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Research on Optimal Selection of Drainage Gas Recovery Technology Based on Critic-ahp Combination Weighting and Mahalanobis Distance Topsis Method

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Abstract

Drainage and gas production technology is an important process technology for increasing production in gas fields in the later stage. In order to optimize the drainage and gas production technology for gas wells with liquid accumulation, a TOPSIS model based optimization study was conducted based on the technical and economic adaptability analysis of different drainage and gas production technology and well condition parameters. This model characterizes the priority level of each alternative solution by calculating the distance and relative progress between each alternative solution and the ideal solution. In response to the problem that the weights determined by traditional single weighting methods cannot meet the principle of subjective and objective unity, the CRITIC-AHP combination weighting method is proposed. Based on the subjective and objective weighting, the optimal weight is calculated based on the concept of game theory; A Mahalanobis distance calculation model based on the modified Cosine correlation coefficient matrix and absolute ideal point representation is proposed to address the Euclidean distance failure and reverse order issues caused by the correlation and dimensional inconsistency between indicators in the TOPSIS method. Combined with actual production data, a comprehensive evaluation system for economic and technical indicators of drainage and gas production processes is established, and the well condition parameters of XX well are selected for optimal drainage and gas production processes. The results show that after implementing the drainage gas production process, the average water production of XX well increased from 29.41m^3/d when liquid was accumulated, and the gas production was less than 1200m^3/d. The gas production increased to 8500-9200m^3/d, with a significant increase in production.

Keywords: Drainage Gas Recovery Technology, Optimal Selection, CRITIC-AHP Combination weighting, Mahala-Nobi's Distance, TOPSIS Method

1. Introduction

In the later stage of gas field development, as the gas reservoir pressure and natural gas flow rate gradually decrease, the wellbore temperature gradient increases, and some of the produced water in the gas reservoir condenses in the wellbore to form condensate. When the gas production of the gas well is insufficient to carry out this part of the condensate, the condensate will fall back and remain at the bottom of the well, forming gas well fluid accumulation [1,2]. Liquid accumulation in gas wells can create dead gas zones, thereby reducing gas phase permeability, increasing pressure loss during gas well seepage, affecting gas well production, and leading to a decline in oilfield economic benefits. In severe cases, liquid accumulation in gas wells can also cause water flooding, leading to the accumulation of liquid directly crushing the gas well [3]. Therefore, it is necessary to establish a comprehensive evaluation model for gas well drainage and gas production technology based on the law of gas well accumulation, and optimize the drainage and gas production technology.

At present, there have been some research results on the optimization of drainage and gas production technology in China. Shi Shubin et al. combined the theoretical knowledge of fuzzy mathematics and established an evaluation model for coalbed methane extraction methods using the fuzzy comprehensive evaluation method[4]; Guo Zhihui et al. [5] selected the C2R model with non Archimedean infinitesimal quantities and the super efficient DEA model to optimize the drainage and production process of C11 well, and successfully restored the production capacity of the gas well to its pre liquid accumulation capacity. Zheng Xinxin [6] established a fuzzy consistent matrix based optimization model for drainage and gas production processes, and comprehensively evaluated various drainage and gas production process schemes; Han Changwu [7] established an optimization model for drainage and gas production technology based on the Analytic Hierarchy Process (AHP) utility function method; The above research results provide reference and support for the optimization of drainage and gas production processes. However, existing research directions mostly focus on the design of drainage and gas production processes after the optimization results are obtained, and there is a lack of research on the establishment of evaluation models during the optimization process, as well as exploration of the rationality and importance distribution of evaluation index selection.

Therefore, it is urgent to establish a fully logical evaluation and optimization model for drainage and gas production processes, from indicator proposal to evaluation matrix establishment, weight allocation, and scheme optimization. The TOPSIS method is a commonly used comprehensive evaluation method that can fully utilize the information of the original data, digitize the degree of superiority or inferiority of the scheme into geometric distance, and its results can accurately reflect the differences between the evaluation schemes. There is very little research on the application of TOPSIS method in the optimization of drainage and gas production processes, and none of them have solved the problems of weight allocation and calculation distortion in this model. Therefore, this article proposes the CRITIC-AHP combination weighting method and improves the TOPSIS method by replacing the Euclidean distance with the Mahalanobis distance represented by the Person coefficient matrix. Combining the actual operating parameters and economic indicators of gas wells, an evaluation model for drainage and gas production process indicators is established, and yan XX well is selected for practical engineering application, in order to provide reference and theoretical guidance for the TOPSIS method's application in the optimization of drainage and gas production processes.

