of development of the times, and the promotion and implementation of green production must be scientific and effective green production evaluation as a support.

In recent years, many scholars have carried on the related research to the comprehensive evaluation of the thermal power unit. Reference [4] used principal component analysis to reduce the dimension of evaluation index for comprehensive evaluation of thermal power unit and obtained the principal component of unit operation, in order to improve the operation management level of thermal power unit and realize energy saving and consumption reduction. In [5], a mathematic element evaluation model based on rough set is constructed. The rough set attribute reduction theory is used to reduce the energy efficiency comprehensive evaluation index of the thermal power unit and to eliminate the redundancy of the index. Reference [6] applied multilevel grey relational analysis method to thermal power unit operation evaluation, which improved the accuracy of small sample

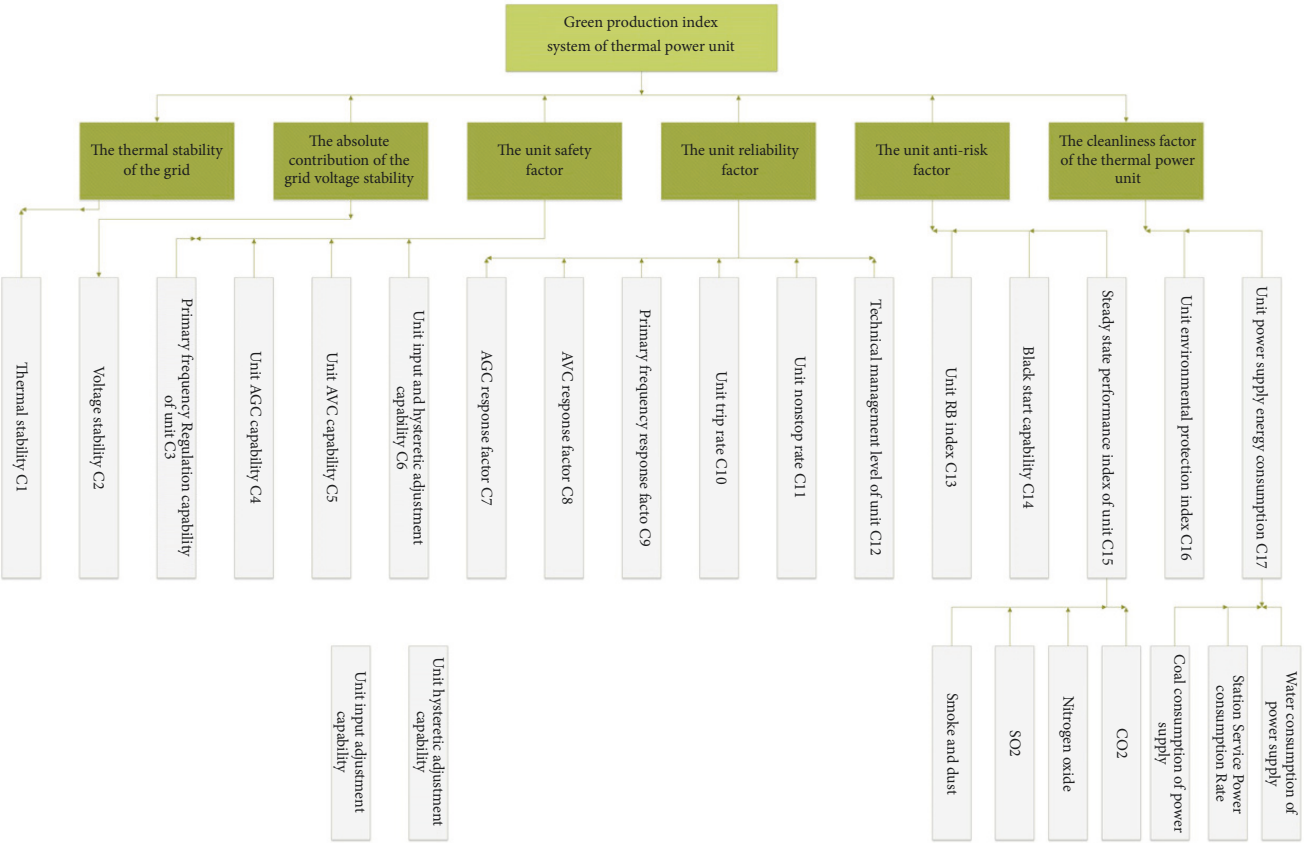

Figure 1: Green production evaluation index system of thermal power unit.

index evaluation. Reference [7] combined the variable fuzzy set theory with the fuzzy optimization neural network and improve the scientific and rationality of the interregional from evaluation criteria and the index weight determination method for the multi-index evaluation problem. Reference [8] combined the improvement of weight calculation and distance in TOPSIS method; the operational reliability of thermal power unit is comprehensively evaluated. Reference [9] focuses on the selection of judgment factors and the hierarchical division of multiple indicators, the selection and establishment of membership functions, and the method of determining the degree of importance of fuzzy sets. Reference [10] is based on time domain index; the performance evaluation of thermal power unit load control system is comprehensively evaluated. The performance evaluation grade of the overall time domain index is divided, and the qualitative evaluation of unit load control system performance is realized. Reference [11] adopts the covariance index based on historical data. By calculating the ratio of the evaluation function between the baseline data and the monitoring data, the index values of the performance evaluation of the control system are obtained.

