Research on regional adjustment method of power grid operation and maintenance cost level based on information entropy considering multiple differences

Mao Yudong\textsuperscript{1}, Ma Lin\textsuperscript{1}, Ren Yan\textsuperscript{2}, Tong Ruigang\textsuperscript{3}, Liu Jia\textsuperscript{4}, Zhang Si\textsuperscript{4}, Zhao Lei\textsuperscript{2}, Liu Jinpeng\textsuperscript{5}, *

\textsuperscript{1}State Grid Corporation of China, Beijing, China.
\textsuperscript{2}State Grid Economic and Technology Research Institute Co., Ltd., Beijing, China.
\textsuperscript{3}State Grid Shandong Electric Power Company, Jinan, Shandong, China.
\textsuperscript{4}State Grid Shandong Electric Power Company Dezhou Power Supply Company, Dezhou, Shandong, China.
\textsuperscript{5}School of Economics and Management, North China Electric Power University, Beijing, China.
*Corresponding author’s e-mail: 1182306191@ncepu.edu.cn

Abstract: Scientific investment in asset operation and maintenance is a key issue for grid companies. The current grid operation and maintenance cost level is affected by multiple factors such as the natural environment and the market environment. How to combine the actual differences in different regions to propose an adjustment and optimization method for the grid operation and maintenance cost level can further improve the level of precision investment in operation and maintenance costs, and better facing the operating shock brought by the complicated internal and external situation. This paper first uses the system dynamics model to identify the factors affecting the operation and maintenance cost of power grid assets from different dimensions such as the natural environment and the market environment, clarifies the impact mechanism from different perspectives such as quantity and price, and determines the input variables for the analysis of the difference in operation and maintenance cost levels, combined with the results of variable selection, information entropy theory is introduced to construct an adjustment and optimization model based on information entropy. Finally, empirical research is conducted in different regions, and the results show that the model can provide theoretical support and method reference for the reasonable determination and dynamic adjustment of operation and maintenance cost level under the requirements of precise investment management and control.

1. Introduction
Operation and maintenance investment is an important guarantee for the safe operation of the power grid and an important part of the management and control of power grid enterprises. In recent years, power grid companies have carried out a series of standard cost research and management work, and the analysis of the difference in operation and maintenance costs in different regions has always been a research focus and difficulty.
In terms of related research on asset operation and maintenance investment, the literature [1] combined accounting, statistics and other related theories to design a standard cost system for power grid infrastructure projects, and explore the comparison between actual costs and estimated costs, which are engineering projects for power grid infrastructure projects and other industries. The application of standard cost provides reference. Literature [2] analyzed in detail the deficiencies of the existing cost control system, and based on the historical cost and expense level, it initially established a standard cost control system with scientific standards, uniform specifications, and strong operability. Literature [3] introduced the basic connotation and important significance of standard cost management, combined with actual work, through practical application in power grid enterprises, explored the methods and effects of implementing standard cost management. Literature [4] takes a 220kV substation as an example to study the standard cost of substation engineering of construction and installation enterprises in order to guide the cost control of substation engineering.

At present, more researches focus on the calculation and analysis of operation and maintenance standard cost, lack of analysis on influencing factors and investment difference of operation and maintenance cost, and have not formed a method model for adjusting and optimizing operation and maintenance cost according to different regional standards, which can not effectively solve the problem of reasonable determination of operation and maintenance cost under current lean control.

In order to meet the lean development needs of power grid asset operation and maintenance management under the new situation, and realize the differential determination of operation and maintenance costs, this paper is based on the system dynamics model to systematically identify and analyze the influencing factors of the difference in operation and maintenance costs; proposes the operation and maintenance based on information entropy Cost adjustment optimization model; finally, an empirical analysis is carried out to verify the feasibility and effectiveness of the model.

