Comprehensive Evaluation of Air Conditioning Cold/Heat Source System Based on Fuzzy Mathematics Theory

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Keywords: Air Conditioning Cold/Heat Source Systems, Fuzzy Mathematics Theory, Fuzzy Comprehensive Evaluation

Abstract. This article use fuzzy comprehensive evaluation to quantitative analysis each factor which effect the selection of air conditioning cold/heat source systems. Meanwhile, offer a reasonable and feasible method to air conditioning cold/heat source system selection through a concrete example.

Introduction

There are many effect factors to air conditioning system selection, so its hard to make a reasonable evaluation to an air conditioning cold/heat source system. At present, it mainly rely on experts judgement which has its boundedness. First, the accuracy is based on the experts' structure of knowledge and practical experience; second, its has a strong subjectivity; the most important is that the expert review will take a long time and much money and hard to extend in medium and small project. Every year, medium and small projects take a large rate in china, so find a reasonable evaluation methodology for the air conditioning cold/heat source system has important significance to reduce air conditioning system energy consumption and standard air conditioning industry.

Fuzzy Mathematics Theory

Fuzzy Mathematics Theory

Fuzzy mathematics theory was put forward by American famous computer and control experts professor L.A.Zadeh in 1965[1]. Fuzzy mathematics is a mathematic theory and method to research and dispose fuzziness phenomenon, people use concept to judge, evaluate, inference, decision and control qualitative process which can use fuzzy mathematics theory turn it to quantitative process. This article use this method to quantitative treat each factor which effect the air conditioning cold/heat source system selection, and use fuzzy comprehensive evaluation[2] to sorting the research object in fuzzy environment or fuzzy system, to pick out the optimal objects from decision discourse according to some fuzzy constraints.

Procedure of Fuzzy Comprehensive Evaluation

Fuzzy comprehensive evaluation is a kind of method which use the theory of fuzzy relation synthesis and use many factors to comprehensive evaluation be-evaluated objects membership grade condition, its specific steps are:

1) Determine be-evaluated objects factor theory field U, $U=(u_1,u_2,u_3,\ldots u_n)$;

2) Determine comment grade theory field V, $V=(v_1,v_2,v_2,\cdots v_n)$. Usually, comment grade V =(highest, higher, high, …, low, lower, lowest);

3) Single factor evaluation, build fuzzy relation matrix R:

$$R=\begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{pmatrix} \qquad 0 \leq r_{ij} \leq 1 \qquad (1\text{-}1)$$

r_{ij} is the subjection relation for factor u_i to grade v_i;

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4) Determine judging factor weight vector $A=(a_1,a_2,a_3,\cdots a_n)$, A is the subjection relation for the factors of U and be-evaluated objects, which depend on the vantage point of people when make fuzzy comprehensive evaluation.

5) Choose co mposition operator $B=(b_1,b_2,b_3,\cdots b_m)$, combine A and R to get

$$B = AOR = (a_1,a_2,\cdots,a_n)O\begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{pmatrix} \quad (1\text{-}2)$$

$$b_j = (a_1 \cdot r_{1j}) + (a_2 \cdot r_{2j}) + \cdots + (a_n \cdot r_{nj}) \quad (1\text{-}3)$$

among it, j=1,2, $\cdots$,m

6) Choose an optimal results of b_j according to the fuzzy constraints.

Use Fuzzy Mathematics Theory to Analysis a Case of Air Conditioning Cold/Heat Source System Selection

This article use a case of air conditioning cold/heat source system selection for example, use fuzzy mathematics theory to finalisation the air conditioning cold/heat source system of the project.

