Research on Investment Decision of Substation Project Based on Life Cycle Cost

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Abstract. In this paper, the life cycle cost theory is applied to the study of investment decision-making of substation engineering, and the scientific, reasonable and objective comprehensive evaluation of substation engineering is realized. Based on the analysis of the calculation method of life cycle cost, a theory-based investment decision model for substation engineering is established. Finally, taking a substation project as an example, it proves that the model can effectively analyse the investment cost of different schemes, objectively reflects the economic differences between schemes, and provides a favorable judgment basis for investment decision-making of Power Grid Substation projects, which has a certain practical value.

1. Introduction

The large number of investment and long construction period of substation projects can accurately and effectively carry out investment decision-making analysis, which is helpful to the overall improvement of the construction efficiency of power grid enterprises [1]. Substation project investment has always been the core part of fixed assets investment of power enterprises. The success or failure of investment decision-making is directly related to the efficient use of funds of power enterprises, and affects the market competitiveness of enterprises. Therefore, it is of great significance for the power industry to make investment decisions for the substation project [2].

At present, scholars at home and abroad have studied the investment decision-making of substation engineering. Based on the theory of fuzzy multi-objective, Hu Gaoyang studies the investment decision-making dimension of power grid project. It proves the practical feasibility and practicability of the fuzzy comprehensive evaluation method [3]. Wang Xun is actively promoting the management of life cycle assets for State Grid Corporation and its subordinate units [4]. Li Yanchao integrates the whole process management of the project from the aspects of organizational structure, resource allocation, investment decision-making, so as to ensure the realization of the project management and control objectives [5]. Hou Jieexu considers investment decision-making from the aspects of technical and economic evaluation, financial evaluation, investment estimation and project investment approval [6].

At present, in the stage of investment decision-making, substation projects in China tend to focus on one-time investment cost, which is underestimated after the equipment is put into operation, seriously affecting the accuracy of investment decision-making. In this paper, the life cycle cost theory is applied to the study of investment decision-making of substation engineering. The investment cost of Substation Engineering covers all the investment involved in the whole life cycle from planning, purchasing, using
to scrapping of substation equipment. The scientific, reasonable and objective comprehensive evaluation of substation engineering is realized.

2. Life cycle cost analysis of substation engineering
Predicting future cost by studying historical cost and current cost is the core content of LCC theory. It is the direct goal of LCC theory to compare various alternatives or to evaluate assets by using NPV method. The ultimate goal of LCC theory is to achieve the minimum cost of life cycle or maximize profit of life cycle.

The life cycle of substation engineering refers to all stages of the process from project conception to final abandonment. According to the sequence of time, the life cycle can be divided into design, construction, operation and decommissioning stages. Each life cycle stage will correspond to a cost. We divide the life cycle cost into purchase cost, operation cost, maintenance cost and decommissioning treatment cost. By linking the cost of each stage with each stage of the life cycle, we establish the investment decision model for each stage of the life cycle of substation project.

(1) Acquisition cost
Acquisition cost is one-time expenditure or expenditure concentrated in the short term, which belongs to the expenditure items in the design and construction stage. In the design stage, the expenditure is mainly used for demonstration, development, test and finalization, that is, demonstration cost, development cost and production cost.

(2) Operation cost
Operation cost is the cost that the purchaser needs to use in the whole service period of the equipment after acceptance and reception of the purchased equipment, including consumptive cost, energy consumption of auxiliary equipment, operator cost and training cost, equipment management cost, technical data cost, etc.

(3) Maintenance cost
Maintenance cost refers to the maintenance and support expense paid regularly in order to ensure the normal operation of equipment, including preventive maintenance cost, repair and maintenance cost, support personnel cost and training cost, spare parts support cost, support facilities cost, insurance cost, etc.

(4) Failure cost
Equipment failure cost refers to the penalty cost caused by equipment failure, including direct failure cost and indirect failure cost. Direct failure cost refers to the cost of power outage loss, equipment performance and life loss. Indirect loss cost refers to the compensation cost that may occur, the adverse social impact caused, and the loss of the company's reputation.

(5) Decommissioning cost
Decommissioning cost refers to the cost of various post-treatment of equipment in the process of decommissioning. This part often accounts for a small proportion of the total. This is because that in addition to paying for the necessary post-treatment, including expenses for waste disposal and contamination disposal, some equipment residual CR can also be recovered.

3. LCC investment decision model for substation engineering

3.1. Life cycle cost model
If the time value of funds is not considered, the static calculation formula of LCC for power equipment is obtained.

\[
LCCD = CA + CO + CM + CF + CD - CR
\]

Where,  
LCC——Life Cycle Cost of Equipment;  
CA—— Acquisition Cost;  
CO—— Operation Cost;  
CM—— Maintenance cost;
CF——Failure cost;  
CD——Decommissioning cost;  
CR——Residual value of equipment.

The cost of each item in the above formula is the cost in different years, without considering the time value of the funds, which is the static cost. At present, the interest rate in the capital market changes sharply and the consumer price index keeps rising. It is not enough to consider only the static cost. Interest rate and inflation rate should be taken into account, according to the principle of capital equivalence calculation, the cost occurring at different times should be converted to the same time point to calculate LCC dynamic cost of equipment, which has practical value in practical engineering.

(1) Acquisition cost (CA)

The acquisition time of equipment is regarded as the discount base time (set at the beginning of the year), so the acquisition cost is not affected by interest rate and inflation, and its expression is unchanged.

