Research on Decision Analysis Technology of Main Transformer Based on Operation Status Evaluation and Whole Life Cycle Cost Prediction

Shuyi Pan[1,a], Ming Jing[1,b], Fangzhou Liu[2,c], Xiaohong Zhang[3,d], Wei Cheng[2,e], Lei Zhao[2,f*]

[a]235170452@qq.com, [b]315574930@qq.com, [c]2634075269@qq.com, [d*]626549366@qq.com, [e*]2130350013@qq.com, [f*]30446740@qq.com

[1]State Grid Shandong Electric Power Company, Jinan, Shandong Province, 251000 , China
[2]State Grid Economic And Technological Research Institute CO. LTD, Beijing, 102206, China
[3]State Grid Shandong Electric Power Company Weifang Power Supply Company, Weifang, Shandong Province, 261000, China

Abstract: With the deepening of the reform, the operation cost, power supply quality and electricity price formulation of power grid enterprises all need higher management requirements. However, due to the rapid expansion of the power grid scale and the continuous increase of the number of equipment, the construction of smart grid in recent years is also increasing investment, and the rapid development speed has led to the low utilization rate and backward asset management of the power grid in the management of equipment assets. Therefore, from the comprehensive consideration of the reliability and economy of power transformers, this paper constructs the decision analysis technology of main transformer based on operation status assessment and full life cycle cost prediction, so as to provide reference and reference for power grid enterprises to formulate scientific and reasonable equipment operation and maintenance management and cost expenditure management.

Key words: operation status assessment, main change, whole life cycle cost, technical transformation decision, analysis technology

1. Introduction

For a long time, the equipment maintenance of China's power grid enterprises is using the mode of regular planned maintenance, so the maintenance mode is easy to cause excessive maintenance or insufficient maintenance (repair and underrepair). At the same time, with the improvement of information intelligence technology, the intelligent level of China's power grid is getting higher and higher, and the technology of online monitoring and big data prediction also makes more scientific and effective equipment management methods possible.

In terms of equipment status assessment technology, the operation state is the key factor affecting the investment in the technical transformation of power grid equipment, and the design of real-time monitoring and evaluation technology of power grid equipment operation health status is proposed in literature [1-3] combined with the operation data of power grid equipment, so as to provide a reference for ensuring the operation safety of power grid

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equipment. In terms of the influencing factors of technological transformation investment, literature [4] summarized the impact on investment in production technological transformation projects from the aspects of budget control links, budget control fineness, and budget control intensity, and puts forward corresponding countermeasures and suggestions. Literature [5] analyzed the impact of T&D price reform on the investment in power grid technological transformation, and put forward relevant suggestions. In terms of equipment technology technology prediction technology, literature [6-10] applied the "asset wall" analysis theory to coordinate the correlation between the value scale, commissioning time, age of use and other information of power grid equipment and future investment, and combined the results of equipment health status assessment to make a reasonable prediction of the scale of technological transformation investment. Literature [11] proposes the distribution network performance and the level of equipment failure rate in the case of voltage dips and outages considering network protection settings. Literature [12] proposes a DERS-based adaptive robust investment planning method for distribution network.

To sum up, the current technology for forecasting the scale of technological transformation investment mainly adopts the asset wall theory, which mainly considers the equipment operation time, while the analysis of the equipment operation status is relatively weak, so the prediction accuracy is unsatisfactory. Therefore, this paper comprehensively considers the equipment operation status, equipment operation time and other factors, and constructs a scientific and reasonable prediction model for technological transformation investment to support the rational decision-making of power grid enterprises.

2. Research on the operation state assessment technology of the main transformer

The prediction model adopted in this paper is the dynamic prediction model based on grey theory, that is, on the basis of the GM1,1 prediction model, the prediction value to the original sequence, remove the sequence value, the original sequence and the original sequence dimension, the original sequence, the new prediction, repeat the above steps, to replace step by step, successively, until the prediction required steps.