Project profile

This example is an air conditioning project for a cosmetic medical organization, and only need to design air conditioning system on work area and inpatient department for the ask of the first part. Overall floorage is 5300m^2, among them, air conditioning use area is 3800m^2, total air conditioning cooling load is 490KW, heating load is 300KW. According to its cold and hot load, intends to use three cold and heat source scheme as follows table 1.

table 1

Scheme	Scheme one	Scheme two	Scheme three
Cold and heat source shape	Water Source Heat Pump	Air-cooled heat pump module and Electric booster heater	Water cooled screw unit and Boiler
Total refrigerating capacity/heating capacity(KW)	515/576	520/552	485
The number of machine	1	4	1
Total refrigerating power (KW)	109	260	130
Total heating power (KW)	134	287	
Remarks			Choose a 300,000 kilocalorie boiler for heating in winter

The choose of evaluation index for air conditioning cold/heat source system

There are many influencing factors for the choose of air conditioning cold/heat source system, which among quantitative factors and qualitative factors, the completeness and rationality is the premise to judge the quality of air conditioning cold/heat source system. This article comprehensive evaluation it from first cost u_1, year operating cost u_2, service life of air conditioning cold/heat source system u_3, years costs of operation and maintenance u_4, life cycle cost u_5, operational stability u_6, construction conditions and construction period u_7, environment-protected and energy-saving character u_8. Among them, u_1, u_2, u_3, u_4 are quantitative factors while u_5, u_6, u_7, u_8 are qualitative factors.

Determine index of quantitative assessment

1) Determine first cost u_1

This article only take cold and heat source system cost as central air conditioning cold/heat source system's first cost.

2) Determine year operating cost u_2

Year operating cost is calculate by the actually cooling and heating period of the project city and the price of electricity and gas. In this article, cooling and heating period all design as120 days, 8 hours a day, electricity price is 1.2 yuan per kwh, gas price is 2.5 yuan per m^3.

3) Determine service life of air conditioning cold/heat source system u_3, years costs of operation and maintenance u_4

Service life of air conditioning cold/heat source system and years costs of operation and maintenance are determined by the recommendation of handbooks[3][4] and manufacturers data. Years costs of operation and maintenance is calculate as the average annual cost of a 12-years-service life system (minor repair when the refrigeration compressor runs 700-1000 hours, medium repair when it runs 2500-3000 hours).

4) Determine life cycle cost (LCC) u_5

LCC is a response about first cost and year operating cost, and is an important index to overall consideration first cost and operating cost[5].

Each quantitative evaluation index is shown in the following table 2

table 2

Quantitative evaluation index	Scheme one	Scheme two	Scheme three
First cost u_1(ten thousand yuan)	68	45.1	36.5
Year operating cost u_2(ten thousand yuan)	28	63	23
Service life of air conditioning cold/heat source system u_3(year)	17	15	20
Years costs of operation and maintenance u_4(ten thousand yuan)	1.5	0.8	1.0
Life cycle cost (LCC) u_5	232.5	401.0	165.9

Determine qualitative evaluation index

1) Determine operational stability u_6

Water source heat pump and air-cooled module unit use "free" energy from groundwater or air, while water cooled screw unit and boiler rely on cooling tower to discharge heat of condensation in summer and gas-heating in winter. Groundwater temperature remain stable below a certain depth, while air temperature and relative humidity change largely with season, which make the performance stability of air-cooled module and water cooled screw unit not as good as water source heat pump. At winter heating period, boiler heating is stabiler than air-cooled module. For this reason, operational stability of each scheme is like follow. Scheme one is "Good", scheme two is "Bad", and scheme three is "Common".

2) Determine construction conditions and construction period u_7

Consider many uncertain factors in reality project, this article overall consider construction period as qualitative factors. Water source heat pump is great difficulty because it need to dig a well, water cooled screw unit and boiler need install cooling tower and boiler. So, the construction conditions and construction period is as follow. Scheme one is "Long", scheme two is " Short", and scheme three is "Common".

3) Determine environment-protected and energy-saving character u_8

Heat absorb and heat release of water source heat pump system are underground, it will cause certain thermal pollution to underground environment for long run. While air-cooled heat pump module absorb and release heat to air and will cause local environment cold or heat pollution, water cooled screw unit and boiler unit set waste heat and humidity to air in summer, and set gaseous pollutant in winter. According to environment evaluation index to get the evaluation result as: cheme one is "Good", scheme two is " Bad", and scheme three is "Common".

