Research on Purchasing Strategy of 110 kV Cable Accessories based on Life Cycle Cost Management

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Abstract. Cable accessories, as an important part of cable system, we often only focus on its initial acquisition costs and ignore the late costs in its life cycle. In order to maximize the economic benefits and to play the use of cable accessories, we need to introduce an equipment life cycle cost management (LCC) for 110kV cable accessories. In this paper, a life cycle cost management of 110kV cable accessories is studied, and an evaluation model of cable accessories purchase based on LCC is established. The LCC theory is applied to the bidding and purchasing of cable accessories, which can make the purchased and managed reasonably, and save the social resources effectively.

1. Introduction
Life Cycle Cost (LCC) manages the asset management in the whole life cycle of planning, project approval, design, operation and retirement to find the best solution to achieve the overall optimization throughout the various stages. Its concept originated in the Swedish railway system in 1904 [1]. In 1996, the International Electrotechnical Commission (IEC) issued the international standard "credibility management" (IEC60300-3-3) [2], to further promote the application of LCC. In 2004, the International Conference on Large Power Grid (CIGRE) proposed the use of LCC equipment management, to encourage manufacturers to provide products LCC report.

At present, life cycle cost management of electric power equipment is mainly applied to the main transformer, circuit breaker and other equipment in the world. The literature [3] introduced a life cycle cost method covering a complete 110 kV overhead transmission grid with air insulated substations which can be used effectively for comparing different network topologies and equipment types. In [4], a life cycle cost method was used for analysing the various operational scenarios of maintenance power transmission lines. A principle calculation on the power transformer was showed in [5] which can determine the economic life cycle from economic aspect of asset management.

Chinese electric power enterprises explored its own LCC method with the characteristics of Chinese electric power. The literature [6] showed a more comprehensive transformer life cycle cost model with environmental cost and preventive test cost. In [7], a new power transformers maintenance decision making model was showed to solve the large financial losses to electric enterprises based on life cycle cost analysis. The literature [8] introduced the LCC method and application of the 2010 Shanghai Expo 500kV underground substation GIS procurement, which became the first successful use of LCC method of bidding and purchasing.

The LCC management technology of main transformers and circuit breakers is becoming more and more mature in China. However, cable accessories, as an important part of cable system assets, lack
the applicable LCC management method to control their economy and reliability. In order to fill the vacancy of 110kV cable accessories in LCC management, this paper presents a modified LCC management model for cable accessories, which is applied to the bidding and purchasing of cable accessories, and the application case is used.

2. Research on Evaluation Model of LCC Purchasing for 110kV Cable Accessories

At present, the LCC model of power equipment widely used IEC60300-3-3 application guide. Cable accessories as an important part of the cable line is the weakest link of whole cable line insulation, coupled with its complex construction process and special underground laying layout, we should amend the evaluation model according to the actual operation of the situation in LCC evaluation. The corresponding amendments can be expressed as:

\[ LCC = CI + COM + CF + CD \]  
\[ (2-1) \]

\( LCC \): Life Cycle Cost  
\( CI \): Investment Costs  
\( COM \): Operation and Maintenance Costs  
\( CF \): Failure Costs  
\( CD \): Disposal Costs

2.1. The Cost of Inputs (CI)

Electricity enterprises can learn the composition of quotation from equipment manufacturers by CI which including cable accessories price and installation costs. Cable accessories price includes the purchase price of equipment, factory test inspection fees, special tools and first time spare parts price, after-sales service fees, supplier-shipping costs, etc. The input cost CI can be expressed as:

\[ CI = C_{ij} + C_{ac} \]  
\[ (2-2) \]

In the formula, \( C_{ij} \) indicates the price of the cable accessories, \( C_{ac} \) indicates the cable attachment installation fee.

Cable accessories are usually packaged to purchase. The calculation of different equipment classification can help power enterprises to understand the structure of input cost longitudinally. Therefore, \( C_{ij} \) also expressed as the price of cable terminal fittings, insulated joints, coaxial cables, direct grounding boxes and other complete sets of cable accessories. It should be noted that the values of \( C_{ij} \) calculated in two ways should be equal.

