Thermal Economic Analysis of an Underground Water Source Heat Pump System

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Abstract: The paper presents the thermal economic analysis of an underground water source heat pump system in a high school building based on usage per exergy cost as an evaluation standard, in which the black box model has been used and the cost of underground water has also been considered. The economics of the heat pump and other cooling and heating sources has been compared and then several simple methods to improve the thermal economics of the underground water heat pump system have been put forward.

Key words underground water source heat pump; thermal economics; black box model

1 PREFACE

In past several decades, many people analyzed the thermal economics of the underground water source heat pump, but still some applied techniques didn't get thorough research, and the current the underground water source heat pump system is still exist many problems in application aspect, such as underground water return irrigating block problem hasn't get solve basically; after underground water changing heat by the heat pump and return irrigate to underground whether to affect underground water matter ,which is still in the issue; and the underground water cost accounted into the system cost whether to affect the thermal economics of the underground water source heat pump, which have caused people' value and so on, such are consumedly disadvantageous on application and expansion of the underground water source heat pump, therefore, for the underground water source heat pump proceeding the thermal economic analysis and looking for the theories of application and expansion are very necessary.

2 THE THERMAL ECONOMIC ANALYTICAL METHOD OF THE UNDERGROUND WATER SOURCE HEAT PUMP

Establish a math analytical model for studying system, ignoring middle process no matter how to change, only to the exergy flow difference or the fund flow difference of passing in and out system proceed analysis, and we will get the exergy efficiency,the exergy loss, the exergy-loss cost and the per exergy cost, which of the handle method is called the black box model, then for the establishing model list exergy equilibrium equation or exergy cost equilibrium equation, then proceed analysis and calculation.

2.1 The Exergy Black Box Model

For instance Fig. 1 show, we may list exergy equilibrium equation for the studying system:

$$E_{in} = E_{pr} + D_y$$

Namely , $D_y = E_{in} - E_{pr}$ （1）

In formula, E_{in}—the exergy of input the system,MJ;
E_{pr}—the exergy of output the system,MJ;
D_y—the exergy loss of the system, MJ.

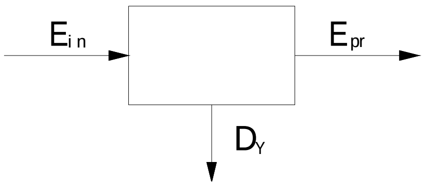

Fig. 1 Exergy equilibrium model of the system

2.2 Exergy-Funds Black Box Model

For instance Fig. 2 show, we may list exergy equilibrium equation for the studying system:

$$c_{pr}E_{pr} = c_{in}E_{in} + Z_f \qquad (2)$$

In formul, c_{in} — the average cost of per input exergy,Yuan / MJ;

c_{pr} — the average cost of per output exergy, Yuan/MJ;

Z_f —consuming no energy expenses in the system (like equipments depreciation, the fixing, personnel wages etc. creating the expenses), Yuan.

Due to formula (2) may get the per exergy cost of the system:

$$c_{pr} = \frac{c_{in}E_{in}}{E_{PR}} + \frac{Z_f}{E_{pr}} = \frac{c_{in}}{\eta} + \frac{Z_f}{E_{pr}} \qquad (3)$$

In formula, η —the exergy efficiency of the system.

3 THE THERMAL ECONOMIC ANALYSIS OF THE UNDERGROUND WATER SOURCE HEAT PUMP

3.1 Engineering General Situation

The engineering building locates Shen Yang, used to work for the school officers and workers mainly, building area is 11000 m^2, divided into five layers totally, among them except for the file room of the first layer, two small council chambers of the second layer and a big council chamber of the third layer adopting low speed all-air system, other eachroom adopts primary air fan coil system. Adopting two the underground water source heat pumps to realize summer refrigerating and winter heating, summer refrigerating running time: June~Septemb-er, everyday: 8:00~18:00, winter heating running time: November~March, everyday 24 hours runnin- ng.

