Research on Decision Making Technology of Regional Maintenance Cost Considering Multi-Attribute Factors

Yan Ren[1a], Jinpeng Liu[2b], Jing Yu[3c], Zebang Yu[1d], Fangzhou Liu[1e], Chao Chen[2f*]

[a]juzen123@126.com, [b]hbdlljp@163.com, [c]345332300@qq.com,
[d]304460740@qq.com, [e]juzen123@163.com, [f]*hbbdcc@126.com

[1]State Grid Economic and Technological Research Institute Co. Ltd., Beijing 102209, China.

[2]School of Economics and Management, North China Electric Power University, Beijing 102206, China.

[3]State Grid Economic and Technological Research Institute of Fujian Electric Power Co., Ltd., Fuzhou 100031, China.

Abstract: at present, cost control and strict supervision have become the main tone of the government's supervision of power grid enterprises. The contradiction between high-quality development and the operation of power grid enterprises is becoming increasingly prominent. Therefore, strengthening the reasonable and accurate investment of funds is the inevitable direction of the development of power grid enterprises. Improving the reasonable level of maintenance cost investment is the key to solve the development problems of power grid enterprises. The maintenance cost is affected by regional differences, management level and asset scale. The decision-making of maintenance cost investment in different regions is more complex. Therefore, combined with the operation characteristics of power grid enterprises, this paper systematically analyzes the main factors affecting maintenance cost investment, clarifies the correlation between maintenance cost investment and various factors, and uses neural network method combined with factor correlation analysis results to realize the scientific prediction of maintenance cost, which can provide some reference for accurate decision-making and scientific investment of maintenance cost, it provides a certain reference basis for the reasonable allocation of maintenance cost.

Keywords: Power grid maintenance cost, regional characteristics, benefit output, distribution method

1 Introduction

The investment in power grid equipment maintenance is not only an important guarantee for the safe operation of power grid, but also an important part of the operation and control of power grid enterprises. At present, power grid enterprises are facing a severe situation, and the problems of unbalanced and uncoordinated maintenance cost investment in different regions are prominent. How to make a scientific decision on maintenance cost investment is the focus of power grid enterprises. Through the construction of prediction model, this paper can

ICIDC 2022, June 17-19, Qingdao, People's Republic of China

DOI 10.4108/eai.17-6-2022.2322713

effectively guide the scientific and reasonable determination of maintenance cost, guide the cost lean management of power grid maintenance projects, and provide effective reference for cost control and operation decision-making of power grid enterprises.

Zheng Xiaoyun Duan [1] asserts builds a power supply cost prediction model under big data conditions, and applies time series analysis, regression analysis and cluster analysis methods to establish models from three perspectives of overall power supply cost prediction, prediction of key influencing factors of power supply cost and risk point prediction of power supply cost control. Wang Ling [2] asserts first analyzed the main influencing factors of the investment of power grid enterprises, and then predicted the investment scale of a municipal power grid company under different boundary conditions using the support vector machine model optimized by the tarp group optimization algorithm. Luo Yu [3] asserts puts forward the prediction method of operation and maintenance resources of power grid enterprises, presents the design principles and specific analysis process based on asset wall theory, analyzes the life selection method of real assets of power grid enterprises, and gives the operation and maintenance resource prediction method based on Monte Carlo random simulation. Yang Xi [4] asserts uses the asset projection model and Monte Carlo simulation to predict the technical transformation investment scale of four types of primary transformation main equipment of Guangdong power supply Bureau Jiangmen power supply Bureau of 110 kV or above, and predicts the expected medium-and long-term technical transformation investment scale of the existing equipment of the power supply Bureau.

To sum up, there is less research on maintenance cost investment scale prediction, which cannot provide support for the precise decision of maintenance cost of power grid enterprises. Maintenance cost involves the power grid demand, equipment condition, enterprise operating benefits and other factors, only rely on some index information, it is difficult to reasonably reflect the relationship between the index and maintenance cost input and its impact degree, and may lose the potential closely related to the maintenance cost input index, such input decision may bring adverse impact on the development of power grid enterprises. This paper combines the analysis of influencing factors and uses the neural network model to consider the multi-factor attributes of different regions to realize the accurate prediction of maintenance input.