The above methods are used to decompose the price from the two dimensions of the cost nature and equipment classification, which can intuitively show the composition and proportion of price, and the quotation of "foaming price" is eliminated to the maximum extent. Purpose.

2.2. Cost of Maintenance (COM)

Remote manipulation such as on-line monitoring is usually used for daily inspections of cable accessories, so the daily inspection costs are negligible. At the same time, cable connector and terminal in the event of a fault or defect, usually directly replace the replacement. Therefore, the cable accessories operating and maintenance costs can be simplified according as COM, which can be expressed as:

\[ COM = C_{jb} + C_{ew} \]  
\[ (2-3) \]

In the formula, \( C_{jb} \) indicates the basic maintenance costs, and \( C_{ew} \) indicates additional maintenance costs. Let \( A \) be the best life cycle of the 110kV cable accessory, \( C_{jb}(t) \) for the basic
operation maintenance cost of the year $t$, and $i$ for the discount rate, then the basic maintenance costs converted to the initial purchase can be calculated using the formula (2-4).

$$C_{jb} = \sum_{t=1}^{n} \frac{C_{jb}(t)}{(1+i)^t}$$

(2-4)

Similarly, conversion to the initial purchase of the additional maintenance costs can be used to calculate (2-5).

$$C_{ew} = \sum_{t=1}^{n} \frac{C_{ew}(t)}{(1+i)^t}$$

(2-5)

2.3. The Cost of Failure (CF)

The failure costs for 110kV cable accessories include failure and maintenance losses, which can be expressed as:

$$CF = C_{gf} + C_{gs}$$

(2-6)

In the formula, $C_{gf}$ indicates the troubleshooting fee, $C_{gs}$ indicates the cost of the failure. $C_{gf}$ can be expressed as:

$$C_{gf} = \alpha \cdot C_{ar}$$

(2-7)

In the formula, $\alpha$ indicates the equipment failure rate guaranteed by the equipment manufacturer $C_{ar}$ indicates the average repair cost of 110kV cable accessories failure, which is provided by the power company. $C_{gs}$ can be expressed as:

$$C_{gs} = \alpha \cdot C_{at} \cdot P_{rt} \cdot MTTR$$

(2-8)

In this formula, $C_{at}$ indicates 110kV average transmission price, $P_{rt}$ indicates rated conveying capacity, $MTTR$ indicates the repair recovery time, provided by the power companies.

2.4. The Cost of Disuse (CD)

As the scrap recovery costs of the cable accessories are too small to be ignored, so the cost of disuse can be expressed as:

$$CD = C_{cc}$$

(2-9)

In the formula, $C_{cc}$ indicates the removal costs of cable accessories.

2.5. Life Cycle Cost Evaluation Model of 110kV Cable Accessory

According to the above analysis, the LCC calculation model of the 110kV cable accessories can be sorted into:

$$LCC = C_{gf} + C_{cc} + \sum_{t=1}^{n} \frac{C_{jb}(t)}{(1+i)^t} + \sum_{t=1}^{n} \frac{C_{ew}(t)}{(1+i)^t} + \alpha \cdot C_{ar} + \alpha \cdot C_{at} \cdot P_{rt} \cdot MTTR + C_{cc}$$

(2-10)

The LCC evaluation model Breakdown Structure can be shown in Figure 2-1.
3. Research on Bidding and Purchasing Strategy of LCC Evaluation Model Based on 110kV Cable Accessories

After finished the bidding evaluation of technical and business conditions, electric power company can choose a number of top equipment manufacturers to conduct the LCC evaluation. Firstly, before the equipment manufacturers provide the LCC calculation data, the electric power company needs to convene the equipment manufacturers to convene the preface, detailing the filling way of calculation data and the needing attention. After that, the equipment manufacturers shall complete the LCC evaluation report according to the actual situation and then perform the LCC verification by the electric power company to ensure that the LCC calculation data provided by the equipment manufacturer is real. Finally, based on the preliminary verification and clarification, we can get the final LCC calculation results and evaluation by summarizing the cost of power enterprises and equipment manufacturers, which are the main foundations to evaluate the bidding.

