

The Fuzzy Mathematical Evaluation of New Energy Power Generation Performance

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Abstract: With the rapid development of new energy industry, there are more and more evaluation researches about it. On the basis of consulting lots of reference, I determine the evaluation system of new energy power generation performance in this paper, and determine the weight of each evaluation index by employing hierarchical comparison method. Using fuzzy mathematical knowledge to establish the fuzzy comprehensive evaluation model of new energy power generation performance, it is divided into 5 levels. The first-level index judgment vector could be obtained by using expert judgment method to judge the second-level index. Grade judgment vector of new energy power generation performance could be obtained through first-level index weight vector. And the levels of new energy power generation performance could be determined based on the maximum principle.

Keywords: Evaluation, fuzzy comprehensiveness, new energy power generation, performance.

1. INTRODUCTION

Since reform and opening up, new energy industry develops rapidly in China. As the development of wind energy, solar energy, biomass power generation, nuclear energy and intelligent electric grid, new energy power is widely used. Government and civilian organizations have invested in new energy construction massively while new energy power ability is increased fleetly. On this background, there are more and more related researches on new energy power generation performance evaluation [1, 5].

2. THE ESTABLISHMENT OF INDEX SYSTEM OF NEW ENERGY POWER GENERATION PERFORMANCE EVALUATION

Based on the field work combined with lots of reference, 17 rating indexes from four aspects of new energy power generation performance evaluation could be determined in this paper [2]. The specific details see Table 1.

3. BRIEF INTRODUCTION OF FUZZY MATHEMATICS COMPREHENSIVE EVALUATION METHOD

Fuzzy mathematics comprehensive evaluation method is one of the most common methods in fuzzy decision problem, which is also a comprehensive evaluation method to the things affected by multiple evaluation indexes based on fuzzy mathematics. The aim is to determine the factor sets and judgments sets of all evaluation indexes by using fuzzy mathematics knowledge system, and structure the grade evaluation matrix, fix the judgement grade, thereby get the overall evaluation [3].

1. Determine the evaluation factor set $P = \{p_1, p_2, \dots, p_n\}$, there are n kinds of evaluation indexes;

2. Determine the grade evaluation set $V = \{v_1, v_2, \dots, v_m\}$, and m is the judgement grade number.

3. Determine the fuzzy evaluation matrix $R = (r_{ij})_{n \times m}$, the basic method can be divided into two steps:

(1) Make a grade judgement $f(p_i)$ ($i = 1, 2, \dots, n$) to all index factors P , you can get a fuzzy mapping f , from P to V , namely

$$f: P \rightarrow F(P), p_i \rightarrow f(p_i) = (r_{i1}, r_{i2}, \dots, r_{im}) \in F(V)$$

(2) You can induce a fuzzy relation $R_f \in F(P \times V)$ from the fuzzy mapping f , namely

$$R_f(p_i, v_j) = f(p_i)(v_j) = r_{ij}, \quad i = 1, 2, \dots, n; \quad j = 1, 2, \dots, m,$$

Thereby the fuzzy evaluation matrix $R = (r_{ij})_{n \times m}$ could be determined (Table 2).

(3) The determination of each evaluation index weight

The geometric average method is used to calculate the weight vector of each evaluation index, the specific process is divided into three steps:

(i) Product each line elements in comparison matrix and get vector α ;

(ii) Square root vector α n times, and vector β ;

(iii) Carry out normalization processing to vector β , and get index weight vector γ .

(4) Consistency check

Table 1. New energy power generation performance evaluation index system.

	First-Level Index	Second-Level Index
New energy power generation performance evaluation index system P	Economic A	Investment cost A1; Operation and maintenance cost A 2; Electricity cost A 3; Fuel cost A 4; Investment recovery period A 5;
	Environment B	CO2 emissions B1; SO2 emissions B2; Noise B3;
	Society C	Social acceptance C 1; Land use C 2; Social benefits C 3; Providing employment C4
	Technology D	Technical efficiency D1; Initial energy ratio D2; Security D3; Maturity D4; Reliability D5

Table 2. 1-9 scale value.