(1) Suppose sequence $X^0 = (x^{(0)}(1), x^{(0)}(2),..., x^{(0)}(n),$ where : $x^0(k) \geq 0, k = 1,2,..., n.$

(2) Accumulate the original sequence $x^{(0)}$ once, and get the sequence $x^{(1)}$ generated by an accumulation of $x^{(0)}$.

$$x^{(1)}(k)\sum_{i=1}^{k} x^{(0)}(i) = x^{(1)}(k-1) + x^{(0)}(k), \quad k = 1,2,...,n) \tag{1}$$

(3) Calculate the sequence generated immediately adjacent to the mean, where：

$$x^{(1)}(k)\sum_{i=1}^{k}x^{(0)}(i)=x^{(1)}(k-1)+x^{(0)}(k),\quad k=1,2,...,n) \tag{2}$$

where : $z^{(1)}(k)=\frac{1}{2}(x^{(1)}(k)+x^{(1)}(k-1)),\ k=2,3,....,n),$ then called : $x^{(0)}(k)+az^{(1)}(k)=b$ is the mean value formation of the GM(1,1) model. Substituting the adjacent sound field sequence to get:

$$\begin{cases} x^{(0)}(2)+az^{(1)}(2)=b, \\ x^{(0)}(3)+az^{(1)}(3)=b, \\ \cdots \\ x^{(0)}(n)+az^{(1)}(n)=b, \end{cases} \tag{3}$$

Let:

$Y=\begin{pmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \cdots \\ x^{(0)}(n) \end{pmatrix}, B=\begin{pmatrix} -z^{(1)}(2),1 \\ -z^{(1)}(2) \\ \cdots \\ -a^{(1)}(n) \end{pmatrix}$, and let a be the parameter vector to be estimated, then

$$a=\begin{pmatrix} a \\ b \end{pmatrix}=(B^{T}B)^{-1}B^{T}Y \tag{4}$$

(4)Solve the whitening differential equation of GM(1,1) and get its corresponding function:

$$\hat{x}^{(1)}(k+1)=\left[\left(x^{(0)}(1)^{(1-r)}-\frac{u}{a}\right)e^{-a(1-r)k}+\frac{u}{a}\right]^{\frac{1}{1-r}},r\neq 1,k=1,2,3,...,\ n \tag{5}$$

When $k=1,2,...,n-1$, $\hat{x}^{(1)}(k+1)$ is the fitted value of $x^{(1)}$, when $k=n$, $\hat{x}^{(1)}(k+1)$ is the predicted value of $x^{(1)}$; then perform the post-reduction operation, when $k=1,2,...,n-1$, $\hat{x}^{(1)}(k+1)$ is the fitted value of $x^{(1)}$, when $k=n$, $\hat{x}^{(1)}(k+1)$ is the predicted value of $x^{(1)}$.

3. Empirical analysis

3.1Basic data

In this paper, the main transformer equipment of a power grid company is selected as the research object to make scientific prediction of the failure rate of the equipment. The object of defect rate prediction is selected: oil immersed transformer of the power grid company with operation life within [1,17] range.

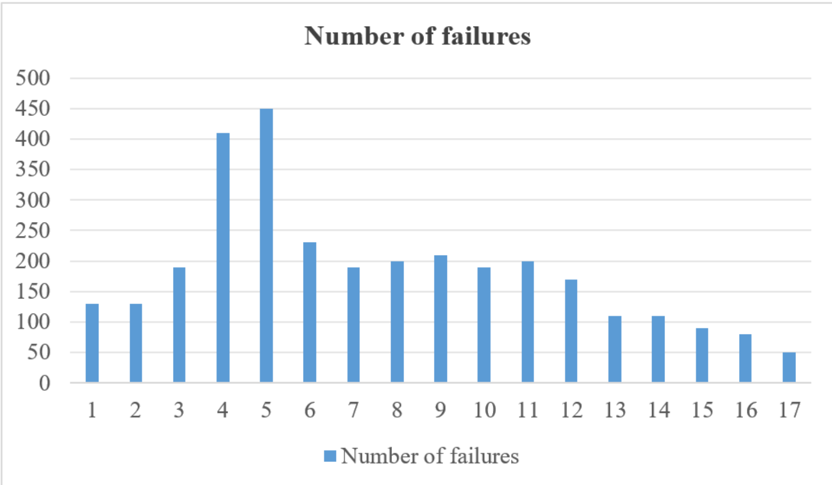

Figure 1. Basic data map.

