THOMSON REUTERS ENDNOTE

[Li Na-na* *et al.*, 5(7): July, 2016] ISSN: 2277-9655
IC™ Value: 3.00 Impact Factor: 4.116

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

THE COMPREHENSIVE EVALUATION OF ENERGY SAVING AND EMISSION REDUCTION PERFORMANCE OF THERMAL POWER ENTERPRISES BASED ON THE ENTIRE-ARRAY-POLYGON INDICTOR MODEL

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DOI: 10.5281/zenodo.58644

ABSTRACT

The effectiveness of Thermal energy saving and pollutants reduction as an important area of energy affects overall goals of our country. Based on the requirements of relevant national policies, a comprehensive index system of thermal energy saving and energy reduction was established from the management benefit, energy consumption, waste recycling, pollutants emission, and clean production management. And then a method based on the Entire-Array-Polygon Indictor evaluation model was built to evaluate the performance dynamically, which can overcome the influent of subjective factors. Finally, taking a thermal power plant as an example, an evaluation of its energy saving and pollutants reduction effect was performed, which showed that the overall performance of this plant's energy reduction index is upward with seasonal fluctuations and the performance of the technological transformation projects is obvious. The evaluation method is feasible.

KEYWORDS: Energy Saving and Emission Reduction; Comprehensive Evaluation; Entire-Array-Polygon Indictor Model.

INTRODUCTION

Facing the serious situation of energy and environment, thermal power enterprise should take more responsibility for energy conservation and emissions reduction, which is the focus of energy saving and emission reduction in our China. The energy conservation and emissions reduction of thermal power enterprises not only affects the development of enterprise, but also relates to the sustainable development. As a result, more and more enterprises continue to strengthen the management of energy saving and emission reduction, so as to improve the performance of enterprise energy conservation and emissions reduction.

At the same time, many scholars have paid attention to the research related to performance evaluation of energy conservation and emissions reduction. [1-3] discussed the index system of performance evaluation of energy saving and emission reduction. Literature [2] established the index system of thermal power enterprise from energy saving and energy conservation management. Based on the perspective of input and output, literature [3], selected the index system of energy saving and emission reduction from financial, customer, internal processes, and learning. However, these indicators are always focused on only one particular perspective of energy saving and emission reduction, which are incomplete and lack of national policies and standards support.

Performance evaluation methods of energy conservation and emissions reduction mainly include fuzzy comprehensive evaluation method, principal component analysis, factor analysis and structural equation method, etc. Literature [4] achieved the comprehensive factor score and efficacy coefficient for energy conservation and emissions reduction in China by using the factor analysis method and effect coefficient method. Literature [5] used principal component analysis method to evaluate the performance of regional energy conservation and emissions reduction. Concerning the multi-level and fuzziness of performance evaluation, literature [6] analyzed the performance of energy saving and emission reduction based on the fuzzy analytic hierarchy process (AHP) and fuzzy comprehensive evaluation method. Combing the quantitative and qualitative methods, literature [7] established the structural equation model to evaluate the performance of energy saving and emissions reduction, which realized the performance evaluation in China. Above all, these traditional methods have lots of deficiencies. Fuzzy hierarchy analysis method is hard to avoid subjective problem. Although the principal component analysis can avoid the subjective problem, the requirement for data integrity is higher. Moreover, the structure equation of comprehensive evaluation method requires a large number of sample data to build mathematical model for evaluation[8]. Therefore, on the basis of predecessors' research, we should look for a more scientific and reasonable evaluation method to realize dynamic evaluation for energy saving and emissions reduction.

In order to realize scientific and dynamic evaluation for energy saving and emission reduction in thermal power enterprise, a comprehensive scientific performance evaluation index system was established based on the relevant national policies and requirements. Then, a comprehensive evaluation model based on the entire-array-polygon indictor method was established. Finally, the energy saving and emission reduction performance evaluation was presented, which realized the dynamic evaluation of the performance of energy saving and emission reduction in the thermal power enterprise.

