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Operation level evaluation system and indicators in the middle and deep geothermal heating projects

DU li, TANG guo, LI qingrong, XIANG ye

Sinopec Star New Energy Research Institute, Beijing, China

duli.xxsy@sinopec.com

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ABSTRACT

In order to continuously improve the operation level and profitability of middle and deep geothermal heating projects, it is necessary to establish a set of systematic and comprehensive evaluation methods and indicators for operation effects. This paper will be evaluated on the basis of systematic, normative and practical principles. However, the results of the effect evaluation are multiple and multilevel. This paper will also be based on the characteristics of middle and deep geothermal heating projects. So it will establish a set of evaluation index system for the benefit of deep geothermal heating engineering, combining technical and management indexes, economic and non-economic indexes. It has determined 3 aspects and 10 evaluation indicators in technical level, management level and economic benefits. Therefore the analysis of the specific operation project shows that the evaluation method and index are in line with the reality, and the operation level of the project is quantified. In addition, it also puts forward specific improvement directions which can effectively guide the improvement of operation level and efficiency of middle-deep geothermal heating projects.

1. INTRODUCTION

Geothermal energy is a kind of underground renewable energy, which is green, low-carbon, recyclable, stable and reliable. The promotion and utilization of geothermal energy will help achieve the "carbon peaking and carbon neutrality goals" and promote the transformation of energy revolution.At present, China has realized the large-scale utilization of deep geothermal energy in the region with relatively good resource conditions，The most widely used is geothermal heating.The advantages of this kind of project are significant social and environmental benefits, but the economic efficiency of the project is general, because the initial investment is high and the investment payback period is long, which causes some projects even suffer from losses. So, this is a key factor hindering the development of the geothermal heating industry. Hence, we need to focus on analyzing the operation and management level of the existing geothermal heating projects, so as to find out the main factors affecting the implementation benefits of the project. Only in this way can we optimize it, improve quality and increase efficiency.We need to use this approach as the primary tool to increase the value of the project.

The existing methods of project analysis and evaluation basically adopt qualitative analysis as the main method and quantitative analysis as the auxiliary method. Common methods:(1) Investigation and research method, mainly through on-site visits and telephone consultation and other ways, through this method to collect information related to the project.(2) Comparison method. This method can be used for multi-angle comparison of the project, including before and after comparison, with and without comparison and horizontal comparison.By comparing the actual data after the project is put into operation with the actual data when the project is set up, such as the immediate target, macro target and other indicators. Then identify their deviations and changes, and analyze the reasons. Finally, we summarize the experience and lessons, and then evaluate the completion of the project.(3) Cash flow method, mainly used to analyze the economic benefits after the implementation of the project. Combine reality with prediction，from the perspective of investment-cost-income, according to the actual investment, income and cost incurred during the operation of the project, the income and expenditure that the project may generate in the subsequent evaluation period are predicted. And then we use the input-output method to calculate net cash flow. First of all, we should predict the profitability of the project under the premise of considering the value of money and time. On this basis, the key factors affecting the economic benefits of the project are found out by comparing with the previous prediction indicators.Although the existing methods can provide a certain basis for the analysis and evaluation of projects, they all have some shortcomings.First of all, qualitative analysis in the above methods mainly relies on the subjective judgment ability of researchers to infer the nature and development trend of things.Therefore, this method of analysis will be affected by factors such as the completeness of collected data, the level of preset standards and the professional ability of researchers, and the conclusions obtained are subjective and lack of certain rigor. Secondly, the quantitative analysis of cash flow method only considers the economic benefit, but it ignores the impact of other factors on the overall benefit of the project. Moreover, this method only focuses on the ratio of input and output of the project, without further exploring the deep reasons that affect the value of the project, such as the impact of the operation and management mode of the project on its economic benefits.