2. The Basic Principle of TOPSIS Method

2.1 Basic Concepts

The TOPSIS method, also known as the approximate ideal solution ranking method, is a method that uses the concepts of positive ideal solutions and negative ideal solutions to evaluate the relative advantages and disadvantages of multiple alternative solutions, and find the best and worst solution [8]. Positive ideal solutions and negative ideal solutions represent the optimal and worst ideal states that the evaluation object can achieve, respectively。

2.2 Traditional TOPSIS Mathematical Model

Let a multi-attribute decision-making problem have a set of options A={A_1, $A2$, A_3, ⋯, A_n}, representing n alternative options; Attribute set B={B_1, B_2, B_3, ⋯ , B_m}, representing m attributes that affect alternative solutions. The decision matrix $P = (p_{ij})_{n\times m}$ is composed of a solution set and an attribute set[9]

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1m} \\ p_{21} & p_{22} & \cdots & p_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nm} \end{bmatrix} \quad (1)$$

Among them, P_{ij} represents the value of attribute B_j under the condition of alternative solution A_i.

In order to eliminate the problem of dimensional inconsistency and negative values between different attribute values, it is necessary to normalize P:

For benefit oriented attributes

$$x_{ij} = \frac{p_{ij} - p_j^-}{p_j^+ - p_j^-}, i \in n, j \in m \quad (2)$$

For cost based attributes

$$x_{ij} = \frac{p_j^+ - p_{ij}}{p_j^+ - p_j^-}, i \in n, j \in m \quad (3)$$

Among them, $\begin{cases} p_j^- = \min\limits_{i\in n} p_{ij} \\ p_j^+ = \max\limits_{i\in n} p_{ij} \end{cases}$

Obtain the standardized decision matrix X is:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \quad (4)$$

After normalizing the matrix, it is necessary to determine the weight of each attribute in the comprehensive evaluation. Generally, the entropy method, AHP method, or expert scoring method are used to determine the weight vector. If there are m attributes, the weight vector is:

$$W = (w_1, w_2, w_3, \cdots, w_j, \cdots, w_m), w_j > 0 \quad (5)$$

Multiplying the weight vector with the standardized decision matrix yields the weighted decision matrix V, which is:

$$V = (v_{ij})_{n\times m}，其中 v_{ij} = w_j * x_{ij}，i = 1,2,3 \cdots n, j = 1,2,3 \cdots m \quad (6)$$

The positive ideal solution S^+ and the negative ideal solution S^- are:

$$S^+ = \{s_1^+, s_2^+, s_3^+, \cdots, s_j^+, \cdots, s_n^+\}，S^- = \{s_1^-, s_2^-, s_3^-, \cdots, s_j^-, \cdots, s_n^-\} \quad (7)$$

When attribute B_j is a benefit type attribute

$$\begin{cases} s_j^+ = \max\{v_{ij} | 1 \le j \le m\} \\ s_j^- = \min\{v_{ij} | 1 \le j \le m\} \end{cases} \quad (8)$$

When attribute B_j is a cost type attribute

$$\begin{cases} s_j^+ = \min\{v_{ij} | 1 \le j \le m\} \\ s_j^- = \max\{v_{ij} | 1 \le j \le m\} \end{cases} \quad (9)$$

Calculate the Euclidean distance from each scheme to positive and negative ideal solutions D^+, D^-

$$D^+ = \sqrt{\sum_{j=1}^{m} (v_{ij} - s_j^+)^2}，D^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - s_j^-)^2}，\mathrm{i} \in 1,2,\cdots,\mathrm{n} \quad (10)$$

The relative progress f_i between each solution and the rational solution can be calculated using the following formula:

$$f_i = \frac{D^-}{D^+ + D^-}，i = 1,2,\cdots,n, f_i \in [0,1] \quad (11)$$

Finally, sort according to the size of the f_i value. The larger the f_i value, the better the solution.