ESTABLISH THE INDEX SYSTEM OF ENERGY SAVING AND EMISSION REDUCTION IN THERMAL POWER ENTERPRISE

The energy saving and emission reduction index system should be form by a series of independent criteria, which is established based on the principle of energy saving and emission reduction. This index system should effectively reflect the energy saving and emission reduction results. Moreover, is also should match the requirements of national and related departments on energy saving and emission reduction, which can reflect the progress of thermal power enterprise on energy saving and emission reduction. At the same time, according to the principle of the construction of index system, all the selected criteria should be typical, scientific, objective and operational.

According to above principles and related requirements of national policies, the index system of energy saving and emission reduction in thermal power enterprises is established. The specific policy documents are show as below: (1) " Energy saving and emission reduction plan in 13th five year"; (2) " Evaluation guide of cleaner production in thermal power enterprises"; (3) " Evaluation index system of cleaner production in thermal power enterprise";(4) "Monitoring statistics report of energy saving and emissions reduction"; (5) " Indicators standards of energy saving and emission reduction". The final index system of energy saving and emission reduction for thermal power enterprises in this paper are involved with the management benefit, energy consumption, waste recycling, pollutants emission, and clean production management. The specific criteria and related properties are shown in Table 1.

Table.1 The Evaluation System of Energy Saving Thermal Power Enterprise Performance

Management benefit（B1）	Gross value of industrial output (C11)	
	Per capita income (C12)	
	Operating Profit Margin（C13）	
	Comprehensive energy consumption of ten thousand yuan output value (C14)	
Energy consumption (B2)	The power supply coal consumption (C21)	
	Power consumption rate (C22)	
	Water consumption of unit capacity(C23)	
	Soda loss rate（C24）	
	Petrol consumption per year（C25）	
Waste recycling (B3)	water reuse efficiency (C31)	
	Utilization rate of fly ash slag (C32)	
	Desulphurization production utilization (C33)	
pollutants emission (B4)	Smoke emissions of unit capacity(C41)	
	SO2 emissions of unit capacity(C42)	
	NO emissions of unit capacity(C43)	

	Waste water emission of unit capacity（C44）	
	Fly ash slag emission（C45）	
	The factory bound noise（C46）	
clean production management（B5）	Pollution charge of unit capacity（C51）	
	Investment proportion of energy saving and emission reduction(C52)	
	Implementation of clean production equipment (C53)	
	Recycling facilities（C54）	
	Publicity and assessment of situation of circular economy（C55）	

Note: "-" means the smaller the better; "+" means the larger the better.

COMPREHENSIVE EVALUATION MODEL BASED ON THE ENTIRE-ARRAY-POLYGON INDICTOR METHOD

The entire-array-polygon indictor method can achieve dynamic comprehensive evaluation by comparing comprehensive indexes of different objects. The comprehensive index is the relationship of the upper limit value, the critical value and the lower limit value, which can realize the longitudinal comparison of the same indicator. At the same time, the indicator information can be mapped from high dimension space to low dimensional space, which can reflect the classification information and ordering information of evaluation object [9,10]. The specific evaluation procedure is as follows:

Suppose there are n evaluation indicators, all the upper limits of these indicators constitute a centrosymmetry with n sides. The connecting lines of all indicators constitute an irregular graphics with n sides, and there are (n-1)!/2 kinds of graphics. The comprehensive index can be defined the ratio between the average area of all kinds of irregular graphics and the area of the centrosymmetry with n sides.

Standardization function F (x) in [L, U] parameter values are mapped to [1, + 1], and the mapping value has changed the growth rate of original indicators. When index value is below the critical value, the growth rate of standardization indicators will gradually decrease. On the contrary, when the index value is more than the critical value, the growth rate of standardized index will gradually increase. The standardization indicators will grow in nonlinear, and the critical value is the turning point of growth speed. According to the characteristics of the above standardization, standardization of hyperbolic function was used to construct function:

$$F(x)=\frac{p}{qx+c}$$

Among them, p, q, c are the parameters of hyperbolic function.