However, in the field of comprehensive evaluation of thermal power units, there are few studies on the selection of key indicators for green production of thermal power units. In this paper, ANP is used to determine the local and global weights of the indicators, and the green production evaluation model of thermal power units is constructed according to the matter-element extension theory. The green production grade of thermal power units is obtained, and the green production grade characteristic value is taken as the consideration criterion. The principal component analysis of the green production process of the thermal power unit is carried out by the factor substitution principle, so as to find out the key factors that affect the green production of the thermal power unit, in order to provide reference for the green production of the thermal power unit.

2. Construction of Green Production Index System for Thermal Power Units

Based on the field research data and data, combined with the relevant thermal power units in the production of staff and scientific research units of the synergistic results, from the six dimensions: the thermal stability of the grid, the absolute contribution of the grid voltage stability, the unit safety factor, the unit reliability factor, the unit antirisk factor and the cleanliness factor of the thermal power unit to evaluate the green production degree of the thermal power unit, the construction index system is shown in Figure 1. Among them,

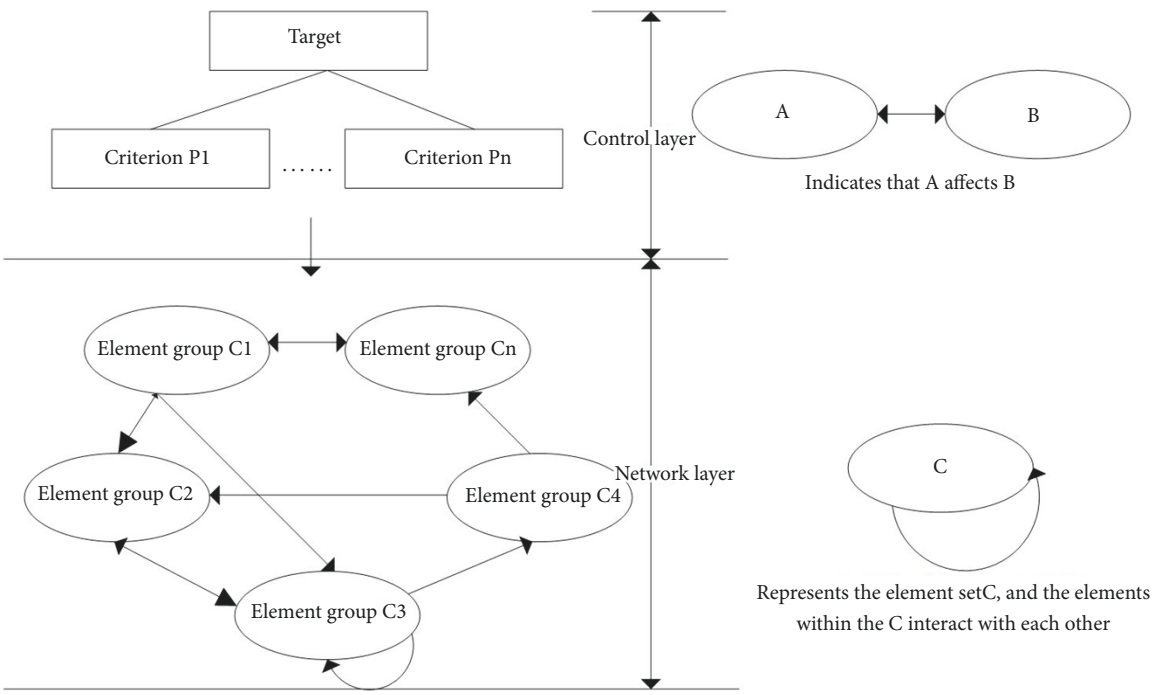

Figure 2: The typical ANP structure.

the smoke, sulfur dioxide, and nitrogen oxides emissions (or emission rate) are taken from a city environmental monitoring system of real-time data.

3. Theoretical Analysis of Green Production Evaluation of Thermal Power Units

3.1. ANP Weight Calculation Model. ANP consists of two layers: the control layer and the network layer. The control layer includes the elements to be evaluated and the associated evaluation criteria [12]. The network layer is determined by the control layer, and its internal is the network structure that affects each other [13], as shown in Figure 2.

The ANP weight determination procedure is as follows.

(1) Determine the relevance of the indicators.

(2) Determine the ratio of the comparison matrix and the importance degree of each layer element outside of the target layer.

(3) According to the comparison matrix and its importance degree, we can get the unweighted hypermatrix of each subdivision element and internal elements to sort a certain criterion.

(4) Based on the unweighted hypermatrix, we consider the influence of mutual feedback between the subgroup elements; weighted matrix can be obtained.

(5) We deal with the weighted hypermatrix stability matrix to obtain the limit matrix.