3. Improvement of CRITIC-AHP Combination Weighting and Mahalanobis Distance

3.1 CRITIC-AHP Combination Weighting Method

When determining the weight of indicators, subjective weighting and objective weighting methods are generally used. In engineering problems, there is usually a strong correlation between indicators, and using a single subjective or objective weighting method cannot balance the subjective intention and objective randomness of decision-makers. Therefore, this study proposes the CRITIC-AHP combination weighting method, which uses AHP method and CRITIC method to subjectively and objectively weight indicators, and based on game theory, combines the subjective and objective weighting results to determine the combination weight.

3.1.1 AHP Subjective Weighting Method

The AHP method decomposes decision-making problems into different hierarchical structures in the order of overall objectives, sub objectives at each level, evaluation criteria, and specific alternative solutions. It obtains the priority weights of each element at each level for a certain element at the previous level, and finally combines the final weights of each alternative solution for the overall objective using a weighted sum method. [10] The specific steps are as follows:

1、Establish a hierarchical model that includes the target layer, attribute layer, and scheme layer.

2、Consult experts to determine the relative importance of indicators pairwise, and construct

a judgment matrix using the 1-9 scale method based on the results. The 1-9 scale method and its significance are shown in the Table:

Scale level	meaning
1	Two attributes are equally important
3	Compared to two attributes, one is slightly important than the other
5	Compared to two attributes, one is clearly important than the other
7	Compared to two attributes, one is strongly important than the other
9	Compared to two attributes, one is absolutely important than the other
2, 4, 6, 8	The middle value of the two adjacent meanings mentioned above

Table 1: Judgment Matrix Scale and Its Meaning

According to Table 1, if two factors (a, b) are compared to obtain a scale level i, then (b, a) is compared to a scale level i/1.

Calculate the single-layer weight vector and perform consistency checks on the judgment matrix$A = (a_{ij})_{n\times n}$. The maximum eigenvalue of a generally generated judgment matrix λ_Max is greater than the order n of the matrix when λ The more it is larger than n, the more severe the inconsistency of A, and the greater the judgment error caused. If the maximum eigenvalue of the judgment matrix is set λ_If max is close to n, it can make the judgment matrix have good consistency.3、

Obtain the maximum eigenvalue of the judgment matrix using Matlab λ_{max} and the corresponding eigenvectors, and the consistency index CI is introduced to calculate the consistency of the judgment matrix:

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \tag{12}$$

The closer the CI value is to 0, the better the consistency of the judgment matrix. At the same time, in order to measure the relative size of CI values, a random consistency index RI is introduced.

The determination of RI values is to randomly construct 500 paired comparison matrices A_1, A_2, A, A_{500}, and obtain 500 consistency indices $CI_1, CI_2, \cdots, CI_{500}$. The RI value is:

$$RI = \frac{CI_1 + CI_2 + \cdots + CI_{500}}{500} \tag{13}$$

The relative consistency coefficient CR is obtained from the ratio of CI to RI:

$$CR = \frac{CI}{RI} \tag{14}$$

When the relative consistency coefficient CR<0.1, it can be considered that A is within the allowable range and has satisfactory consistency. The normalized eigenvector B of the matrix can be used as the subjective weight vector ω_1. Otherwise, some a_{ij} values need to be adjusted.

3.1.2 CRITIC Method Evaluation Index Weight

The CRITIC method is an objective weighting method that comprehensively measures indicators based on the comparative strength of evaluation indicators and the conflict between indicators. The specific steps are as follows:

1、Construct the original evaluation matrix well for standardization processing to obtain the standardized decision matrix X:

$$X=\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix}$$

2、Calculate the conflict between attributes The Spearman coefficient is used to represent the correlation between attributes. The Spearman coefficient does not require the distribution of the original variable and is not sensitive to the presence of outliers, making it more widely applicable. The calculation formula is as follows:

$$r_{ij} = \frac{1}{n}\frac{\sum_{i=1}^{n}\left[\left(R(x_i) - \overline{R(x)}\right) \times \left(R(y_i) - \overline{R(y)}\right)\right]}{\sqrt{\left(\frac{1}{n}\sum_{i=1}^{n}\left(R(x_i) - \overline{R(x)}\right)^2\right) \times \left(\frac{1}{n}\sum_{i=1}^{n}\left(R(y_i) - \overline{R(y)}\right)^2\right)}}$$