Suppose that $F(x)|_{x=L}=-1, F(x)|_{x=T}=0, F(x)|_{x=U}=1$, where U is the upper limit of x, L is the lower limit of x, T is the critical value. According to the above conditions, the concrete form of $F(x)$ can be obtained.

$$F(x)=\frac{(U-L)(U-T)}{(U+L-2T)x+UT+LT-2UT} \quad (1)$$

To achieve the longitudinal comparison of the composite index, the lower limit is the minimum of indexes, the upper limit is the maximum of indexes, and the critical value is the average of indexes. "-" means the smaller the better; "+" means the larger the better.

Therefore, the standardized value of index i, S_i can be defined as follows:

$$S_i=\frac{(U_i-L_i)(U_i-T_i)}{(U_i+L_i-2T_i)x_i+U_iT_i+L_iT_i-2U_iT_i} \quad (2)$$

n indexes constitute a centrosymmetry with n sides, the fixed point of the centrosymmetry represents $S_i=1$, and the center of the centrosymmetry represents $S_i=-1$. The interval between center point to fixed point is ［- 1，+1

]. The $S_i = 0$ represent the critical path of the centrosymmetry. The inner regions of the critical path represent the standardized value of indexes are smaller than the critical values. On the contrary, the outer region represents of the critical path represent the standardized value of indexes are larger than the critical values.

The comprehensive value S of the evaluation object based on the entire-array-polygon indictor model can be defined as follows:

$$S = \frac{\sum_{i<j}^{i,j} (S_i + 1)(S_j + 1)}{2n(n-1)} \qquad (3)$$

Finally, the performance of different evaluation objects can be judged according to the comprehensive indexes. For example, the higher the energy resource consumption index is, the lower the resource consumption in the process of production is; The higher the comprehensive index of energy saving and emission reduction is, the better the performance of enterprise is.

CASE STUDY

Energy saving and emission reduction data of thermal power plant.

The Empirical object is a 2 x 60 mw coal-fired power plant, which has installed desulphurization and dust removal device in 2009 and reformed the dust removal system in 2011. The thermal power plant has been responding to the call of the national energy saving and emission reduction, and constantly promote enterprise technology innovation, application and popularization of energy saving and emission reduction.It has successively optimized the boiler combustion adjustment and coal blending, unit, smooth the pressure curve etc. In this paper, the energy saving and emission reduction performance of thermal power plant from 2009-2013 has been evaluated. Moreover, the performance of each criteria for evaluation has been analyzed to reflect the improvement of energy saving and emission reduction in this thermal power plant. The quantitative and qualitative indicators are listed in table 2, in which the quantitative data is obtained from operation system and the qualitative data is obtained by 20 experts.

Table.2 Energy Conservation Evaluation Index Values

	2009	2010	2011	2012	2013
Gross value of industrial output (C11)	13433.8	187560.9	277776.8	221795.2	289122.1
Per capita income (C12)	2050	2602	2805	3201	3308
Operating Profit Margin（C13）	-1.27%	3.98%	3.62%	2.79%	8.21%
Comprehensive energy consumption of ten thousand yuan output value (C14)	6.4081	6.3411	5.2601	5.2062	5.1378
The power supply coal consumption (C21)	319.459	317.5078	317.2465	315.8228	314.9611
Power consumption rate (C22)	5.3743	5.3103	5.213	5.1386	5.2769
Water consumption of unit capacity(C23)	0.3712	0.2548	0.2931	0.2779	0.2653
Soda loss rate（C24）	1.60%	1.70%	1.63%	1.50%	1.37%
Petrol consumption per year（C25）	209.923	285.372	244.565	278.77	200
water reuse efficiency (C31)	80%	82%	84%	88%	92%
Utilization rate of fly ash slag (C32)	65%	70%	74%	80%	89%
Desulphurization production utilization (C33)	88%	89%	88%	90%	95%
Smoke emissions of unit capacity(C41)	0.1444	0.1561	0.0941	0.0749	0.0572
SO2 emissions of unit capacity(C42)	1.4873	1.4186	1.1089	0.8514	0.4217
NO emissions of unit capacity(C43)	1.3853	1.5261	0.9055	0.8546	0.5731
Waste water emission of unit capacity（C44）	0.4349	0.2851	0.1356	0	0
Fly ash slag emission（C45）	100122	155495.7	143590.3	9373.91	7321.98
The factory bound noise（C46）	87	85	84	75	65
Pollution charge of unit capacity（C51）	0.3421	1.03424	1.0536	1.3214	0.9772

