The Research on comprehensive benefit Evaluation model of pumped storage power station based on improved G1-entropy weight method

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Abstract. In this paper, the comprehensive benefit evaluation index system of pumped storage power station will be established from four aspects: operation effect, functional benefit, financial benefit and environmental benefit. The improved sequence relationship analysis method will be combined with entropy weight method, and TOPSIS will be used to establish comprehensive evaluation model to quantitatively evaluate the comprehensive benefit of pumped storage power station in the power system. Then, through the analysis of the results of typical case studies, it is concluded that the index to be strengthened and the index that has reached the standard for power station, which is convenient for targeted measures to improve the comprehensive benefits of the power station in the future.

1. Introduction

With the rapid development of renewable energy, large-scale grid connection of wind power, photovoltaic and other renewable energy with fluctuating and random output has brought severe challenges to the safe operation of power system. Because the pumped storage unit has good performance in peak frequency modulation and auxiliary service, it has good benefits in ensuring the safe and stable operation of power grid and improving the absorption capacity of new energy [1]. Therefore, on the basis of economic benefits, the construction of pumped storage power station should pay more attention to its peak-frequency and environmental benefits. How to evaluate the value of pumped storage power station in power system scientifically is an urgent problem to be solved at present.

The existing studies on the benefit evaluation of pumped storage power stations mainly focus on the analysis and calculation of economic benefits [2] [3], and the static benefit analysis is too much [4], lacking the comprehensive analysis on the technical benefits, functional benefits and environment benefits of pumped storage power stations. In addition, in terms of evaluation methods, existing studies mainly focus on subjective empowerment and expert evaluation [5] [6]. Due to cognitive limitations, the evaluation results are highly subjective.

In view of this, this paper selects evaluation indexes from the four aspects of operation effect, function benefit, economic benefit and environment benefit, constructs the comprehensive benefit evaluation index system of pumped storage power station, and analyzes the relationship between the improved type sequences.
2. Establishment of Comprehensive Benefit Evaluation Index System for Pumped Storage Power Station

The value of pumped storage power station in power system is mainly reflected in three aspects: technical benefit, economic benefit and environmental benefit. Technical benefit refers to the operation benefit of pumped storage power station and the cost saving benefit of power system realized when providing auxiliary service. The above two kinds of technical benefits can be measured from unit operation effect and functional benefit. Economic benefit refers to the economic income obtained by the operation of pumped storage power station itself, which can be evaluated by financial index, and the environmental benefit is mainly the increase of clean energy consumption brought by the pumped storage power station to provide the regulating means for the power system.

Therefore, this paper takes the operational effect, functional benefit, financial benefit and environmental benefit as the first class index, and follows the principles of systematization, science, rationality and comparability[7], the comprehensive benefit evaluation index system of pumped storage power station is constructed from the above four aspects, as shown in Table 1.

| First class index | Second class index |
|-------------------|-------------------|
| Operational effects $E_1$ | Startup success rate $I_{1}$ |
| Functional benefits $E_2$ | Frequency modulation benefits $I_{4}$ |
| Economic benefits $E_3$ | Internal recovery rate $I_{6}$ |
| Environmental benefits $E_4$ | Wind power increases $I_{9}$ |
| | Electricity $I_{10}$ |
| | Increased PV power $I_{11}$ |

2.1. Operational effectiveness indicators

The operation effect of pumped storage power station is mainly reflected in the success rate of startup and the number of hours per year, which is determined as the following two secondary indexes.

1) Start-up success rate: Start-up success rate refers to the unit in a certain period of time according to the standard start-up success probability. The formula is as follows.

\[ I_1 = \frac{N_2}{N_1} \]

In the above formula, $I_1$ is the success rate of start-up; $N_1$ is the total number of start-up times of the unit in a certain time; and $N_2$ is the number of successful start-up times of the unit in a certain time.

2) Number of operating hours per year: the number of operating hours per year is an indicator of the time utilization level of the unit. The formula is as follows.

\[ I_2 = h_1 + h_2 \]

In the above formula, $I_2$ is the number of annual operating hours of the unit, $h_1$ is the number of pumping hours of the unit's annual operation, and $h_2$ is the number of hours of generating electricity in the unit's annual operation.