In the formula, R(x) and R(y) respectively represent the positions of x and y, $\overline{R(x)}$ and $\overline{R(y)}$ represent the average order separately The conflict coefficient R_j can be obtained from the Spearman coefficient matrix using the following equation:

$$R_j = \sum_{i=1}^{n}\left(1 - |r_{ij}|\right), \quad j = 1,2,3,\cdots,m \tag{16}$$

3、Calculate the differences between attributes

The difference between attributes is represented by the coefficient of difference s_j, which is calculated using the following formula:

$$s_j = \frac{\sigma_j}{\bar{x}_j} \tag{17}$$

In the formula, σ_j is the standard deviation of the jth attribute value in the standardized evaluation matrix, $\bar{x}_j$ is the average value of the jth attribute value

4、Calculate CRITIC weight vector

Determine the objective weights of each attribute based on the parameters obtained above ω_2

$$\omega_2 = \frac{C_j}{\sum_{j=1}^{m} C_j}, \quad j = 1,2,3,\cdots,m \tag{18}$$

In the formula, $C_j = s_j R_j$, $j = 1,2,3,\cdots,n$ represents the amount of information contained in this indicator

3.1.3 Combination Weighting Method Based on Ideal

points and Lagrange multipliers Weights obtained from subjective and objective weighting method ω_1,ω_2 needs to be combined to meet the expectations of decision-makers and objective mathematical models. The specific steps are as follows:

1、Synthesize an equivalent single objective optimization model using the equal weighted linear weight sum method:

$$maxZ = \sum_{i=1}^{n} v_{ij} = \sum_{i=1}^{m}\sum_{j=1}^{n}(x_j^* - x_{ij})^2(\beta_1\omega_1 + \beta_2\omega_2) \tag{19}$$

$$\beta_1{}^2 + \beta_2{}^2 = 1, \quad \beta_1, \quad \beta_2 \geq 0 \tag{20}$$

In the formula , β_1, β_2 is the weight coefficient;

v_{ij} is the weighted attribute value;;

b_{ij} is the normalized attribute value;

$x_j^*$is a positive ideal solution

2、Constructing Varangian functions for equations (19) and (20):

$$L = \sum_{i=1}^{m}\sum_{j=1}^{n}(x_j^* - x_{ij})^2(\beta_1\omega_1 + \beta_2\omega_2) + \frac{\lambda}{2}\left(\beta_1{}^2 + \beta_2{}^2 - 1\right) \tag{21}$$

In the formula, λ For the Lagrange multiplier, let partial $\frac{\partial L}{\partial \beta_1} = 0$, $\frac{\partial L}{\partial \beta_2} = 0$ can be combined with equation (20) to obtain

$$\lambda = -\sqrt{\left[\sum_{i=1}^{m}\sum_{j=1}^{n}(x_j^* - x_{ij})^2\omega_1\right]^2 + \left[\sum_{i=1}^{m}\sum_{j=1}^{n}(x_j^* - x_{ij})^2\omega_2\right]^2}$$

3、The obtained λ Reverse substitution of partial $\frac{\partial L}{\partial \beta_1} = 0$ and $\frac{\partial L}{\partial \beta_2}$ = 0 = 0 β_1, β_2 the value of 2 is:

$$\beta_1 = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(x_j^* - x_{ij})^2\omega_1}{\sqrt{\left[\sum_{i=1}^{m}\sum_{j=1}^{n}(x_j^* - x_{ij})^2\omega_1\right]^2 + \left[\sum_{i=1}^{m}\sum_{j=1}^{n}(x_j^* - x_{ij})^2\omega_2\right]^2}} \tag{22}$$

$$\beta_2 = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(x_j^* - x_{ij})^2\omega_2}{\sqrt{\left[\sum_{i=1}^{m}\sum_{j=1}^{n}(x_j^* - x_{ij})^2\omega_1\right]^2 + \left[\sum_{i=1}^{m}\sum_{j=1}^{n}(x_j^* - x_{ij})^2\omega_2\right]^2}} \tag{23}$$

