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To cite this article: Hua Shen *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **394** 042097

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Main Fault Types and Classification Methods of Metering Box

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Abstract. This article classifies and analyzes the failures of low-pressure metering boxes to ensure accurate and reliable energy metering. Component Critical Assessment (CCA) method was used to evaluate various components of the metering box system. Failure Mode and Effect Analysis (FMEA) method was used for risk assessment of the low pressure metering box. Establish a database of low-pressure metering faults, responsible for the storage, management, and maintenance of fault data. A fault crossover analysis model was established to analyze the strength of the correlation between the impact factors of the low pressure metering box. Optimize the transportation, storage and use of low-pressure metering boxes to reduce the failure of metering boxes.

1. Introduction

The energy metering box is the first layer of protection for metering equipment and key components such as smart energy meters, acquisition terminals, and circuit breakers. At present, the electric energy metering box used at the scene has the faults that affect the accuracy of metering and the maintenance of electricity safety for operation and maintenance, and may even cause electric shocks, fires and other safety accidents [1, 2]. With the large-scale use of smart energy meters and full coverage of electricity information collection, it provides a good measurement environment. Due to the lack of analysis and processing methods for various types of fault data of the energy metering box, the measurement failure analysis of the metering box is rarely carried out. The understanding of the cause of the failure of the metering box is not comprehensive and in-depth, and it is impossible to formulate an evaluation plan for the operation status of the effective energy metering box. It is difficult to meet the requirements of the life cycle management of the assets of the State Grid Corporation.

The analysis of the fault type of the energy metering box and the research of the influencing factors provide a basis for analyzing the failure mechanism of the energy metering box, testing the project and ensuring the accuracy and reliability of the energy metering [3, 4]. It is a necessary measure to improve product quality and craftsmanship, and can further urge production companies to improve product quality and ensure safety of electricity use.

2. Determination of key components of the low pressure metering box

The Critical Assessment of Components (CCA) method is used to critically assess the various components that directly affect the metering system, based on the quality parameters of the final product [5, 6]. The function of the low-pressure metering box is divided, and the critical assessment is performed in units of individual parts.

Through evaluation, parts can be classified as both critical and non-critical. Classified according to the following criteria: (1) Does the component failure affect the safety of people and equipment? (2)



Does the component failure affect the normal use of electricity? (3) Does the component failure affect the correct metering? (4) Does the failure of the component affect maintenance? (5) Is there a risk of electricity theft or failure of the component? If a component of a low pressure metering box meets any one or more of the above criteria, that part is categorized as a critical component. The key components of low pressure metering box are shown in Table 1.

Table 1. Key Components Evaluation Chart of Low Pressure Metering Box.

Part Name	Cabinet	Box door	Umbrella	Door lock	Nameplate	Identification	Line switch	Terminals	wire	guide	Hinge chain	Connectors
Does the fault affect personal and equipment safety?	Yes	Yes					Yes		Yes			
Does the fault affect normal power usage?	Yes	Yes							Yes			
Does the fault affect correct metering?	Yes								Yes			
Does the fault affect maintenance?	Yes	Yes		Yes				Yes	Yes			
Is there a risk of power theft?		Yes		Yes			Yes	Yes	Yes			Yes
Is it a key component?	Yes	Yes					Yes	Yes	Yes			Yes

It can be seen from the above table that the box, box door, door lock, inlet and outlet switch, terminal block and connector are the key components of the low pressure metering box.

3. Risk assessment of key components of low pressure metering boxes

The FMEA method is used for risk assessment of key components of the low pressure metering box [7, 8]. The FMEA risk assessment method mainly assesses the degree of risk from the following three aspects: Severity (S), if potential failure occurs, the degree of impact on product quality and patient safety. Possibility (P), the probability of a particular potential failure occurring. Detectability (D), the probability that a potential failure can be detected when it occurs. The risk priority (RPN) value is calculated: $RPN = S \times P \times D$. According to the size of the RPN value, it is judged whether it is necessary to carry out risk control and determine the priority of risk control.