ISSN: 2277-9655
Impact Factor: 4.116

Investment proportion of energy saving and emission reduction(C52)	0.90%	0.80%	0.86%	1.73%	2.32%
Implementation of clean production equipment (C53)	3	5	6	8	9
Recycling facilities（C54）	4	4	5	7	8
Publicity and assessment of situation of circular economy（C55）	2	4	5	8	9

Results

Based on the above index system and evaluation model of thermal power plant, the performance for energy saving and emission reduction has been evaluated from the management benefit, energy consumption, waste recycling, pollutants emission, and clean production management. The evaluation results are shown in table 3, figure 1-6.

Table 3. The comprehensive evaluation indexes

	B1	B2	B3	B4	B5	Comprehensive indicators
2009	0.000000	0.032978	0.000000	0.007796	0.012286	0.013921
2010	0.110476	0.079469	0.062049	0.005128	0.031487	0.050882
2011	0.483848	0.226075	0.056842	0.180229	0.107056	0.199367
2012	0.490927	0.384700	0.397113	0.656964	0.391858	0.483977
2013	1.000000	0.716553	1.000000	1.000000	0.786176	0.891733

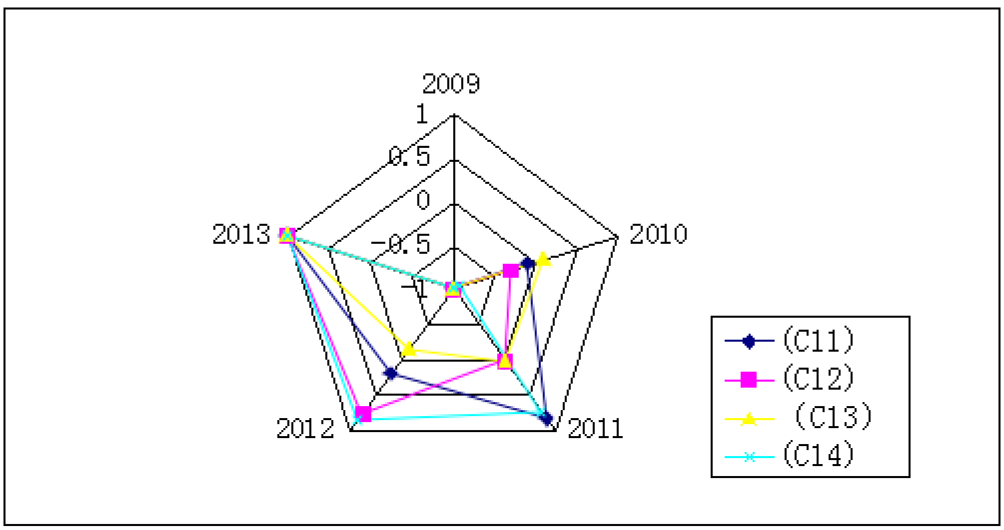

Figure1. The performance of management benefit aspect.

