INDEX SYSTEM OF GROUNDWATER SOURCE HEAT PUMP SYSTEM IN FEASIBILITY

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Abstract: The famous methods of systems engineering, Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE), are used in this paper. And the index system of Groundwater source heat pump (GWSHP) system in feasibility is established, which is composed of four layers: objective (level A), criteria (level B), index (level C), and sub-index (level D). A comprehensive assessment of GWSHP system is made based on some key factors, such as, hydrogeology condition, air-conditioning system load characteristic, groundwater injection, and design of heat source wells. Finally, the index system of GWSHP system in feasibility is validated by a practical project. The paper supplies references to the designers and managers of the GWSHP system, especially in choice and design.

Key Words: ***groundwater source heat pump system, index system, Analytic Hierarchy Process (AHP), Fuzzy Comprehensive Evaluation (FCE), practical project assessment***

1 INTRODUCTION

In recent years, groundwater source heat pump (GWSHP) system is used widely in China, which is highly valued. In the process of using GWSHP system, people pay much attention to energy conservation, but forget its applicability. This leads to use GWSHP system blindly, and some problems appear in design and application of system, such as, insufficient water in production wells, injecting ability depressing. Finally, the system is low-effective in operation, even not working normal. However, the GWSHP system is a complex and multi-links system, whose influencing factors are complicated, involving hydrogeology condition, air-conditioning load characteristic, groundwater recharge, heat source well craft and technology, and so on.

Therefore, Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) are used, which are famous methods in systems engineering. In this paper, the index system of GWSHP system in feasibility is established to supply references to the designers and managers of the GWSHP system, especially in choice and design.

2 THE INDEX SYSTEM FRAME

AHP-Fuzzy Comprehensive Evaluation is that AHP is used to confirm the weighing of each index, and the feasibility of the GWSHP system is evaluated through FCE (Xu Shubo 1996 and Wu Bingjian 1994). The index system of GWSHP system in feasibility is composed of four levels: objective (level A), criteria (level B), index (level C), and sub-index (level D), as shown in Figure1. The objective level (A) is a comprehensive evaluation, combining qualitative analysis with quantitative one. There are three main criteria in the second level including technical effect (B1), environmental effect (B2) and economical effect (B3). Many key factors appearing in design and application are in the third level (C), and the level of sub-index (D) specifies those key factors mentioned in level C.