2 Identification of influencing factors

Combined with the metering ability of factors, the scientific and guidance of the selection of factors, build a collection of influencing factors of maintenance input cost, including asset scale attributes: line length, transformer capacity, total fixed assets, and scale of assets over age. Asset status attributes: the average equipment operation life, equipment defect rate, equipment fault rate, line heavy load ratio, main variable heavy load ratio. Asset contribution attributes: power supply reliability rate, comprehensive voltage qualified rate, electricity price contribution ratio, etc. At the same time, the maintenance cost investment is also affected by the policy restrictions of different regions and the relevant government requirements, including the national policy tendency, the development orientation, the intensity of government support, and the shortcomings of the hierarchical power grid of each voltage.

3 Analysis of the influence factors based on the gray correlation degree model

3.1 Basic principle of the model

Gray correlation analysis (Grey Relational Analysis) is a multivariate (factor) statistical analysis method, based on the sample data of each variable, to describe the strength, size and order of their relationship. The basic idea is: take the sample data of the variables as the sequence, the sequence will form a curve, the closeness of a certain two variables is judged by the proximity of the two curves. The closer the curve indicates the greater the correlation between the corresponding sequences and vice versa.

Calculculation steps for gray correlation analysis:

(1) Determine the reference sequence and the comparison sequence. The reference sequences are the data series that reflect the behavioral characteristics of the system, and the comparison sequences are the data series that reflect the factors affecting the behavior of the system. In the analysis of the cost influencing factors of power transmission and transformation projects, the reference sequence is the data sequence of the cost, and the comparison sequence is the data sequence of each influencing factor.

(2) The reference and comparison sequences were undimensionized. The physical significance of the factors in the system varies, so the effects of the magnitude must be eliminated.

Let $X_i = (x_i(1), x_i(2), \ldots, x_i(n))$ be the behavior sequence of X_i. Common processing methods are:

1) Initialization transformation

$$X_i' = \frac{1}{x_i} X_i = (x_i'(1), x_i'(2), \ldots, x_i'(n)) = (1, \frac{x_i(2)}{x_i(1)}, \ldots, \frac{x_i(n)}{x_i(1)}), x_i(1) \neq 0 \tag{1}$$

In general, for a relatively stable economic and social system sequence, more initial value transformation is adopted. Such columns show a stable growth trend, the initial value processing can make the growth trend more obvious.

2) Mean transformation

$$X_i' = \frac{1}{\bar{x}_i} X_i = (x_i'(1), x_i'(2), \ldots, x_i'(n)) = (\frac{x_i(1)}{\bar{x}_i}, \frac{x_i(2)}{\bar{x}_i}, \ldots, \frac{x_i(n)}{\bar{x}_i,}) \tag{2}$$

$$\bar{x}_i = \frac{1}{n} \sum_j^n x_i(j) \tag{3}$$

3) Interval transformation

$$\bar{x}_i{}'(j) = \frac{x_i(j) - \min_j x_i(j)}{\max_j x_i(j) - \min_j x_i(j)}, j = 1,2,...,n \tag{4}$$

4) Standardized transformation

$$\bar{x}_i{}'(j) = \frac{x_i(j) - \mu}{\sigma} \tag{5}$$

Where μ and σ are the mean and variance of the sequence, respectively.

(3) Calculate the correlation coefficient

After dimensionless processing, the reference number column is $\{x_0(t)\}$, and the comparison number column is $\{x_i(t)\}$. At time $t = j$, the correlation coefficient between the two is:

$$\delta_{0i}(j) = \frac{\Delta \min + \rho \Delta \max}{\Delta_{0i}(j) + \rho \Delta \max}, i = 1,2,...,k; j = 1,2,...,n \tag{6}$$

$$\delta_{0i}(j) = |x_0(j) - x_i(j)| \tag{7}$$

$$\Delta_{\min} = \min_i \min_j \Delta_{0i}(j), \Delta_{\max} = \max_i \max_j \Delta_{0i}(j) \tag{8}$$

ρ is the resolution coefficient, and its meaning is to weaken the distortion caused by the large value of $\Delta_{\max}$ and improve the significance of the difference between the correlation coefficients. $0 < \rho < 1$, generally 0.5.