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Impact Factor: 4.116

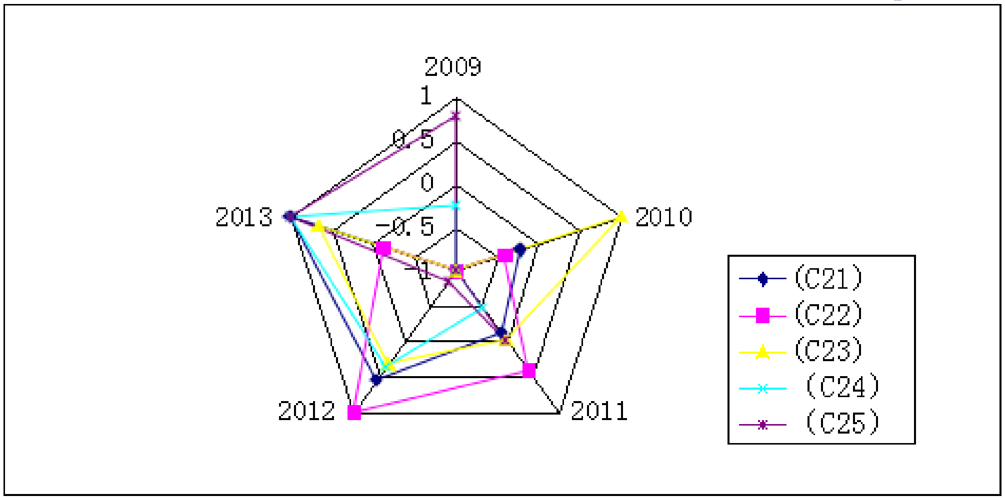

Figure2. The performance of energy consumption aspect.

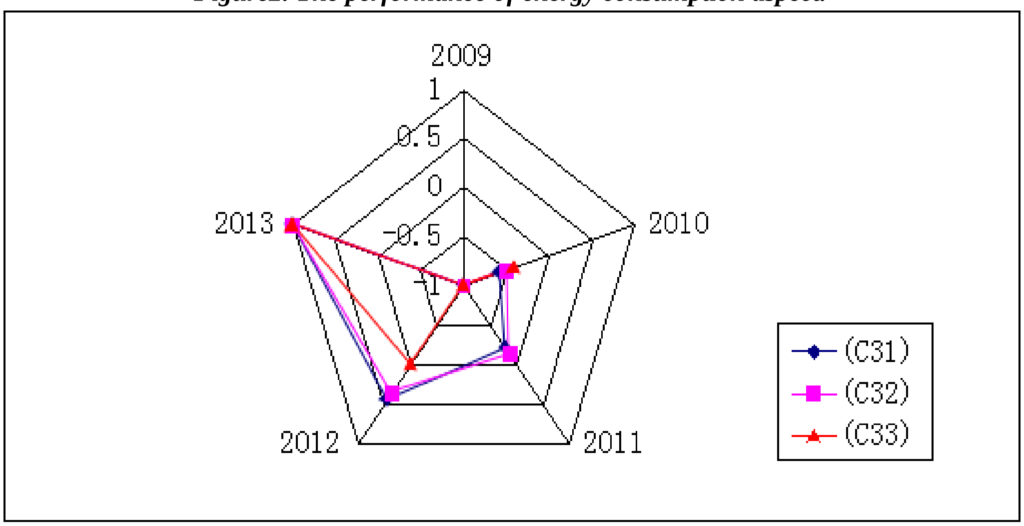

Figure3. The performance of waste recycling aspect.

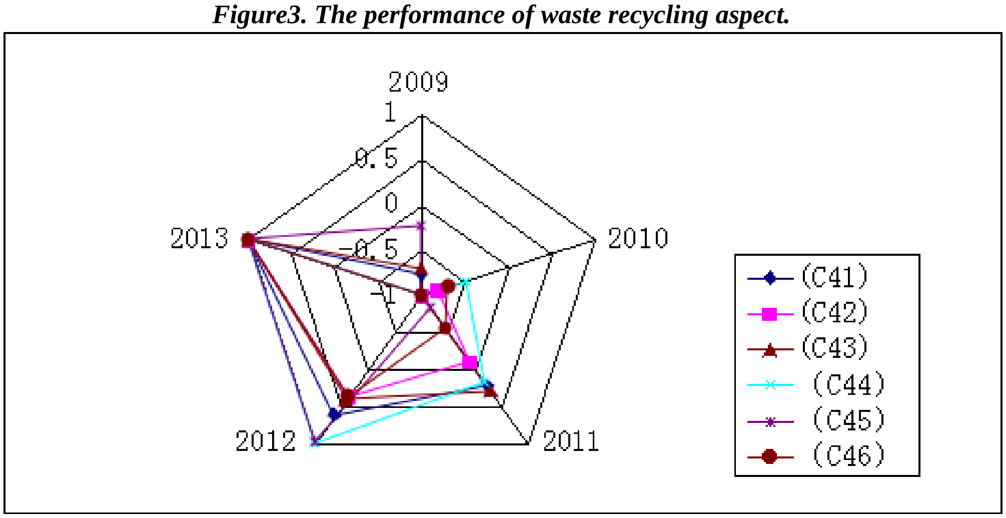

Figure4. The performance of pollutants emission aspect.