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Determine quantitative membership degree

We choose the maximum v_{ij} and minimum v_{ij} as the up and down limit of this article's quantitative membership degree[2]. Each membership degree equation is as follow.

For the objective which is optimal when the number larger.

$$r_{ij} = \frac{v_{ij}}{\max(v_{ij})} \tag{2-1}$$

For the objective which is optimal when the number smaller.

$$r_{ij} = 1 - \frac{\min(v_{ij})}{v_{ij}} \tag{2-2}$$

Among the equation, r_{ij} —— The number i evaluate object quantitative membership degree of air conditioning cold/heat source system solutions j.

Determine qualitative membership degree

According to section 2.4 and expert evaluation method, we can make sure the qualitative membership degree for those cannot use function of quantitative membership degree. This article use 5 grade to contrast the Strengths and weaknesses of each object. The 5 grade are: better, good, common, bad, worse.The interval of such grade is [0,1]. Expert evaluation method is N experts quantitative evaluation according to themselves cognition to each qualitative index and take its arithmetic mean value. The equation is:

$$r_{ij} = \frac{\sum x_{kij}}{n} \tag{2-3}$$

Among the equation, x_{kij} —— The number N expert's quantitative evaluation value to number j scheme's number i qualitative evaluation index. The larger r_{ij} is , the object is more optimal.

According to quantitative and qualitative membership degree evaluational principle, we can get each scheme's membership degree of different influencing factors as follow table 3.

Table 3

Quantitative index	Scheme one	Scheme two	Scheme three
First cost u_1(ten thousand yuan)	0	0.34	0.46
Year operating cost u_2(ten thousand yuan)	0.56	0	0.63
Service life of air conditioning cold/heat source system u_3(year)	0.85	0.75	1
Years costs of operation and maintenance u_4(ten thousand yuan)	0	0.47	0.33
Life cycle cost (LCC) u_5	0.42	0	0.59
Operational stability u_6	0.84	0.33	0.62
Construction conditions and construction period u_7	0.2	0.78	0.6
Environment-protected and energy-saving character u_8	0.84	0.62	0.35
System feasibility u_9	0.22	0.8	0.58

Determine weight vector A

The certainty principle of weight vector A[2] is adopt to experts and building side evaluation method, and use equation 2-3 to calculate. According to equation 2-3 to calculate weight vector A:

$A = (a_1、 a_2、 a_3、 a_4、 a_5、 a_6、 a_7、 a_8)$

A=(0.3、0.2、0.1、0.1、0.05、0.05、0.1、0.1)

Evaluation result

Set evaluation synthetic operator as B, fuzzy relation matrix is

$$R=\begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{pmatrix}=\begin{bmatrix} 0 & 0.34 & 0.46 \\ 0.56 & 0 & 0.63 \\ 0.85 & 0.75 & 1 \\ 0 & 0.47 & 0.33 \\ 0.42 & 0 & 0.59 \\ 0.84 & 0.33 & 0.62 \\ 0.2 & 0.78 & 0.6 \\ 0.84 & 0.62 & 0.35 \end{bmatrix},$$

Then, $B=[b_1,\ b_2,\ b_3]=A*R=[a_1、a_2、a_3、a_4、a_5、a_6、a_7、a_8]*\begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{pmatrix}=[0.364, 0.380, 0.553]$

From the evaluation result can see that $b_3 > b_2 > b_1$, which can intuitive get that scheme three is better than scheme two, scheme two is better than scheme one. So advice building side choose scheme three as final project.

Conclusion

Use fuzzy mathematics theory to evaluate air conditioning cold/heat source system can not only make the evaluation result more visual but can also fully reflect the influence degree to the system of each factors. This article analysis a to give a concrete example feasible method to the selection of air conditioning cold/heat sources system design.

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