The correlation coefficient reflects the closeness of the two sequences X_0 and X_i at the moment. $0 < \delta_{0i} \leq 1$.

3.2 Empirical analysis

Combined with the factor selection results, the power grid enterprises in region A were selected for empirical analysis, and the basic data were collected as shown below.

Table 1. The Basic Data Table.

Influence elements	A	B	C	D	E	F	H	I
Total fixed assets (RMB 100 million)	14.88	21.08	16.12	13.64	19.84	17.36	32.24	18.6
Line length (km)	5496.92	8140.6	6625.32	5225.36	7606.16	7105.2	15402.04	7342.04
Distribution capacity (KVA)	1682308	2657816	1902284	1732032	2434616	2080844	3760052	2076380
Average equipment operating life (year)	6.67	8.68	7.95	6.45	8.51	7.33	7.76	7.76
equipment failure rate (%)	4.18	5.10	4.76	3.94	5.22	4.41	4.41	5.22

Equipment defect rate of (%)	3.60	4.41	3.71	3.60	4.41	5.68	3.60	4.87
Power supply reliability rate is (%)	99.90	99.85	99.88	99.90	99.89	99.87	99.86	99.87
Average user power failure power outage time (hours)	0.52	0.65	0.61	0.48	0.56	0.52	0.48	0.56
Comprehensive voltage qualified rate is (%)	89.20	89.15	89.18	89.20	89.19	89.17	89.16	89.17
Line heavy load ratio is (%)	11.44	14.68	6.52	5.93	5.42	5.36	4.08	14.17
Distribution and overload ratio (%)	5.45	8.11	3.72	3.78	6.38	6.24	3.48	8.29
Electricity sold (Wan KWH)	42058.90	63411.40	44911.10	49771.80	53544.40	57434.00	91419.90	51057.50
Annual annual occurrence number of natural disasters (times)	12	10	8	4	5	8	6	7
GDP(100 million)	204.60	306.80	182.60	179.20	257.20	295.20	523.00	318.20
Total population (ten thousand people)	82.00	106.50	80.50	87.50	89.50	83.50	136.50	91.50
Power supply area (square kilometer)	931.60	1284.60	1084.60	1290.80	992.80	1297.20	1557.60	1169.80
Maintenance cost (ten thousand yuan)	14105.70	17920.00	16391.90	13255.90	19770.10	14904.40	27349.70	17539.20

Combined with the data characteristics, the maintenance cost and its different influencing factors have different dimensions. In the gray association analysis, nothing-classification processing needs to be done first, and standardization is used to adjust each sequence here.Set the resolution coefficient r first, and then according to the calculation steps of formula (1-5), calculate the gray correlation degree between the maintenance cost input sequence and each influencing factor sequence in Table 1. where the resolution factor r = 0.5. The calculation results are shown in Table 2.

Table 2. Gray Association Results Table.

order number	influencing factor	Grey correlation degree
1	Total fixed assets	0.9091
2	line length	0.8994
3	Variable capacity	0.8794
4	GDP	0.8475
5	population measurement	0.8443
6	Sales of electricity	0.8113
7	Equipment defect rate	0.7362
8	Power supply area	0.7279
9	Average operating life of the equipment	0.7265
10	Average user failure and power outage time	0.7234
11	equipment failure rate	0.7178
12	Variable reload ratio	0.6810
13	Line reload ratio	0.6505
14	Comprehensive voltage qualified rate	0.6415
15	Power supply reliability rate	0.6415
16	Annual and annual occurrence number of natural disasters	0.6373

Finally, combined with the gray correlation analysis results, the total fixed assets, line length, distribution capacity, GDP, electricity sales, the defect rate of the equipment, and the average operation life of the equipment were selected as the input variables to build the neural network prediction model.

4 Maintenance cost input prediction based on the neural network model

Thirty regions were selected as samples, and the BP neural network was trained on the data of the above 30 samples to build the neural network model.