The 5-point scoring system was used to evaluate the low-pressure metering box, and scores from 1 to 5 were evaluated for the S, P, and D items (the lowest RPN value was 1, and the highest was 125). The higher the value, the greater the risk of failure mode. According to the ranking results of RPN values, determine the potential risks that should be given priority control.

The risk level is determined by the RPN value. In the risk assessment table, when the RPN value is greater than 18, it means that the risk is unacceptable and the risk control measures need to be taken. When the RPN value is less than 18, it indicates that the risk is acceptable and no risk control measures are required. After adopting risk control measures, when the RPN value is >18 , it indicates that the risk is unacceptable and the risk has not been effectively controlled. When the RPN value is less than 18, it indicates that the risk is acceptable and the risk has been effectively controlled.

The FMEA method was used to analyze and evaluate the risk of each key component, and a risk assessment form was made. Taking the low pressure metering box as an example, the risk assessment table is shown in Table 2.

Table 2. Risk Assessment Table for Low Pressure Metering Tanks.

part	Failure mode	Effect of failure	Reason for failure	Before the measures				Control measures	After measures				Accept risk
				S	P	D	RPN		S	P	D	RPN	
Cabinet	Cracked box	Personal safety	Ageing	4	2	1	8	Improve the structure	3	2	1	6	Yes
	appearance of the cabinet fades	Exterior	Ageing	4	2	1	8	Improved Design	3	2	1	6	Yes
	Casing coating wear peeling	Exterior	Ageing	4	2	1	8	Improve the process	3	2	1	6	Yes
	Box corrosion rot	Stealing	Ageing	4	2	1	8	Improve the process	3	2	1	6	Yes
	Box deformation	Stealing	Impact	4	2	1	8	Improve the structure	3	2	1	6	Yes

After long-term use of the metering box, it will fade, crack, wear/peel the coating, deform the box door, obsolete or damage the observation window, and the nameplate is blurred or rusted. It is easy to cause theft and personal safety, and the product quality is flawed. After the improvement of the structure, the stiffness test of the shell of the metering box, the static load test of the side wall of the shell, and the torsion resistance test were performed. The box was subjected to temperature impact test, mechanical vibration test, mechanical impact test, and ball impact test. Verify that the metering box is in good condition. After the structure is improved, the RPN value of the box is acceptable.

Similarly, other key components of the low-pressure metering box are subjected to risk assessment. After the defects are structurally improved or the process is optimized, and after corresponding performance tests, the RPN values are acceptable.

4. Low pressure metering box fault library establishment

The construction of the database of low-pressure metering faults is an important basic task for which energy measurement is urgently needed. Establish fault databases that cover typical environmental areas such as high frost, high dry heat, high salt fog, and high altitude. Accurately and accurately grasp the fault information of the low-pressure metering box, realize the technical guarantee for the dynamic monitoring of the electric energy metering, and ensure the nation's intelligence to strengthen the construction of the power grid.

A statistical analysis of the operation of the old low-pressure metering boxes in Shanghai was conducted to verify that environmental, mechanical, electrical, and other factors had influence on the failure of low-pressure metering boxes. For the convenience of analysis, various types of influencing factors are quantified for the operation of low-pressure metering boxes. The sample data was further screened and a total of 1094 groups of data were screened out. The material of the cabinet is fiberglass and the working environment is basically the same. The statistics of the key components of the metering box are shown in Table 3.

Table 3. The key components of the low pressure metering box.

Cabinet	fade	slight	1075
		serious	17
		All	2
	Shell cracking	slight	1089
		serious	3
		All	2
	Coating wear or peeling	slight	1073
		serious	19
		All	2
	Corrosion	slight	1071
		serious	21
		All	2
	Box door	Slight deformation can close	1068
		Distortion cannot be closed	17
		Severe deformation	2
breaker		damaged	223
wire		exposed	53
		Scorch	3
Terminal Blocks / Terminal Blocks / Junction Boxes		damaged	5
Connectors	plug	damaged	21
	Connector body	Slight deformation	17
	Conductive sheet	Slight deformation	6

Based on the complex composition of the low-pressure metering box and the number of its components, database storage, management, and maintenance are used.