3.1. LCC Evaluation Report

The LCC evaluation report written by equipment manufacturers should focus on the measures, which are used to reduce the failure rate, repair and maintenance costs in design, manufacture, material selection and testing. In this report, electric power company can learn the experiences and effect in reducing the LCC costs from manufacturers.

3.2. LCC Verification Method

The LCC calculation data and LCC report should be verified after picked up. According to the "grasp the big release" principle, the verification of LCC calculation data mainly consider the following 4 points:

- Verify the initial cost of input: according to the initial cost of input provided by the equipment manufacturer, we can use contrastive method to verify the rationality. The price of calculated in terms of cost nature and equipment classification shall be equal.
- Verify the basic operation and maintenance costs: the basic operation and maintenance costs can refer to the operation and maintenance technical standards of local power grid and verify by contrastive method and experiences preliminarily.
- Verify the additional maintenance costs: The additional maintenance costs usually refers to other maintenance costs other than periodic maintenance requirements, such as special commissioning costs, condition monitoring equipment costs, etc. We can verify the additional maintenance costs by actual situation. For equipment with distinct differences, the manufacturer can clarifies if necessary.
• Verify 110kV cable accessories failure probability: the power company can be provided by the equipment manufacturers in recent years, the failure rate guarantee value and the relevant failure statistics and power companies in the region where the power grid for several years of failure to compare the situation, for the statistics. To determine part of the further research, clarify, eliminate the dead ends of statistics.

3.3. The Punishment when LCC Verification Fail to Performance Assurance Assessment
When LCC calculation data provided by the equipment manufacturer is verified to be inaccurate or excessive from the actual value, the bid shall be annulled, furthermore, this equipment manufacturer may automatically be listed in the credit blacklist. If the equipment during the warranty period cannot meet the commitment at the purchase time and failure or defect, the equipment manufacturer should repair it within specified time, restore power transmission, take responsibility for the accident, and bear the costs of maintenance, replacement and actual loss. If the equipment outside the warranty period happen to failure or make an extra loss, the equipment manufacturer should compensate for the direct loss and bear the corresponding expenses.

4. Applications
This section selects three 110kV cable accessories bidding plans for LCC calculation. Among them, set the depreciation rate of $i$ is 5%, the best life of cable accessories $A$ for 30 years to calculate.

4.1. LCC analysis

4.1.1. The Cost of inputs (CI)
The input cost CI is mainly composed of the quotation and the final value of the CI converted to the best life of the equipment is shown in Table 4-1:

| Table 4-1. Input Costs of Three Plans. (Unit: RMB) |
|------------------------------------------|--------|--------|--------|
|                                           | Plan A | Plan B | Plan C |
| Cable accessories manufacturing cost      | 50000  | 45000  | 65000  |
| Factory test inspection fee               | 800    | 1000   | 1500   |
| Special tools and initial spare parts cost| 1000   | 2000   | 2000   |
| After-sales service fee                   | 2000   | 1500   | 2000   |
| Supplier shipping cost                    | 800    | 1000   | 1500   |
| Taxes and fee                            | 5000   | 4500   | 6500   |
| Other fee                                | 1000   | 500    | 2500   |
| 110kV cable terminal price                | 24000  | 18000  | 24000  |
| 110kV insulated connector price          | 24000  | 24000  | 45000  |
| Coaxial cable price                      | 1000   | 500    | 1200   |
| Ground wire price                        | 500    | 500    | 1100   |
| Direct grounding box price                | 3000   | 4000   | 3000   |
| Cross-connect protection earth box price  | 4000   | 4000   | 2500   |
| With protective earth box price          | 3500   | 4000   | 3000   |
| Return line price                        | 600    | 500    | 1200   |
| Cable attachment installation fee         | 2000   | 5000   | 2500   |
| CI present value                         | 62600  | 60500  | 83500  |
| CI final value                           | 270553.59 | 261477.51 | 360882.19 |

In table 4-1, the $C_j$ calculated by cost nature and equipment classification (gray shading part) in the three plans are equal, LCC calculation is valid.
4.1.2. The Cost of inputs (CI)

The value of COM for conversion to the best life of the equipment is shown in Table 4-2.

