Research on Safety Risk Management and Control of Live Work in Distribution Networks

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Research on Safety Risk Management and Control of Live Work in Distribution Networks

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Abstract. To ensure the power quality and satisfaction of power users, at the same time to reduce power outage losses for power supply companies, live operations are increasingly used in operation and maintenance of the distribution networks, which poses a great challenge to operator safety. This paper systematically studies the safety management and control of live working in the distribution network, analyzes the safety risks in the live working process, proposes corresponding safety protection measures, and calculates the rank member of the index based on the subjective and objective weights, introduces the D-S evidence theory fusion principle to fuse the hierarchical membership of the indicators, and gets security risk assessment results based on the principle of maximum membership.

1. Introduction

With the rapid development of the national economy and the improvement of residents' living standards, enterprises and the public have put forward higher requirements for the stability of power operations. To ensure the user's power quality, improve user satisfaction with electricity, at the same time reduce power outage losses for power supply companies, live operations are increasingly used in operation and maintenance of the distribution networks. The live-work poses great challenges to worker safety, and the safety risks become the focus of attention in electric power maintenance work. Only by adopting scientific management norms and selecting a reasonable operating process, the safe operation of live electricity can be truly achieved [1-3]. This paper systematically studies the safety management and control of live-work in the distribution network, analyzes the safety risks in the live working process, proposes corresponding safety protection measures, and calculates the rank member of the index based on the subjective and objective weights. The paper introduces the D-S evidence theory fusion principle to fuse the hierarchical membership of the indicators and gets the security risk assessment results based on the principle of maximum membership.

2. Security risk analysis

Usually, the distribution network operation space is small, and the environment is complex. For example, road congestions, numerous residential plots, and large mobility, etc., make it more difficult to live work. Although, with the continuous advancement of standardized and professional management ideas, the level of distribution network operation management has improved to some extent, it is constrained by factors such as a low historical starting point, complex personnel structure, and insufficient investment. And the basic management level of the grassroots units is still relatively low, the system is not implemented in place, and the execution is not strong enough. On the other hand, the overall quality of the power distribution team is low, safety awareness and self-protection are not strong, and habitual violations still exist, which brings many risks to safety management.

The distribution network live work has the following characteristics: (1) Large amount of aerial work. Overhead lines still occupy a large proportion in the distribution network, and the operating height is basically above 2 meters, so there is a danger of falling from high altitude. (2) Multi-department coordination is required. Distribution network operations involve multiple departments such as operation and maintenance, dispatch control, and marketing, so high overall coordination is required. In technical aspects, it requires the participation of professionals from multiple disciplines, including primary, secondary, and automation. (3) The vast majority of operations are carried out in the open air, which is greatly affected by the weather. Some equipment is still in the area with dense crowds, and pedestrians and vehicles interfere with the operation. (4) The complexity of operations and the diversity of equipment. With the introduction of new technologies and equipment such as power distribution automation and circuit breakers, the operating conditions, operating environment, and technical characteristics are constantly changing. It is necessary to understand the characteristics of new technologies and new equipment and take corresponding measures to prevent operators from being unfamiliar with the equipment and pose a safety risk.

The security risks of live operation of the distribution network can be divided into personnel risk, power consumption risk, management risk, and environmental risk, as shown in Figure 1. Among them, personnel risks include poor psychological quality of the workers, weak work focus, insufficient experience, low technical level, and lack of safety protective equipment. Risks of power consumption include that the power supply to important users may not meet the N-1 operating mode due to operations, and power outages caused by operational errors, etc. Management risks include inadequate safety management and control systems, inadequate development and implementation of safety objectives, insufficient safety education, and professional training, inadequate organizational supervision at the job site, improper operation organization, and inadequate supervision of operators and tools. Environmental risks include bad weather conditions, complex environmental traffic conditions around the operation, and large staff turnover.