As can be seen from Figure 1, the equipment defects of the power grid enterprise show a development trend of increasing first and then increasing. Combined with the gray theory principle, the comparison between the predicted value and the actual value of equipment defect is as follows:

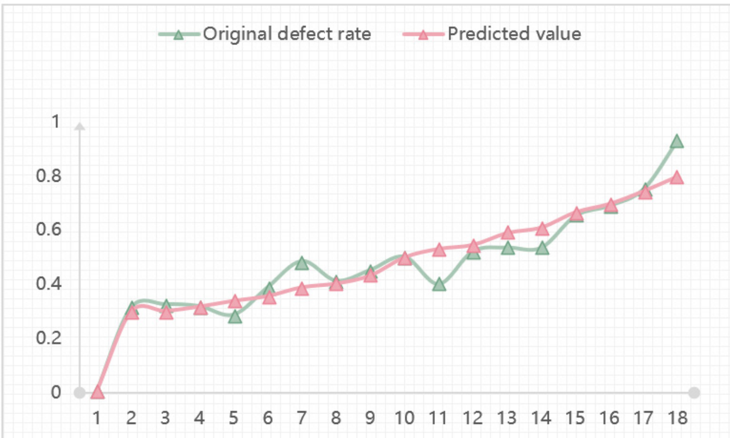

Figure 2. Comparison of predicted values and actual values.

From the results of Figure 2 of the oil-immersed transformer, it can be found that most of the (k) are in the range of (0.905, 1.105), which meets the prerequisite for grey prediction of the original data series of the oil-immersed transformer.

3.2Research on the full life cycle cost prediction technology of the main transformer

Based on the characteristics of high reliability requirements of grid substation main equipment, long life cycle and high maintenance cost, the whole life cycle cost model as the prototype, fully considering the characteristics of the equipment and production operations, establish the initial investment cost of the cost, operation cost, maintenance cost, fault loss cost and retirement cost for the whole life cycle cost model. The evaluation criteria for the selection of technical equipment repair equipment is the comparison of net annual value.

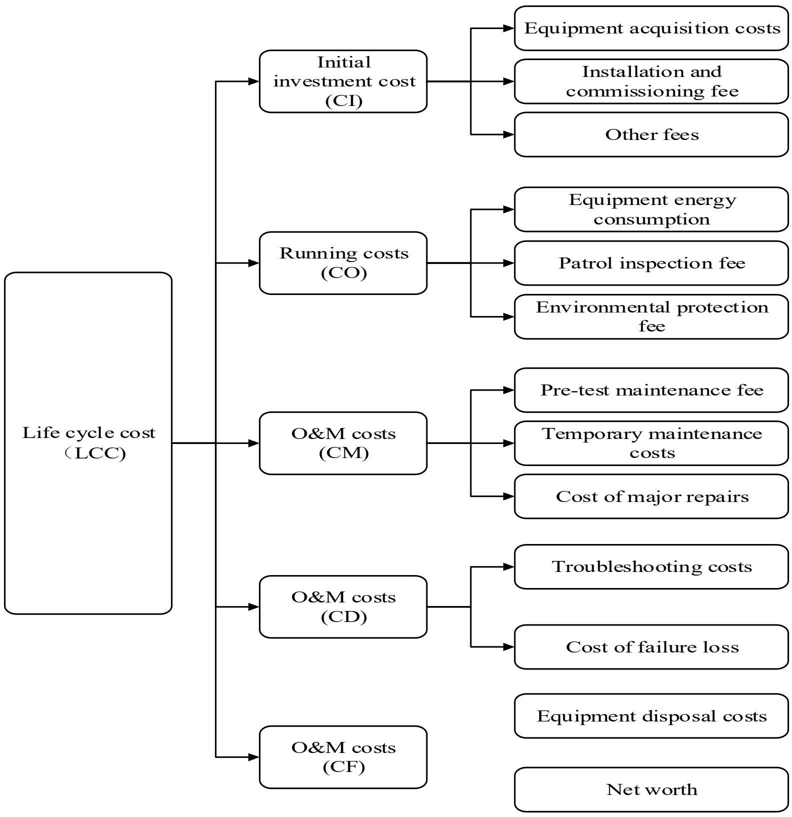

Figure 3. Full life cycle cost composition of the main transformer.

As shown from Figure 3, the full life cycle cost composition of the main transformer includes:

(1) Initial investment cost (CI)

The initial investment cost CI is the capital investment of the transformer at the beginning of its operation. For equipment technical renovation projects, it shall include: equipment purchase cost, equipment installation cost, debugging cost and original equipment demolition cost.

