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The Research on the LCC Modelling and Economic Life Evaluation of Power Transformers

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Abstract. In order to improve the economic life and reduced life cycle cost of the power transformers, the power transformer life cycle calculation model was built which considered key factors in all sections of the life cycle. Then the economic life evaluation method was researched to get the least total cost in the life cycle. At last, Practical example was calculated to obtain the life cycle cost and verified the accurateness of the method. The research result could provide theoretical support for equipment LCC management.

1. Introduction

Along with the quickly development of smart grid and the construction of UHV grid, a lot of devices faced the problems such as maintaining and scrapping. Life cycle cost meant cost least in the cycle from generation to ending, in condition of ensuring the safety of power grid and power supply stable [1-2]. Equipment life cycle management meant to use corresponding management model and technical method to guarantee the equipment operational reliability and achieve the life cycle cost least. As the most important equipment, the LCC management of power transformers involved many links. So the LCC management could not be controlled quantitatively. The research on the LCC modelling and economic life evaluation of transformers became an important direction.

Research on the LCC of transformers has been carried out at home and abroad. Reference [3] divided the LCC into some stages and established the cost model of equipment LCC, which was simple and with low accuracy. Reference [4] divided LCC model into 5 stages, which were investment cost, operating cost, maintenance cost, failure cost and scrap cost. Reference [5-8] used different methods to analyze the LCC but limited by modelling. Reference [9-11] used Monte-Carlo method to simulate the operating fault condition of power transformers and then calculated the overall cost of the equipment. This method could simulate the LCC of transformers accurately but with slow calculating speed, and the accuracy was greatly affected by the number of calculation times.

This paper established the LCC model of power transformers based on five stages of the life cycle for the equipment, and then researched the economic life evaluation of the equipment. The actual example verified the accuracy and practicability of the model.

2. Establishing the equipment life cycle analysis model

Based on the data integration, cost allocation and five yards correspondence, the factors affecting equipment life cost was researched and the LCC model of transformers was built.



2.1. Investment cost model

The investment cost has been fully spent when the equipment was put into operation, which could be obtained by collecting statistical data on the expenditure of funds during the construction period. The original value of the assets for every single equipment was distributed to the annuals according to the operating years of the equipment. The average value for every year could be regarded as the investment cost of the equipment over the years.

First of all, selected the equipment that the operating year was more than t . The ratio between initial asset value and the operating year was the equalization original assets of the equipment. The ratio between the total equalization original assets for all the equipment and the equipment number was the investment cost in the t^{th} year, which could be showed as formula (1) and (2).

$$C_1 = \frac{a_1 + a_2 + \dots + a_n}{n} \quad (1)$$

$$a_n = \frac{A}{t} \quad (2)$$

In formula (1) and (2), a_n meant the equalization original assets of one equipment. n meant the number of the commissioned equipment in the t^{th} year. A meant the initial asset value of one equipment. t meant the operating years.

2.2. Operation and maintenance cost model

First of all, selected the equipment whose operating year was more than t . Obtained the sum of all the initial assets values for selected equipment, then obtained the total initial assets values for the substation corresponding with the equipment. At last, calculate the operation and maintenance cost in the t^{th} year using initial assets of equipment, initial assets of the substation and the operating standard cost, which was showed as formula (3).

$$C_2 = \frac{C_1}{A} * B \quad (3)$$

In formula (3), C_1 was the investment cost of the equipment. A was the total assets of the corresponding substation. B was the standard operating cost of the equipment.

2.3. Repairing cost model

Combined with the result for “three-in-one”, the repairing cost of the equipment could be calculated by using average cost method. First of all, selected the repairing cost data satisfied that difference between the repairing cost year and the equipment put in service year was t . Then obtained the sum of all the repairing cost in t years. Secondly, obtained the number of equipment needing repairing in the t^{th} year according to the selected repairing cost data. At last, the repairing cost for every equipment in the t^{th} year could be obtained by the sum of the repairing cost for the t^{th} year divided by the equipment number needing repairing, which could be showed as formula (4).

$$C_3 = \frac{b_1 + b_2 + b_3 + \dots + b_n}{n} \quad (4)$$

In formula (4), b_n expressed the repairing cost of every equipment in the t^{th} year. n expressed the operating equipment number in the t^{th} year.

2.4. Failure cost model

Because the failure cost data was lack, this paper provided a new failure cost calculation method.

The failure loss cost in the t^{th} year = the failure rate in the t^{th} year * (outage loss of load * outage time) * unit price of power supply. The failure cost model could be showed as formula (5).

$$C_4 = r_t * R + r_t * W * T * A \quad (5)$$

In formula (5), r_t expressed the outage rate in the t^{th} year. R expressed the filed repairing cost of the equipment, which could be calculated by historical data. W expressed the annual load loss of the

equipment. T expressed the actual outage time of the equipment. A was the average electrical price.

2.5. Retired cost model

The calculation stages of the retired cost for the t^{th} year could be showed as below.

The retired treatment cost of the t^{th} year = cleaning cost rate * engineering installation cost.

The retired residual value = residual rate * purchasing cost of the equipment.

The retired cost could be showed as formula (6).

$$C_5 = a * (E - C) - b * C \quad (6)$$

In formula (6), a expressed the cleaning cost rate of the equipment, which could be taken as 32%. E was the original assets of one equipment. C was the purchasing cost. b was the residual rate, which was 5%.