2. Research technical routes and ideas
Grid operation and maintenance costs are affected by many factors. Constructing operation and maintenance cost adjustment parameter models to realize the calculation of grid equipment operation and maintenance costs under various factors will help improve the efficient and refined management of grid enterprises’ operation and maintenance projects. The specific ideas of this article are shown in Figure 1.

![Figure 1. Model flow chart.](image)

As shown in the figure above, the process of model construction mainly includes the following steps: (1) Identification of influencing factors, combined with the determination of operation and maintenance costs, from different perspectives such as quantity and price, using system dynamics models to identify influencing factors, screening and analysis from the perspective; (2) Combining different regional differential index data, introducing entropy weight method to determine the weight.
of different factors, and combining the data normalization results to calculate the standard cost status level of each region; (3) According to the calculation results, Determine the adjustment coefficient of operation and maintenance costs in different regions.

3. Propose the regional multi-attribute difference index of grid operation and maintenance cost

The system analyzes the main factors affecting the operation and maintenance cost of the power grid, clarifies the interaction between the operation and maintenance cost and various factors, and uses it as a differentiated indicator for the adjustment of the operation and maintenance cost. This paper takes the method of determining the composition of operation and maintenance costs as the research basis, combining the main factors of quantity and price, and identifying from different aspects such as equipment status and meteorological environmental conditions. Introduce system dynamics theory to sort out the conduction relationship between operation and maintenance cost and difference index, as shown in Figure 2.

![Figure 2: Factor identification diagram.](image)

The main influencing factors are the operating life, temperature, load rate, and price adjustment coefficient of human resources machines. It also analyzes the conduction relationship of different factors to operation and maintenance costs. The larger the operating life, load rate, and the price adjustment coefficient of human resources, the greater the scale of operation and maintenance costs. Combining actual operation and maintenance experience and analysis of research results, taking the transformer as an example, the temperature is 20 degrees as the most suitable temperature for operation, so the operation and maintenance cost is the minimum temperature. As the temperature increases or decreases, the operation and maintenance costs show an upward trend.

4. Constructing an optimization model based on information entropy

As a main method of objective weight determination, entropy weight method determines the weight according to the amount of information transmitted to the decision maker by each indicator.

4.1 Normalization processing

Suppose that $n$ evaluation indicators are used to decide and evaluate $m$ candidates. $D_{ik}$: Estimated value of the evaluation index $i$ of the alternative $k$. $d_{ik}$: The result after normalization.

According to the characteristics of the indicators, the indicators are divided into positive indicators and reverse indicators. The normalization method of the positive indicators is as follows:

$$ d_{ik} = \frac{D_{ik}}{\max D_{ik}} $$  

The normalization method of the reverse index is:

$$ d_{ik} = \frac{(\max D_{ik} - D_{ik})}{\max D_{ik}} $$

4.2 The calculation steps of entropy weight method are as follows:

1) Overall entropy: using $n$ evaluation indicators to evaluate the entropy $E$ of $m$ candidate options:
\[ E = - \sum_{i=1}^{n} \sum_{k=1}^{m} d_{ik} \ln d_{ik} \]  

(3)

2) Use the normalized processing result to obtain the entropy value that characterizes the importance of the evaluation index \( i \).

\[ e(d_i) = - \frac{1}{l_{m}} \sum_{k=1}^{m} \frac{d_{ik}}{d_i} \ln \frac{d_{ik}}{d_i} \]  

(4)

3) Determine the evaluation weight of evaluation index \( i \) by \( e(d_i) \):

\[ \theta_i = \frac{1}{n - E_e} [(1 - e(d_i))] \]  

(5)

Where:

\[ E_e = \sum_{i=1}^{n} e(d_i), \quad \sum_{i=1}^{n} \theta_i = 1 \]  

(6)

4.3 Calculation of adjustment coefficient

Based on the above analysis, the standard cost status of different regions is determined, namely:

\[ F_i = \sum_{j=1}^{m} w_j x_{ij} \]  

(7)

Where: \( w_j (i=1,2,...,n, j=1,2,...,m) \) is the weight of the indicator, and B is the standardized data of the indicator.

