WITH TRANSMISSION GRID ASSET OPERATION AND MAINTENANCE FIXED QUOTA TO SUPPORT LIFE CYCLE COST ABSORPTION AND ANALYSIS

Xiaodong FANG
Shanghai Municipal Electric Power Co.
fangxd@ sh.sgcc.com.cn

Wanrong XU
Shanghai Municipal Electric Power Co.
xuwr@sh.sgcc.com.cn

Weimin WANG
Shanghai Municipal Electric Power Co.
wangwm@ sh.sgcc.com.cn

ABSTRACT

During the Grid Asset life cycle, operation and maintenance (Abbr. O&M) period covers more than 95% of the life cycle. In China, the proportion of Grid Asset O&M period costs in the Life Cycle Cost (Abbr. LCC) is much greater than the international average standard. Therefore, how to control the asset operation cost effectively becomes a significant issue. Asset operation period cost consists of Operation cost and Repair cost. After publishing the Equipment Repair Cost Fixed Quota, Shanghai Municipal Electric Power Company (Abbr. the Company) steps further to develop a research on O&M cost fixed quota system. Because of dispersion of equipment and multiple-activities, O&M cost has been the weak part of the cost control for a long time, which makes the O&M budget cannot match with the asset base. The Company conducted a comprehensive research on O&M activities of substation equipment, transmission lines (overhead and cable) and various assistant facilities, which made all activities be linked to certain assets. The Company also collected and analyzed the cost data of labor, material, machinery and the external environment of each activity. Moreover, it standardizes the key information including activity object, content and frequency at the same time. For those activities which are more complicated and labor operation hour of which is difficult to estimated, such as switching, permitting and inspection, the Company implemented process decomposition method and use relevant historical data within the information system to conduct comprehensive quantitative analysis and formed a reasonable fixed quota standard calculation method. Ultimately an O&M fixed quota system is formed that can be implemented in information system and applied for O&M cost monitor, control and lean management. It also provides reliable basic data to estimate single asset O&M costs, consequently provides strong support for asset O&M activity model optimization, LCC bidding model improvement, supplier evaluation, Input-output analysis for asset group, human resources optimization and Asset Life Cycle Cost analysis and control.

1 BACKGROUND

During the calculation of equipment Life Cycle Cost (Abbr. LCC), calculating the term for Operation and Maintenance (Abbr. O&M) Cost, C2, has always been a difficult task due to grid assets' complex working procedures, many uncertainties involved. Moreover, it is even more difficult to allocate it to single asset. Meanwhile, as Operation and Maintenance period occupies more than 95% of the asset's whole life cycle, it is critical to effectively control the cost during this period in the scope of Life Cycle Asset Management.

The Company has launched a research project to design a cost evaluation method for power grid asset during its whole life cycle. The research was conducted utilizing historical data of cost on key categories of asset. Through analysis and evaluation of these historical data, it is found that the portion of O&M cost is much greater than international average.

Meanwhile, Cost Collection, especially for single asset, has always been a weak part of cost control during O&M period, which is usually done by estimation from previous year's budgeting and current year's adjustments for special situation. This always leads to problems like asset base does not match with their allocated resource due to lack of quantitative calculation standard. In order to solve these issues, the Company conducted a comprehensive analysis on its O&M cost. Thus actual needs for labor, material and machine, as well as the cost induced by related activities, can be clarified. Ultimately, the cost calculation method and standard for O&M activities were formed. In this paper, the design methodology of grid asset O&M fixed quota system and cost calculation standard, as well as key issues and solutions were introduced. Finally, the future application of the fixed quota system was discussed.

2 INTRODUCTION TO OPERATION PHASE COST

Asset Operation Phase Cost is any costs related to O&M activities, inspection and repair, and fault repair during the usage of the asset. Therefore, Asset Operation Phase Cost can be sorted into three categories, which are O&M cost, repair cost, and failure cost, as shown in Table I.