(6) We obtain the local weights and global weights of the index elements.

The above steps can be implemented by Super Decisions software.

3.2. Improved Model of Matter-Element Extension Evaluation. Matter-element extension evaluation model is mainly based on the theory of matter-element and extension set theory. Based on the establishment of classical domain, joint domain, and evaluation level, through the correlation function, we get the degree of correlation between the level of the evaluation objects and the rating level and finally determine the grade of the evaluation object. The specific evaluation process is represented in [14]. However, when the measured value of any index exceeds the joint domain, the correlation function of the model can not be calculated. We cannot use the method of matter-element extension method to carry out risk evaluation. Therefore, this paper can improve the matter-element extension evaluation model by normalizing the classical domain and the object to be evaluated. This method can guarantee that the measured value of any index does not exceed the joint domain, so as to avoid the problem that the correlation function can not be calculated of the situation.

The concrete steps of the improved matter-element extension evaluation model are as follows.

(1) Each index is divided by the right end of its joint domain, getting the normalization of the classic domain and the evaluation object. The classical domain matter elements are normalized:

$$R'_{\mathrm{j}} = \left(N_j, C_i, V'_{ji}\right) = \begin{bmatrix} N_j & c_1 & v_{j1} \\ & c_2 & v_{j2} \\ & \cdots & \cdots \\ & c_n & v_{jn} \end{bmatrix}$$

$$= \begin{bmatrix} N_j & c_1 & \left[\frac{a_{j1}}{b_{p1}}, \frac{b_{j1}}{b_{p1}}\right] \\ & c_2 & \left[\frac{a_{j2}}{b_{p2}}, \frac{b_{j2}}{b_{p2}}\right] \\ & \cdots & \cdots \\ & c_n & \left[\frac{a_{j2}}{b_{p2}}, \frac{b_{j2}}{b_{p2}}\right] \end{bmatrix},$$

$$R_0' = \begin{bmatrix} p_0 & c_1 & \frac{v_1}{b_{p1}} \\ & c_2 & \frac{v_2}{b_{p2}} \\ & \cdots & \cdots \\ & c_n & \frac{v_n}{b_{pn}} \end{bmatrix} \tag{1}$$

Wherein N_j is the level of the object to be evaluated, C_i is the characteristics of the object to be evaluated, V_{ji}' expresses the normalization of V_{ij}, $c_1, c_2, \cdots, c_n$ are the indexes of the object to be evaluated, $v_{j1}, v_{j2}, \cdots, v_{jn}$ are the ranges of $c_1, c_2, \cdots, c_n$ (classical domain), p_0 is the object to be evaluated, $v_1, v_2, \cdots, v_n$ are p_0 measured data about $c_1, c_2, \cdots, c_n$ a_{ij}, and b_{ij} are the bounds of V_{ij}.

(2) For the normalized object to be evaluated, the distance D between the new classical domain and the value range of the classical domain can be calculated by the lower form:

$$D\left(v, V_{ji}'\right) = \left|v - \frac{a+b}{2}\right| - \frac{b-a}{2} \tag{2}$$

Wherein v is point value, a and b are the left and right endpoints of the interval.

(3) The calculation of the degree of correlation: with D_{ij} instead of the correlation function $K_j(v_i)$, to calculate the comprehensive correlation degree $K_j(p_0)$,

$$K_j\left(p_0\right) = 1 - \sum_{i=1}^{n}\left(w_i D_{ij}\right) \tag{3}$$

wherein w_i is weight.

(4) Evaluation level: if $K_j(p_0) = \max\{K_j(p_0)\}$ ($j = 1, 2, \cdots, m$), the evaluation object p_0 belongs to evaluation level j:

$$\overline{K}_j\left(p_0\right) = \frac{K_j\left(p_0\right) - \min K\left(p_0\right)}{\max K\left(p_0\right) - \min K\left(p_0\right)} \tag{4}$$

$$j^* = \frac{\sum_{j=1}^{m} j\overline{K}_j\left(p_0\right)}{\sum_{j=1}^{m} \overline{K}_j\left(p_0\right)} \tag{5}$$

Wherein j^* is p_0's risk level variable eigenvalue, from the numerical value of j^*, we can judge the degree to which the evaluation object is biased to the adjacent grade.

3.3. Key Index Screening Method Based on Principal Component Analysis. Principal component analysis is one of the commonly used methods in multivariate statistical analysis. The basic principle is on the basis of the data array formed by the sample values of the m sets with certain dependence relation of the n parameters. By establishing a smaller number of aggregate variables, it is more concentrated to reflect the change information contained in the original parameter [15]. According to the size of the data change, the principal and subordinate position of the change direction is determined, and each principal component is obtained according to the order of priority. In the principal component analysis, the weights taken are directly corresponding to the contribution rate of the principal components. The more the information that a principal component can reflect in the comprehensive evaluation, the greater the corresponding weights [16].