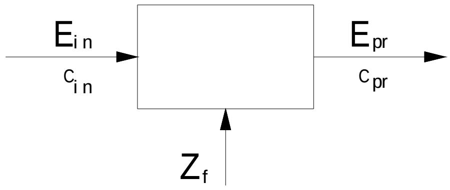

Fig. 2 Exergy-fund equilibrium model of the system

3.2 Exergy Analysis Comparison of Cooling and Heat- ing Source Projects

3.2.1 Cooling and heating source projects

Adopting six kinds of cooling and heating source projects for the office floor engineering：

project 1：The underground water source heat pump
project 2：Air source heat pump
project 3：Soil source heat pump
project 4：Fuel oil boiler+cooling water chiller
project 5：Fuel air boiler+cooling water chiller
project 6：Fuel coal boiler+cooling water chiller

3.2.2 Exergy analysis of each project

Proceeding exergy analysis for each project and listing calculation results into Tab. 1.

3.2.3 The thermal economic analysis and comparison of each project

1) Apportionment of refrigerating investment and heating investment

Because of demand of computing refrigerating cost and heating cost respectively, must apportion the total investment of project 1, project 2 and project3 into refrigerating investment and heating investment. Apportioning method is as follows: Taking the same comparison refrigerating investment and heating investment of project 1, Project 2 between average refrigerating investment and average heating investment of project 4~6, apportioning electricity

Tab. 1 Exergy analysis calculation results of each project

	Refrigerating running		Heating running	
	Exergy loss (MJ)	Exergy efficiency (%)	Exergy loss (MJ)	Exergy efficiency (%)
Project 1	25094.4	43.0	601602.3	44.4
Project 2	79274.5	19.2	903899.7	34.7
Project 3	50401.5	27.3	633345.3	43.1
Project 4	42447.6	30.8	4777744.8	9.1
Project 5	42447.6	30.8	11619729.6	4.0
Project 6	42447.6	30.8	8233212.9	5.5

heat investment of project 2 into heating investment; □Installing cost and other costs of each project according to investment comparison of refrigerating and heating proceed homologous apportionment.

2) Form of refrigerating exergy cost and heating exergy cost

1. Running cost λ_X—Including running costs of energy consume primarily, when project 4~6 is in refrigerating running ,it still include make-up water cost of the cooling water system.

2. Fixing cost λ_Y—Including cost of machine fixing, maintain and managing personnel welfare etc.

3. Investment cost λ_Z—This is apportioning one-off investment of the equipments into every year cost, it is equal to the depreciation cost of the equipments.

Namely: $c = \lambda_X + \lambda_Y + \lambda_Z$ （4）

3) The thermal economic analysis and comparison of each project

At present the usage of the underground water have not still uniform charge standard in the whole country, there is not still proceeding to charge in most regions, but to underground water proceed charge is ineluctable too, so the paper would embody the underground water cost to the thermal economic analysis of the underground water source heat pump.

Proceeding the thermal economic analysis for each project and listing calculation results intoTab. 2.

4 CONCLUSIONS AND PROSPECT

4.1 Conclusions

1) In summer, from Fig. 3 show per cooling exergy cost of project 1 (the underground water source heat pump) and project 4~6 (cooling water chiller) is more than others, project 2 (air source heat pump) and project 3 (soil source heat pump) take second place. Due to adding of underground water cost for project 1 cause its per running exergy cost to be more than others; one-off energy using late of project 4~6 is less than others, and each one-off investment is more than others, which cause its per cooling exergy cost to be more.

2) In winter, from Fig. 4 show that because one-off energy using late of project 5 (fuel air boiler)is the least, which cause its per running exergy cost to be the most ,and cause its per heat exergy cost to be the most; project 1 and project 4 (fuel oil boiler) take second place; project 2 and project 3 are less than others; project 6 (fuel coal boiler) is the least, because coal price is lower, which cause its per running exergy cost to be the least, and cause its per heat exergy cost to be the least .

3) In one year, from Fig.5 show if we think of underground water cost, per year exergy cost of project 2 (air source heat pump) and project 3 (soil source heat pump) are less than others, so their the thermal economics is better, but because Shen Yang belong to cold zone, when environment temperature descend to -15℃, air source heat pump cannot run, therefore the engineering should adopt project 3.

4) In one year, from Fig.6 show if we don't think of underground water cost, its per year exergy cost is the least than others obviously, accordingly cause its the thermal economics to be the best.