2.2. Functional benefits indicators

The functional benefits of pumped storage power station include peak-shaving benefit, frequency modulation benefit and reserve capacity benefit. The secondary indicators are as follows:

1) Peak-shaving benefit

In this paper, the thermal power cost saved when the pumped storage unit replaces the thermal power unit to provide the peak-shaving service for the system is taken as the evaluation index of the peak-shaving benefit of the pumped storage power station. The calculation formula is as follows.
In the above formula, \( F_\gamma \) is the power consumption rate of the thermal power station when the pumped storage power station is not in use; \( b_0 \) is the average coal consumption rate when the thermal power unit does not carry out peak cutting and valley filling according to plan; \( L_P \) is the loss rate of pumped power line; \( f \) is the percentage of low load adjustment required by the system; \( F_j \) is the power consumption rate of the thermal power station after the pumped storage power station is put into use; \( T_P \) is the inefficient operation time of the thermal power unit when only the thermal power unit is used in the system, and \( b_f \) is the coal consumption rate of the generation at this time.

(2) Frequency modulation benefits

The stability of power system frequency is the key index of power supply quality. In order to ensure the stability of frequency, it is necessary to ensure that the output of generator set can be adjusted in real time with the load curve. The frequency modulation of thermal power units often reduces the generation efficiency and increases the coal consumption, while the pumped storage power station can ensure the rapid, flexible and efficient frequency modulation service for the system. In this paper, the dynamic cost of thermal power is saved when the thermal power unit is replaced by the pumped storage unit to provide the system with frequency modulation. As the evaluation index of the frequency modulation benefit of the pumped storage power station, the calculation formula is as follows.

\[
I_4 = \sum_{i=1}^{365} \sum_{m=1}^{nH} (b_i \times n_i + b_{ol} \times T_i) \times N_i \times P_e + \beta \times X \times I (1 + \gamma) - \sum_{i=1}^{365} \frac{V \times H \times S}{367.2} \times n_H \times m_H \times P
\]

(4)

\( b_{ol} \) represents the standard coal consumption of the thermal power unit during peak-shaving; \( P_e \) represents the coal price; \( b_i \) represents the coal consumption rate of the i thermal power unit rising from its minimum technical output to its full capacity output; \( I \) represents the investment of the unit and \( n_i \) represents the number of daily start-up or load-raising times of the i fire motor unit; \( T_i \) represents the number of hours of frequency-modulated operation of the thermal power unit within one day; \( H \) represents the average head of the hydropower station; \( N_i \) represents the capacity of the thermal power unit; \( \beta \) represents the maintenance cost coefficient of the unit failure caused by the frequent change of conditions of the frequency modulation thermal power unit; \( X \) represents the overhual rate of the unit; \( \gamma \) represents the proportion of the unit minor repair fee to the overhaul fee; \( \delta \) represents the no-load water consumption of the turbine starting; \( n_H \) represents the daily start number of the turbine; \( m_H \) represents the corresponding turbine table number; \( P \) represents the electricity price.

(3) Standby benefits

In order to ensure the reliability of power system, there must be a certain proportion of capacity for rotation reserve. The use of fire motor to provide rotary reserve often has a higher cost, but pumped storage power station can provide rotary reserve for the system with lower cost and flexible regulation. In this paper, the dynamic cost of thermal power is saved when the pumped storage unit replaces the thermal power unit to provide the rotating reserve for the system, which is used as the evaluation index of the reserve benefit of the pumped storage power station(6)The formula is as follows.

\[
I_5 = C \times 30\% \times 2 \delta
\]

(5)

Among them, \( I_5 \) is reserve benefit, \( C \) is total installed capacity of power station and \( \delta \) is comprehensive efficiency coefficient of pumped storage power station.

2.3. Economic benefits indicators

In this paper, the internal rate of return and the investment payback period reflecting the profitability of the project, as well as the loan repayment period reflecting the project solvency, are selected as the economic benefit evaluation value of the pumped storage power station. It can better reflect the financial situation of the power station.
(1) Internal rate of return: The internal rate of return is the discount rate of financial net present value equal to 0.00 in the operation period of the project. The main dynamic index to evaluate the economic benefit of pumped storage power station is as follows.

\[ \sum_{t=1}^{n}(CI - CO) \frac{(1 + I_6)^{-1}}{t} = 0 \] (6)

CI is cash inflow; CO is cash outflow; \((CI - CO)_t\) is the net cash flow in the \(t\) year; \(n\) is the calculation period; and \(I_6\) is the internal rate of return.