In this paper, the green production evaluation of thermal power unit is carried out by matter-element extension model, and the green production grade of thermal power unit is determined but failed to screen out the key indicators of green production. Therefore, on the basis of matter-element evaluation grade, comprehensive correlation degree, and risk level variable eigenvalue, according to principal component analysis method, the key quantitative criteria of each index are obtained. According to the contribution degree of green production contribution of thermal power unit, each index is sorted to find out the strong contribution index and barrel short plate index, so as to realize the dimension reduction management of green production of thermal power unit.

4. Example Analysis

4.1. Green Production Basic Data and Pretreatment of Thermal Power Unit. Based on the green index system of thermal power plant, the basic data of quantitative index and qualitative index are determined by the extraction of measured data and expert scoring method, respectively.

In this paper, the normalization method is used to convert the index into the number of 0 ~ 1, which is convenient for the later processing of the original data. In order to unify the index types, we choose to convert the extremely small index into the extremely large index.

After normalization, the data is

$$x_{ij}^* = \frac{x_{ij}}{100} \tag{6}$$

Wherein x_{ij} is Index raw data, x_{ij}^* is normalized data.

The extremely small index is x, which corresponds to the extremely large index of x':

$$x' = 1 - x \tag{7}$$

The original data of each index is processed by the extremum method, as shown in Table 1.

4.2. Weight Design of Green Production Index System for Thermal Power Units. Due to the continuity of the green production process of thermal power units, the interrelationship

Table 1: Example data.

three-level indexes		Raw data			normalized data		
		2012	2013	2014	2012	2013	2014
C1	Thermal stability	48.31	52.34	48.78	0.48	0.52	0.49
C2	Voltage stability	89.61	89.24	83.52	0.90	0.89	0.84
C3	Primary frequency Regulation capability of unit	81.51	80.01	79.92	0.82	0.80	0.80
C4	Unit AGC capability	81.52	79.90	79.85	0.82	0.80	0.80
C5	Unit AVC capability	79.98	79.96	80.00	0.80	0.80	0.80
C6	Unit input and hysteretic adjustment capability	66.79	67.37	68.88	0.67	0.67	0.69
C7	AGC response factor	81.54	79.85	79.69	0.82	0.80	0.80
C8	AVC response factor	80.01	79.96	80.00	0.80	0.80	0.80
C9	Primary frequency response facto	81.53	80.26	79.92	0.82	0.80	0.80
C10	Unit trip rate	77.58	78.28	77.80	0.78	0.78	0.78
C11	Unit nonstop rate	0.00	5.68	5.08	0.00	0.06	0.05
C12	Technical management level of unit	64.21	67.09	68.99	0.64	0.67	0.69
C13	Unit RB index	73.31	70.79	68.40	0.73	0.71	0.68
C14	Black start capability	0.35	12.82	12.26	0.00	0.13	0.12
C15	Steady state performance index of unit	100.00	100.00	100.00	1.00	1.00	1.00
C16	Unit environmental protection index	65.76	76.90	85.90	0.66	0.77	0.86
C17	Unit power supply energy consumption	69.44	74.82	73.21	0.69	0.75	0.73

Table 2: Local weights and global weights of each index.

Two-level index	Global weight	Three-level index	Local weight	Global weight
B1	0.0197	C1	1.00000	0.019898
B2	0.0197	C2	1.00000	0.019898
B3	0.2368	C3	0.30446	0.07164
		C4	0.29869	0.070308
		C5	0.27198	0.064053
		C6	0.12486	0.029386
B4	0.3530	C7	0.16521	0.057961
		C8	0.15499	0.054393
		C9	0.11629	0.040786
		C10	0.19242	0.067585
		C11	0.08506	0.029892
		C12	0.28604	0.101322
B5	0.1526	C13	0.11525	0.016423
		C14	0.04375	0.010904
		C15	0.84100	0.12619
B6	0.2183	C16	0.69346	0.152034
		C17	0.30654	0.067326

between indicators is difficult to avoid. Therefore, this paper adopts ANP weight theory, which can effectively solve the problem of mutual correlation among indexes, using Super Decision software to solve, the index system of the indicators of the local weight, and global weight, as shown in Table 2.

4.3. Example Analysis of Matter-Element Extension

4.3.1. Matter-Element Evaluation Model. Green production of thermal power units is the main focus of urban power green characterization and is the main controlling factor of green realization degree of urban power. Can also from the six dimensions: the thermal stability of the grid, the absolute contribution of the grid voltage stability, the unit safety factor, the unit reliability factor, the unit antirisk factor, and the cleanliness factor of the thermal power unit to elaborate.

In this paper, the green production evaluation of thermal power unit is carried out by matter-element extension model. First of all, the level of green production of thermal power units should be determined; we divide it to five grades: N_1 below low, N_2 low, N_3 normal, N_4 high, and N_5 above high. Then it is necessary to determine the classical domain, the joint domain, and the evaluation object of the subdivision attribute characteristics (three-level indexes) of the six

Table 3: Classical domains of the three-level indexes.