| Table 4-2. Operation and Maintenance Costs of Three Plans. (Unit: RMB) |
|---------------------------------------------------------------|
|                                              | Plan A | Plan B | Plan C |
| Regular operation and maintenance costs in second year    | 30000  | 30000  | 30000  |
| Additional maintenance costs                              | 10000  | 5000   | 5000   |
| COM value in second year                                   | 40000  | 35000  | 35000  |
| COM present value                                          | 36281.18 | 31746.03 | 31746.03 |
| COM final value                                            | 156805.17 | 137204.52 | 137204.52 |

4.1.3. Cost of Failure (CF)

Table 4-3 shows the calculation results of the CF final value of the best life of the equipment.

| Table 4-3. Failure Costs for Three Plans. (Unit: RMB) |
|-----------------------------------------------------|
|                                              | Plan A | Plan B | Plan C |
| Failure rate                                   | 0.5%   | 0.1%   | 0%     |
| Average cost of repair                         | 140000 | 140000 | 140000 |
| 110kV average transmission price (RMB / kW.h) | 0.6    | 0.6    | 0.6    |
| Repair time (h)                                | 3      | 3      | 3      |
| Rated conveying capacity (kW)                  | 50000  | 50000  | 50000  |
| CF second year value                           | 115000 | 115000 | 0      |
| CF present value                               | 104308.39 | 20861.68 | 0      |
| CF final value                                 | 450814.85 | 90162.97 | 0      |

4.1.4. Cost of disuse (CD)

The value of the depreciation cost is the final value, as shown in Table 4-4.

| Table 4-4. Waste Costs for Three Scenarios CD. (Unit: RMB) |
|---------------------------------------------------------------|
|                                              | Plan A | Plan B | Plan C |
| Cable accessories removal costs                  | 8000   | 5000   | 3000   |
| CD final value                                  | 8000   | 5000   | 3000   |

4.2. LCC analysis

Based on the above calculation results, we can get LCC calculation results shown in Table 4-5 and Figure 4-1:

| Table 4-5. 110kV cable accessories LCC cost deconstruction comparison. (Unit: RMB) |
|---------------------------------------------------------------|
|                                              | CI     | COM    | CF     | CD     | Total     |
| Plan A                                        | 270553.59 | 156805.17 | 450814.85 | 8000 | 1313532.37 |
| Plan B                                        | 261477.51 | 137204.52 | 90162.97 | 5000 | 892527.04  |
| Plan C                                        | 360882.19 | 137204.52 | 0      | 3000 | 999173.42  |
Figure 4.1. The Comparison of 110kV Cable Accessories Options of LCC.

From Table 4-5 and Figure 4-1, it can be concluded that LCC final value of plan A is the highest, and the difference between plan B and plan C is small, so the safety should be considered. In this three plans, the CI of program C is the highest, and the three plans are comparatively comparable in terms of COM. The difference between three plans is reflected in the cost of failure. Plan A is guaranteed by the high values of failure rate lead to a significant increase in CF, and the reliability of the equipment is low. Moreover, the failure rate guarantee value of plan C is 0, no CF is generated. If the plan reports the failure rate guarantee value verified by the real effective, we can determine that the program C equipment safety performance is much more higher.

In summary, it can be seen that the cost performance of plan B is higher than that of the other two plans. Although the CI of plan C is slightly higher than the cost of the plan B, the lower COM and higher reliability and security results show some advantages. It is suggested that the electric power company should fully verify the authenticity of COM and the failure rate guaranteed value in bidding process, consider the proportion of COM and CF, and reduce the cost of labour and equipment.

5. Conclusion

The LCC management of the power system is based on the reliability of the equipment to make the life of the lowest cost of ownership management. In the procurement of equipment, we should consider not only the purchase price of equipment, but also the cost throughout the life cycle. Considering all the costs incurred, and seek the best solution, find a balance between appropriate availability and full cost, then find the smallest solution.

In this paper, the traditional LCC evaluation model is amended to establish a LCC evaluation model suitable for 110kV cable accessories, and applied it to the bidding and purchasing of 110kV cable accessories, which is practical significance. At the same time, three different plans are used to analyze the application cases, CI, COM, CF and CD are analysed. The LCC method is not only used to realize the unity of economy and reliability in equipment procurement, but also to deeply promote the power system of LCC technology and management applications.

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