Comprehensive analysis of conductor selection

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Abstract: With the continuous improvement of people's living standard, the consumption of electricity also increased, which requires a larger capacity of the conductor for electricity transmission. Therefore, comprehensive selection of conductor type made higher requirements. Based on the analysis, this paper divides the basic indication of conductor selection into two types: cost type and efficiency type, then each category is divided into a number of specific indicators based on needs, finally, using the grey relational analysis method to compare and analyze the cost indication and efficiency indication of conductors, which draws the optimization scheme of conductor selection, and is used to guide the type selection of conductor type.

1. Introduction
With the development of the national economy, electricity load increased year by year, the transmission capacity of traditional steel-cored aluminum strand conductor is difficult to meet the needs of large electricity load, developing large-capacity energy-saving conductor, increasing the line transmission capacity while reducing line losses, so as to improve the technical level of power transmission in our country has become a target for the power grid. In recent years, with the further improvement of conductor performance, various methods of conductor development and selection have attracted more and more attention. The literatures [1-3] compare the technology and economy of the energy-saving conductor s used in the experiments to make model selection. The literatures [4-5] lead into macroeconomic parameters correction on investment cost, present the operation and maintenance cost formula, put forward the formula to estimate the costs of decommissioning, and finally put forward the selection of the UHV DC transmission line conductor of objective function. The literatures [3,6-7] make a detailed technical and economic comparison and demonstration of various alternative conductors from the aspects of conductor material, ampacity, electrical performance, mechanical characteristics and economy. The literature[8] mainly from the aspects of electricity loss and ampacity, sag, overload capacity, tower load and swing angle, combined with engineering applications makes detailed technical comparisons, and referring to the general design, the tower by factors sums up selections of recommended energy saving conductor . In the previous experiments of conductor selection, the mechanical and electrical performance, economic performance are often regarded as determinant factors [5,8], these factors are numerous and complex, how to combine these factors and simplify the analysis process are very important.

In comprehensive conductor selection, the influence of conductor performance is various, the traditional regression analysis and variance analysis are difficult to apply, and the grey relational analysis method is a method of system analysis, it can make up for the lack of mathematical statistics method. Based on the analysis of various conductor properties, which can be divided into cost index and effect index, using the method of grey correlation analysis to get the optimal combination of the standard
series, and combined with the cost indexes, then compare with the data sequence of the benefit index, the effects of various factors selection problem are changed into a comparison of grey correlation degree, in addition, combined with the results of economic indicators, finally the optimization scheme of various conductor selection is obtained.

2. **Index of Conductor Selection**

Generally, in the selection of traverse scheme, the calculations of electrical performance and mechanical performance of different conductor types are mainly carried out and compare their result. The electrical performance includes the electric field effect, audible noise, radio interference and corona loss. The mechanical performance includes mechanical characteristics, load characteristics and so on. Finally, it is confirmed by comprehensive technical and economic comparison. In this paper, the comprehensive evaluation index can be divided into cost index and benefit index, as shown in figure 1.

![The comprehensive evaluation index](image)

The cost index includes Sag of conductor, horizontal load, vertical load, longitudinal load, DC resistance, AC resistance, and resistance loss. The benefit index includes the conductor overload capacity, the economic current per phase, the economic transmission power per circuit, the ampacity per phase conductor, and the maximum transmission power per circuit. The index of conductor selection in this paper is mainly based on these 12 indexes (7 cost indexes and 5 benefit index).

3. **Grey Relational Analysis**

Grey relational analysis (GRA) is part of grey system theory, which is suitable for solving the complicated interrelationships between multiple factors and variables. GRA is to compare quantitative analysis to the development between every factor in the grey system dynamically, describes the relation degree among main factor and other factors in the grey system. The grey relational analysis is used to determine the relationship between two sequences of stochastic data in a grey system. The procedure may bear some similarity to the pattern recognition technology. One sequence of data is called the “reference pattern” or “reference sequence,” and the correlation of the other sequence (named “comparative pattern” or “comparative sequence”) to the reference sequence is to be identified. The mathematics mode of grey relational analysis is shown as follows:

Let $X_0$ be the reference pattern with $n$ entries

$$X_0 = \{x_0(k)\} = [x_0(1), x_0(2), \ldots, x_0(m)]$$

(1)
and $x_j$ be one of the patterns with $p$ entries to be compared with $x_i$ (each $x_j$ has the same $m$ number of criteria as $x_i$). The $x_j$ is written as

$$x_j = \{x_j(k)\} = \begin{bmatrix} x_1(1) & x_1(2) & \cdots & x_1(m) \\ x_2(1) & x_2(2) & \cdots & x_2(m) \\ \vdots & \vdots & \ddots & \vdots \\ x_p(1) & x_p(2) & \cdots & x_p(m) \end{bmatrix}$$

(1 ≤ $j ≤ p$, 1 ≤ $k ≤ m$)

Like general statistical analysis methods, grey relational analysis first calls for the appropriate normalization of raw data to remove anomalies. The raw data can be transformed into dimensionless forms either by maximum-value processing or average-value processing. These two processing methods defined as follow:

$$x_0^* = \{x_0^*(k)\} = \frac{x_0(k) - \min x_0(k)}{\max x_0(k) - \min x_0(k)}$$