The initial investment cost expression is:

$$CI = CI_m + CI_l + CI_o \tag{6}$$

CI_m CI_l Where it are equipment purchase costs, installation and debugging costs, and other costs. CI_o

(2) Operating cost (CO)

Operation cost CO is the inspection and maintenance cost of equipment, including daily maintenance, professional maintenance, dynamic maintenance and power outage maintenance. Among them, the daily maintenance, professional maintenance and dynamic maintenance formulate operation and maintenance strategies according to the equipment operation status evaluation, and the power outage maintenance work is linked with the equipment power outage plan.

(3) Maintenance and maintenance cost (CM)

Maintenance cost CM, including non-state-based planning activity cost and equipment elimination activity cost.

(4) Failure loss cost (CF)

Fault loss cost CF refers to the loss cost generated after the failure of the transformer equipment, including the cost of troubleshooting and the cost of power outage loss.

(5) Retirement disposal cost (CD)

Decommissidisposal cost CD mainly refers to the labor cost, transportation cost and environmental protection cost of equipment when decommissioning of transformer equipment and minus the residual value of equipment decommissioning.

The net annual value of the whole life cycle cost is the cost of the different time nodes in the life period of the calculation period according to the given discount rate.

$$LCC(\text{Net annual value}) = \left[\text{CI} + \sum_{n=1}^{\text{N}} \left(\frac{CM_n + CO_n + CF_n}{(1+i)^n} \right) + \frac{CD}{(1+i)^N} \right] \times \frac{i \times (1+i)^N}{(1+i)^N - 1} \tag{7}$$

3.3Research on the decision analysis technology of main variable technical transformation based on operation state assessment and whole life cycle cost prediction

Basic information of equipment: The equipment is 110k V main transformer of Guangdong Foshan Transformer Factory, which was put into operation in 1996 and has been put into operation for 18 years, with a rated capacity of 31,500 kVA, three-phase double-winding transformer, with the original asset value of 1.52 million yuan.

The actual project adopts the method of technical reform to replace the equipment. After the replacement, the equipment will run for 30 years, that is, the design life of the equipment. If the equipment is repaired (simulated), and then continue to run for 12 years, when the operating life will reach the design operating life, and then updated.

Table 1. Comparison of LCC costs for equipment overhaul and technical transformation.

Cost category	Repair project LCC		Technical transformation project LCC	
	Total (RMB)	Equal annuity	Total (RMB)	Equal annuity
CI	404094.54	38922.35	3206911.87	154132.89
CO	77973.34	6306.57	182563.46	5836.75
CM	297038.52	23133.52	553900.88	16106.03
CF	702300.42	56958.67	1755751.04	56958.67
CD	-75842.01	-5275.27	-116022.28	-2471.12
Total	1405564.80	147776.43	6872802.21	283823.33

As can be seen from Table 1, the equipment has been in operation for 18 years. The cost of repairing the equipment is ten thousand yuan, calculated by the design life of 30, and it can still run for 12 years after repair. The technical transformation plan requires an initial investment of 2,605,13 million yuan, and the operating life is 30 years. From the perspective of the cost composition of equipment LCC, the total initial investment cost CI of the repair plan is far lower than that of the technical reform scheme. The subsequent operation life of the two schemes is different, and the operation life of the technical reform scheme is longer than that of the repair plan. From the perspective of LCC cost equal annuity, that is, the average annual cost, the initial investment cost of the technical reform plan is higher than the repair plan, but the operation cost, maintenance cost and retirement disposal cost are all lower than the repair plan. By comprehensive comparison, the initial investment amount in the LCC cost of the technical transformation scheme is large, while the equipment service life of the repair scheme is normal, and the model is more inclined to the repair scheme. The repair scheme is recommended from the perspective of equipment full life cycle cost.

4. Conclusion

This chapter combined with the actual equipment operation management of power grid company, build the main transformer equipment running status evaluation model and the whole life cycle cost optimization access model, the power grid company in the main transformer optimization access project example analysis and study, implementation of equipment operational maintenance activities scientific decision and accurate grasp, reasonable allocation of resources, reduce the whole life cycle cost, promote equipment operational maintenance strategy constantly improve.

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