Promotion, Application and System Construction of Reliability Evaluation for Distribution Network Facilities

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Abstract. The ultimate goal of conducting reliability evaluation of distribution network facilities is to seek the lowest life cycle cost without reducing the reliability of the facilities. At the end of 2022, the industry standard "Guidelines for Reliability Evaluation Indicators of Distribution Network Facilities" (draft for approval) was completed and awaiting approval, filling the domestic gap. Identifying the relationship between the cost and reliability indicators of each stage of the entire life cycle of the facility, and optimizing the cost of each stage reasonably based on this is not only the original intention of the industry standard preparation, but also the implementation path of its implementation. Therefore, this article studies the promotion and application of reliability evaluation for distribution network facilities. Firstly, the current status of reliability management for distribution network facilities is sorted out, and the costs at each stage of the life cycle are associated with the reliability evaluation indicators defined in the guidelines. Then, the functions and system construction plan of the facility reliability evaluation information system were provided, and the next steps and future trends were presented.

Keywords: distribution network facilities · reliability assessment · indicator implementation and application

1 Introduction

It is precisely due to the lack of a unified reliability evaluation method and evaluation index system for distribution network facilities that domestic power companies lack sufficient quantitative analysis of the shortcomings of distribution network facilities. Until October 2021, the "Notice of the Comprehensive Department of the National Energy Administration on the Issuance of the 2021 Energy Industry Standard Formulation and Revision Plan and Foreign Language Translation Plan" (Guo Neng Zong Tong Technology [2021] No. 92) issued a summary table of the 2021 Energy Industry Standard

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Formulation Plan projects, with item 312 being the development of reliability evaluation index guidelines for distribution network facilities (project number: Energy 20210312). At present, the preparation team has completed the development and submission of the industry standard approval draft, but how to smoothly implement its implementation and application still needs further research.

The literature on promotion, application and system construction of reliability evaluation for distribution network facilities is very limited. Some literature focuses on the reliability evaluation and evaluation of transmission and transformation facilities [2], or on the analysis of the relationship between reliability and economy [3], while others focus on the prediction methods of reliability parameters [4, 5]. The unified promotion model of reliability evaluation for transmission network facilities and the integrated implementation path relying on specialized information management systems cannot be fully applicable to distribution network facilities.

Therefore, this article explores the implementation path for the implementation and promotion of reliability evaluation of distribution network facilities. Firstly, the current status of reliability evaluation of distribution network facilities was reviewed, and the key content of the "Guidelines for Reliability Evaluation Indicators of Distribution Network Facilities" (draft for approval) [6] was briefly described. Then, the cost of each stage of the life cycle is associated with reliability indicators, and based on the current situation of information system, the functions and implementation plans that the facility reliability evaluation information system should have are provided. Finally, the next steps and future development trends are presented.

2 Current Status of Reliability Evaluation of Distribution Network Facilities

2.1 Current Status of Reliability Evaluation of Distribution Network Facilities

The reliability management of distribution network facilities in China has always been integrated with the reliability management of user power supply. The evaluation of the reliability of distribution network facilities by power enterprises originates from several indicators related to facility reliability in the "Regulations on Reliability Evaluation of Power Supply System Power Supply" (DL/T 836–2016). However, DL/T 836–2016 is not a specific standard for reliability evaluation of distribution network facilities. The analysis of facility reliability only involves counting the number and time of facility shutdowns, and the analysis of the reasons for facility shutdowns is not yet sufficient and is not related to costs, it is insufficient to guide practical work.

This indicates that the lack of guidance from relevant standards results in incomplete indicator calculation, insufficient depth of indicator analysis, and inability to explore deep-seated issues such as facilities, management, and personnel skills. At the same time, it also reflects that power companies generally prioritize transmission and distribution networks over distribution networks, and the transformation and application of existing reliability research results are insufficient.

2.2 Guidelines for Reliability Evaluation Indicators of Distribution Network Facilities

The project preparation team unified the classification of distribution network facilities and facility status in the "Guidelines for Reliability Evaluation Indicators of Distribution Network Facilities" (draft for approval), and calculated various reliability indicators based on facility status. The guidelines classify distribution network facilities into 8 categories. Add backup status to the facility status classification, and subdivide it layer by layer from the perspectives of capacity status, usage status, and status reasons, highlighting the reasons for this status.

In the construction of the indicator system, a "two-dimensional, three category" evaluation system has been formed. The "two dimensions" refer to facility maintenance – "shutdown" and system maintenance – "shutdown and power outage". The "three categories" refers to indicators in three categories—frequency, time, and proportion. Among them, frequency indicators reflect the average number of outages, time indicators reflect the average single outage time, and proportion indicators are comprehensive indicators that reflect the reliability of facilities.