(2) Operation cost (CO), Maintenance cost (CM), Failure cost (CF)

In the life cycle of equipment operation, operation cost, maintenance cost and failure cost can be regarded as annual operation cost (expenditure time point is the end of the first year). Firstly, the annual operating expenses are calculated according to the cost model, and then discounted to the benchmark time year by year.

(3) Decommissioning cost (CD)

Retirement costs occur at the end of the last year of the life cycle (the end of year T), and can be discounted to the base time at one time.

Based on the above analysis, the dynamic model of life cycle cost of power equipment is as follows:

\[
LCC_d = CA + \sum_{i=1}^{T} \left( CO + CM + CF \right) \times \frac{1}{(1 + \gamma)^i} \times (1 + CPI)^i + (CD - CR) \times \frac{1}{(1 + \gamma)^T} \times (1 + CPI)^T
\]

Where, \( \gamma \) —— interest rate;  
CPI——Consumer price index, reflecting inflation.

4. Empirical research

4.1. Case background

This chapter will give an example of the whole life cycle cost study of substation engineering. Taking a 500 kV substation project in a certain province as an example, according to the actual situation of the project, the scientific validity of the investment model of the substation project is verified by comparing the life cycle cost of its main wiring technology and economy, and the practical value of the model in the engineering field is proved.

4.2. LCC investment decision analysis

4.2.1. Comparison and selection of main wiring. This project introduces the concept of life cycle management. On the basis of guaranteeing the safety and reliability of all functions of substation, it strives for the lowest main wiring cost in order to achieve the best comprehensive benefits. In the design of the substation, the reliability, safety, flexibility, intensiveness and extensibility of the substation are fully considered, and an electrical main wiring scheme is proposed for the project. The following comparisons will be made one by one. The options are as follows:

- Scheme 1 is a line-transformer wiring scheme consisting of two circuit breakers;
- Scheme 2 is a delta connection consisting of three circuit breakers;
- Scheme 3 consists of 1 series of half-circuits consisting of 5 circuit breakers.

It is known that the equipment allocation at the end of the project is exactly the same according to the three schemes, that is, if the time value of the funds is not taken into account, the total investment of the three schemes is the same. However, in actual electric power projects, the investment of funds is large,
and the time value of funds must be fully considered, otherwise it will cause huge and unnecessary waste of funds.

Figure 1. 500KV main electrical connection scheme in the current period

Following is a comparison of the major distribution equipment costs involved in the three schemes, including: primary electrical equipment, secondary electrical equipment, brackets, foundations, etc. The determination of the cost is first calculated according to the percentage stipulated in the standard, and refers to the experience data of similar projects. The economic comparison of these three schemes in this project is shown in the table.

Table 1. 500Kv various wiring methods comparison of investment economy in this period (Unit: ten thousand yuan)

| Category                              | Unit          | Unit Price | Scheme 1 | Scheme 2 | Scheme 3 |
|---------------------------------------|---------------|------------|----------|----------|----------|
|                                       |               |            | Number   | Price    | Number   | Price    | Number   | Price    |
| Major equipment                       | Circuit breaker (SF6) | set 192.34 | 2        | 384.68   | 3        | 577.02   | 5        | 961.7    |
|                                       | Current transformer | set 22.42  | 6        | 134.52   | 9        | 201.78   | 15       | 336.3    |
|                                       | Vertical opening disconnector (single ground) | set 35.4 | 1        | 35.4     | 2        | 70.8     | 4        | 141.6    |
|                                       | Horizontal open disconnector | set 70.8 | 2        | 141.6    | 2        | 141.6    | 3        | 212.4    |
|                                       | Voltage transformer | set 9.558 | 9        | 86.022   | 9        | 86.022   | 11       | 105.138  |
|                                       | lightning arrester | set 5.428 | 18       | 97.704   | 18       | 97.704   | 18       | 97.704   |
|                                       | Failure Protection of Reclosure and Circuit Breaker | set 12.98 | 2        | 25.96    | 3        | 38.94    | 4        | 51.92    |
| Supporting insulator set | 2.006 | 3 | 6.018 | 6 | 12.036 | 15 | 30.09 |
|-------------------------|-------|---|------|---|--------|----|------|
| Equipment basic cost    | 192.34| 42| 43   | 69 |
| Installation and other expenses | 22.42 | 55 | 67   | 91 |
| Total                   | 1008.904 | 1335.902 | 2196.852 |
| Investment balance      | --    | 326.998 | 824.824 |

The above table shows that the investment of the three schemes is 1008.904 million yuan, 1335.902 million yuan, and 2196.852 million yuan respectively. The project investment amount of scheme 1 is the least, and that of scheme 3 is the largest, which is 824.824 million yuan higher than that of scheme 1, and the life cycle cost of scheme 1 is the lowest. Therefore, in the case of fully considering the time value of the funds, scheme 1 should be chosen as the implementation plan of the project. In addition, the wiring mode of scheme 1 involves less equipment and less workload of operation and maintenance, which can greatly reduce the cost of operation and maintenance of the project. Combining with previous reliability and scalability analysis, scheme 1 is selected as the best recommendation scheme for this project.

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5. Conclusion
In this paper, the life cycle theory is applied to investment decision-making of substation engineering, and the multi-stage objectives of the project are unified. On the basis of considering the time value of funds, it involves the cost generated in each stage of the substation engineering from concept formation to retirement recovery, and achieves the optimum of the whole and the system to the greatest extent. At the same time, it meets the technical and economic indicators of the project. It also ensures the correctness of medium and long-term decision-making in the increasingly fierce market competition, and effectively realizes the comprehensive advantages of cost and benefit.

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