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Study on Feasibility Evaluation of Wind Power Generation Based on Grey-AHP

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Abstract. The paper builds a Grey-AHP model, which combines gray relative analysis method and Analytic Hierarchy Process. Through analysis of the feasibility of wind power, it establishes the feasibility evaluation system of wind power generation. It evaluates the feasibility of wind power in a certain region by Grey-AHP model. Compared with the actual situation, it proves to that the results are credible and reliable, and also proves the applicability and practical value of the Grey-AHP model.

Introduction

Economic development is accelerating in nowadays, and the pace of human consumption of fossil energy has been far faster than the Earth's carrying capacity, and the concepts of sustainable development, green economy and low-carbon economy have become a global trend and fashion. In order to seek greater development and living space, a more active countries in the world look for a greener economic development model.

In recent years, China's demand for electrical energy has been increasing, while 80% of the electrical energy comes from coal power generation, which is very detrimental to our environment green development. In order to seek power industry low-carbon and sustainable development, the development trend of China's wind power, nuclear power, thermal power and other clean energy is unstoppable. As of 2010, China's wind power installed capacity was 44.73GW, surpassing the United States, and rank the first in the world. Total installed capacity of Inner Mongolia Autonomous Region was 13.86GW, leading China's wind power development, followed by Gansu, Hebei, and Liaoning. Wind power has become the important power generation mode.

China's wind power added 18.93 GW in 2010, wind power generation developing rapidly. As the development pace of wind power generation is very fast, there are some problems in wind power project design, construction and operation. Assessment of wind energy projects will help to identify problems timely, to ensure the wind power industry keep healthy and stable development.

Gray-AHP Model

In this paper, firstly, we will use AHP to determine the weights of indicators; secondly, we will use the gray relational analysis to evaluate the sustainability assessment of wind energy projects; thirdly, the correlation analysis method is applied to hierarchical structures, then we will build the evaluation model.

Determine the weight of indicator by using AHP

AHP is proposed by U.S. operations research experts T.L.Saaty in the 1970s, this method is a multi-objective method combined with qualitative and quantitative analysis, decomposing the fuzzy or complex decision problem into component, and the various factors form a hierarchy according to relations of domination, then it can effectively analyze the non-sequence relationship between system-levels of objective criteria, and at the same time, test the reasonableness of the results and finally determine the weight of each factor.

The first step to determine the weight by using AHP is to establish the hierarchy. To begin with, according to the problem characteristics, it will be broken down into numbers of level, usually it contains the target level, main criteria level and sub-criteria level. When indicator of some levels is excessive, it can be further decomposed. Furthermore, construct judgment matrix. It always invite several experts making comparison of every two indicators, and then construct judgment matrix $C = (c_{ij})_{n\times n}$, and the form of it as following: $\begin{pmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \vdots & \vdots & & \vdots \\ c_{n1} & c_{n2} & \cdots & c_{nn} \end{pmatrix}$,among it, c_{ij} represents the relative significance of index i compared to index j.

Consistency test is also very important step. Inconsistency is prone to appear under the multi-stage judgment. Therefore, it is necessary to check its consistency. Use Random consistency ratio CR as a standard. if and only if CR is less than or equal to 0.1, the inconsistency of the matrix is acceptable. Finally, we can get the certain weight. Solve to determine the matrix eigenvalue and eigenvector. The largest eigenvector corresponding the largest eigenvalue is the corresponding index weights, with $W = (W_1, W_2, W_3)$.

The grey relational analysis evaluation

First, make sure the optimal index series. Suppose the system consists of m indicators and n programs, then $X_{ik} = [X_{i1}, X_{i2}, \cdots X_{im}]$,$(i = 1,2,\cdots n; k = 1,2,\cdots m)$ it represents the i-th program consisting of m-series indicators. N programs consisting of the original data matrix are as follows:

$$X = \begin{pmatrix} X_{11} & X_{12} & \cdots & X_{1m} \\ X_{21} & X_{22} & \cdots & X_{2m} \\ \vdots & \vdots & & \vdots \\ X_{n1} & X_{n1} & \cdots & X_{nm} \end{pmatrix}$$

Let $X_{0k} = [x_{01}, x_{02}, \cdots x_{0m}]$ represents the optimal index series. X_{0k} is K-th index in the optimal value of the programs.

Secondly, the indicators are normalized. Indicators tend to have a different dimension, need to be normalized before they can be compared. For different types of data, different methods for standardization are used. For the better indicator of value, equation (1) is used. For the smaller the better indicator for the value of, equation (2) is meet and for the closer the value of a fixed interval [a, b] the better, equation (3) is taken.

$$y_{ik} = (x_{ik} - \min_i x_{ik}) \Big/ (\max_i x_{ik} - \min_i x_{ik}) \tag{1}$$

$$y_{ik} = (\max_i x_{ik} - x_{ik}) \Big/ (\max_i x_{ik} - \min_i x_{ik}) \tag{2}$$

$$y_{ik} = (\max_i \Delta_{ik} - \Delta_{ik}) \Big/ (\max_i \Delta_{ik} - \min_i \Delta_{ik}) \tag{3}$$

$\Delta_{ik} = \max\{x_{ik} - a, b - x_{ik}\}$, y_{ik} indicates the normalized value of x_{ik}, $\min_i x_{ik}$ indicates the k-th of the minimum value in programs, $\max_i x_{ik}$ indicates the k-th maximum value.