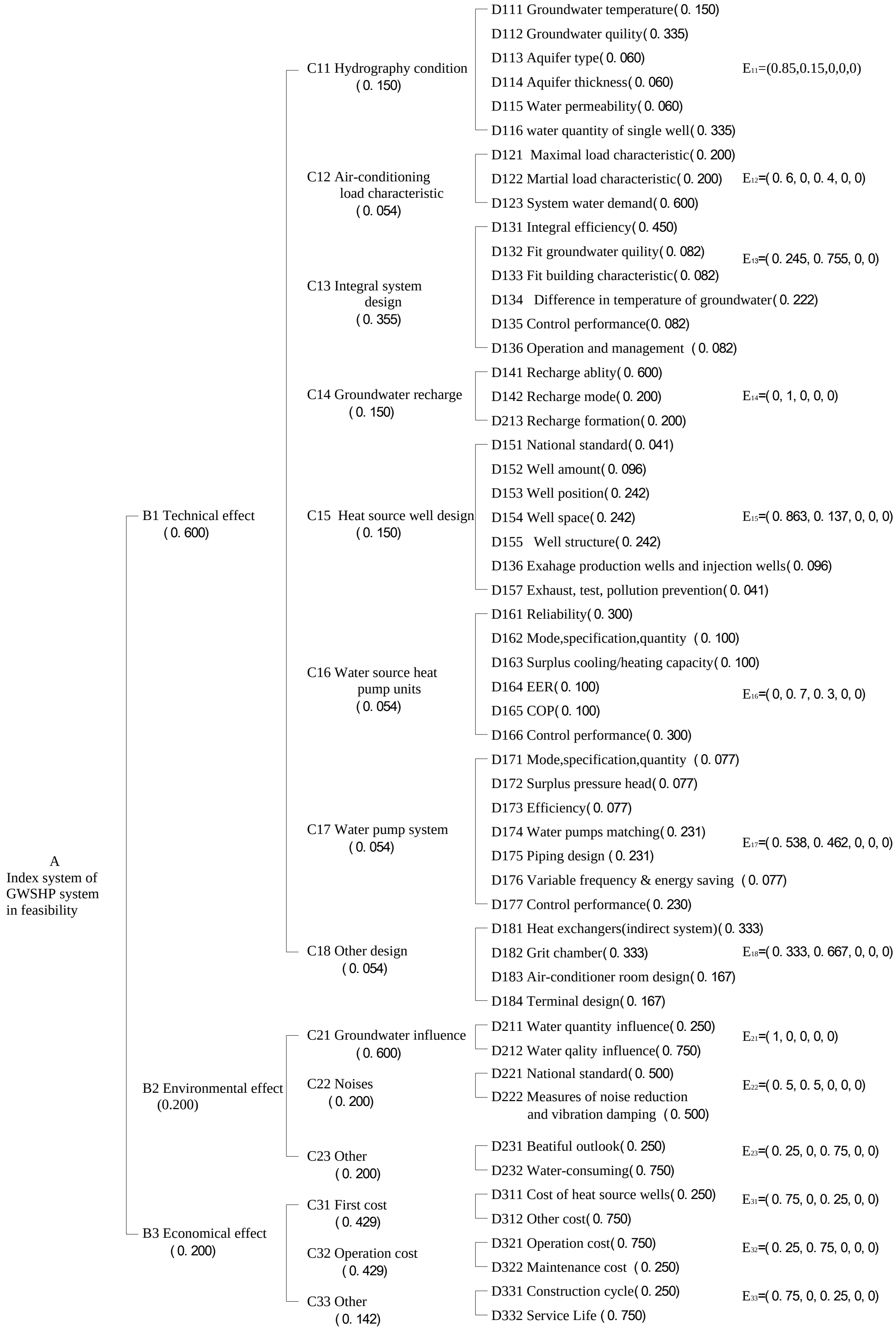

Figure 1: The Frame Of Index System

2.1 Hydrography condition (C11)

The hydrography condition is the most direct influence in technical effect (B1), whose weighing is maximal in the level of criteria (B). The hydrogeology condition is the key factor in GWSHP system, which relates to pumping & recharging ability, disposal plan for groundwater, heat source well craft and technology, and system design. And it also affects the applicability of the GWSHP system directly. The groundwater temperature (D111) is the primary factor in index of hydrography condition, and affects the efficiency of GWSHP system. The groundwater temperature is different in different region, for example, the groundwater temperature is 14~20℃ in Beijing, but 8~10℃ in Harbin. In general, the best temperature for GSWHP unit is about 20℃ (Geng Jian et al. 2003). And the groundwater temperature is generally higher 1~2℃ than the local air temperature. The index of groundwater quality (D112) is the secondary factor to affect the efficiency of GWSHP system, which determines the complexity of water disposal. When the groundwater quality is below standard, measures should be taken. In addition, the aquifer type (D113), aquifer thickness (D114), water permeability (D115) and water quantity of single well (D116) are the key factors for GWSHP system.

2.2 Air-conditioning load characteristic (C12)

Another important influence factor of GWSHP system is air-conditioning load characteristic. The air-conditioning load is not only relates to heat pump units, water pumps, and terminal units, but also the strategy of system operation. If the heat between gained and lost cannot balance, the auxiliary apparatus for heating or refrigeration must be set. Designers should calculate dynamic cool/heat load according to the character of buildings, not only in the design day of winter or summer, but also in one year. The method of estimating load index should be given up. This index level is composed of three sub-index, maximal load characteristic (D121), partial load characteristic (D122) and system water demand (D123).

2.3 Groundwater recharge (C14)

The precondition of adopting GWSHP system is that users only utilize heat of groundwater, and not destroy the groundwater resource and environment. Therefore, it is the prerequisite that groundwater is recharged into underground after used. This index is evaluated from three sub-index, recharge ability (D141), recharge mode (D142) and recharge formation (D143). Any formation or mode of well has its respective characteristic, and it is not good to absolutize it in any time. Users can select the appropriate formation or mode, according to actual condition.

2.4 Heat Source Well Design (C15)

For the GWSHP system, the heat source well is the most difficult and costly part. In the actual projects, although the designers and users are unable to control or change hydrogeology condition of the project, they could design and construct the heat source well scientifically to improve the efficiency and reliability of GWSHP system.

With the seven sub-index (in Fig.1) of this index layer, well position (D153) and well space (D154) should be paid particular attention. To prevent groundwater from being polluted by sewage is the primary job for well position design. Meanwhile, the distance between well and building (or wiring, cables) should be regarded, as well as beauty of project area. The heat source wells are often put around buildings so that the production wells and injection wells are not too close to each other. The problem of “heat short-circuiting” should be considered during designing well space, and the actual experience has shown that the well distance is about 100 m for good permeability coefficient, and more than 50 m for bad permeability coefficient (Xue Yuwei 2003).

2.5 Other index

The GWSHP should be considered as a integral system (C13) to enhance the system comprehensive performance coefficient. The large temperature difference (D134) can not only reduce the extraction volume of groundwater, which is benefit for groundwater recharge and energy saving of water pumps, but also can save the first cost of heat source wells and pipelines.

During the choice of water pumps and heat pump units, it is allowable and necessary to increase the design capacity properly in actual projects. Usually, the surplus cooling /heat capacity of the heat pump units (D163) should not exceed 5%-10% of the maximal load of the whole building, and the surplus pressure head of water pumps (D172) is about1-2m (Cao Qi 2005). In GWSHP system, if there are heat exchangers and grit chamber, it is more complex than the general air-conditioning system. The operation of complex GWSHP system is not only affected by heat pump units, but also affected by many components of the groundwater heat exchanger system. Therefore, the water pumps matching (D174) is more important in GWSHP system. It not only affects the power consumption of the system, but also relates to the stability of system operation, especially the matching between deep-well pump and circulation pump.