(2) Investment payback period: The investment payback period refers to the time required to repay the total investment of the annual net income of the power station and is the main static index for evaluating the economic benefits of the pumped storage power station. The calculation formula is as follows.

\[ \sum_{t=1}^{T}(CI - CO) = 0 \] (7)

CI is the year's cash inflow; CO is the \(t\) year's cash outflow; and \((CI - CO)_t\) is the first year's net cash flow.

(3) Loan repayment period: Loan repayment period refers to the income, depreciation and other profits generated after the operation of the power station are used to repay the principal and interest of the loan the time required under the state regulations and the actual financial situation. The calculation formula is as follows.

\[ Y = \sum_{t=1}^{I_B} (R_d + D + R_0) \] (8)

\(Y\) is the sum of principal and interest of the loan; \(I_B\) is the repayment period of the loan; \(R_d\) is the total amount used to repay the loan in the annual income; \(D\) is the total amount used to repay the loan in the annual depreciation fee; and \(R_0\) is the total amount used to repay the loan in the annual profit.

2.4. Environmental benefit indicators
As an important means of system regulation, pumped storage power station "bundling and dispatching" with renewable energy such as wind power, photovoltaic power generation, hydropower and so on, will be able to improve the utilization rate of renewable energy and reduce the waste of renewable energy under the condition of ensuring the safe and reliable operation of the system. This paper mainly considers the proportion of wind power, photovoltaic power generation and hydropower increase after the pumped storage power station is connected to the local provincial or regional power grid, and takes the renewable energy generation as the evaluation index to promote the renewable energy utilization benefit of the pumped storage power station.

3. Comprehensive benefit evaluation model of pumped storage power station
The comprehensive benefit evaluation index of pumped storage power station selected in this paper is quantitative index, and the index weight can be determined by objective weighting method. However, the objective weighting method is generally used to obtain the final weight coefficient through mathematical calculation, and the weight result is often affected by the selected mathematical model, so that there is a certain gap between the obtained weight value and the objective situation. Therefore, this paper makes use of subjective weighting method to make up for the deficiency of objective weighting method, constructs an improved G1-entropy combination weighting model, and realizes the organic combination of subjective and objective weighting methods in logic. On this basis, TOPSIS method is further applied to establish the comprehensive benefit evaluation model of pumped storage power station.
3.1. Improved G1-entropy weight combination weighting method

3.1.1. Improved G1 analysis method. As a common method of subjective weighting [8], order relation analysis method is an improved method of determining weights based on AHP. It not only reflects the experience and knowledge of experts, but also reduces the amount of calculation. It does not need to construct judgment matrix and check consistency, but it is vulnerable to the influence of subjective preferences of experts to a certain extent. In this paper, the weight coefficient is redefined on the basis of the original order relationship analysis method, and the weight value determined by experts is converted from fixed value to interval value, so as to reduce the influence of experts' subjective preferences, an improved G1 analysis method is proposed. Operation steps are as follows:

① Determine order relation. Set the evaluation index set\{ x_1, x_2, \ldots, x_m \}, and if the relative importance of the evaluation index \( x_i \) is no less than that of the evaluation standard \( x_j \), it is denoted as \( x_i > x_j \).

② The ratio of relative importance between adjacent indexes is obtained. Experts rationally judge the importance degree of adjacent evaluation index \( x_{k-1} \) and \( x_k \) according to their knowledge reserve and accumulated experience, and calculate the ratio of importance degree \( w_{k-1}/w_k \).

\[
\begin{align*}
\frac{r_k}{w_k} &= \frac{w_{k-1}}{w_k}, \quad k=m, m-1, \ldots, 3, 2 \\
\end{align*}
\]

(9)

③ Calculation of weight coefficient. Suppose the rational judgment value made by experts, and the formula to calculate the weight is

\[
\begin{align*}
&w_m = (1 + \sum_{k=2}^{m} \prod_{i=k}^{m} r_i)^{-1} \\
&w_{k-1} = r_k w_k, \quad k=m, m-1, \ldots, 3, 2 \\
\end{align*}
\]

(10)

(11)

Generally, due to the limitations of cognition and the complexity of the problem, experts cannot accurately determine the exact value of \( r_k \) (k = 2, \ldots, m) and are more likely to determine the interval. Therefore, the traditional order relation analysis method is improved and the weight coefficient is redefined.

