Research on quality assessment method based on statistical analysis of full life cycle of power grid equipment

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Abstract. The quality of power grid equipment is related to the safe and stable operation of the power grid, and to a large extent determines the future operation and maintenance, maintenance, the cost. How to carry out equipment selection and supplier selection, and do a good job in equipment access, is an important issue facing the power grid companies. Combined with the whole life cycle theory, considering the influence of different equipment operation life, defects, and early decommissioning due to quality problems, build a relatively complete equipment defect rate, failure rate and equipment life evaluation model, and combining the three factors to form the overall evaluation of equipment quality, to provide a more scientific decision basis for equipment selection procurement and equipment operational strategy optimization.

Keywords: power grid equipment, full life cycle, big data statistical analysis, quality assessment method

1 Introduction

With the construction and promotion of the production management system, massive amounts of equipment operation data (equipment defects, faults, maintenance, retirement data, etc.) have been accumulated. Relying on the analysis and evaluation of the equipment operation data, the objective evaluation of the equipment is of great significance to change the current relatively extensive quality evaluation method and improve the lean equipment management.

Document [1] proposes a multi-source heterogeneous data aggregation method of transmission and transformation equipment panoramic information based on improved hybrid ontology for transmission and transformation equipment management and power grid operation risk management. It fully utilizes the semantic characteristics of ontology to solve the semantic heterogeneity problem in data aggregation, so as to better guide power grid risk management and control. Literature [2] proposes a risk index system for regional power grid based on spatial dimension, and gives the appli-

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cation of the risk index system. Finally, an example is given to verify the feasibility of the proposed index system. Literature [3] revised the planned maintenance interval based on the operation life calculation, analyzed the impact of maintenance on equipment reliability based on the state evolution, combined with the state evaluation process and power grid risk assessment, evaluated the importance of equipment indicators based on information entropy and fault risk cost, and analyzed whether to consider the impact of equipment indicators on equipment reliability assessment, so as to guide a more scientific equipment indicator monitoring strategy. Literature [4] proposes a method for evaluating the utilization rate of distribution network equipment, which provides decision-making reference for power grid construction planning. Literature [5], combined with the rapid development of the current power market, how to provide reliable power and improve power quality has become very important. In this paper, the influencing factors of power quality are discussed, and the measures to improve power quality are discussed. Literature [6] applies probability and statistical methods to reasonably evaluate the power quality of power grid equipment. Literature [7] constructs a power quality evaluation model based on fuzzy analytic hierarchy method by setting the corresponding index system.

To sum up, the current relevant scholars pay more attention to power grid operation risk analysis and power quality assessment, while the comprehensive assessment and analysis of equipment quality is relatively weak.

2 Basic ideas of power grid equipment quality assessment based on the full life cycle theory

From the perspective of asset full life cycle management, the ultimate goal of equipment management is to pursue the maximization of equipment performance. Device performance is a measure of the value created by the entire lifetime of the device, and is largely determined by the quality of the device itself. Therefore, equipment quality evaluation should be based on equipment performance evaluation, through the comprehensive decomposition of equipment performance evaluation model, select the heavy indicators related to equipment quality, based on a comprehensive evaluation of equipment quality. The research idea of this paper is shown in Figure 1 below:

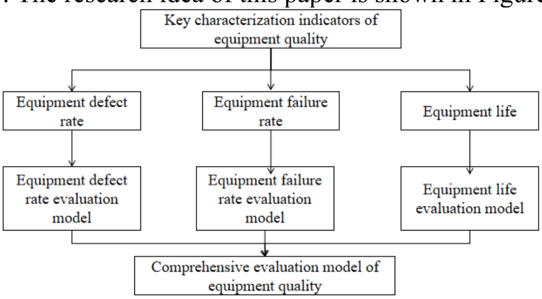

Fig. 1. Construction idea of equipment quality comprehensive evaluation model.

It can be seen from Figure 1 that the basic idea of this paper is that by decomposing the equipment quality characterization index and its causes, the equipment quality evaluation model can be constructed from three aspects: the occurrence of equipment defects, the occurrence of equipment failures, and the impact of faults on equipment life.