4、Derived from the above equation β_1, β_2 normalization is also required to eliminate the adverse effects caused by singular sample data and obtain the optimal weight combination coefficient $\beta_1{}^*$, $\beta_2{}^*$ is:

$$\beta_1^* = \frac{\beta_1}{\beta_1 + \beta_2}, \quad \beta_2^* = \frac{\beta_2}{\beta_1 + \beta_2} \tag{22}$$

The optimal combination weight is

$$\omega^* = \beta_1^*\omega_1 + \beta_2^*\omega_2 \tag{23}$$

3.2 The Mahalanobis Distance Represented by the Modified Cosine Correlation Coefficient Matrix

The traditional TOPSIS method, when there is correlation between attributes and the dimensionality is not uniform, will make the calculation results of Euclidean distance unreliable, and will generate reverse order problems when the number of alternative solutions dynamically changes. In response to the above shortcomings, due to the maximum value of all normalized attribute values being 1 and the minimum value being 0, the determination of positive and negative ideal solutions in each TOPSIS evaluation process can be limited to fixed values, so that the determination of positive and negative ideal solutions will not change due to the increase or decrease of the candidate solution set.

Therefore, the absolute positive ideal solution S'^+ and the absolute negative ideal solution S'^- can be taken as

$$S'^+ = (1,1,\cdots,1), \quad S'^- = (0,0,\cdots,0) \tag{24}$$

The traditional Mahalanobis distance is based on the covariance matrix. Although it solves the problem of correlation between attributes, its calculation still depends on the dimensionality between indicators and is only effective for linear correlation. The improvement of the traditional TOPSIS method by replacing the Euclidean distance with the Mahalanobis distance represented by the modified Cosine correlation coefficient matrix can effectively solve the above problems.

The modified Cosine correlation coefficient calculation formula is as follows:

$$cos_{xy} = \frac{x \cdot y}{\|x\| \cdot \|y\|} = \frac{\sum_{i=1}^{n} x_i y_i - \overline{xy}}{\sqrt{\sum_{i=1}^{n}(x_i)^2 - (\bar{x})^2} \times \sqrt{\sum_{i=1}^{n}(y_i)^2 - (\bar{y})^2}} \quad (25)$$

The formula for calculating the Mahalanobis distance represented by the Person coefficient matrix is:

$$d^+ = \sqrt{(B_j - 1)\sum (B_j - 1)^T} \quad (26)$$

$$d^- = \sqrt{(B_j - 0)\sum (B_j - 0)^T} \quad (27)$$

Among them, B_j is the weighted decision matrix vector, and Σ is the modified Cosine correlation coefficient matrix for m indicators

4. Engineering Example Application - Taking Yan XX Well as an Example

4.1 Engineering Background

This article takes the optimization of drainage and gas production technology for XX well in the Sudong gas area as an example. After being put into operation, the gas area has accumulated 143 gas wells, and currently 127 gas wells have been put into operation, all of which have varying degrees of water output. The average daily water production is about 380m^3, with a water to gas ratio of 1.56m^3/10000 m^3 and an average casing pressure drop of 12.32MPa. In the well area, there are 3 gas wells with a daily water production of more than 100m^3, and 8 gas wells with a daily water production of more than 10m^3. The maximum daily water production is 704.2m^3, and the average daily water production of a single well is about 4m^3. The average water production density is 1.12- 1.14. Since production, the production process has faced difficulties such as fast pressure drop, high water production, and difficulty in water and gas drainage, ineffective drainage and gas extraction measures by mechanical pumping, and short effective period. Therefore, it is necessary to establish different evaluation systems for drainage and gas production process indicators and optimize the drainage and gas production process。

4.2 Constructing an Optimal Index System for Drainage and Gas Production Processes

In order to ensure the accuracy and reliability of the optimization evaluation results, taking into account the production status of the well area, XX well was selected and a total of 9 attribute indicators, including water production, gas production, oil jacket pressure difference, lifting efficiency, investment recovery period, process cost, net present value, shortest operating cycle, and net present value ratio, were selected from technical and economic perspectives for 7 drainage and gas production process schemes, including electric submersible pump, jet pump, plunger, gas lift, velocity pipe, and bubble discharge. A drainage and gas production process optimization index evaluation system was established.