Suitable design of heat exchanger (D181) and grit chamber (D182) is important. In actual projects, heat exchangers and grit chamber are widespread, but they make the system more complex. Designers should evaluate comprehensively from the aspects of the difference in temperature of the two sides of the heat exchanger, the water properties of the grit chamber, and the effect of the underground water.

Table 1; The Design Information Of Practical Project

Building Area	87948 ㎡	**Air-conditioning Area**	About 70000㎡
Cooling Load	64 W/㎡	**Heat Load**	51.8 W/㎡
Heat Source Well	4 wells (2 production wells, 2 injection wells, exchange); rate: 200 m^3/h; well spacing:120m		
Heat Pump Unit	Household-type water source heat pump		
Primary Circulating Pump	3 pumps; constant flow（200 m^3/h，58 m）		
Air-conditioning Circulating Pump	6 pumps; variable frequency（180 m^3/h，38 m）		
Deep Well Pump	6 pumps; constant flow（200 m^3/h，58 m）		
Heat Exchanger	4 heat exchangers; in/out water temperature： 14/24℃(summer, primary side), 32/18℃ (summer, secondary side); 14/8℃(winter, primary side)、6/12℃（winter, primary side）		
System Cost	RMB 15,500,000（RMB 176.27/㎡）; heat source costs: RMB 3,540,000， 22.8%		
Operation Cost	RMB 6 /(㎡·period) (summer)， about RMB 16 /(㎡·period) (winter)		

3 PRACTIAL PROJECT

To test the credibility of the index system of GWSHP system in feasibility, which has been described above, a GWSHP project of a high-grade residential building in Beijing is studied and evaluated. The information of this project design is given in table 1, the schematic diagram and the heat well position are given in Figure 2 and 3.

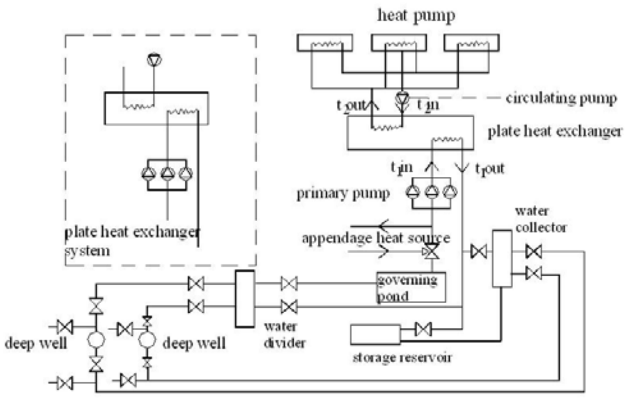

Figure 2: Principle chart of GWSHP system

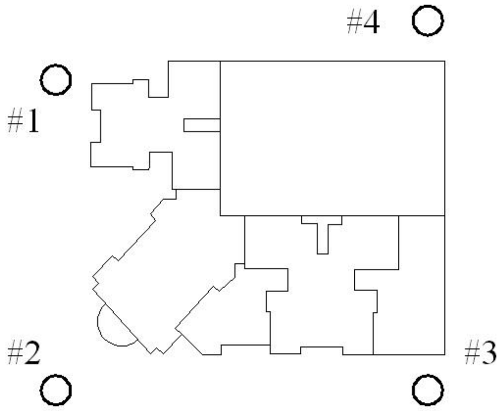

Figure 3: The heat source wells layout

The data of index weighting for this case is given in Figure1. According to the index weighting and evaluation matrix (as shown in Fig.1), the total evaluation matrix can be calculated.

$$E = (0.518 \quad 0.411 \quad 0.081 \quad 0 \quad 0) \qquad (1)$$

According to the principle of maximum degree of membership, the evaluation of this case is excellent; and the comprehensive score is 88.54.In fact, the system has been put into operation since 2002, its operation has been in good condition all the time, and the groundwater recharge is also normal. So this practical project verifies the credibility of the index system.

4 CONCLUSIONS

Results of practical project assessment show that it is feasible to apply “AHP and FCE” to evaluate GWSHP system in feasibility. Much investigation will be done to make the level index, weighting and value much more scientific and objective, and to improve the index system.

5 REFERENCES

Wu Bingjian. 1994.Fuzzy math and its economic analysis Standards Press of China, Beijing

Xu Shubo. 1996.Analytic Hierarchy Process, Tianjin University Press, Tianjin

Geng Jian, Liu Zhichun, Zhang Zhaojiang. 2003. “Water source heat pump and its application,” Coal Engineering, Vol.50(5) , pp. 49-50

Xue Yuwei, Li Xinguo, Zhao Jun, Zhu Qiang, Huang Jinqiu.2003. “Research on underground-water source heat pump’s water source,” Energy Engineering,Vol.(2),pp.10-13.

Cao Qi.2005. “ Energy consumption evaluation of air conditioning machine rooms by anenergy efficiency maturity model,” Journal of HV&AC, Vol. 35(4), pp 39-41