Definition 1 If the expert determines that the ratio \( r_k \) of the evaluation index \( x_{k-1} \) and \( x_k \) to the degree of importance is an interval number, it is called \( r_k \) an indefinite ratio judgment, denoted as \( \overline{r}_k \) (k = 2, \ldots, m). Set \( \overline{r}_k = [r_k^L, r_k^R] \), \( r_k^L \leq r_k^R \), \( r_k^L \) and \( r_k^R \) to be selected continuously on the interval [1,1.8], that is, \( r_k^L, r_k^R \in [1,1.8] \).

Definition 2 If \( r_k^* \) is a random variable with continuous and uniform distribution in the judgment of indefinite ratio \( \overline{r}_k \) (k = 2, \ldots, m) interval, then \( u = (u_1, u_2, \ldots, u_m)^T \) is called the order relation simulation weight, where

\[
\begin{align*}
&u_m = (1 + \sum_{k=2}^{m} \prod_{i=k}^{m} r_i^*)^{-1} \\
&u_{k-1} = r_k u_k, \quad k=m, m-1, \ldots, 3, 2 \\
\end{align*}
\]

(12)

(13)

The subjective weight of the index determined by the improved G1 method is set as \( u = (u_1, u_2, \ldots, u_m)^T \).
3.1.2. Entropy weight method. The entropy weight method belongs to the objective weighting method, which objectively reflects the importance degree of the index from the quantitative value difference degree the index weight is calculated to reflect its objectivity. [9] The specific operation steps are as follows:

① Calculate the characteristic specific gravity, i.e

\[ P_j = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \]  

Where, assume \( x_{ij} \geq 0 \), \( \sum_{j=1}^{n} x_{ij} > 0 \); \( i \) is the evaluation index; \( j \) is the evaluated object; \( x_{ij} (i = 1, 2, \ldots, m; j = 1, 2, \ldots, n) \) is the forward index value of the ith index to the jth object; \( P_j \) is the characteristic proportion of the ith index to the jth object.

② Calculate the entropy value of each index, namely

\[ e_i = -k \sum_{j=1}^{n} P_j \ln(P_j) \]  

Where, \( k = 1/\ln(n) \), \( k > 0 \), \( e_i > 0 \); \( e_i \) is the entropy value of the ith index.

③ Determine the weight (entropy weight) of the evaluation index, i.e Entropy Redundancy

\[ d_i = 1 - e_i \]  

Index weight

\[ v_i = \left(1 - e_i\right) / \sum_{i=1}^{m} \left(1 - e_i\right) \]  

Where, \( i = 1, 2, \ldots, m \), \( v_i \) is the weight coefficient treated by the normalization method.

3.1.3. Combination weight calculation. The objective function is established with the minimum deviation sum of squares between the combined weight and G1 method and the minimum deviation between the combined weight and entropy method. Under the condition of the minimum deviation sum of squares between the combined weight and the subjective and objective weight, the optimal result of the combined weight is obtained.

\[ \min z = \sum_{j=1}^{m} \left[ (W_j - u_j)^2 + (W_j - v_j)^2 \right] \]  

\[ W_j = \beta u_i + (1-\beta) v_i \]  

Where, is the minimum objective function, and is the ith index weight after the combination of the two weighting methods. To represent as a linear combination of sum; Is the proportion of subjective preference coefficient weight in combination weight; Is the improved G1 method weight of the ith index; (1-) is the proportion of objective preference coefficient in combination weight; Is the weight of entropy method of the ith index.