Alternative solutions	Water production rate (m^3/d)	Gas production rate (10^{4}m^3/d)	Differential pressure of oil sleeve (MPa)	Lift efficiency (%)	Process cost (/m^3)	Shortest homework cycle (d)	Net present value (10^4)	Investment payback period (year)	Net present value ratio
Plunger	48.52	2.18	3.5	62.43	0.649	298	572	0.597	21.96
Gas lift	46.34	1.82	4.1	60.27	0.761	353	629	0.624	18.62
Jet pump	59.54	2.05	4.0	58.62	0.871	241	483	0.473	19.37
Electric submersible pump	67.27	2.21	3.8	57.34	0.760	368	819	0.882	22.41
Velocity column	43.40	1.94	4.2	61.27	0.849	285	703	0.606	19.70
Pipe string optimization	49.72	1.96	3.9	59.41	1.294	268	414	0.708	17.92
Foaming	52.06	2.03	4.1	60.33	1.043	——	758	0.314	18.25

Table 2: Basic Indicator Data of Different Drainage and Gas Production Technologies

4.2.1 Based on the data in Table 2, construct a decision matrix and standardize it to obtain the standardized matrix X

$$\begin{bmatrix} 0.2145 & 0.9231 & 0 & 1 & 0 & 0.0751 & 0.3901 & 0 & 0.8997 \\ 0.1231 & 0 & 0.8571 & 0.5756 & 0.1736 & 0.1475 & 0.5308 & 0.6936 & 0.1559 \\ 0.6761 & 0.5897 & 0.7143 & 0.2514 & 0.3442 & 0 & 0.1703 & 0.5141 & 0.3229 \\ 1 & 1 & 0.4285 & 0 & 0.1721 & 0.1673 & 1 & 1 & 1 \\ 0 & 0.3077 & 1 & 0.7721 & 0.3100 & 0.0579 & 0.7136 & 0.2799 & 0.3964 \\ 0.2643 & 0.3589 & 0.5714 & 0.4066 & 1 & 0.0355 & 0 & 0.5457 & 0 \\ 0.3628 & 0.5384 & 0.8571 & 0.5874 & 0.6108 & 1 & 0.8494 & 0.4982 & 0.0735 \end{bmatrix}$$

4.2.3 Determination of Attribute Weight Vector W using CRITIC-AHP Combination Weighting Method (1)AHP method for determining subjective weights In engineering, it is believed that economic indicators have a slightly stronger impact on the quality of the process than technical indicators, and the judgment matrix B1 can be obtained as

	Technical indicators	Economic indicators
Technical indicators	1	1/3
Economic indicators	3	1

Table 3: The First Tier of Technical and Economic Indicators

The maximum eigenvalue of the judgment matrix for economic indicators calculation is λ_{max} = 2, consistency index CR_1=0, normalized feature vector is $\omega = [0.25\ 0.75]^T$ Similarly, judgment matrices B_2 and B_3 can be obtained for 4 technical indicators and 5 economic indicators: like Table 4 and Table 5

	Water production rate	Gas production rate	Differential pressure of oil sleeve	Lift efficiency
Water production rate	1	1/4	3	2
Gas production rate	4	1	6	3
Differential pressure of oil sleeve	1/3	1/6	1	1/5
Lift efficiency	1/2	1/3	5	1

Table 4: The Second Tier of Technical Indicators Marking.

	Process cost	Shortest homework cycle	Net present value	Investment payback period	Net present value ratio
Process cost	1	3	5	3	4
Shortest homework cycle	1/3	1	4	3	1/3
Net present value	1/5	1/4	1	4	5
Investment payback period	1/3	1/3	1/4	1	1/5
Net present value ratio	1/4	3	1/5	5	1

Table 5: The Second Tier of Economic Indicators Marking.