Cost Item	
Operation cost	Inspection Cost
	Daily Maintenance Cost

Repair cost	Minor Repair cost
	Major repair cost
Failure cost	Failure repair cost

Table 1 Operation Phase Cost Composition

In 2007, the Company has already designed and published the calculation method and standard for repair (includes minor and major repair) cost, and realized automatic repair cost collection for single asset through work order in IT system. Failure cost can be calculated in two ways according to its characteristics. Failure cost is calculated as capital expenditure according to construction project budgeting standard if the failed equipment is replaced entirely. Failure cost is calculated and collected as cost expenditure according to repair cost fixed quota if failed equipment is repaired. Since there is no precise and mature cost collection method and calculation standard, O&M cost calculation usually requires extra cost. For example, it takes much effort to record and collect actual cost of each O&M activity for single asset. Therefore, the Company uses standardized O&M cost collection method, which means to record and collect actual cost for labor, material and machine of each O&M activity for single asset through unified O&M cost calculation method and standard, to form O&M cost fixed quota.

3 DESIGN METHODOLOGY OF O&M COST FIXED QUOTA

The Company has started the design of O&M cost fixed quota in the second half of 2009. It takes 1.5 year for the Company to complete the design and pilot calculation of O&M cost fixed quota for assets covering substation asset, overhead lines and underground cables from 35kV to 500kV.

The cost fixed quota is based on historical data analysis, experienced expert estimation and onsite experiment. Its design follows the principle that pilot first and then rollout. Taking typical substation or work area as sample, the formation of fixed quota was done by 4 steps: 1. Defining activity object; 2. Listing O&M related activities; 3. Estimation of resource consumed; 4. Fixed quota calculation. The design procedure of cost fixed quota for 220kV substation is shown in Table 2 as an example.

Steps	Description
Defining activity object	1.select typical substation as the pilot 2.collect the list of equipments, then matching the equipments with appropriate asset or asset category 3.form the structure and the list of activity objects
Listing O&M related activities	1.collect the contents of each O&M activity, form the comprehensive activity list of pilot substation. 2.standarlize the definition and category of each activity, then mapping them with working objects
Estimation of resource consumed	1.collect the sample of resource consumed(working hour, material and machine) of each activities according to the working standard, experience and historical data 2. verify the outcome through multi-sample testing, thus to form the stand of resource consumed in normal working condition
Fixed quota calculation	1.collect the unit price of labor, material and machine 2. multiply the unit price with the resource consumed of each activity to formulate the O&M fixed quota of the 220kV pilot substation

Table 2 Design methodology of cost fixed quota

Taking findings from previous pilot as foundation, data and information collection was extended to other working areas and substations. Moreover, adjustments and optimizations to original O&M cost fixed quota, which is based on the sample substation, was made according to feedback from different management levels of the Company. And then, the O&M Cost fixed quota was finalized through further extending the test and estimation to all equipments of required categories within the Company.

4 EXAMPLES OF O&M COST FIXED QUOTA FORMULATION

In this chapter, we take substation equipment as example to introduce the O&M cost fixed quota design procedure, key problems encountered and corresponding solutions in detail.

4.1 Activity Object

O&M cost fixed quota corresponds to assets or asset groups which have independent asset card or belong to a specific asset category. Based on the Company's existing physical asset catalog, equipment list and corresponding relationship between them, a list of working objects was formed for substations taking into account the characteristics of their related production activity. The list includes a tree structure chart showing objects from substation as a whole to single equipment category, as well as a list covering all assets or asset groups involved in single O&M related activity. See figure 1.