3 Construction of power grid equipment quality evaluation model

3.1 Analysis of the key characterization indicators of power grid equipment quality

Combined with the actual operation and management data of the equipment in the power grid enterprises, the key characterization indicators reflecting the equipment quality mainly include the load rate, the available coefficient, and the actual life / life expectancy.

The determinant of the load rate level lies in the early planning and investment of the equipment manager, which depends on the equipment manager's assessment of the existing load situation and the estimation of the future load growth situation. In the actual operation, due to the defects of some equipment, the dispatching department can adjust the operation mode and limit the high-load operation of the equipment, resulting in the reduction of the load rate, which is reflected in the equipment defects.

The available coefficient depends on the planned and unscheduled outage times of the equipment. Unplanned outage time is largely caused by equipment defects and faults, which is an important embodiment of equipment quality.

The determinants of the service life of the equipment are more complex. There are two situations: one is the fatal failure that causes the equipment to return, and the other is the planned shutdown. Therefore, the actual life / life expectancy level may be caused by the equipment operation and maintenance level, or it may be caused by the equipment quality problems or external environmental impacts.

Through the decomposition of the key factors affecting equipment performance and their causes, the equipment quality evaluation model can be constructed from three aspects: equipment defects occurrence, equipment failure occurrence, and the impact of failure on equipment life.

3.2 Construction of equipment defect evaluation model

Equipment quality problems is the main factor leading to equipment defects and faults. The evaluation of equipment defects and faults can reflect the quality level of a certain manufacturer or some type of equipment. In the actual research process, the failure rate and failure rate are often evaluated. Defect rate and failure rate are calculated as follows:

$$\mathrm{E_{dr}} = \frac{Q_m}{E_m * N} \tag{1}$$

$$\mathrm{E_{fr}} = \frac{S_m}{E_m * N} \tag{2}$$

In the formula, E_{dr} represents the equipment defect rate, unit: project/100 sets per year. Q_m represents the number of defective equipment, E_m represents the total number of equipment, and N represents the number of years. E_{fr} refers to equipment failure rate, unit: item/100 sets per year, S_m refers to the number of equipment accidents and incidents.

3.3 Equipment life evaluation model construction

Equipment life is an important information to measure the quality of the equipment. Early decommissioning of the equipment will cause the loss of the equipment itself value and the value created, but this loss cannot be reflected in the above equipment defects and failure rate evaluation. Therefore, the actual operation life of the equipment must be considered when carrying out the equipment quality evaluation.

In the evaluation of equipment early retirement loss due to quality problems, can learn from the calculation equipment time utilization ideas in the performance evaluation model, namely the calculation equipment failed according to the expected operating life and equipment life expectancy ratio, with time utilization proportion as the equipment because of early retirement and expected benefit loss ratio. The calculation formula of the life evaluation index of an individual equipment is as follows:

$$\mathrm{EI_{lf}} = \frac{t_{\exp} - t_l}{t_{\exp}} \tag{3}$$

In the formula, $\mathrm{EI_{lf}}$ represents the life evaluation index of equipment I, t_l represents the actual operating life of equipment I, $t_{\exp}$ represents the expected life of device I. If $t_{\exp} > t_l$, it is considered that the benefits provided by the equipment have reached the expected benefits, and the life evaluation index of the equipment is 0.

For the benefit loss caused by specific manufacturers, the following calculation formula can be adopted:

$$\mathrm{EI_{total}} = \sum_{l=1}^{n} \mathrm{EI_{lf}} \tag{4}$$

The above formula calculates the total benefit loss of equipment due to quality problems. However, the formula does not consider the different manufacturer equipment has reached the expected life, but is not retired. In order to fairly compare the operating life of different manufacturers, this factor must be taken into account. LI represents the equipment life evaluation index of the manufacturer, u represents the number of equipment retired due to quality problems, and u'represents the number of equipment that has reached the expected life but is not retired. The calculation formula of the equipment life evaluation index of the specific equipment manufacturer is as follows:

$$\mathrm{EI} = \frac{\sum_{l=1}^{n} \mathrm{EI}_{\mathrm{lf}}}{u+v} \tag{5}$$

4 Empirical analysis

The quality of equipment is related to the safe and stable operation of the power grid, and to a large extent determines the cost of later operation and maintenance. How to make a scientific and scientific, objective and fair evaluation of the quality of different manufacturers and models of equipment. Based on the accumulation of a large number of equipment defects, faults and retirement data in the production management system, we can carry out the equipment defect rate evaluation, failure rate evaluation and equipment life evaluation, and then carry out the overall evaluation of the manufacturer's equipment quality, which can provide a more scientific decision basis for equipment selection and procurement, equipment operation and maintenance strategy optimization.

(1) According to the equipment defect rate, failure rate and life evaluation model, calculate the defect rate evaluation index, failure rate evaluation index and life evaluation index of different manufacturers and different models of equipment. (2) The specific deduction value is determined according to the defect rate, failure rate and life evaluation index of the manufacturer: for a manufacturer's equipment, the defect rate evaluation index is AIi, AIk. The deduction value calculation formula is as follows:

$$S_k = S_{\max} * \frac{AI_k - AI_{\min}}{AI_{\max} - AI_{\min}} \tag{6}$$

In the formula,, S_k is the deduction value of the manufacturer; $S_{\max}$ is the maximum deduction value of defects in the whole evaluation system; $AI_{\max}$ is the maximum value of failure rate evaluation index of all manufacturers; $AI_{\min}$ is the minimum value of failure rate evaluation index of all manufacturers; AI_k is the defect rate evaluation index of the manufacturer.

(3) Assuming that the original score of defect rate, failure rate and life of each manufacturer is 100 points, the equipment quality of different manufacturers can be sorted according to the defect rate of each manufacturer, failure rate and the final actual score of life evaluation. The specific effect is shown in Table 1.

Table 1. Equipment quality ranking results of different manufacturers.

Manufacturer name	Quantity put into operation	total value	Defect score	Fault score	Life rating
vender A	6	300	100	100	100
vender B	8	298.5	99.23	100	99.3
vender C	5	297.8	98.56	100	98.6
vender D	20	296.7	98.03	100	98.1
vender E	14	296.5	97.46	100	98.1
vender F	9	295.6	97.44	100	98
vender G	8	295.5	97.02	100	97

According to Table 1 above, the manufacturer A equipment quality comprehensive score is the best.

5 Conclusion

Based on the operation data of equipment defect, failure and retirement in production management system, considering the influence of different equipment defect rate, defect failure level and early retirement, and combining these three factors to form the overall evaluation of equipment quality, providing a more scientific and objective decision basis for equipment selection and procurement and equipment operation strategy optimization.

References

1. Xiong Shiwang. Power Grid Operation Risk Control Considering factors of Power Transmission and Transformation Equipment [D]. Zhejiang University, 2016.
2. Chen Jun. Regional power grid operation risk assessment based on maintenance mode [D]. South China University of Technology, 2013.
3. Wu Zijie. Study on the Reliability Evaluation method of power transmission and transformation equipment [D]. South China University of Technology, 2018.
4. Fang Shengchen. Evaluation Method of Distribution Network Equipment Utilization [D]. Tianjin University, 2012.
5. Zhang Lu, Liu Shu. Factors and improvement countermeasures of power quality [J]. Technology Outlook, 2014 (17): 122.
6. Caramia P, Carpinelli G, Russo A,et.al. Power Quality Assessment in Liberalized Market:Probabilistic System Indicesfor Distribution Networks with Embedded Generation. Sweden:The 9th International Conference on Probabilistic Methods Applied o Power Systems, 2005,1-6.

7. Farghal S A,Kandil M S,Elmitwally A. Quantifying Electric Power Quality via Fuzzy Modeling an Analytic hierarchy. IEE Proceedings-Generation,Transmission an Distribution, 2002,149(1): 44-49.