Scale a_{ij}	1	2	3	4	5	6	7	8	9
The comparison between index i and j	The same		slightly strong		strong		Obviously strong		Absolute strong

Consistency check process has three steps:

- (i) Calculate consistency index:

$$CI = \frac{\lambda_{max} - n}{n - 1}, \lambda_{max} = \frac{1}{n} \sum_{i=1}^n \frac{a_{ii}}{r_i}$$

as the largest eigenvalue;

- (ii) Determine random consistency index RI according to evaluation index number n , the specific values are shown in Table 3.
- (iii) Calculate the consistency ratio $CR = \frac{CI}{RI}$, when $CR < 0.10$, pass the consistency check.
- (5) Get the comprehensive evaluation vector $w = \gamma^T R$ by using multiply operation in matrix according to each evaluation index weight and evaluation matrix.

4. THE FUZZY EVALUATION MODEL OF NEW ENERGY POWER GENERATION PERFORMANCE

- (1) Determine the evaluation index factor set of new energy power generation performance

$P = \{p_1, p_2, \dots, p_{17}\}$, and draw the hierarchical structure diagram of evaluation index. The specific details are shown in Fig. (1).

- (2) Determine 17 second-level index grade evaluation set of new energy power generation performance $V = \{v_1, v_2, \dots, v_5\}$, that is, according to certain classification principle, all second-level indexes are divided into 5 evaluation levels (Table 4). At the same time the evaluation results of new energy power generation performance are divided into 5 levels: good, better, general, poor, very poor [4, 6, 7].
- (3) Determine the fuzzy evaluation matrix $R = (r_{ij})_{n \times m}$

The expert judgment method is used to carry out the second-level index grade judgement of new energy power generation [8], and the group includes 10 experts. Thus we could get the following in Fig. (1):

$$R_A = \begin{bmatrix} r_{11}^{(A)} & r_{12}^{(A)} & \dots & r_{15}^{(A)} \\ \dots & \dots & \dots & \dots \\ r_{41}^{(A)} & r_{42}^{(A)} & \dots & r_{45}^{(A)} \end{bmatrix}$$

Table 3. Random consistency index.