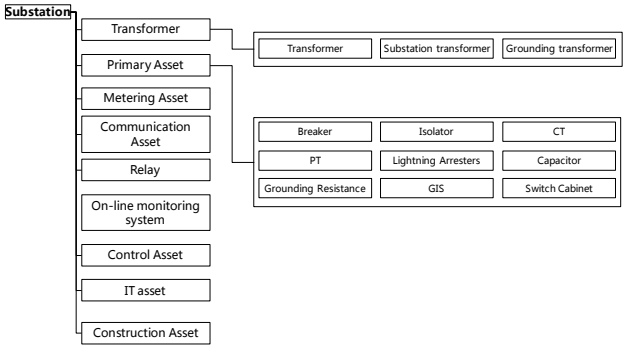

Figure 1 Sample activity object list of substation assets

4.2 Listing O&M related activity

For each O&M related activity, information including name, detailed content, frequency and activity instruction was collected, clarified and named in a standardized manner to form a list of working procedure. According to its characteristic, activity can be divided into two categories, Operation and Maintenance. Operation activities include switching, work permit, inspection and special inspection. Maintenance activities include professional maintenance, general maintenance and property maintenance. Calculation method and standard was confirmed based on executing entities (shown in Table 3) involved in actually activity.

Executing Entity		Numbers of activity	Portion
Executed by substation operating personnel		46	46%
Executed by other personnel	External operating personnel	3	3%
	Overall and repair personnel	18	18%
	Outsourced personnel or supplier	32	32%

Table 3 Substation O&M activities statistics

4.3 Estimation of resource required

Based on the list of O&M related activity and their various characteristics, estimation of resource required was conducted in three ways, which are analysis on historical data, onsite experiment and experienced expert estimation.

- Analysis on historical data

This method is suitable for high frequency activities whose lasting time varies largely. Since working hours and machine hour required by this type of activity is hard to estimate based on past experience, the estimation was obtained from analysis on historical data from Production Management System (Abbr. PMS).

Take switching activity for substation as an example, we exported near 120,000 actual O&M records of almost 100 substations of 220kV between year 2007 to 2009 from PMS for analysis and calculation.

The activity can be broken into several steps including acceptance of operation order from dispatching officer, pre-creation of operation order, dispatching officer giving order, switching, report back to dispatching officer, filling out electronic operation order, and register the change of relay protection. See Figure 2.

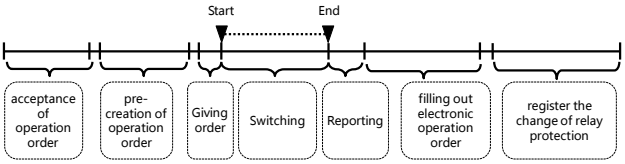

Figure 2 Steps of switching activity

Most of these procedures possess relatively standardized execution time which can be obtained taking advantage of actual experience of production experts. However, executing time required for switching varies largely each time due to different task complexities. Therefore, it required to be obtained from statistical analysis of historical data. From analysis of 3 years' operation order records of 100 substations, it is found that almost 90% of these activity procedures were completed within 2 minutes (1minute on average), 10% of them take more than 2 minutes to be completed (7 minutes on average), as shown in Figure 3.

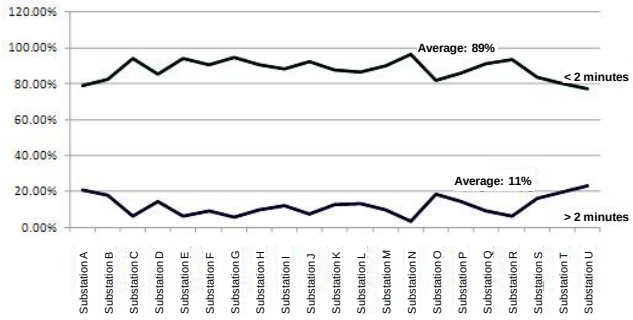

Figure 3 Execution time distribution of 220kV substation O&M activity for year from 2007 to 2009

According to above result, we can calculate implementation time as two independent parts:

(1) Switching time less than 2 minute: Average implementation time 1 minute multiplied by its weighting 89%.

(2) Switching time greater than 2 minute: Average implementation time 7 minute multiplied by its weighting 11%.

The sum of these two parts is the execution time for switching and working hour fixed quota can be calculated by adding other procedures' standardized execution time to it.

Working hour fixed quota found by this method was proved to be reasonable through pilot applications to a number of substations and recognized by experts and

frontline production staffs.

- Onsite Experiment

For activities with clear and continuous contents and procedures, the resource required can be defined by onsite experiment after clarifying testing situation and standard, activity contents and procedures, and calculation method and standard.