The constructed neural network cost prediction model is shown in Fig:

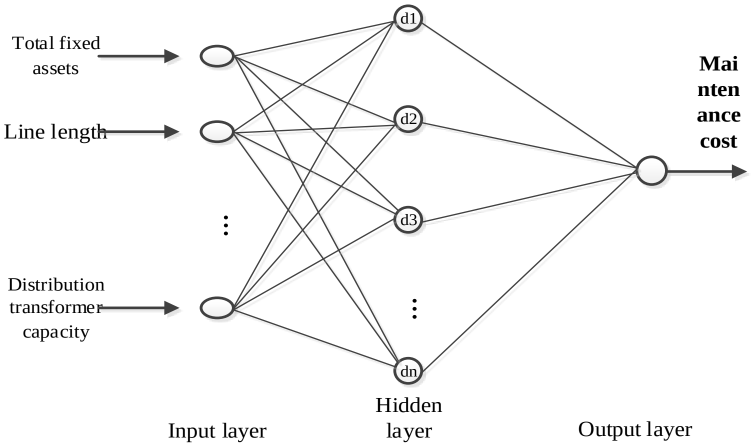

Figure 1 BP Nnetwork Fig

The influencing factor data for five samples are known, as shown in the appendix. The constructed neural network model is used to predict the maintenance cost. Combined with the basic data in Table 1, the results of the predicted samples are shown in Table 3.

Table 3. Table of predicted values versus actual values.

sample book	Total fixed assets	line length	Variable capacity	GDP	Sales of electricity	Equip ment defect rate	Average operating life of the equipment	Actual value, ten thousand yuan	Predicted value, ten thousand yuan	error rate
1	32.74	12093.22	3701077.60	409.20	84117.80	4.65	9.36	31032.54	35811.55	15%
2	46.38	17909.32	5847195.20	613.60	126822.80	5.70	12.18	39424.00	44233.73	12%
3	35.46	14575.70	4185024.80	365.20	89822.20	4.80	11.15	36062.18	33032.96	-8.40%
4	30.01	11495.79	3810470.40	358.40	99543.60	4.65	9.04	29162.98	26188.36	-10.20%
5	43.65	16733.55	5356155.20	514.40	107088.80	5.70	11.94	43494.22	45973.39	5.70%

It can be seen from Table 3 that the average prediction error is less than 15%, and the prediction model is accurate and reliable, meeting the requirements.

5 Conclusion

This paper first identifies the influencing factors of maintenance cost, and then determines the influence degree of different factors based on the gray correlation analysis method, and further applies the neural network model to realize the prediction and analysis of the maintenance cost of different regions considering regional characteristics. The empirical results prove that the model has certain practicability and rationality. Through the study of this paper, we should further deepen the lean control of power grid maintenance cost, break the limitations of the traditional decision-making mode, find the innovative concept of maintenance cost investment decision-making ideas, pay more attention to the efficiency, efficiency and scientific consideration of capital investment, and meet the actual needs of the refined management level of power grid enterprises.

Acknowledgments. This paper is Sponsored by State Grid Science and Technology Project “Research on the allocation decision and efficiency evaluation technology of maintenance and operation cost of power grid under fine-grained management.” (1400-202156226A-0-0-00)

References

[1] Zheng Xiaoyun Duan. Power supply cost prediction model and big data-based construction [J]. Enterprise reform and management, 2020 (04): 179-181.

[2] Wang Ling, Wu Hongliang, Peng Daoxin.Grid investment scale prediction under the new round of transmission and distribution price supervision cycle. —— is based on the optimized support vector machine model [J].Technical and economic, 2020,39 (10): 45-53.

[3] Luo Yu.Research of Asset Operation and Maintenance Based on Asset Wall [D].South China University of Technology, 2019.

[4] Yang Xi, Chen Xing, Song Yiqun, Yang Jianfei, Wen Xiaosheng, Chen Zhifeng.Investment forecast of primary transformation based on asset wall [J].Guangdong Electric Power Power, 2015,28 (03): 25-29.

[5] Chi Jiankun, Wang Yujie, Han Shaoqing. Application of activity-based costing method for power grid maintenance [J]. New Finance, 2020(07):45-47.