3.2. TOPSIS evaluation method

The evaluation and analysis of the comprehensive benefits of different pumped storage power stations can be abstracted as a multi-objective evaluation problem. In this part, TOPSIS method suitable for multi-objective evaluation is selected to evaluate the comprehensive benefits of pumped storage power stations by constructing TPOSIS model based on combinatorial weight [10]. The specific steps are as follows.
(1) Build index matrix
Suppose the number of samples to be evaluated is \( m \), the evaluation index is \( n \), and the value of each forward index is \( v_{ij} \) \((i = 1, 2, \ldots, m; j = 1, 2, \ldots, n)\), then the index matrix \( V \) is:

\[
V = \begin{bmatrix}
v_{11} & \cdots & v_{1n} \\
\vdots & \ddots & \vdots \\
v_{m1} & \cdots & v_{mn}
\end{bmatrix}
\]  
(20)

(2) Standardized index matrix the standardized index matrix is obtained by standardizing the index matrix \( X = (x_{ij})_{m \times n} \).

\[
x_{ij} = \frac{v_{ij}}{\left( \sum_{i=1}^{m} (v_{ij})^2 \right)^{1/2}}
\]  
(21)

(3) The index matrix is weighted to form the decision matrix \( B \)

\[
B = X \times W = (b_{ij})_{m \times n}
\]  
(22)

Where \( W_{j} \) is the weight index of each evaluation index combination.

(4) Determine the positive and negative optimal solutions

\[
S^+ = [b_1^+, b_2^+, \ldots, b_n^+] = [\max \{b_{11}, b_{21}, \ldots, b_{m1}\}, \max \{b_{12}, b_{22}, \ldots, b_{m2}\}, \ldots, \max \{b_{1n}, b_{2n}, \ldots, b_{mn}\}]
\]  
(23)

\[
S^- = [b_1^-, b_2^-, \ldots, b_n^-] = [\min \{b_{11}, b_{21}, \ldots, b_{m1}\}, \min \{b_{12}, b_{22}, \ldots, b_{m2}\}, \ldots, \min \{b_{1n}, b_{2n}, \ldots, b_{mn}\}]
\]  
(24)

Where, \( S^+ \) and \( S^- \) represents the positive and negative optimal solutions respectively.

(5) Evaluation scheme and the optimal solution of the positive and negative distance measure.

This article through the Euclidean distance represent different evaluation scheme and the positive and negative to the optimal solution, the distance measure, specific expression as shown below:

\[
D_i^+ = \sqrt{\sum_{j=1}^{n} (b_{ij} - b_{ij}^+)^2}, i = 1, 2, \ldots, m; j = 1, 2, \ldots, n
\]  
(25)

\[
D_i^- = \sqrt{\sum_{j=1}^{n} (b_{ij} - b_{ij}^-)^2}, i = 1, 2, \ldots, m; j = 1, 2, \ldots, n
\]  
(26)

The larger the relative value is, the farther the research object is from the worst solution, the better the research object will be.

(6) to calculate the evaluation, scheme and the closeness between the optimal solution.

The calculation formula of closeness degree is as follows:

\[
C_i = D_i^- / \left( D_i^- + D_i^+ \right)
\]  
(27)

(7) Judge the pros and cons of each alternative according to the degree of closeness, and the alternative with a larger value is the optimal one.

4. Analysis of examples

4.1. Basic data

This article selects three capacity of 2400 MW, 1200 MW and 1000 MW pumped storage power station as the evaluation objects respectively, application by building the appraisal model of comprehensive benefit of pumped storage power station on the comprehensive benefit evaluation, evaluation raw data such as power stations are shown in table 2.
Table 2. Evaluation basic data

| Indicator                              | A power station | B power station | C power station |
|----------------------------------------|----------------|----------------|----------------|
| Startup success rate (%)               | 97.59          | 97.58          | 98.92          |
| Annual operating hours (h)             | 2750           | 2736           | 2750           |
| Peak-shaving benefits (thousand yuan)  | 5314.60        | 1757.30        | 789.06         |
| Frequency modulation benefit (thousand yuan) | 2310.60        | 505.30         | 344.36         |
| Standby efficiency (thousand yuan)     | 2026.65        | 1053.30        | 372.18         |
| Internal rate of return (%)            | 18.23          | 17.69          | 14.35          |
| Payback period (year)                  | 11.24          | 11.5           | 13.23          |
| Loan repayment period (year)           | 16             | 14             | 15             |
| Wind power increase (GWH)              | 7225           | 5800           | 3709           |
| Water and electricity increase (GWH)   | 49084          | 20180          | 5400           |
| Photovoltaic power increase (GWH)      | 66917          | 3310           | 14770          |

4.2. Determination of index weight

According to the steps of the improved G1-entropy weight combination weighting method proposed above, the evaluation index is weighted. Firstly, the improved G1 method is adopted to determine the subjective weight, and the second-level index of functional benefit is taken as an example. The specific solving process is as follows.