Calculate the maximum eigenvalue $\lambda_{max-B_1} = 4.238$, $\lambda_{max-B_2} = 5.827$,consistency indicators CR_2=0.0793， CR_3=0.0738, corresponding to normalized feature vectors are $\omega_{B_1} = [0.21 \quad 0.54 \quad 0.07 \quad 0.18]^T$, $\omega_{B_2} = [0.03 \quad 0.20 \quad 0.54 \quad 0.07 \quad 0.16]^T$

Based on the normalized vector results obtained above, obtain the subjective weights of each indicator ω_1,the result show as Table 6:

Indicators	Water production rate	Gas production rate	Differential pressure of oil sleeve	Lift efficiency	Process cost	Shortest homework cycle	Net present value	Investment payback period	Net present value ratio
Weight	0.052	0.135	0.018	0.045	0.023	0.150	0.405	0.052	0.120

Table 6: Subjective Weight Allocation Table

(2)CRITIC method for determining objective weights

The conflict coefficient and difference coefficient for each indicator obtained from equations (16) and (17) are shown in the Table 7 below:

	Water production rate	Gas production rate	Differential pressure of oil sleeve	Lift efficiency	Process cost	Shortest homework cycle	Net present value	Investment payback period	Net present value ratio
Conflict coefficient	4.093	4.428	5.362	5.524	5.270	6.558	5.499	6.181	5.072
Difference Coefficient	0.852	0.661	0.519	0.644	0.898	0.712	0.693	0.621	0.973

Table 7: Table of Conflict and Difference Coefficients Between Indicators

Calculate objective weights based on Table 7ω_2As shown in Table 8

Indicators	Water production rate	Gas production rate	Differential pressure of oil sleeve	Lift efficiency	Process cost	Shortest homework cycle	Net present value	Investment payback period	Net present value ratio
Weight	0.100	0.084	0.080	0.102	0.138	0.134	0.109	0.111	0.142

Table 8: Objective Weight Allocation Table

(3) Determination of Combination Weights by Lagrange Multiplier Combination Weighting Method By solving the Lagrange multiplier, the subjective and objective weight coefficients are obtained as β_1^* =0.615, β_2^* = 0.385, the combination weights are shown in Table 9, and the distribution of subjective, objective weights, and combination weights is shown in Table 9

Indicators	Water production rate	Gas production rate	Differential pressure of oil sleeve	Lift efficiency	Process cost	Shortest homework cycle	Net present value	Investment payback period	Net present value ratio
Weigh	0.071	0.115	0.042	0.067	0.068	0.144	0.290	0.075	0.128

Table 9: Combination Weight Table

(4) Determine the weighted decision matrix V

$$V = \begin{bmatrix} 0.015 & 0.106 & 0 & 0.067 & 0 & 0.011 & 0.113 & 0 & 0.115 \\ 0.009 & 0 & 0.036 & 0.038 & 0.012 & 0.021 & 0.153 & 0.052 & 0.020 \\ 0.048 & 0.068 & 0.030 & 0.168 & 0.023 & 0 & 0.049 & 0.386 & 0.041 \\ 0.071 & 0.115 & 0.018 & 0 & 0.012 & 0.024 & 0.290 & 0.075 & 0.128 \\ 0 & 0.035 & 0.042 & 0.052 & 0.021 & 0.001 & 0.207 & 0.021 & 0.051 \\ 0.019 & 0.041 & 0.024 & 0.027 & 0.068 & 0.001 & 0 & 0.041 & 0 \\ 0.026 & 0.062 & 0.036 & 0.039 & 0.041 & 0.144 & 0.246 & 0.037 & 0.001 \end{bmatrix}$$

(5) Calculate the Euclidean distance from each scheme to positive and negative ideal solutions D^+, D^-, view as Table 10

	Plunger	Gas lift	Jet pump	Electric submersible pump	Velocity column	Pipe string optimization	Foaming
d_i^+	2.359	2.367	2.049	2.102	2.290	2.430	2.427
d_i^-	0.183	0.152	0.243	0.167	0.168	0.062	0.227

Table 10: The Mahalanobis Distance from Each Alternative Solution to Positive and Negative Ideal Solutions

(6) Relative progress of each indicator f_i

f_i = (0.072 0.060 0.106 0.073 0.068 0.025 0.085)

(7) The optimal solution is determined by sorting the progress of pasting from small to large, as shown in the Table 11 below:

Ranking	1	2	3	4	5	6	7
Process	Jet pump	Foaming	Electric submersible pump	Plunger	Velocity column	Gas lift	Pipe string optimization