The calculation method of the distribution ratio is:

\[ F_i^* = \frac{F_i}{{AVERAGE(F_i)}} \]  

(8)

In the formula: \( F_i^* \) is the adjustment coefficient, and \( {AVERAGE(F_i)} \) is the average value of the comprehensive state results.

5. Empirical analysis

This paper selects 10 regions including Heilongjiang, Jilin, Beijing, Henan, Sichuan, Shandong, Zhejiang, Jiangsu, Fujian, and Xinjiang to carry out statistical analysis of relevant data. Taking transformer equipment in various regions as an example, the basic data of the first projection index is shown in Table 1.

| area                      | unit      | A   | B   | C   | D   | E   | F   | G   | H   | I   | J   |
|---------------------------|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Equipment investment years| year      | 13.6| 12.2| 11.4| 13.4| 12.8| 12.1| 10.7| 10.9| 12.3| 13.5|
| Equipment load rate       | %         | 48.1| 49.2| 56.4| 47.3| 51.5| 54.2| 59.4| 57  | 54.3| 44.3|
| average temperature       | °C        | 12.9| 13.2| 12.5| 15.7| 15.4| 14.6| 18.1| 17.3| 21.9| 17.1|
| Personnel price level     | %         | 6.52| 6.31| 7.45| 6.06| 6.87| 6.05| 7.73| 7.19| 7.13| 6.85|
| adjustment factor         |           |     |     |     |     |     |     |     |     |     |     |
| Material price level      | %         | 21.8| 20.73|22.44|21.42|23.83|21.09|20.47|20.18|21.83|22.59|
Among them, the most suitable temperature of the transformer is $20^\circ C$ through investigation and analysis. Combining the above indicator data, the standard value and weight of each indicator are obtained through normalization processing and weight calculation, as shown in the following table.

**Table 2. Normalization processing and weight calculation table.**

| area | Equipment investment years | Equipment load rate | average temperature | Personnel price level adjustment factor | Material price level adjustment factor | Machinery price level adjustment factor |
|------|----------------------------|---------------------|---------------------|----------------------------------------|---------------------------------------|----------------------------------------|
| A    | 1.00                       | 0.81                | 0.65                | 0.84                                   | 0.91                                  | 0.90                                   |
| B    | 0.90                       | 0.83                | 0.66                | 0.82                                   | 0.87                                  | 0.85                                   |
| C    | 0.84                       | 0.95                | 0.63                | 0.96                                   | 0.94                                  | 0.94                                   |
| D    | 0.99                       | 0.80                | 0.79                | 0.78                                   | 0.90                                  | 0.90                                   |
| E    | 0.94                       | 0.87                | 0.77                | 0.89                                   | 1.00                                  | 1.00                                   |
| F    | 0.89                       | 0.91                | 0.73                | 0.78                                   | 0.89                                  | 0.88                                   |
| G    | 0.79                       | 1.00                | 0.91                | 1.00                                   | 0.86                                  | 0.86                                   |
| H    | 0.80                       | 0.96                | 0.87                | 0.93                                   | 0.85                                  | 0.86                                   |
| I    | 0.90                       | 0.91                | 0.91                | 0.92                                   | 0.92                                  | 0.91                                   |
| J    | 0.99                       | 0.75                | 0.86                | 0.89                                   | 0.95                                  | 0.90                                   |
| Weights | 0.16                     | 0.18                | 0.41                | 0.15                                   | 0.05                                  | 0.05                                   |

Combining the above methods to obtain the comprehensive state level of operation and maintenance costs in different regions, the specific results are shown in the table below.