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.54

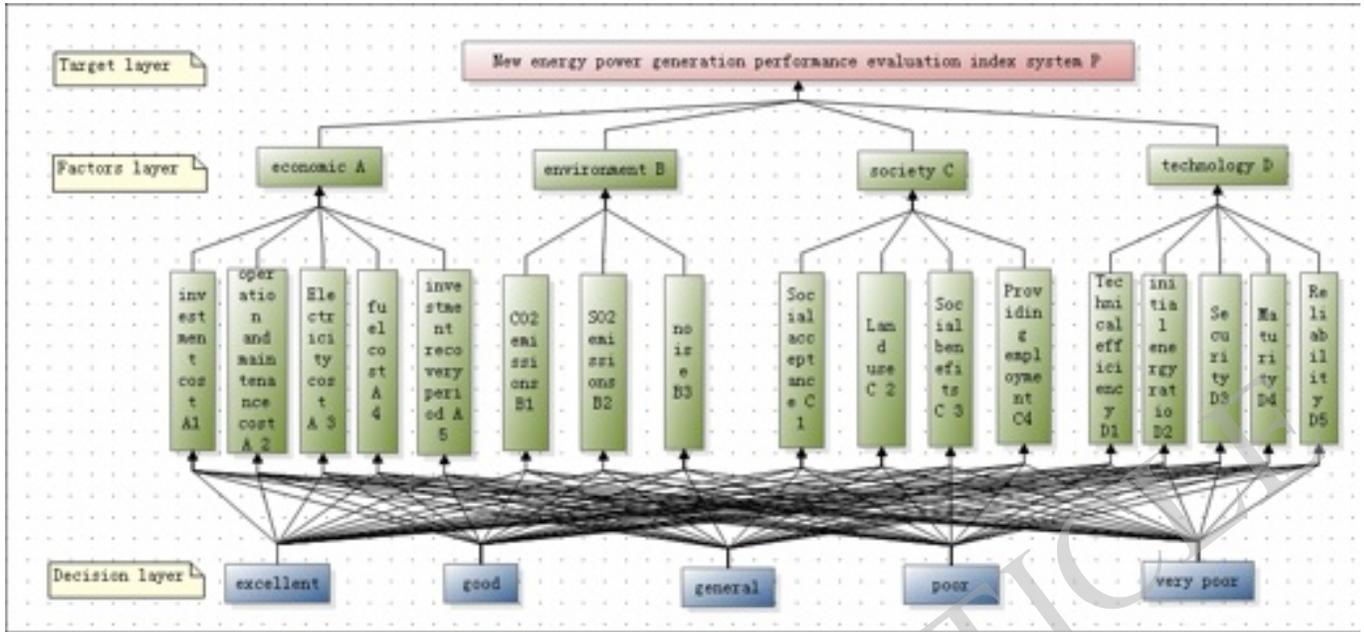


Fig. (1). The hierarchical structure diagram.

and r_{ij} = the number of j level experts /10.

Similarly available: R_B, R_C, R_D .

(4) Determine the evaluation index weights of each level

(i) Select 10 expert to score and get the average value, confirm the influence between each index, thereby determine comparative matrix: A, B, C, D, P;

(ii) Calculate the index weight vector of each level, and get five weight vector: $\gamma_A, \gamma_B, \gamma_C, \gamma_D, \gamma_P$.

(iii) Carry out consistency check.

(5) According to the corresponding second-level index weights, calculate and get five fuzzy evaluation matrix of first-level index:

Table 4. The second-level evaluation index levels of new energy power generation performance.

The Second-Level Index	Level				
Investment cost A1;	low	lower	general	higher	high
Operation and maintenance cost A 2;	low	lower	general	higher	Very high
Electricity cost A 3;	low	lower	general	higher	Very high
Fuel cost A 4;	low	lower	general	higher	Very high
Investment recovery period A 5;	short	shorter	general	longer	Very long
CO2 emissions B1;	little	less	general	more	Very more
SO2 emissions B2;	few	few	general	more	Very more
Noise B3;	small	small	general	larger	Very larger
Social acceptance C 1;	strong	stronger	general	poor	Very poor
Land use C 2;	reasonable	More reasonable	general	poor	Very poor
Social benefits C 3;	high	high	general	poor	Very poor
Providing employment C4;	more	more	general	few	Very few
Technical efficiency D1;	high	high	general	poor	Very poor
Initial energy ratio D2;	high	high	general	poor	Very poor
Security D3;	safe	safer	general	poor	Very poor
Maturity D4;	mature	More mature	general	poor	Very poor
Reliability D5;	reliable	More reliable	general	poor	Very poor

Table 5. The comparison matrix and the test results of first-level index aiming at target layer.

The Target Layer	New Energy Power Generation Performance Evaluation Index System P					The Largest Eigenvalue	The Consistency Ratio
First-Level Index	Economic A	Environment B	Society C	Technology D	Weight		
Economic A	1	1/6	1/2	3	0.1161	4.0777	0.0291
Environment B	6	1	4	9	0.6293		
Society C	2	1/4	1	5	0.2064		
Technology D	1/3	1/9	1/5	1	0.0482		

Table 6. The comparison matrix and the test results of second-level index aiming at first-level economic A.

First-Level Index	Economic A						The Largest Eigenvalue	The Consistency Ratio
Second-Level Index	Investment Cost A1	Operation and Maintenance Cost A 2	Electricity Cost A 3	Fuel Cost A 4	Investment Recovery Period A 5	Weight		
Investment cost A1	1	1/2	1/4	1/5	1/9	0.0458	5.0237	0.0053
Operation and maintenance cost A 2	2	1	1/2	1/3	1/5	0.0864		
Electricity cost A 3	4	2	1	1/2	1/3	0.1573		
Fuel cost A 4	5	3	2	1	1/2	0.2553		
Investment recovery period A 5	9	5	3	2	1	0.4551		

Table 7. The comparison matrix and the test results of second-level index aiming to first-level index environment B.