(3)

$$x_j^* = \{x_j^*(k)\} = \frac{x_j(k) - \min x_j(k)}{\max x_j(k) - \min x_j(k)}$$

(4)

The set of the sequence $x_j^*$ is generally the influencing factor to $x_0$. The grey relational coefficient between the compared pattern $x_j^*$, and the reference pattern $x_0$ at the $k$th entry ($k = 1, 2, \cdots, m$) is defined

$$\eta_{0j} = \gamma_{0j}(x_0^*(k), x_j^*(k)) = \min_{j} \left[ \frac{\min_{j} \left| x_0^*(k) - x_j^*(k) \right| + \xi \max_{j} \left| x_0^*(k) - x_j^*(k) \right|}{\left| x_0^*(k) - x_j^*(k) \right| + \xi \max_{j} \left| x_0^*(k) - x_j^*(k) \right|} \right]$$

(6)

Where $\left| x_0^*(k) - x_j^*(k) \right|$ is the absolute difference of two comparative sequence, $\min_{j} \left| x_0^*(k) - x_j^*(k) \right|$ and $\max_{j} \left| x_0^*(k) - x_j^*(k) \right|$ are the minimum and maximum value of $\left| x_0^*(k) - x_j^*(k) \right|$ respectively, and $\xi$ is the distinguish coefficient which its value is adjusted with the systematic actual need and defined in the range between 0 and 1. A value of 0.5 is used in most situations. If the higher the value of the criterion, the better the alternative, the $\eta_{0j}$ is equal to 1. Otherwise, it is equal to zero. The grey relational factor $\gamma_{0j}(x_0, x_j)$ between the reference pattern $x_0$ and the compared pattern $x_j$ is taken as the average of $\eta_{0j}$ over all $k$ entries.
The factor of grey relation $\gamma_{0j}$ is the similarity indicator of the pattern $x_0$ and the pattern $x_j$. A higher grey relational grade indicates that the compared sequence is the most similar to the reference sequence. However, there are unresolved problems in the above investigation.

4. Empirical Analysis of Conductor selection

This study, taking the traditional conductor, the new high-conductivity ACSR (Aluminum conductor steel reinforced), the new ACA (Aluminum conductor alloy reinforced), and the new AAAC (All aluminum alloy conductor) for example, using the grey relational analysis described above, analyzes cost indicators and benefit indicators respectively, and then carries out a comprehensive analysis. The comprehensive evaluation results are shown in Table 1.

Table 1 Calculation results based on the grey relational analysis

| Reference sequence | Grey relational grade | Conductor sequence | Grey relational grade |
|---------------------|-----------------------|--------------------|-----------------------|
| $\gamma_{01}$       | 0.38455               | $\gamma_{02}$     | 0.61293               |
| $\gamma_{02}$       | 0.42283               | $\gamma_{03}$     | 0.60269               |
| $\gamma_{03}$       | 0.62785               | $\gamma_{04}$     | 0.59791               |
| $\gamma_{04}$       | 0.6239               | $\gamma_{05}$     | 0.87207               |
| $\gamma_{05}$       | 0.48891               | $\gamma_{06}$     | 0.82375               |
| $\gamma_{06}$       | 0.49855               |                     | 0.76997               |

Table one shows that $\gamma_{11} > \gamma_{12} > \gamma_{13} > \gamma_{10} > \gamma_{14} > \gamma_{19} > \gamma_{10} > \gamma_{16} > \gamma_{10} > \gamma_{17} > \gamma_{10}$, which indicates that the grey relational grades of the new ACSR, and the new ACA, and the new AAAC are closer to 1, compared with that of the reference sequence, and higher than that of the traditional ACSR. It can be seen that cost indexes of new type of capacity-increasing, energy-saving conductor have decreased significantly, and benefit indexes of that have been significantly improved, compared with the traditional ACSR.

Compared with the traditional conductor, the cost indicators of the new high-conductivity ACSR, the new ACA, and the new AAAC have obviously decreased, the benefit indicators have been greatly improved. The new energy-saving conductor has an advantage in the mechanical and electrical performance to some degree, which is suitable for use if the price is appropriate. However, the final selection still needs to be based on the tender price of conductors with reference to the economic indicators. Under the same external conditions, the new AAAC is most economical. Through comprehensive consideration, the new AAAC is optimal in every aspect.

5. Results and Discussion

Considering various influenced factors of the conductor selection, this paper presents a method of conductor selection based on gray relational analysis, and applies the results of various conductor performances to the optimal selection. Firstly, conductor performance is divided into cost and benefit indicators. Then the gray relational grade of every sequence is calculated and analyzed on the basis of gray relational analysis. Through comprehensive evaluation, it was observed that the conductivity of the new high-conductivity AAAC is optimal. The overall electrical and mechanical performance indicators of the new high-conductivity AAAC have been improved compared with the traditional ACSR. The cost indicators have significantly decreased, the benefit indicators have been significantly improved, and the correlation degree with the standard sequence is the highest, making the conductor play the best benefit under the most economical circumstance. The accuracy and the simplicity of the calculation based on the grey relational analysis have also been proved simultaneously.
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