In the actual operation process, the operation effect of the project can be reflected from many aspects. Both economic level, also have management level and technical level. And different types of projects have certain uniqueness, so there is no comprehensive evaluation method for middle and deep geothermal heating projects.Based on this, according to the specific characteristics of the geothermal heating project, we constructed a system by combining quantitative analysis with qualitative analysis and dynamic analysis with static analysis. We have built a comprehensive evaluation system for the operation level of medium and deep geothermal heating projects, which comprehensively considers the technical factors, management factors and economic factors of the projects.

2. COMPREHENSIVE EVALUATION SYSTEM OF OPERATION LEVEL

2.1 Fuzzy evaluation theory

The fuzzy comprehensive evaluation method was put forward by L.A.Zadeh, a cybernetics expert from the University of California in 1965. With the objective needs of the development of science and technology, he proposed the method of using accurate mathematical methods to describe fuzzy concepts. However, this approach provides a bridge between classical mathematics and the ambiguous uncertainty of the real world. When we evaluate something, we often encounter such confusion: how to evaluate comprehensively? Because the matter of evaluation is determined by many factors, it is necessary to evaluate each factor. So, after each factor evaluation, how to consider all factors to make a comprehensive evaluation, this is the problem we face. However, many things are not so clearly defined that it is difficult to place them into a category when evaluating them. This requires us to evaluate a single factor first, and then evaluate all factors in a comprehensive fuzzy way, so as to prevent missing any statistical information and intermediate losses. There are ways to help solve the problem of deviation from objective evaluations, such as "yes" or "no" deterministic evaluations that tend to deviate from the real situation.Fuzzy comprehensive evaluation method is a systematic analysis method, which uses the principle of fuzzy mathematics to analyze and evaluate the things with "fuzziness". It is a kind of analysis and evaluation method, mainly based on fuzzy reasoning, combining qualitative and quantitative, and unifying precision and imprecision. Because of the unique superiority of this method, it can deal with a variety of complex system problems which are difficult to be described by exact mathematical methods. It has been widely used in many fields in recent years.

2.2 Process Description

Fuzzy comprehensive evaluation is a method, which should comprehensively consider the technical indexes of the evaluation object. It should take into account the various characteristics of the evaluation object, all aspects of the factors, and then the indicators are quantified. Moreover, it needs to allocate the weight coefficient according to the influence degree of different indicators on the evaluation object, so as to give a value to each evaluation object, which is the quantitative comprehensive evaluation value. The steps of comprehensive evaluation of the operation level of heating project by fuzzy comprehensive evaluation method are as follows:

(1) Establish the factor set of the evaluation object U={u1, u2, …, un}. Factors are various attributes or performance of the object. In different occasions, they are also called parameter indexes or quality indexes. They can comprehensively reflect the quality of the object, so the object can be evaluated by these factors.

(2) Establish judge set V={v1, v2, …, vn}, a collection of levels of the judged object.

(3) Establish the single factor evaluation, establish the fuzzy mapping from U to V.

(4) Comprehensive evaluation is concentrated in the evaluation object factors. Due to the different contributions of various factors, it is necessary to give different weights to each factor and then evaluate the effect according to the established comprehensive evaluation model.

In the above 4 steps, the establishment of single factor evaluation matrix and the determination of weight allocation set are two key tasks. But there is no uniform format to follow these works, usually we are using statistical tests, expert scores and other methods to work out.

2.3 Comprehensive evaluation index system

The evaluation index system according to the operation level of different geothermal heating projects is the basis of comprehensive evaluation, and also the basic guarantee of accurate and reasonable evaluation results. A set of index system is established, which is scientific, standard, systematic and normative, and can comprehensively and objectively reflect the implementation status of miscible flooding test. It adopts the method of combining technical indexes with management indexes, and combining economic indexes with non-economic indexes. In order to better evaluate the operation level of heating projects, this paper comprehensively considers various factors including technical indicators, management indicators and economic indicators, and subdivides them into 10 second-level indicators (Figure 1).