Index	Classical domain				
	Below low	Low	Normal	High	Above high
Thermal stability	[0~0.1]	[0.1~0.2]	[0.2~0.3]	[0.3~0.5]	[0.5~1]
Voltage stability	[0~0.3]	[0.3~0.6]	[0.6~0.7]	[0.7~0.9]	[0.9~1]
Primary frequency Regulation capability of unit	[0~0.3]	[0.3~0.6]	[0.6~0.7]	[0.7~0.9]	[0.9~1]
Unit AGC capability	[0~0.3]	[0.3~0.6]	[0.6~0.7]	[0.7~0.9]	[0.9~1]
Unit AVC capability	[0~0.3]	[0.3~0.6]	[0.6~0.7]	[0.7~0.9]	[0.9~1]
Unit input and hysteretic adjustment capability	[0~0.3]	[0.3~0.6]	[0.6~0.7]	[0.7~0.9]	[0.9~1]
AGC response factor	[0~0.3]	[0.3~0.6]	[0.6~0.7]	[0.7~0.9]	[0.9~1]
AVC response factor	[0~0.3]	[0.3~0.6]	[0.6~0.7]	[0.7~0.9]	[0.9~1]
Primary frequency response factor	[0~0.3]	[0.3~0.6]	[0.6~0.7]	[0.7~0.9]	[0.9~1]
Unit trip rate	[0~0.3]	[0.3~0.6]	[0.6~0.7]	[0.7~0.9]	[0.9~1]
Unit nonstop rate	[0~0.3]	[0.3~0.6]	[0.6~0.7]	[0.7~0.9]	[0.9~1]
Technical management level of unit	[0~0.3]	[0.3~0.6]	[0.6~0.7]	[0.7~0.9]	[0.9~1]
Unit RB index	[0~0.3]	[0.3~0.6]	[0.6~0.7]	[0.7~0.9]	[0.9~1]
Black start capability	[0~0.1]	[0.1~0.2]	[0.2~0.3]	[0.3~0.5]	[0.5~1]
Steady state performance index of unit	[0~0.6]	[0.6~0.8]	[0.8~0.9]	[0.9~0.95]	[0.95~1]
Unit environmental protection index	[0~0.3]	[0.3~0.6]	[0.6~0.8]	[0.8~0.9]	[0.9~1]
Unit power supply energy consumption	[0~0.3]	[0.3~0.6]	[0.6~0.8]	[0.8~0.9]	[0.9~1]

dimensions of the thermal power unit. Since the original data of all the indexes are processed uniformly and normalized, the joint domain in each of the three-level indexes is [0 to 1]. The classic domains of each of the three-level indexes are shown in Table 3.

When the measured value of any index exceeds the joint domain, the correlation function of the model cannot be calculated. We improve the matter-element extension evaluation model by normalizing the classical domain and the object to be evaluated. That is to say, all indexes are divided by the right end value of the node region, and then the classical domain and the matter-element to be evaluated are obtained. The distance between the new matter-element and the new classical domain D_{ij} is calculated at random. We can get 2012 ~ 2014 the evaluation object in each of the new data on the distance of the new classic domain.

4.3.2. Green Production Grade Division of Thermal Power Unit

(1) Grade Evaluation. Through calculation, the correlation degree of green production level of thermal power plant is as shown in Table 4 and Figure 3.

The degree of green production in each year can be derived from the correlation degree of green production level of thermal power plants each year. It shows that $K_4(p_0) = \max K_j(p_0)$, $j = 1, 2, \cdots, 5$ green production degree of thermal power plant (N_4) in 2012 is high; similarly, the green production levels of thermal power plants (N_4) in 2013 and 2014 are high.

(2) To Calculate the Degree to Which the Evaluation Object Is Biased to the Adjacent Grade. According to the correlation degree of green production grades in thermal power plants in each year, the risk level variable eigenvalue j^* of the evaluation object can be calculated (see Table 5 and Figure 4).

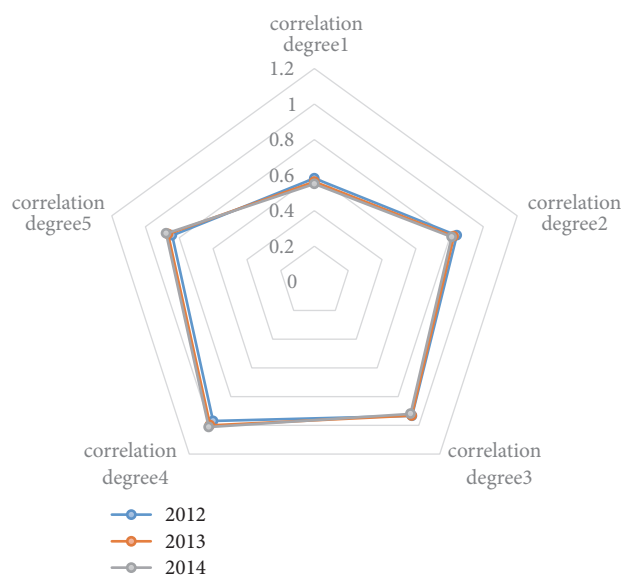

Figure 3: Correlation analysis of green production grades in thermal power plants from 2012 to 2014.

