Research on Comprehensive Evaluation Method of Technology and Economy of Energy Supply System

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Abstract. This paper focuses on the fuzzy comprehensive evaluation method of multi-energy supply system based on analytic hierarchy process. The main contents include: principles based on scientific, operability, integrity, independence and other indicators, from economics and energy consumption. The aspect determines the evaluation index system, and introduces the analytic hierarchy process to obtain the index weights. On the basis of the analytic hierarchy process, the fuzzy comprehensive evaluation method is introduced to determine the membership function and establish the fuzzy relationship matrix.

1. Introduction
With the increase of China's population and the improvement of people's living standards, users' demand for cold, heat and electricity continues to grow. Energy conservation and environmental protection have become the trend of development in the future. Traditional energy research considers different energy systems independently and lacks an overall system analysis. In order to improve the efficiency of energy system use and enhance the synergy between energy sources, the paper treats the energy of different qualities and tastes such as cold, heat and electricity in the multi-energy supply system, and studies the evaluation methods of multi-energy supply systems. Starting from different quality load requirements, various energy prices and technical information of various equipments, the analytic hierarchy process and fuzzy comprehensive evaluation method are used to solve the evaluation index values of different systems.

2. Evaluation index system
The indicator is the abbreviation of the statistical indicator, which can comprehensively reflect the concept and value of the object feature. It consists of the indicator name and the indicator value, which is the combination and unification of quality and quantity. The Analytic Hierarchy Process (AHP) is a quantitative decision-making method for comprehensive evaluation of multiple indicators proposed by T.L. Saaty, a scholar in American operations research in the 1970s. By expressing a complex problem as an ordered hierarchical hierarchy, the initial weights of the evaluation indicators in the same level are determined. The AHP quantifies the qualitative factors, which reduces the subjective influence to a certain extent and makes the assessment more scientific. Based on the advantages of the analytic hierarchy process, this paper introduces the idea of analytic hierarchy process in the comprehensive evaluation of the multi-energy supply system, and stratifies the influencing factors to obtain a structured and hierarchical indicator system.
The evaluation architecture generally consists of three layers, which are the target layer, the criteria layer, and the indicator layer. The target layer is to comprehensively consider various indicators; the criterion layer is to evaluate the underlying indicators, so that relevant personnel can understand the calculation; the indicator layer is the most direct and most important factor affecting the technical and economic evaluation of the multi-energy supply system, and these indicators are the entire evaluation basis. The hierarchical structure model is shown in Figure 1.

![Hierarchy chart](image)

**Figure 1. Hierarchy chart**

3. Hierarchical Membership Function and Fuzzy Comprehensive Evaluation Based on Analytic Hierarchy Process

The indicators are designed according to their respective meanings and purposes. Different indicators, meanings and design purposes are different. Therefore, it is necessary to use the means of standardization to replace the qualitatively described indicators with standardized quantitative data when scoring the indicators.

There are many ways to determine the scoring criteria of the indicators. In the fuzzy comprehensive evaluation method, most of them adopt the method of fuzzy membership. The so-called fuzzy membership method is to describe the degree of difference in factors, not only simply "belonging" or "not belonging", but by the degree of membership of the factor. The method used in this paper is the membership function determination method.

There are many kinds of membership functions. Common distribution functions such as normal distribution, trapezoidal distribution, and triangular distribution can be used as membership functions to express some fuzzy sets. According to the characteristics of the multi-energy supply system, in the evaluation method of this paper, the trapezoidal distribution membership function is used to determine the membership degree of each index, as shown in Figure 2:

![Membership function](image)

**Figure 2. Membership function**
The x of Fig. 2 represents the score of the factor under consideration, and $\mu(x)$ represents the position of x in a certain level, the range is between $[0, 1]$, that is, the degree of membership of x to a certain level of a decision comment.

$$\mu(x) = \begin{cases} \frac{x-a}{b-a} & x \in [a,b) \\ 1 & x \in [b,c] \\ \frac{x-d}{c-d} & x \in (c,d] \\ 0 & x \in R - (a,d) \end{cases}$$

According to the meaning of the fuzzy evaluation of the above evaluation indicators, according to formula (1), the technical and economic comprehensive evaluation scores of the multi-energy supply system are fuzzified.