2.3 The Correlation Between Cost and Reliability Indicators

The corresponding relationship between the cost and reliability indicators of distribution network facilities in each stage is shown in Fig. 1.

It should be noted that live working and pre-arranged shutdowns do not involve power outages to users and will not result in energy loss, only involving various costs incurred during operation or maintenance.

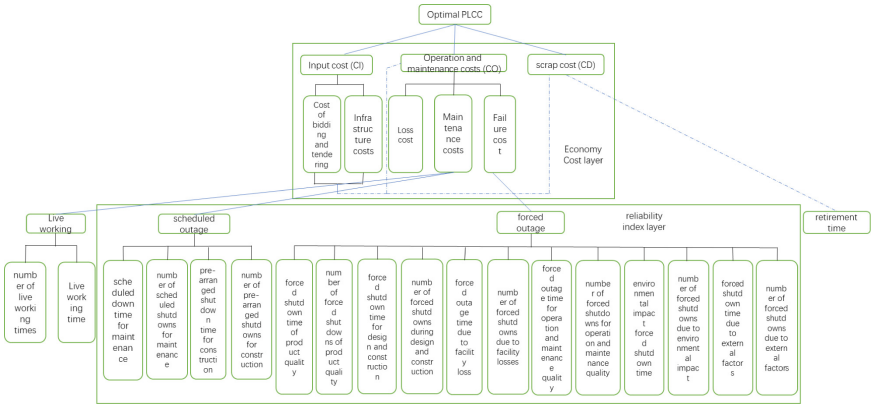

Fig. 1. Corresponding Relationship between Cost and Reliability Indicators of Distribution Network Facilities.

3 Construction of Facility Reliability Information Management System

3.1 Information System Construction

The research model for the evaluation system of facility reliability is divided into data foundation layer, calculation method layer, indicator calculation layer, and evaluation result layer, as shown in Fig. 2.

The data foundation layer is mainly responsible for collecting basic data such as facility reliability accounts, work orders, facility shutdown data, and cost data. The indicator calculation method layer uses the methods specified in the guidelines to calculate frequency, time, and proportion indicators at each level, responsible for the calculation of various indicators and statistical data. The analysis method layer includes a set algorithm library and calculation conditions for various analysis methods. When the input indicator data changes, the calculation results will be updated in real-time. The evaluation result layer provides the function of analyzing the reliability indicators of distribution network facilities and displaying the results. While providing vertical analysis of the reliability status and development status of different dimensions of distribution network facilities in each district, it can also achieve horizontal analysis of the evaluation and ranking of the reliability level of multi-dimensional facilities. It can also achieve analysis of the main influencing factors of distribution network facility reliability and auxiliary decision-making. By setting statistical analysis conditions, a chart of the analysis results of evaluation indicators can be automatically generated.

The information management system for reliability evaluation indicators of distribution network facilities considers accessing data from GIS systems, user information collection systems, equipment accounts/asset management systems, power supply reliability management systems, other business systems, or "6 + 1" integrated systems to

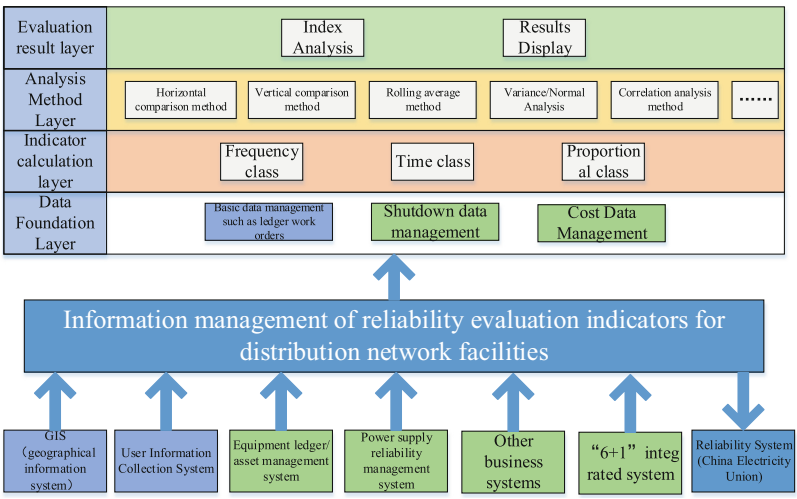

Fig. 2. Implementation of Information Management Module for Reliability Evaluation Indicators of Distribution Network Facilities.

generate a unified data format for reliability evaluation of distribution network facilities required by regulatory agencies (such as the China Electric Power Enterprise Federation). Support viewing the reliability evaluation indicators of various distribution network facilities within a certain range of GIS geographical wiring diagrams selected by users. Data generation is achieved through operations such as extraction, transformation, transmission, and loading, thus completing data centralization and aggregation, and then uniformly reporting to the reliability system of regulatory agencies.