The main functions of the low-voltage metering tank fault library software are:

- (1) Add root node: Add a large module that has failed.
- (2) Adding a middle node: Subdivide a smaller module in a faulty module.
- (3) Add a child node: Add the final failed module section under the module.
- (4) Fault Record Management: Add, delete and update fault record pictures.
- (5) Fault query: Select the item attribute, view the corresponding fault record, and count the number of times.
- (6) Fault statistics: The histogram shows fault statistics.
- (7) Fault analysis: According to the selected time period, the histogram shows the fault record for each month.

The object-oriented method was used to develop the low-pressure metering box fault management system, and the use case was used to describe the system function.

5. Cross-analysis of failure and influencing factors of low pressure metering box

The factors affecting the failure of the low pressure metering box can be mainly divided into four categories: environmental, mechanical, electrical and other factors. Cross-analysis theory was used to establish cross-analysis model analysis. In order to analyze the correlation between the influencing factors of the low pressure metering box, it is necessary to collect historical failure data of the low pressure metering box. Collecting old low-pressure metering boxes operating in Shanghai Company's jurisdiction for more than 10 years. The operation conditions of the low-temperature metering box in Heilongjiang Mohe high cold typical environmental testing base, the high salt-fog typical environmental testing base in Fujian Meizhou Island, the high-altitude typical environmental experiment base in Tibet, and the high dry heat typical environment in Xinjiang. Based on the

statistical analysis and the influencing factors of the metering box, a cross-model for failure analysis of the low-pressure metering box was established.

Through SPSS cross-analysis, the influencing factors of the key components of the low-pressure metering box such as cabinets, box doors, door locks, inlet and outlet switches, terminal blocks and connectors can be obtained.

Taking the low-pressure metering box as an example, the cracking of the box in the failure factor is strongly related to the impact of mechanical factors on the impact, and weakly related to electrical and other factors. The box cracking has nothing to do with the inlet and outlet switches, terminals, wires, connectors. In the process of transporting low-pressure metering boxes in the latter period, it is necessary to pay attention to the safe transportation of the low-pressure metering boxes to avoid impact and vibration, so as not to affect the performance of the low-pressure metering boxes.

The deformation of the box is related to the strong impact, corrosion of the box, and strong door lock in the failure factor, which is related to the corrosion of the box, fading of the box appearance, and weak salt fog. Box deformation has nothing to do with inlet and outlet switch, wiring segment, wire, and connector. In mechanical factors, related to the impact, in the event of vibration, due to the vibration stress, the metal structure of the box, plastic structural parts are prone to fatigue, deformation, bending and other failure modes.

The correlation between the fading of cabinet appearance, box coating wear and peeling, box corrosion and other influencing factors can also be obtained through SPSS cross-analysis.

According to the analysis result of the fault effect of the low-pressure metering box, the contents of its inspection and acceptance are proposed:

(1) Based on the analysis results of environmental factors on the performance of the metering box, it is recommended that insulation material performance be tested for non-metallic metering boxes. For the metal metering box, physical and chemical performance tests are recommended, including corrosion resistance test and coating adhesion test.

(2) Based on the analysis results of mechanical factors on the performance of the metering box, it is recommended to perform mechanical performance tests such as static load capacity test, dynamic load test, and impact load test.

(3) Based on the analysis results of the influence of the electrical factors on the performance of the metering box, it is recommended to perform electrical performance tests such as clearances, creepage distances, and verification of the effectiveness of the protection circuit.

(4) According to the results of other factors affecting the performance of the metering box, it is recommended that the metering box enclosure protection class (IP code) verification test, door lock performance test and operation test be performed, and the operation and maintenance management of the energy metering device be strengthened.

6. Conclusion

The electric energy metering box is an important equipment that guarantees the safe and stable operation of the electric energy metering device. Its quality has a direct impact on the corporate image of the State Grid Corporation and the safety of electricity for millions of households. Carrying out the research on multi-stress cross-correlation analysis model of the measurement box fault can further analyze the failure factors of the metering box and provide theoretical basis for improving the production process and improving the product quality.

Acknowledgments

The content of this article is the research results of the key technology of electric energy metering box detection and quality evaluation of the State Grid Corporation of China headquarters [Project No. 52094017001A].

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