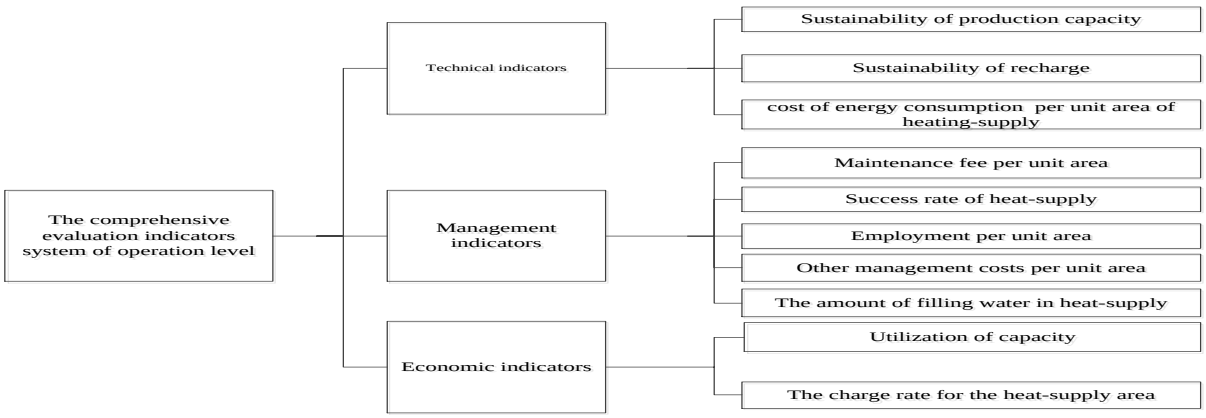

Figure 2: The comprehensive evaluation indicators system of operation level

2.4 Determination of evaluation criteria

This paper establishes a set of evaluation criteria for the operation level of middle and deep geothermal heating projects, which is based on the comprehensive analogy of various factors, such as the evaluation criteria of geothermal field development, statistical rules, the characteristics of indicator changes, expert opinions and so on.It defines "good", "better", "medium", "poor", "very poor" and the boundaries of these five evaluation grades. The specific evaluation criteria are shown in Table 1.

Table 1 Evaluation criteria for operation level of deep geothermal heating project

Indicators	Good	Better	Medium	Poor	Very poor
Sustainability of production capacity	>90%	90-80%	70-80%	60-70%	<60%
Sustainability of recharge	>90%	90-80%	70-80%	60-70%	<60%
cost of energy consumption per unit area of heating-supply	<60%	60-80%	80-100%	100-120%	>120%
Maintenance fee per unit area	<30%	30-50%	50-70%	70-90%	>90%
Success rate of heat-supply	>99%	98-99%	96-98%	95-96%	<95%
Employment per unit area	<2	2-3	3-4	4-5	>5
Other management costs per unit area	<40%	40-60%	60-80%	80-100%	>100%
The amount of filling water in heat-supply	<200	200-300	300-400	400-500	>500
Utilization of capacity	>90%	80-90%	70-80%	70-60%	<60%
The charge rate for the heat-supply area	>90%	80-90%	70-80%	70-60%	<60%

2.5 Determination of weight

Multi-index comprehensive evaluation method selects multiple factors or indicators, and then transforms them into information through certain evaluation methods, which can reflect the overall characteristics of the evaluation object.

The weight of a single index will directly affect the result of the comprehensive evaluation.

There are many methods to determine the weight, including analytic hierarchy process, comprehensive scoring method, fuzzy evaluation method, entropy method, neural network analysis method, grey correlation analysis method, principal component analysis method and so on.

It is considered the initial information and characteristics provided by each indicator of the geothermal project, the analytic hierarchy process (AHP) was used in this study.

In this study, relevant experts were invited to fill in the form "Saaty's Relative Importance Scale" (as shown in Table 2) according to the AHP method. According to the assigned value specified in the table, they compare the indicators at each level in their own levels, assign importance levels to each other, and then write the matrix form. Finally, the corresponding weights of each factor are obtained through calculation (Table 3).