The fuzzy relation matrix is obtained by fuzzy evaluation of each evaluation index:

$$R = (r_{ij})_{n \times m} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix}$$

In the formula, $r_{ij}$ is the membership of the jth comment of the index set U belonging to the jth comment of the comment set V; $i=1,2,\cdots,n; j=1,2,\cdots,m$.

It is mentioned in this paper that the evaluation model is divided into several levels, so multi-level fuzzy synthesis is required. Let n sub-factors of the i-th layer form a set of factors, and the fuzzy synthesis operation of their fuzzy comment matrix $R_i$ is:

$$B_i = w_i \circ R_i = (w_{i1}, w_{i2}, \cdots, w_{in}) \circ \begin{bmatrix} r_{11}^{(i)} & r_{12}^{(i)} & \cdots & r_{1m}^{(i)} \\ r_{21}^{(i)} & r_{22}^{(i)} & \cdots & r_{2m}^{(i)} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1}^{(i)} & r_{n2}^{(i)} & \cdots & r_{nm}^{(i)} \end{bmatrix} = (b_{i1}, b_{i2}, \cdots, b_{im})$$

In the formula, $\circ$ is a fuzzy operator. In the fuzzy operation, there are generally several kinds of arithmetic operators: main factor prominent type, comprehensive constraint type, and weighted average type.

Due to the comprehensive consideration of the impact of different indicators on the assessment, a multi-energy supply system technical and economic comprehensive assessment can be recommended to use the weighted average model for fuzzy synthesis. Each evaluation indicator has a certain contribution to the evaluation target according to its weight. The calculation process is:
\[ b_j = \sum_{i=1}^{n} \omega_i r_{ij} \]  

Where \( \omega_i \) is the weight vector of the factor set, and the fuzzy vector \( B_i = (b_{i1}, b_{i2}, \ldots, b_{im}) \) obtained by the fuzzy synthesis operation is a fuzzy comment vector corresponding to the evaluation index of the first layer of the factor set.

The fuzzy integrated operation is performed layer by layer in turn, and finally the multi-energy supply system technical and economic comprehensive evaluation fuzzy vector \( B = (b_1, b_2, \ldots, b_m) \) can be obtained. Based on the judgment set and the principle of maximum membership, the state level of the system and the corresponding adjustment decisions can be determined.

4. Indicator scoring criteria and their fuzzification vectors

The evaluation levels are generally classified into good (Class I), better (Level II), general (Level III), poor (Level IV), and very poor (V). By consulting the relevant literature, the scoring criteria for the economic indicators of the multi-energy supply system are obtained, as shown in Table 1:

| Evaluation level | Scoring criteria | Score |
|------------------|------------------|-------|
| lower I          | Investment cost (ten thousand yuan) | Program annual operating cost (ten thousand yuan) | Maintenance costs (ten thousand yuan) |
| lower II         | 300–450          | 125   | 5–6.5  | 62.5–87.5 |
| general III      | 450–600          | 140–155 | 6.5–8  | 37.5–62.5 |
| expensive IV     | 600–750          | 155–170 | 8–9.5  | 12.5–37.5 |
| more expensive V | >750             | >170  | >9.5   | 0–12.5  |

According to the parameter values of the energy supply system, the scoring criteria are set, and the trapezoidal membership function is used to draw the energy supply system to comprehensively evaluate the hierarchical membership function graph, as shown in Figure 3:

For example, if the benefit score of the energy supply system is 97, the fuzzification vector is \( (1, 0, 0, 0, 0) \); if the score is 88, the fuzzy calculation is performed according to the trapezoidal membership function parameters, which belongs to the membership degree of the I level. 

\[ \mu = \frac{81.25–88}{81.25–93.75} = 0.54 \]
belonging to class II membership \( \mu_z = \frac{88 - 93.75}{81.25 - 93.75} = 0.46 \), then the russification vector is \((0.54, 0.46, 0, 0, 0)\).