- Experienced expert estimation

This method is suitable for medium frequency activities whose lasting time does not vary significantly. The time, material and machine hour consumed by this type of activity can be estimated from experts' experience and validated through comparison with onsite experiment or historical data.

4.4 Fixed quota calculation

After collecting standardized quantity of resource consumed for each O&M activity, unit price of each resource was also collected for calculation of cost fixed quota (represented by price). Cost fixed quota includes cost standard for labor, material and machine.

$$\text{Labor cost} = \sum (\text{working hour} \times \text{unit price})$$

Labor cost of each activity is the product of labor working hour consumed by the specific activity and corresponding unit price of labor working hour. Moreover, by gathering labor working hour consumed by each working procedure within a substation, portion of labor working hour occupied by each procedure can also be obtained. As shown in Figure 4, procedures occupied most O&M labor working hours is respectively monitoring, inspection, switching, and special inspection.

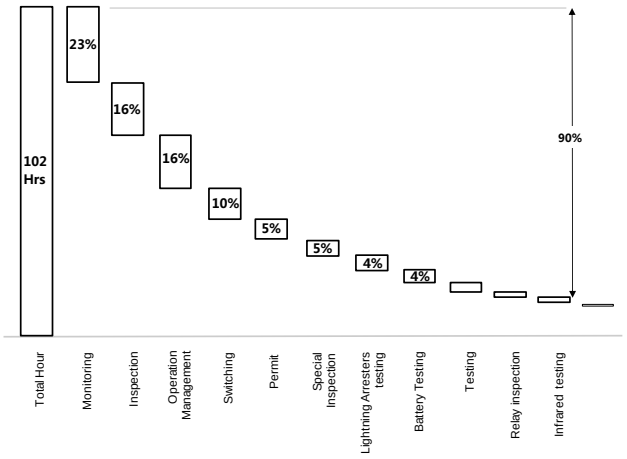

Figure 4 Portion of labor working hour occupied by different activities

$$\text{Material Cost} = \sum (\text{quantity} \times \text{unit price})$$

There exist differences between material consumed by each O&M activity in term of quantity and category. For example, some activities might not involve any material consumption while material involved in some activities might be reused for times. Therefore, collection of material consumption by O&M activities must be done by comprehensive analysis on statistics of actual consumption collected, calculation with reasonable allocation model, and comparison between obtained value and actual value. Thus ultimate quantity of consumption obtained will be reasonable and consistent with reality. According to market unit price of the material, final material consumption cost is the product of consumed quantity and corresponding unit price.

$$\text{Machinery Cost} = \sum (\text{working hour} \times \text{Unit price})$$

Machinery working hour is obtained from their actual usage time (includes waiting time). However, since most of machines involved in O&M activity are purchased and scheduled for use by the Company, it is difficult to find machinery working hour using above method. Therefore, we record data the workload of a working group and machinery usage frequency during a specific period and allocate obtained data to related machines (include waiting hours) reasonably.

5. SOME IDEAS OF FURTHER APPLICATION OF O&M COST FIXED QUOTA

The Company will apply grid asset O&M fixed quota in the following ways in order to improve its management.

(1) To setup corresponding quantitative relationship between grid asset O&M workload and O&M cost. The Company will gradually set O&M cost budgeting based on actual O&M workload so that O&M cost is recordable, and controllable. Thus the seamless link between finance and asset management can be formed during asset life cycle.

(2) To provide strong support for O&M labor allocation, position setting and technical force assignment.

(3) To calculate the O&M cost of single assets using the standard cost.

(4) To analyze the rationality of working standard and rules through collect the actual workload and then calculating the man-hour consumed by O&M activities. Thus the improvement of working standard and rules can be achieved gradually.

(5) To support the automatic collection of Life Cycle Cost of single grid asset through IT system such as ERP and PMS to provide data for asset evaluation and LCC biding.

REFERENCES:

[1] Production Department. 2007, Equipment Repair Cost Fixed Quota, Shanghai Municipal Electricity Power Company, Shanghai, China