Table 2 Saaty's Relative Importance Scale

Assigned value	Definition
1	The two elements are of equal importance
3	Of the two elements, the former is weak importance
5	Of the two elements, the former is strong importance
7	Of the two elements, the former is demonstrated importance
9	Of the two elements, the former is absolute importance
2, 4, 6, 8	Intermediate values
Reciprocal	The latter is more important than the former

Table 3 Weight measurement table of indicators

Indicators classification		Comprehensive weight
Technical indicators	Sustainability of production capacity	0.09
	Sustainability of recharge	0.09
	cost of energy consumption per unit area of heating-supply	0.12
Management indicators	Maintenance fee per unit area	0.12
	Success rate of heat-supply	0.12
	Employment per unit area	0.04
	Other management costs per unit area	0.04
	The amount of filling water in heat-supply	0.08
Economic indicators	Utilization of capacity	0.15
	The charge rate for the heat-supply area	0.15

3 CASE ANALYSIS

Take a geothermal heating project as an example. In October 2016, this project has built a geothermal heating station, laid heating pipelines of about 2.6km, and developed 6 geothermal Wells (3 mining Wells and 3 recharge Wells). It provides heat for a building area of 32.7×104 m2, while it is designed to have a heating capacity of 11.39MW.

Due to changes in the actual construction situation, since 2018, the project has actually provided heat source for a building area of about 27.96×104 m2. Using the above methods to carry out quantitative analysis, the comprehensive evaluation results were “Very poor”(0.37, 0.202, 0.214, 0.038, 0.416).(As shown in Table 4)

Table 4 Summary of evaluation indicators for a geothermal station

Indicators classification	Evaluation indicator	Value	Membership grade	Evaluation grades
Technical indicators	Sustainability of production capacity	1	(1, 0, 0, 0, 0)	Good
	Sustainability of recharge	1	(1, 0, 0, 0, 0)	Good
	cost of energy consumption per unit area of heating-supply	0.97	(0, 0.85, 1, 0.15 ,0)	Medium
Management indicators	Maintenance fee per unit area	0.24	(1, 0, 0, 0, 0)	Good
	Success rate of heat-supply	1	(1, 0, 0, 0, 0)	Good
	Employment per unit area	1	(1, 0, 0, 0, 0)	Good
	Other management costs per unit area	0.84	(0, 0, 0.2, 1, 0.8)	Poor
	The amount of filling water in heat-supply	31	(1, 0, 0, 0, 0)	Good
Economic indicators	Utilization of capacity	0.38	(0, 0, 0, 0, 1)	Very poor
	The charge rate for the heat-supply area	0.89	(0.1, 1, 0.9, 0, 0)	Better

Through the quantitative analysis in the above table, we can find that the main reason affecting the operation level of the heating station is low capacity utilization rate, which leads to low investment returns. In view of this result, we suggest that the project will expand the surrounding heating market and use the idle capacity of geothermal stations to transfer excess heat to the neighboring heating communities, so as to improve the utilization rate of geothermal energy, save energy and reduce consumption, and improve economic benefits.

4 CONCLUSION

This study constructs a set of index system and methods to evaluate the operation effect of medium and deep geothermal heating projects. It also aims at the operation and management field of medium and deep geothermal heating projects. This paper provides a

more comprehensive evaluation method from three perspectives: technology, management and economy. It also analyzes the key factors that affect the operation level and profitability of middle and deep geothermal heating projects in a multi-dimensional and multi-level manner. It can provide a comprehensive evaluation for the project in terms of technical analysis, economic benefit analysis and management level analysis. The project analysis case shows that this evaluation method can analyze the actual operation status of existing projects and accurately identify problems. Then, researchers can provide scientific and reasonable suggestions to project managers based on the results, so as to improve the operation level and profitability of mid-deep geothermal heating projects.

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