Table 11: Optimal Solution Ranking Result

4.3 Design of Drainage and Gas Production Process

According to the wellbore parameters of XX well in the gas area, the inclination point of the well is 1426m. In order to facilitate the sealing and unsealing of downhole tools, the oil pipe is anchored in the vertical section. The power fluid column uses a $\emptyset 60.3mm$ oil pipe, while the mixed fluid column uses a $\emptyset 73mm$ oil pipe. The jet pump is lowered to a depth of 2054m underground (vertical depth of 1872m). The downhole tools consist of $\emptyset 73mm \times 8m$ tail pipes, $\emptyset 73mm \times 3m$ screen pipes, jet pump barrels, and $\emptyset 73mm$ oil pipes. The diameter of the jet pump barrel is 85mm, the length is 1.3m, and the nozzle ratio is 2.12/3.38. The ground pump set adopts a three cylinder plunger pump with a rated pressure of 38MPa. The rated displacement is Ranking 1 2 3 4 5 6 7 Process Jet pump Foaming Electric submersible pump Plunger Velocity column Gas lift Pipe string optimization 8.4m^3/h, and the motor and frequency converter have a power of 42kW.

XX well has been carrying out jet pump drainage and gas production operations since August 2023. During the stable production stage, the daily water production is 17-22m^3, and the daily gas production is 8500-9200m^3/d. The production period is stable, and the drainage and gas production effect is good. The production curve of this well is shown in Figure 1.

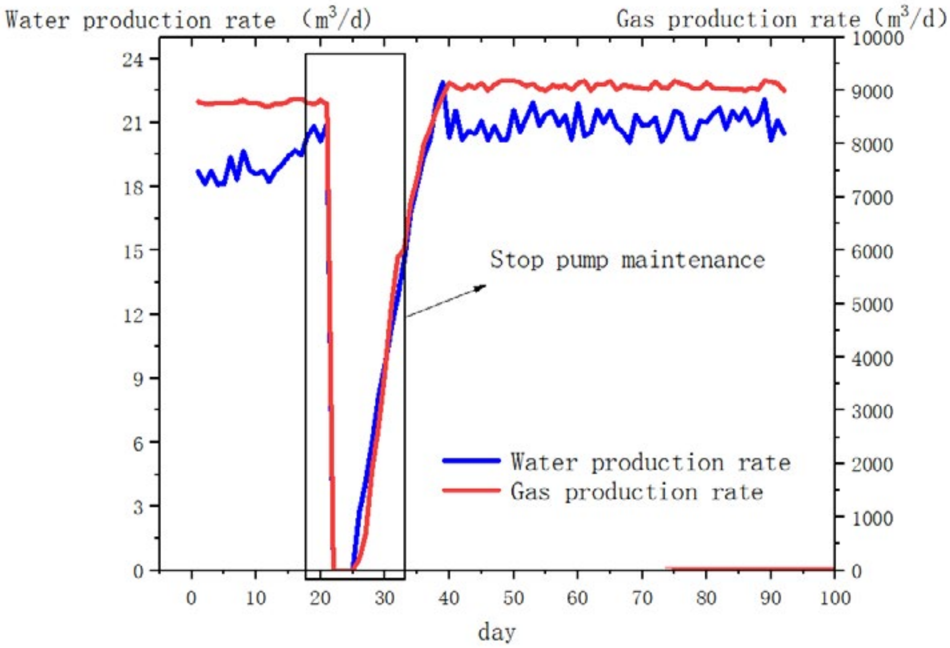

Figure 1: Production Curve of XX Well Drainage and Gas Production Process

5. Conclusion

A TOPSIS comprehensive evaluation model based on CRITIC-AHP combined weighting method and Mahalanobis distance was established by evaluating the economic and technical aspects of different drainage and gas production processes, and applied to a selected well. The results indicate that after the implementation of the process, the gas well production capacity gradually recovered to normal levels, and the wellbore fluid accumulation was effectively eliminated, indicating that the method is highly reliable and the optimization results meet the actual process requirements. At the same time, it has certain guiding significance for the optimization research and application of TOPSIS method in drainage and gas production processes.

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