4.2 Prospect

Tab. 2 Form of per cooling exergy and per heat exergy cost

	Form of unit cold exergy (Yuan / MJ)				Form of unit hot exergy (Yuan / MJ)				Subtotal (Yuan / MJ)
	λ_X	λ_Y	λ_Z	c_R	λ_X	λ_Y	λ_Z	c_H	$c_R + c_H$
Project 1	3.546	0.244	8.135	11.925	0.876	0.006	0.185	1.067	12.992
Project 2	1.647	0.236	7.860	9.743	0.573	0.005	0.179	0.785	10.528
Project 3	1.663	0.255	8.513	10.431	0.524	0.006	0.194	0.724	11.155
Project 4	2.344	0.280	9.328	11.952	1.073	0.006	0.216	1.296	13.248
Project 5	2.344	0.281	9.355	11.980	3.051	0.007	0.221	3.278	15.258
Project 6	2.344	0.280	9.328	11.952	0.457	0.006	0.199	0.662	12.614

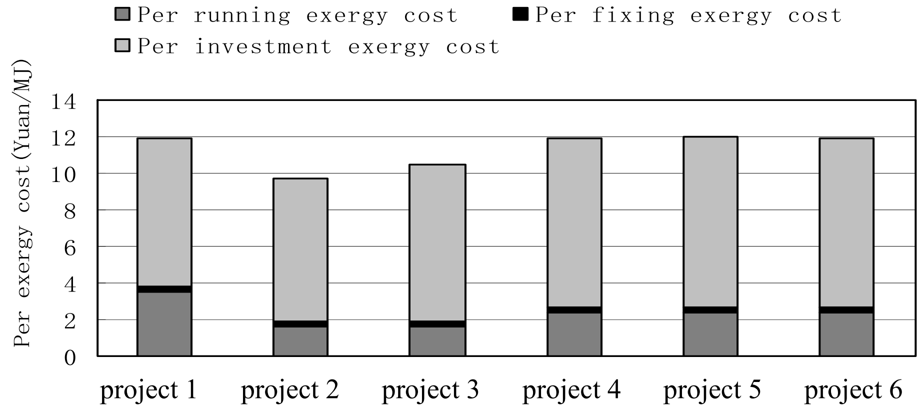

Fig. 3 Form of per cooling exergy

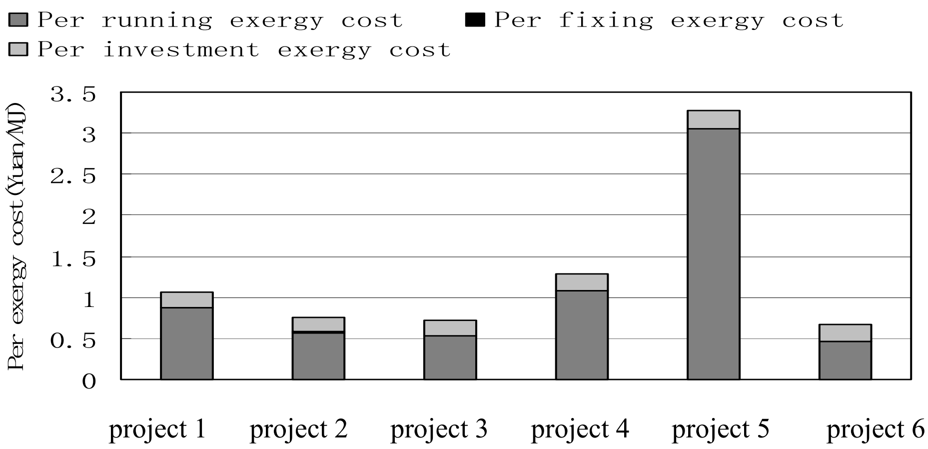

Fig. 4 Form of per heat exergy

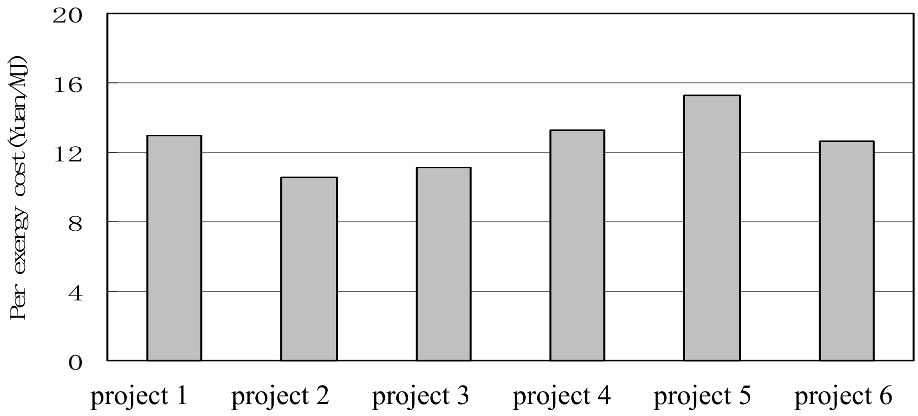

Fig. 5 Comparison of each per year exergy cost (including underground water cost)