From the evaluation results, thermal power plant green production level rating is high in 2012~2014; combining with the risk level variable eigenvalue j^* of the evaluation object j^*, we can get the degree to which the evaluation object is biased to the adjacent grade. In 2012 j^*=3.51, indicating that green production in thermal power plants is in the fourth grade, but developing towards to the third level, strictly speaking, belonging to the 3.51 level. Similarly, in 2013 j^*=3.57, indicating that green production in thermal power plants is in the fourth grade, but developing towards to the third level, strictly speaking, belonging to the 3.57 level.

Table 4: Grade correlation degree of green production in thermal power plant.

year	$K_1(p_0)$	$K_2(p_0)$	$K_3(p_0)$	$K_4(p_0)$	$K_5(p_0)$
2012	0.5812	0.8423	0.9348	0.9703	0.8422
2013	0.5619	0.8247	0.9325	0.9997	0.8660
2014	0.5496	0.8123	0.9201	1.0127	0.8778

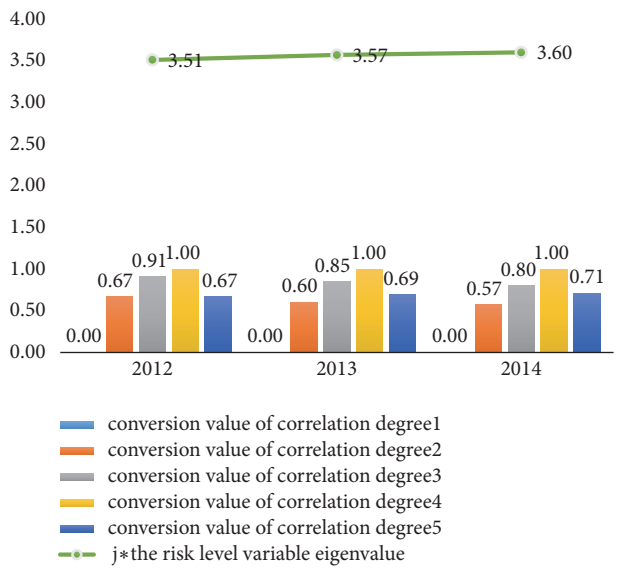

Figure 4: 2012 to 2014 deviated variable eigenvalues.

Compared to 2012, thermal power units' green production performance is gradually strengthened. In 2014 j^*=3.60, reaching the highest value in nearly three years, which indicates that green production in thermal power plants is in the fourth grade, but developing towards to the third level, strictly speaking, belonging to the 3.60 level.

From the risk level variable eigenvalue, we can see that thermal power plant green production showed a steady increase in the trend in 2012~2014; growth rates reached 20.1% and 7.0% in 2013 and 2014; growth absolute value is 0.57 and 0.24; the green production in thermal power plant reached the highest value in nearly three years.

4.4. Trend Analysis of Principal Component of Green Production in Thermal Power Unit Based on Factor Substitution

4.4.1. Step-by-Step Factor Substitution Set. In this paper, the principle of factor substitution is used to analyze the principal components of green production process in thermal power plants, the key factors and main contradictions affecting the green production process of thermal power unit are found out, and the green production dimensionality reduction control of thermal power unit is realized. From the key point of green production process, the green production process of Shanghai thermal power unit can be promoted efficiently, scientifically and purposefully. The inverted triangle structure is formed after step-by-step factor substitution set, following rolling data in 2014, are shown in Table 6.

Table 5: Evaluated metarisk variables eigenvalues.

Year	2012	2013	2014
j^*	3.5139	3.5695	3.6015

4.4.2. Correlation Analysis of Substitution Sets of Factors. Based on step-by-step factor substitution set, the matter-element extension simulation is carried out for different situation factor sets; the comprehensive correlation degree of each evaluation grade can be obtained in different situations in 2013 and 2014. As illustrated in Figure 5, in 2013 (complete absence of substitution), the process was gradually extended to 2014 (complete replacement state); the green production evaluation result of thermal power unit is always in the fourth grade, that is to say, better grade. There is no sudden change or great change, and green power production is stable. Similarly, in 2012 (complete absence of substitution), the process was gradually extended to 2013 (complete replacement state). The green production evaluation result of thermal power unit is also in the fourth grade, that is to say, better grade, and green power production is stable.

4.4.3. The Risk Level Variable Eigenvalue of Step-by-Step Factor Substitution Set. With the matter-element extension assessment of the risk level variable eigenvalue as the ultimate consideration criteria, we analyze the various indexes of the final risk variable level variable eigenvalue of absolute and relative influence of different situations; through model simulation, we can get the risk level variable eigenvalue of step-by-step factor substitution set in 2013 and 2014; 2014 is given in Table 7.