3.2 Reliability Economy Analysis

3.2.1 Procurement Selection

Compare the reliability indicators of similar facilities provided by different manufacturers in similar operating environments horizontally (with the same time section). If some indicators differ significantly, it may indicate that some manufacturers have quality issues with their products. Further compare the reliability indicators of such facilities provided by the manufacturer in different operating environments. If the difference in comparison results is not significant, it may indicate that the manufacturer's products have familial defects.

In addition to comparing the reliability of facilities of the same type from different manufacturers, it is also possible to compare the reliability of the same type of facilities in different operating environments, the reliability of facilities of the same model with different operating years, and the reliability of similar facilities in different regions with the same operating years. This provides multi-dimensional analysis for facility procurement and selection.

3.2.2 Construction and Installation

Compare the reliability indicators of similar facilities with different construction and installation methods in similar operating environments to ensure sufficient data samples and evaluation cycles. If the difference in reliability indicators gradually increases with the extension of operation time, it may indicate that different construction and installation processes have varying degrees of impact on facility reliability.

3.2.3 Operation and Maintenance

The average outage rate and average outage interval hours of facilities can reflect the problems that exist in operation and maintenance. For example, the average number of hours between facility shutdowns can reflect the average interval between repeated shutdowns of the facility. If the interval time is significantly shorter than the historical average time of the facility, further analysis of this indicator based on the facility status can easily determine whether it is caused by the facility itself, inadequate maintenance quality, or unreasonable construction plan arrangement.

It is also possible to compare the reliability indicators of similar facilities in different operation and maintenance methods horizontally. If the comparison results show significant differences, it may indicate that different types of facilities are suitable for different

operation and maintenance methods. It can provide quantitative indicators for regional differentiated operation and maintenance.

3.2.4 Troubleshooting

Differentiated fault maintenance can be carried out for different facilities based on the cost of each stage of the facility. For example, reliability centered maintenance (RCM) can be implemented for key facilities, condition-based maintenance can be implemented for some key facilities, passive maintenance (regular maintenance or corrective or corrective maintenance) can be carried out for key equipment with hidden faults and occasional occurrences, and passive maintenance can be carried out for non-key facilities. At the same time, it is necessary to establish an economically reasonable guarantee mechanism for spare parts.

3.2.5 Retirement Processing

In today's practice of "low-carbon emission reduction", remanufacturing technology refers to the technology of reusing existing components through processes such as reshaping, restoring accuracy, and restoring performance, which can minimize product carbon emissions, maximize resource utilization, and minimize cost investment. Therefore, in the procurement and selection stage, consideration should be given to whether the components can be recycled, treated, and reused.

3.2.6 Reliability Improvement Effect

Through data accumulation over a period of time, statistics and summaries can be conducted based on different types of facilities, and then relevant analysis of cost and facility availability coefficient can be conducted to determine the optimal cost interval that meets the reliability indicators of distribution network facilities.

Starting from the overall efficiency of the enterprise and based on the reliability indicators of the facility's historical years, the costs of various distribution network facilities at different stages are calculated. The facility availability coefficient is selected as the horizontal axis and the cost is selected as the vertical axis. Based on the cost analysis of each stage mentioned above, the relationship curves between the full life cycle cost PLCC and reliability of the distribution network facilities before and after the implementation of facility reliability management in the area can be obtained. By comparison, it is easy to determine whether the current area has shifted to the optimal area after implementing facility reliability management.

4 Conclusions

Due to the numerous and extensive distribution network facilities, the implementation and promotion of facility reliability evaluation cannot be achieved overnight. Adopting a pilot area first approach, starting with cable lines and overhead lines with significant reliability outage times and impact as pilot facilities, then gradually expanding to switchgear and distribution facilities, and finally extending to low-voltage and DC facilities. In this

way, the pilot line project can better build the line and subsection data architecture, and then fill in the data architecture through the expansion of switching facilities and distribution and transformation facilities, gradually improve and finally realize the reliability evaluation of all types of facilities. Areas with good reliability data conditions should be selected as pilot areas. Typical problems encountered in the application of pilot areas should be recorded and dynamically updated, and successful experiences should be copied to other areas to gradually accumulate experience and consolidate application results.

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