According to expert opinions, determine the order relationship as $I_4 > I_3 > I_5$; arranged as $x_1 > x_2 > x_3$ ;

According to the experts' own experience and knowledge reserve, the indeterminate ratio judgment of functional benefit is given $\beta = ([1.034, 1.172], [1.265, 1.405])$;

By definition 1 and 2, the random simulated weight vector of functional benefits can be obtained:

$u = (u_1, u_2, u_3)^T = (0.377, 0.352, 0.271)$

Similarly, determine the subjective weight of other indicators according to the above steps.

Then the entropy weight method is used to determine the objective weight, and the objective weight value is calculated according to formula (14) - (17). Finally, the comprehensive weight value is calculated according to formula (18) - (19), and the results are shown in Table 3.

As a kind of special power source in the power system, the pumped storage power station cannot be evaluated simply by the benefit evaluation index of the general power plant. The benefit of the pumped storage power station should be investigated at the whole system level. From the weight vector, the function benefit brought by the construction of pumped storage power station index weight is the largest, accounted for 34.60%, 6.95% weight than running effect and economic benefit of weight 33.12% and 25.33% of the weight of environmental benefits were high, which conforms to the common recognition of pumped storage power station, is the first target of the construction of pumped storage power station is in order to reach their peak cut in power grid of special function. Among the weight results obtained by entropy weight method, the operation effect is objectively influenced by the original data, and the weight is 0, which is significantly different from the general cognition. However, the result obtained by subjective and objective combination analysis is 6.95%. This indicates that the improved G1-entropy weight method is more comprehensive and accurate in calculating the comprehensive weight, and also reflects that the functional benefits of pumped storage power station are more important, and the dynamic service provided by it can ensure the safe and stable operation of the power grid.
Table 3. Comprehensive weight of indicators

| Level indicators | Subjective weight | Objective weight | The comprehensive weights | The secondary indicators | Subjective weight | Objective weight | The comprehensive weights |
|------------------|-------------------|------------------|---------------------------|-------------------------|-------------------|-------------------|---------------------------|
| $E_1$             | 0.139             | 0.0000           | 0.0695                    | $I_1$                    | 0.533             | 0.0000           | 0.037                     |
|                  |                   |                  |                           | $I_2$                    | 0.467             | 0.0000           | 0.032                     |
|                  |                   |                  |                           | $I_3$                    | 0.352             | 0.0962           | 0.120                     |
| $E_2$             | 0.410             | 0.2820           | 0.3460                    | $I_4$                    | 0.377             | 0.1201           | 0.137                     |
|                  |                   |                  |                           | $I_5$                    | 0.271             | 0.0658           | 0.088                     |
|                  |                   |                  |                           | $I_6$                    | 0.218             | 0.0019           | 0.026                     |
| $E_3$             | 0.229             | 0.4334           | 0.3312                    | $I_7$                    | 0.397             | 0.2658           | 0.178                     |
|                  |                   |                  |                           | $I_8$                    | 0.385             | 0.1656           | 0.127                     |
|                  |                   |                  |                           | $I_9$                    | 0.352             | 0.0125           | 0.045                     |
| $E_4$             | 0.222             | 0.2846           | 0.2533                    | $I_{10}$                 | 0.342             | 0.1001           | 0.088                     |
|                  |                   |                  |                           | $I_{11}$                 | 0.305             | 0.1720           | 0.120                     |