According to Figure 6 shows that, in 2013 (complete absence of substitution), the process was gradually extended to 2014 (complete replacement state). Thermal power unit green production risk level variable eigenvalues in the online floating, the final trend of rising trend, From 3.5695 in 2013 to 3.6015; that is, the production of thermal power unit is constantly improving. However, there are twists and turns in the process, take rolling factor C16 unit environmental protection index characteristic value 3.6042 to scroll factor C17 unit power supply energy consumption index 3.6015 drop process as an example. Through the analysis of the comprehensive correlation degree inverted triangle data, it is not difficult to see that there are some back in 2013 C17 unit power consumption index, from 0.748 back to 0.732, which directly reflects the backward change process in thermal power unit green production risk variable eigenvalue.

4.4.4. Contribution Degree Analysis of Each Factor. Based on the risk level variable eigenvalue of step-by-step factor

Table 6: Level-wise substitution set green production of thermal power units in 2014.

index	Rolling Index																	
	---	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17
C1	0.523	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488
C2	0.892	0.892	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835
C3	0.800	0.800	0.800	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799
C4	0.799	0.799	0.799	0.799	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798
C5	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800
C6	0.674	0.674	0.674	0.674	0.674	0.674	0.689	0.689	0.689	0.689	0.689	0.689	0.689	0.689	0.689	0.689	0.689	0.689
C7	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797
C8	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800
C9	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799
C10	0.783	0.783	0.783	0.783	0.783	0.783	0.783	0.783	0.783	0.783	0.778	0.778	0.778	0.778	0.778	0.778	0.778	0.778
C11	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.051	0.051	0.051	0.051	0.051	0.051	0.051
C12	0.671	0.671	0.671	0.671	0.671	0.671	0.671	0.671	0.671	0.671	0.671	0.671	0.690	0.690	0.690	0.690	0.690	0.690
C13	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.684	0.684	0.684	0.684	0.684
C14	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.123	0.123	0.123	0.123
C15	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
C16	0.769	0.769	0.769	0.769	0.769	0.769	0.769	0.769	0.769	0.769	0.769	0.769	0.769	0.769	0.769	0.769	0.859	0.859
C17	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.732

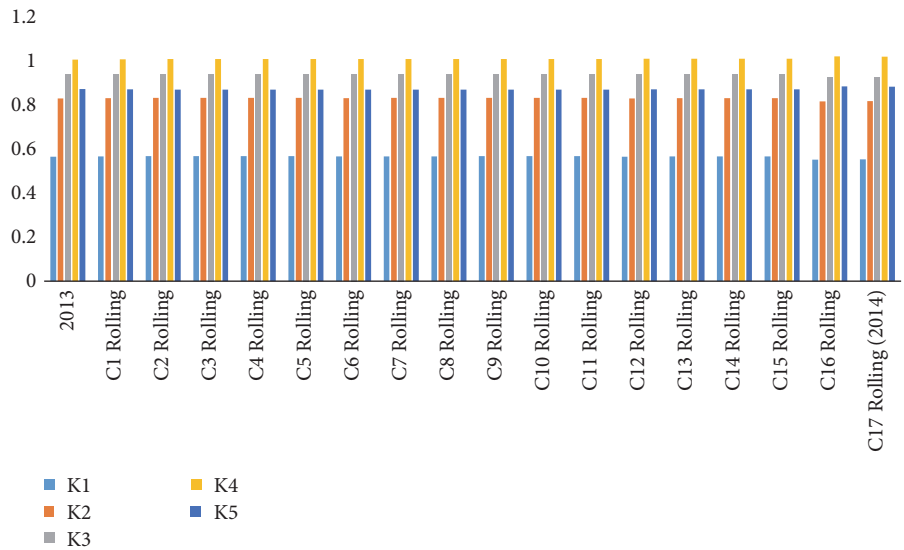

Figure 5: Comparison of each factors of the three generations in 2014.

Table 7: Level-wise substitution set of each evaluated metarisk variables eigenvalues in 2014.

Rolling factor	---	C1	C2	C3	C4	C5	C6	C7	C8
Eigenvalue	3.5695	3.5680	3.5656	3.5655	3.5654	3.5654	3.5666	3.5664	3.5664
Rolling factor	C9	C10	C11	C12	C13	C14	C15	C16	C17
Eigenvalue	3.5661	3.5652	3.5652	3.5704	3.5694	3.5694	3.5694	3.6042	3.6015

Table 8: Contribution degree of each factor in 2014.

Rolling factor	---	C1	C2	C3	C4	C5	C6	C7	C8
Eigenvalue	3.5695	3.5680	3.5656	3.5655	3.5654	3.5654	3.5666	3.5664	3.5664
Difference	---	-0.0015	-0.0024	-0.0002	-0.0001	0.0001	0.0012	-0.0003	0.0001
Contribution degree	----	-0.0469	-0.0750	-0.0063	-0.0031	0.0031	0.0375	-0.0094	0.0031
Rolling factor	C9	C10	C11	C12	C13	C14	C15	C16	C17
Eigenvalue	3.5661	3.5652	3.5652	3.5704	3.5694	3.5694	3.5694	3.6042	3.6015
difference	-0.0003	-0.0009	0.0000	0.0052	-0.0011	0.0000	0.0000	0.0348	-0.0027
Contribution degree	-0.0094	-0.0281	0.0000	0.1625	-0.0344	0.0000	0.0000	1.0875	-0.0844

substitution set, dislocation subtraction can be used to obtain the difference of the feature value of the risk grade variable before and after the substitution of factors, based on the difference between the adjacent situation and the difference between the head and tail (that is, the difference between complete and incomplete alternatives). Calculate the relative contribution between the two and get the final indicators of key quantitative measurement criteria. We can get the contribution degree analysis of each factor in 2013 and 2014; 2014 is given in Table 8.