First-Level Index	Environment B				The Largest Eigenvalue	The Consistency Ratio
Second-Level Index	CO ₂ Emissions B1	SO ₂ Emissions B2	The Noise B3	The Weight		
CO ₂ emissions B1	1	1	8	0.4706	5.0237	0.0053
SO ₂ emissions B2	1	1	8	0.4706		
Noise B3	1/8	1/8	1	0.0588		

Table 8. The comparison matrix and the test results of second-level index aiming at first-level index society C.

First-Level Index	Society C					The Largest Eigenvalue	The Consistency Ratio
Second-Level Index	Social Acceptance C 1	Land Use C 2	Social Benefits C 3	Providing Employment C4	Weight		
Social acceptance C1	1	5	3	2	0.4878	4.1065	0.0399
Land use C2	1/5	1	1/3	1/2	0.0891		
Social benefits C3	1/3	3	1	1/2	0.1753		
Providing employment C4	1/2	2	3	1	0.2479		

$$R_p = \left(\gamma_A^T R_A \quad \gamma_B^T R_B \quad \gamma_C^T R_C \quad \gamma_D^T R_D \right)^T,$$

According to the first-level index weight, get grade evaluation vector of new energy power generation performance:

$$w = \gamma_p^T R_p,$$

Based on the maximum principle, the biggest component of w is the grade of new energy power generation performance.

5. MODEL SOLVING AND ITS APPLICATION

5.1. Model Solving

By visiting the experts, determine the corresponding comparison matrix, the specific results are shown in Tables 5-9.

5.2. Model Application — The Evaluation of a Solar Power Generation Equipment

- (i) Ten experts give the grade evaluation of the second-level evaluation index of a solar power generation equipment [10-13]. The results are shown in Table 10.

Table 9. The comparison matrix and the test results of second-level index aiming at first-level index technology D.

First-Level Index	Technology D						The Largest Eigenvalue	The Consistency Ratio
	Technical Efficiency D1	Initial Energy Ratio D2	Security D3	Maturity D4	Reliability D5	The Weight		
Technical efficiency D1	1	3	1/3	1/6	1/6	0.0701	5.0846	0.0189
Initial energy ratio D2	1/3	1	1/5	1/7	1/8	0.0373		
Security D3	3	5	1	1/2	1/2	0.1869		
Maturity D4	6	7	2	1	1	0.3481		
Reliability D5	6	8	2	1	1	0.3575		

Table 10. The second-level evaluation index grade judgement results of a solar power generation equipment performance.

Second-Level Index	Level				
	3	5	1	1	0
Investment cost A1;	3	5	1	1	0
Operation and maintenance cost A 2;	1	3	5	1	0
Electricity cost A 3;	2	4	4	0	0
Fuel cost A 4;	5	3	2	0	0
Investment recovery period A 5;	0	2	5	2	1
CO2 emissions B1;	0	1	7	1	1
SO2 emissions B2;	0	2	6	2	0
Noise B3;	1	2	4	2	1
Social acceptance C 1;	4	5	1	0	0
Land use C 2;	2	4	3	1	0
Social benefits C 3;	4	3	3	0	0
Providing employment C4;	1	2	4	3	0
Technical efficiency D1;	0	2	6	1	1
Initial energy ratio D2;	1	3	5	1	0
Security D3;	2	3	4	1	0
Maturity D4;	1	3	6	0	0
Reliability D5;	3	2	4	1	0

(ii) Based on data reduction, using the matrix multiplication calculation, we can get the evaluation vector of this solar power generation equipment performance, that is,

$$w = (0.0971 \quad 0.2199 \quad 0.5154 \quad 0.1287 \quad 0.0389)$$

According to the maximum principle, we can get the conclusion that the evaluation level of the solar power generation equipment performance is general.

CONCLUSION

New energy is very important to a country, and its power performance evaluation is particularly significant.

Introducing the fuzzy mathematical evaluation model, considering the four factors including technology, economy, environment and the society, new energy power generation performance is evaluated by this model. It is simple, fair and fast to carry out an evaluation, which also provide theoretical basis for the sustainable development of new energy.

Due to the limited space and limited reading, it may have some defects in establishing the evaluation index system of new energy power generation performance. I hope this paper could inspire readers and promote the development of new energy power generation enterprise.

CONFLICT OF INTEREST

The author confirms that this article content has no conflict of interest.

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