If no thinking of underground water cost, comparison of unit year exergy cost show Fig. 6

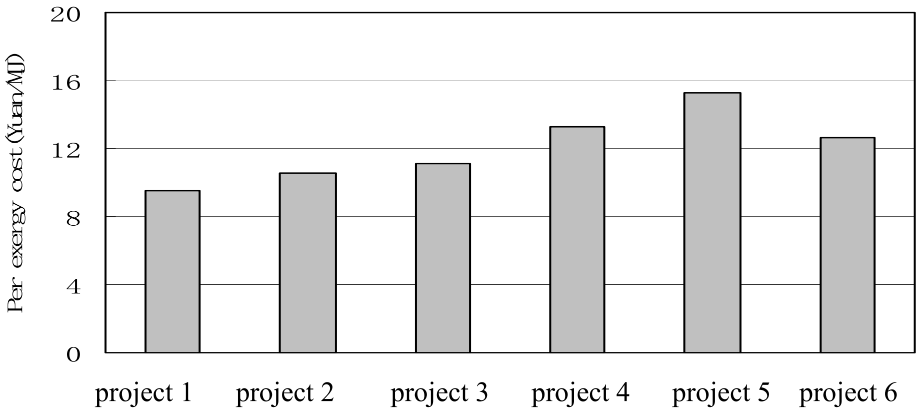

Fig. 6 Comparison of each per year exergy cost (no including underground water cost)

By analyzing the thermal economics of the underground water source heat pump, we can show adding underground water cost cause its per running exergy cost increased on a large extent. Therefore, for reducing per exergy cost of the underground water source heat pump system, and better expanding application of the underground water source heat pump system, we can from reducing using quantity of underground water or improving utilization late of underground water proceed to study.

1.When the underground water source heat pump run ,it is placed in partly load running at a long hours, but the deep well water pump is placed in full load running all along, which will result in wasting the underground water in large quantity. So we should consider to adopt frequency conversion water pump, namely change to take out the underground water, accordingly reduce using quantity of the underground water.

2. Adopt valid measure to solve the block problem of the return- irrigation well, more reduce frequencies of return -pump water or washing well, accordingly improve using late of the underground water.

REFERENCES

[1] Zhuyi Zheng. Analysis and study of heat pump and its the thermal economics process [D]. The Alumni Homepage of. Huazhong University of Science and Technology doctor's degree paper. 1993, 8(In Chinese)

[2] Dong Lin. The thermal economic analysis and application of water source heat pump [D]. 2003, 12(In Chinese)

[3] Yuzhuo Pan, Xuyang Chen, Bihong Lin. A kind of the thermal economics optimizing of no upstream heat pump capability [J]. Journal of Shandong University of Science and Technology.2003, 6. (In Chinese)

[4] Lidong Gao. The thermal economics optimizing analysis of dairy farming desiccating heat pu- mp [J].1992, 3(In Chinese)

[5] Zesheng Yan, Xiaodi Han, Jixiang Liao, Qingyan Ma. The thermal economics engineering dark analysis of water heat pump in Northeast region [J]. Journal of Harbin University of commerce.2004, 10.(In Chinese)

[6] Zhao Yang, Shigang Zhang, Wenhong Yu, Yitai Ma. The thermal economics and the thermal economics optimizing of heat pump in air condittoing [J]. Solar journal.2002, 10. (In Chinese)

[7] Wenxing Shi, Shuangquan Shao. The thermal economic analysis and the thermal economics evaluation heat recovery inverter air-cooling heat pump with domestic hot water [J]. Beijing. (In Chinese)

[8] Mingshan Zhu. Exergy analysis of energy sys-tem [M].Publishing company of Tsinghua Uni-versity.1988. (In Chinese)