**Table 3. Table of calculation results.**

| area | Equipment investment years | Equipment load rate | average temperature | Personnel price level adjustment factor | Material price level adjustment factor | Machinery price level adjustment factor | Comprehensive level | Adjustment coefficient |
|------|-----------------------------|---------------------|---------------------|----------------------------------------|---------------------------------------|----------------------------------------|---------------------|-----------------------|
| A    | 0.16                        | 0.15                | 0.26                | 0.13                                   | 0.05                                  | 0.05                                   | 0.79                | 0.93                  |
| B    | 0.14                        | 0.15                | 0.27                | 0.12                                   | 0.04                                  | 0.04                                   | 0.77                | 0.92                  |
| C    | 0.13                        | 0.17                | 0.26                | 0.14                                   | 0.05                                  | 0.05                                   | 0.8                | 0.95                  |
| D    | 0.16                        | 0.14                | 0.32                | 0.12                                   | 0.04                                  | 0.04                                   | 0.83                | 0.98                  |
| E    | 0.15                        | 0.16                | 0.32                | 0.13                                   | 0.05                                  | 0.05                                   | 0.86                | 1.02                  |
| F    | 0.14                        | 0.16                | 0.3                | 0.12                                   | 0.04                                  | 0.04                                   | 0.81                | 0.96                  |
| G    | 0.13                        | 0.18                | 0.37                | 0.15                                   | 0.04                                  | 0.04                                   | 0.91                | 1.08                  |
| H    | 0.13                        | 0.17                | 0.35                | 0.14                                   | 0.04                                  | 0.04                                   | 0.88                | 1.04                  |
| I    | 0.14                        | 0.16                | 0.37                | 0.14                                   | 0.05                                  | 0.05                                   | 0.91                | 1.08                  |
| J    | 0.16                        | 0.13                | 0.35                | 0.13                                   | 0.05                                  | 0.04                                   | 0.87                | 1.03                  |

It can be seen from the above results that the adjustment coefficient is more severely affected by the price of human resources machines. This paper analyzes and studies the composition of operation and maintenance costs, and concludes that the operating life, load rate, average temperature, and manpower machine prices are the main influencing factors for the difference in operation and maintenance costs. The adjustment coefficient calculation model is constructed based on the theory of information entropy, and different adjustment coefficients are obtained through and with the changes.
of the main factors affecting the main factors, so as to realize the accurate calculation of the operation and maintenance costs of substations and transmission lines.

6. Conclusion
Based on the systematic analysis of the influencing factors of power grid asset operation and maintenance investment, this paper constructs an optimization model of power grid asset operation and maintenance investment regulation based on information entropy theory, and verifies the applicability of the model through empirical analysis. The model can provide technical guidance for reasonable determination and dynamic adjustment of asset operation and maintenance cost of power grid enterprises, so as to improve the lean level of operation and maintenance investment of power grid enterprises.

Acknowledgments
This research was supported by the Headquarters Technology Project (1400-202056414A-0-0-00) of the State Grid Corporation of China.

References
[1] Xiao Sa, Cao Jingbo. Research on Standard Cost of Power Grid Infrastructure Projects[J]. Science and Technology Vision, 2019(29):203-204.
[2] Liu Guozhong, Cheng Yongsheng, Ru Hui, Yu Anying, Xiang Zhicai, Sun Zilian, Ma Ling, Liu Xianglong, Li Xiunuan, Jin Yu. Optimizing cost standards and constructing a control system[J].China Electric Power Enterprise Management, 2019(09): 12-14.
[3] Cai Fang. Research on the Application of Standard Cost Management in Power Grid Enterprises [J]. Finance and Economics, 2018(28): 65-66.
[4] Sun Zilian. Research on the standard cost of substation engineering for collective construction and installation enterprises of State Grid [J]. Southern Entrepreneur, 2018(04): 145-146+148.
[5] Hu Xin, Yin Huan. Measurement of the standard cost of rural power network outsourcing[J]. Journal of Chongqing Electric Power College, 2017, 22(05): 49-53.