ISSN: 2277-9655
Impact Factor: 4.116

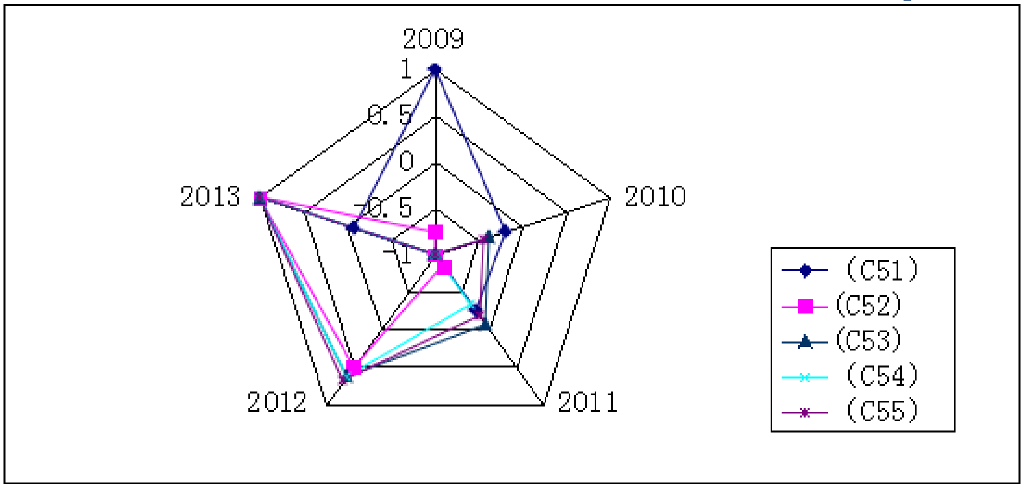

Figure5. The performance of clean production management aspect.

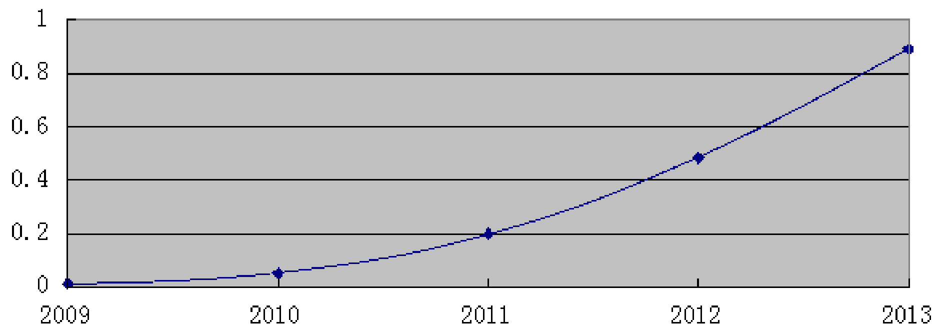

Figure6. Then comprehensive evaluation index of energy saving and emission reduction.

The dynamic evaluation results show that the performance of management benefit, energy consumption, waste recycling, pollutants emission, and clean production management has improved since 2009. And the performance of energy saving and emission reduction gradually improved, which shows that the measures of energy saving and emission reduction have achieved obvious effects. Therefore, this thermal power plant should continue promote energy saving and emission reduction measures.

CONCLUSION

According to related documents and requirements issued by national energy administration, the national development and reform commission and other departments, an evaluation index system has been established from the management benefit, energy consumption, waste recycling, pollutants emission, and clean production management. And then an evaluation model based on the entire-array-polygon indictor model was provided to dynamically evaluate the energy saving and emission reduction performance of thermal power plants. The empirical analysis results showed that the indicators performance of five aspect were improved, and the comprehensive index also gradually improved, the performance of related measures were obvious.

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