3. The evaluation of the economic life for the equipment

3.1. Establishing the evaluation model of the economic life

Based on the model of LCC, this paper provided to research on the economic life evaluation method and established the evaluation model. The operating life of the equipment could be classified into physical life and economic life. Economic life evaluation could research the operating years with the lowest average total cost according to the analysis result of the LCC. When the operating years were over its' economic life, it could be considered to be replaced.

The average total cost of the equipment included the annual average investment cost of the equipment and the annual average using cost of the equipment. The annual average investment cost of the equipment would decrease along with the operating years increasing. Along with the operating years increasing, the productivity and working accuracy of the equipment would decrease, and the power consumption would increase. So the annual average using cost of the equipment would increase with the operating years increasing. In the process of changing, the average total cost of the equipment was a function of time. So it had a balance point for the lowest average total cost of the equipment, which could be regarded as the economic life. The curve of average annual cost, annual using cost and the average investment cost was showed as figure 1.

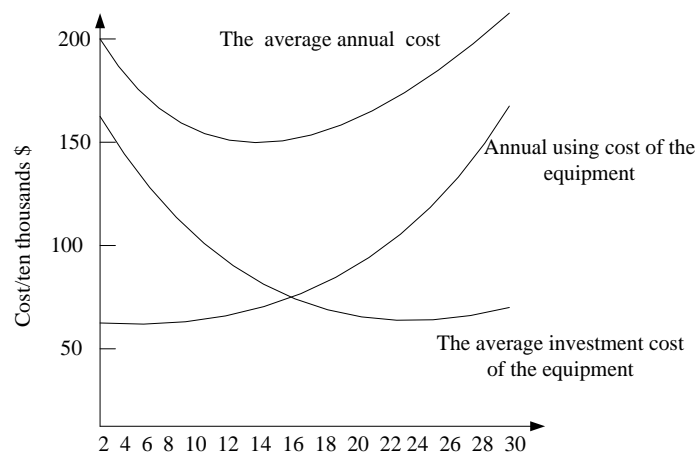


Figure 1. the total life cost comparison of the equipment

According to the theory of the economic life, When the average total cost of the equipment was least, the year was the economic life point. Combined with the established models of every stage in LCC, the evaluation model of economic life could be established as formula (7).

$$C_{LCC} = \frac{C_1 + \sum_{i=0}^t (C_2 + C_3 + C_4) + C_5}{t} \quad (7)$$

In formula (7), C_1, C_2, C_3, C_4, C_5 expressed the investment cost, operation and maintenance cost,

repairing cost, failure cost and retired cost respectively.

3.2. The example for economic life evaluation of transformers

Selecting 750 transformers in operation as the sample data. Combined with the actual investment cost, operation and maintenance cost and repairing cost, if the data of operation and maintenance cost or the repairing cost was lack, taking the average data of the recent 5 years as the corresponding cost. According to the established models of LCC, the total cost of LCC could be calculated. Then the economic life could be evaluated as formula (7). The result showed that the annual total cost was least when the operation years of the transformers were 25, which was the economic life of the equipment. The annual average using cost was showed as figure 2 and the cost in the 25th year was showed as figure 3. As the example showed, the using cost of the transformers would increase 6.6% annual year when the operating years were over the economic life. So at the economic life year, the reasonable decision making was to replace the equipment.

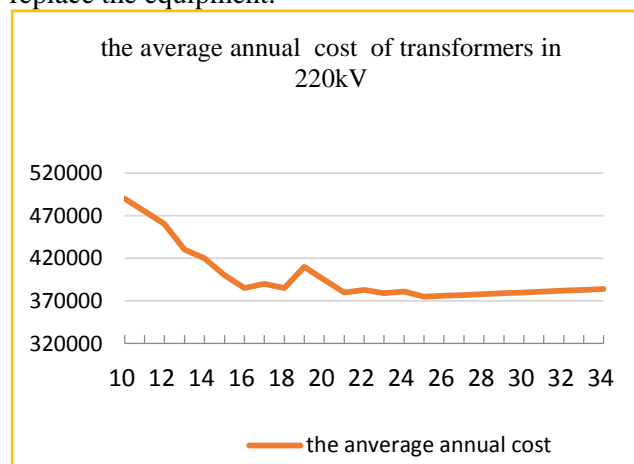


Figure 2. the average annual using cost diagram of transformers

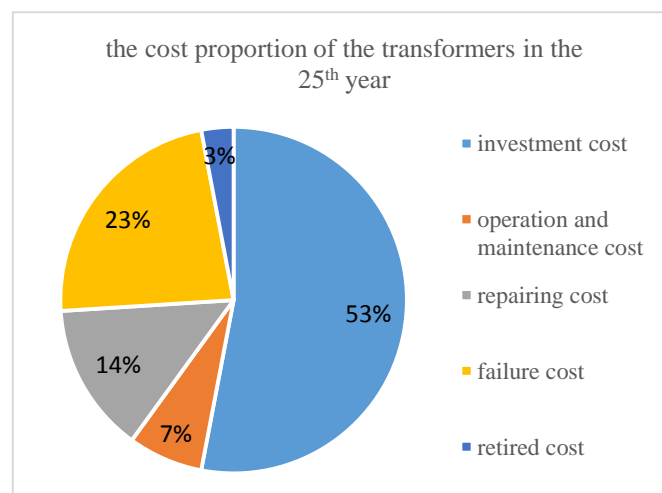


Figure 3. the cost proportion of the transformers in the 25th year

4. Conclusion

This paper established the LCC model of power transformers based on five stages of the life cycle for the equipment, and then researched the economic life evaluation of the equipment. The actual example

verified the accuracy and practicability of the model. The research result could provide theoretical support for equipment LCC management and decrease the total cost of LCC.

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