Standardization of the matrix is as follows:

$$Y = \begin{pmatrix} Y_{11} & Y_{12} & \cdots & Y_{1m} \\ Y_{21} & Y_{22} & \cdots & Y_{2m} \\ \vdots & \vdots & & \vdots \\ Y_{n1} & Y_{n1} & \cdots & Y_{nm} \end{pmatrix}$$

Then the correlation coefficient is calculated. After standardization of the treatment, $Y_{0k} = [y_{01}, y_{02}, \cdots, y_{0m}]$ is a reference sequence. Use the $Y_{ik} = [Y_{i1}, Y_{i2}, \cdots, Y_{im}]$ of each programs as the number of columns to be compared. Then using the following formula, the correlation coefficient ξ_{ik} of the k-th indicators and indicators of the k-th best correlation in the i-th programs is calculated.

$$\xi_{ik} = \frac{\min_i \min_k |y_{0k} - y_{ik}| + \rho \max_i \max_k |y_{0k} - y_{ik}|}{|y_{0k} - y_{ik}| + \rho \max_i \max_k |y_{0k} - y_{ik}|} \tag{4}$$

Among them, the resolution of a general ρ is from 0 to 5. Coefficient matrix E is as follows:

$$E = \begin{pmatrix} \xi_{11} & \xi_{12} & \cdots & \xi_{1m} \\ \xi_{21} & \xi_{22} & \cdots & \xi_{2m} \\ \vdots & \vdots & & \vdots \\ \xi_{n1} & \xi_{n1} & \cdots & \xi_{nm} \end{pmatrix}$$

Evaluation for different objects, single-level evaluation of the gray and gray multi-level evaluation can be used. $R_i = [r_{i1}, r_{i2}, \cdots, r_{im}], (i = 1, 2, \cdots, n)$ is the result of the i-th program evaluation. The formula is as follows:

$$R_i = \sum_{k=1}^{m} W_i \xi_{ik} \tag{5}$$

After the evaluation of the base layer, the results $R_i = [r_{i1}, r_{i2}, \cdots, r_{im}]$ are acquired. Use the results of this level as a basis of indicator, and repeat the evaluation to the next level until to the top. Finally, according to the size of correlation to determine the pros and cons, a large related degree program is better than a small correlation program.

Hierarchical Grey Evaluation Model for feasibility evaluation for wind power generation

Establish Index system for feasibility evaluation for wind power generation.

According to the fact, we constitute an assessment index system for sustainable capacity in wind power project, mainly about the financial situation of wind power projects, business capabilities, resources conditions, status of enterprises management. Focusing on the above, the main four aspects are discussed and a three-level wind power project sustainability index system is established.

Indicators at all levels of sustainability assess index system in wind power project are as follows:

Table 1.Index systems for feasibility evaluation

	Primary index	Secondary index
Wind Energy Project	financial situation	Financial profitability
		Financial solvency
		Staying power
	business capabilities	The scale of operation
		The level of technology
		Year generating capacity
	resources conditions	Wind velocity
		Soil density
		Groundwater level
		Freezing depth
	status of enterprises management	Reserve of talents
		System sophistication
		Incentive system

Determine Indexes' Weights Determination.

Using the above methods, we determine each level index weight and the results are as follows:

$$W = (0.2134, 0.3128, 0.3009, 0.1729)$$

$$W_1 = (0.0896, 0.0469, 0.0768)$$

$$W_2 = (0.0719, 0.1282, 0.1126)$$

$$W_3 = (0.0933, 0.0542, 0.0662, 0.0873)$$

$$W_4 = (0.0553, 0.0657, 0.0519)$$

Gray Correlation Analysis

Original data. We take a wind farm data from 2006 to 2010 of a certain area, as shown in Table 2:

Table 2. The original data of a certain area

Year	2006	2007	2008	2009	2010
W_{11}	4.32%	4.68%	4.46%	4.96%	4.52%
W_{12}	0.48	0.32	0.38	0.28	0.12
W_{13}	0.28	0.49	0.32	0.28	0.59
W_{21}	58.5	58.5	58.5	58 . 5	58.5
W_{22}	0.39	0.52	0.72	0.79	0.82
W_{23}	59	59.2	59.6	72.9	88.9
W_{31}	0.58	0.51	0.45	0.58	0.62
W_{32}	0.81	0.88	0.78	0.83	0.85
W_{33}	0.78	0.75	0.68	0.77	0.71
W_{34}	0.65	0.68	0.71	0.77	0.68
W_{41}	0.58	0.68	0.66	0.71	0.79
W_{42}	0.92	0.91	0.88	0.94	0.95
W_{43}	0.41	0.44	0.38	0.44	0.58

Then, we determine the optimal index series. According to different data types, we select maximum value or minimum value or interval value respectively and confirm correlation value each year. According to the above methods, normalizing the original data to obtain Correlation coefficient matrix, using Multi-hierarchical Grey Evaluation and Single-hierarchical Grey Evaluation in turn, we can get the results of correlation value each year.

From the results we can find that the development of Wind power in this area can be divided into two distinct phases. The first phase is from 2006 to 2007, Wind power's development is slow. The second phase is from 2008 to 2010,the development of wind power accelerated. The second phase was improved a lot over the first phase. Contacted with the actual situation in the region, the results are credible and reliable.

Summary

Through the establishment of Hierarchical Grey Evaluation Model, this paper made qualitative and quantitative analysis, the results are scientific and concise, the results can make a scientific and reasonable evaluation for feasibility of wind power generation. This can be proven by means of evaluating the feasibility of wind power generation of a certain area in the past 5 years. That illustrated the practical value of the model. So the model can be used for the evaluation for feasibility of wind power generation, it can be the basis and provide support for the management and decision-making departments to formulate measures.

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