4.3. The evaluation results

Based on the above TOPSIS model and according to the index system constructed in Section 3.2 and the calculation formula of each index, the original evaluation decision forward matrix and combination weight of pumped storage power station are obtained as follows:

$$V = \begin{bmatrix} 97.59 & 2750 & 5314.6 & 2310.6 & 2026.65 & 18.23 & 0 & 1 & 7225 & 49084 & 66917 \\ 97.58 & 2736 & 1757.3 & 505.3 & 1053.3 & 17.69 & 0.13 & 0 & 5800 & 20180 & 3310 \\ 98.92 & 2750 & 789.06 & 344.36 & 372.18 & 14.35 & 1 & 0.5 & 3709 & 5400 & 14770 \end{bmatrix}$$

$$W = \begin{bmatrix} 0.037 & 0.032 & 0.120 & 0.137 & 0.088 & 0.026 & 0.178 & 0.127 & 0.045 & 0.088 & 0.120 \end{bmatrix}$$

Standardize the original matrix $V$ and bring it into the formula to calculate the closeness of each scheme. The result is $C=(0.974 \ 0.140 \ 0.157)$. That is, the ranking of the comprehensive operating benefits of each evaluation subject is as follows:

A power station > C power station > B power station

From the analysis and evaluation results of TOPSIS, it can be seen that the closeness degree of Power station A is far greater than that of power stations B and C. Main reason is that with the rights to add new energy scale, new energy power generation of intermittent, volatility and uncontrollability influence to power grid operation is gradually increased. Especially A power station is located in the grid populated areas, the system load frequency control pressure is raised, can give full play to A power station in the power grid peak shaving, frequency modulation, spare, gains the highest in terms of functional benefits. At the same time, power station A not only has the largest installed capacity, wind power, hydropower and photovoltaic power increase of power station B and Power station C are significantly less than that of power station A, indicating that power station A not only plays a role of auxiliary service for the power grid, but also plays A key role in absorbing clean energy.

5. Conclusion

Considering the value of pumped storage power station in power system, based on the running effect, function and economic benefits and environmental benefits for the level indicator index system of comprehensive benefit of pumped storage power station is established, and combines the subjective and
objective factors, the modified GI-methods combination of entropy and TOPSIS analysis method the comprehensive benefit evaluation model is constructed. On this basis, the comprehensive benefit of three pumped-storage power station has carried on the empirical analysis, the evaluation results show that the installed capacity of the largest and most functional benefit A power station comprehensive operation efficiency is highest, that give full play to the function of power station auxiliary services more conducive to its development.

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References
[1] A Osamu Kurihara, etc. Measurements of 131I in the thyroids of employees involved in the Fukushima Daiichi nuclear power station accident [J]. Journal of Nuclear Science and Technology, 2013, Vo1.50(2): 122-129P.
[2] Gao Shang, The Financial and Economic Evaluation of Hohhot’s Pumped Storage Project [D]. Hebei: North China Electric Power University.
[3] Chen Tong Fa, Zhang Hui, Zhao Gui Yuan. Thoughts on the Economic Evaluation Mechanism of Pumped Storage Projects [J]. Water Power, 2013.1.
[4] Wang Xueliang, Benefit Assessment and Operation Strategy of The Distributed Pumped Storage Systems [D]. Heilongjiang: Harbin Institute of Technology, 2011.6.
[5] Zeng Jiang, Huang Haiping, Liu Haisheng, e.t. Study on Comprehensive Evaluation of Energy Saving index System of Pumped Storage Power Station [J] Journal of Hydroelectric Engineering, 2015, 34(8): 118-128.
[6] Shen Hailong, Construction quality Evaluation of assembled concrete building based on Combinatorial Evaluation [D]. Zhengzhou University, 2019.3.
[7] Peng Zhanlin e.t. Design principle and construction process of Comprehensive Evaluation Index System [J]. Science Research Management, 2017, 38(S1): 209-215.
[8] Qi Lan, Li Nan. Evaluation and Analysis of mountain flood Hazard Prevention System based on Fault Tree Analysis-Analytic Hierarchy Process [J] Water Resources and Hydropower Engineering, 2017, 48(4): 141-145.
[9] Shan Chengjiu, Dong Zengchuan, Fan Kongming, e.t. Application of Combined Weight Method in the weight calculation of River Health Assessment [J] Journal of Hohai University(Natural Sciences) 2012, 40(6): 622-628.
[10] Peter Wanke, M.D. Abul Kalam Azad, C.P. Barros. Predicting efficiency in Malaysian Islamic banks: A two-stage TOPSIS and neural networks approach [J]. Research in International Business and Finance, 2016(36): 485-498.