As shown in Table 8, the most important indexes of green production contribution of thermal power unit are C16 unit environmental protection index, C12 unit technical management level, C6 unit input and hysteretic adjustment capability, C5 unit AVC capability, and C8 AVC response factor; the contribution degrees were 1.0875, 0.1625, 0.0375, and 0.0031. The contribution degree shows that from 2014 to 2013, the green production risk level variable eigenvalue of thermal power unit can be raised from 3.5695 to 3.6015. because the C16 unit environmental protection index, C12 unit technical management level, C6 unit input and hysteretic adjustment ability, C5 unit AVC capability, C8 AVC response, factor and other aspects have been improved accordingly, and the contribution degree can be expressed as follows: C16 unit environmental protection index >C12 unit technical management level >C6 unit input and hysteretic adjustment capacity >C5 unit AVC capability >C8 AVC response factor.

Similarly, in 2013, between 2013 and 2012, the green production risk level variable eigenvalue of thermal power unit can be raised from 3.5139 to 3.5695, because the C16 unit environmental protection index, C17 unit power supply energy consumption, C12 unit technical management, C1 thermal stability, C10 unit trip rate, and other aspects have been improved accordingly, and the contribution degree can be expressed as follows: C16 unit environmental protection index>C17 unit power supply energy consumption> C12 unit

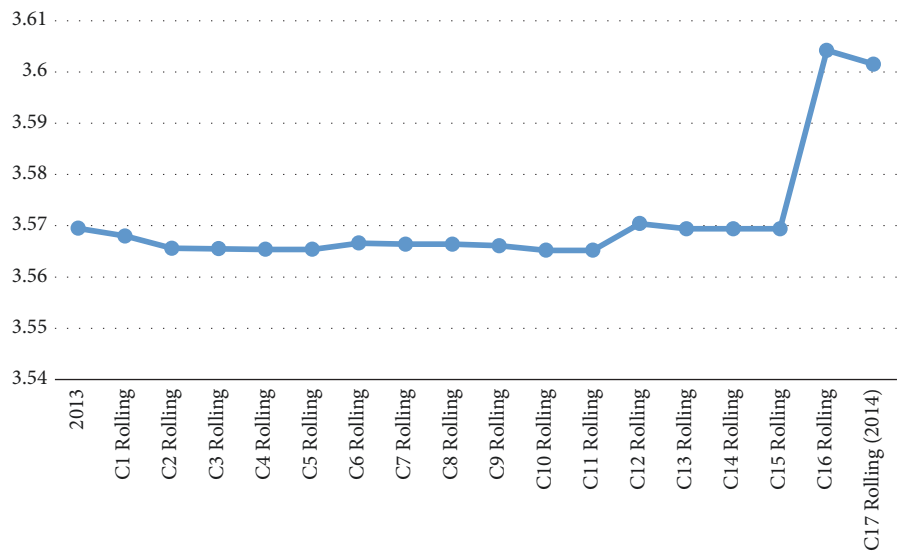

Figure 6: Trends of level-wise substitution set of each evaluated metarisk variables eigenvalues in 2014.

technical management>C1 thermal stability> C10 unit trip rate.

5. Conclusions

The green production of thermal power units is one of the important components of green energy, which is the initial stage of the actual process of power green. It is also the source control point of green control. It is directly related to the final control result of the whole process of green energy control.

(1) Based on the green production index system and basic data of thermal power generating units, the quantitative analysis of green production efficiency is realized and the comparative analysis is carried out for many years to realize the research purpose of green production trend of thermal power generating units.

(2) The analytic network process (ANP) solves the problem of the weighting of the attributes in the production process of the thermal power generating units, which can effectively overcome the problem that the traditional assignment theory (such as AHP) can not solve the problem of strong correlation index.

(3) In this paper, the principle of factor substitution is used to analyze the principal component of the green production process of the thermal power unit, and the key factors influencing the green production of the thermal power unit are found out. The main contradiction in the green production process is found out, and the green production of the thermal power plant is realized.

The future energy structure has been adjusted, and the potential of green power is huge. This is simulated with the 2012-2014 thermal power unit data samples. The results show that the total coal consumption will decrease year by year, and the rising consumption of gasoline and natural gas will slow down, while the growth rate of total energy consumption will continue to increase, and the proportion of green energy will increase.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors' Contributions

It should be noted that the whole work was accomplished by the authors collaboratively. All authors read and approved the final manuscript.

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