5. Fuzzy Comprehensive Evaluation of Energy Supply System Based on Analytic Hierarchy Process

According to the technical and economic value of multi-energy supply system and related literature theory analysis, this paper quantitatively describes its importance. The fuzzy comprehensive evaluation of the power supply system and the heating system in terms of economy and energy consumption are respectively carried out, and then the comprehensive evaluation results of each energy supply system are obtained through normalization processing. The specific operation analysis is as follows:

(A) power supply system

The results of the fuzzy comprehensive assessment of the power supply system in terms of economy and energy consumption are as follows:

(a) Economic fuzzy comprehensive assessment

\[
\begin{bmatrix}
R_{\text{economy}} = 0.7732 & 0.1392 & 0.0877 \\
0.4934 & 0.3108 & 0.1958 \\
0 & 0 & 1
\end{bmatrix} \cdot \begin{bmatrix}
0 & 0 & 0.54 & 0.46 & 0 \\
0.94 & 0.06 & 0 & 0 \\
0 & 1 & 0 & 0
\end{bmatrix}
\]

The above calculation is the fuzzy comprehensive evaluation result of the economic aspect of the power supply system: the “very low” membership degree is 0, the “lower” membership degree is 13.08%, and the “general” membership degree is 51.36%. The “higher” membership degree is 35.57%, and the “very high” membership degree is zero. According to the principle of maximum membership degree, in the fuzzy comprehensive evaluation of the economic level of the power supply system, 0.5136 is the largest among the five membership degrees, and the evaluation result is “general”, indicating that the economic cost of the power supply system is “general”.

(b) Fuzzy comprehensive assessment of energy consumption

\[
\begin{bmatrix}
R_{\text{energy consumption}} = 0.4934 & 0.3108 & 0.1958 \\
0.4934 & 0.3108 & 0.1958 \\
0 & 0 & 1
\end{bmatrix} \cdot \begin{bmatrix}
0 & 0 & 0.62 & 0.38 & 0 \\
0 & 0 & 0.38 & 0.62 & 0 \\
0 & 1 & 0 & 0
\end{bmatrix}
\]

The above calculation is the fuzzy comprehensive evaluation result of the energy consumption of the power supply system: the “very good” membership degree is 0, the “good” membership degree is 0, the “general” membership degree is 61.98%, and the “poor” membership is the degree is 38.02%, and the degree of membership of "very poor" is zero. According to the principle of maximum membership degree, in the fuzzy comprehensive evaluation of the energy consumption level of the power supply system, 0.6198 is the largest among the five membership degrees, and the evaluation result is “general”, indicating that the energy consumption of the power supply system is “general”.

(B) Heating system

The fuzzy comprehensive assessment results of the heating system in terms of economy, energy consumption and environment are as follows:

(a) Economic fuzzy comprehensive assessment
The above calculation is the fuzzy comprehensive evaluation result of the economic aspect of the heating system: the “very low” membership degree is 10.82%, the “lower” membership degree is 75.27%, and the “general” membership degree is 6.403%, “higher”. The membership degree is 7.52%, and the “very high” membership is zero. According to the principle of maximum membership degree, in the fuzzy comprehensive evaluation of the economic level of the heating system, 0.7527 is the largest among the five membership degrees, and the evaluation result is “lower”, indicating that the economic cost of the heating system is “lower”.

(b) Fuzzy comprehensive assessment of energy consumption

The above calculation is the fuzzy comprehensive evaluation result of the energy consumption of the heating (cold) system: the “very good” membership degree is 0, the “better” membership degree is 9.32%, and the “general” membership degree is 21.76%, “The poorer membership rate is 58.07%, and the "very poor" membership degree is 10.85%. According to the principle of maximum membership degree, in the fuzzy comprehensive evaluation of the energy consumption hierarchy of the heating system, 0.5807 is the largest among the five membership degrees, and the evaluation result is “poor”, indicating that the energy consumption of the heating system is “poor”.

6. Summary

This paper focuses on the comprehensive evaluation method of multi-energy supply system technology economy, establishes a comprehensive evaluation model of multi-energy supply system, and uses the analytic hierarchy process to objectively determine the weight of each index, and on this basis, introduces fuzzy comprehensive evaluation method. Using the principle of fuzzy linear transformation and the principle of maximum membership degree, comprehensive consideration of various factors, so as to obtain a correct and comprehensive evaluation results.

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