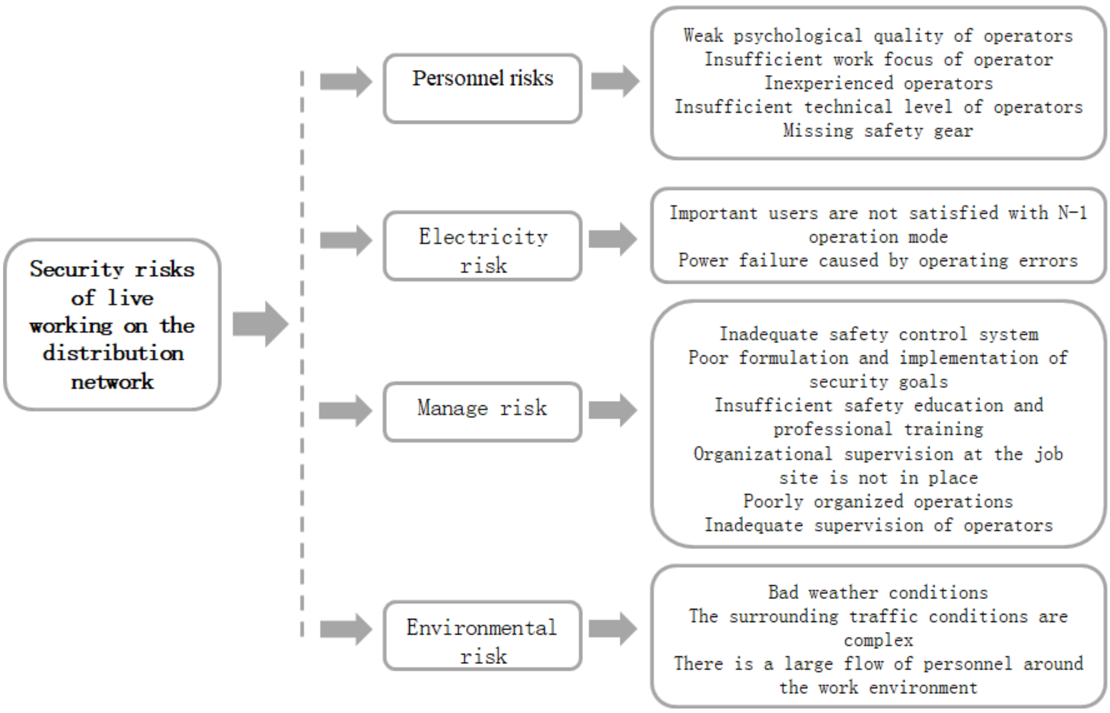

Figure 1. Security risks of live working on the distribution network

3. Security risk control measures

Establishing a scientific management mode of distribution network operation and effective operation management process specifications can improve the standardization and intelligent management of operations and improve the safety of live operations. Safety risk management and control measures for live operation of the distribution network include the following five aspects: site survey before operation, improvement of the overall quality of operators, establishment and improvement of operating procedures and specifications, strengthening of supervision, rational and effective use of safety protective equipment, and reduction of environmental factors Influence.

3.1. Site survey before an operation

A site survey before an operation is the basis to ensure the smooth development of live operations. Only when you are familiar with the job site environment and know what you want, you can calmly cope with the various situations that occur in the job and complete the job tasks on time and with quality and quantity. When conducting a site survey, you must understand the environment of the job site in detail, identify potential safety hazards, and formulate corresponding preventive measures; analyze the emergencies that may occur during the operation and develop countermeasures to prevent them before they occur; or can respond calmly according to the pre-established plan when emergencies occur, to ensure the safety of site operators to the greatest extent.

3.2. Improving the comprehensive quality of operators

Operators must have strong psychological qualities and strong professional skills, which is the key to reducing the safety risk of live work. Therefore, it is important to pay attention to the training and management of operators, and regularly organize the study of safety operation regulations and strengthen relevant practical training to ensure that operators can work in an orderly manner according to the regulations when working on live electricity to avoid safety accidents. Besides, relevant personnel should be organized to summarize and divide the safety accidents or accidents that occurred during the previous live working process to learn lessons and prevent problems before they occur.

3.3. Establish and improve operating procedures and specifications

In the operation approval and operation process, the relevant management system and operation specifications are often in the form and not strictly implemented. Therefore, in live work, the relevant management system and operating specifications should be strictly implemented to avoid accidents due to irregular operating procedures. Secondly, we should establish and improve the current operating procedures and specifications by the actual situation of the operation.

3.4. Strengthening supervision

It is necessary to strictly supervise the operation process by the relevant regulations and regulations, to prevent the supervision work from being superficial or perfunctory. For the emergence of accidents during the operation, preventive and remedial measures must be taken on time. In the event of an accident, it is necessary to sum up experience and lessons on time and strengthen relevant learning and training.

3.5. Reasonable and effective use of safety equipment

Before and after the operation, the safety protective equipment must be strictly checked by the requirements of the Safety Regulations. Once the damage is found, it should be repaired or replaced in time to prevent accidents.

3.6. Reduce the impact of environmental factors

During live work, the adverse effects of environmental factors must be avoided to the greatest extent. It is necessary to understand the relevant weather conditions in detail before an operation, and it is forbidden to carry out live work under severe weather such as wind, rain, and snow. When conducting live work in areas with a large number of people, set up an isolation zone and set up supervision by an expert. It is strictly forbidden to allow unrelated personnel and vehicles to enter the work area to avoid interference with field operations.

The brief content of security risk control measures is shown in Figure 2.

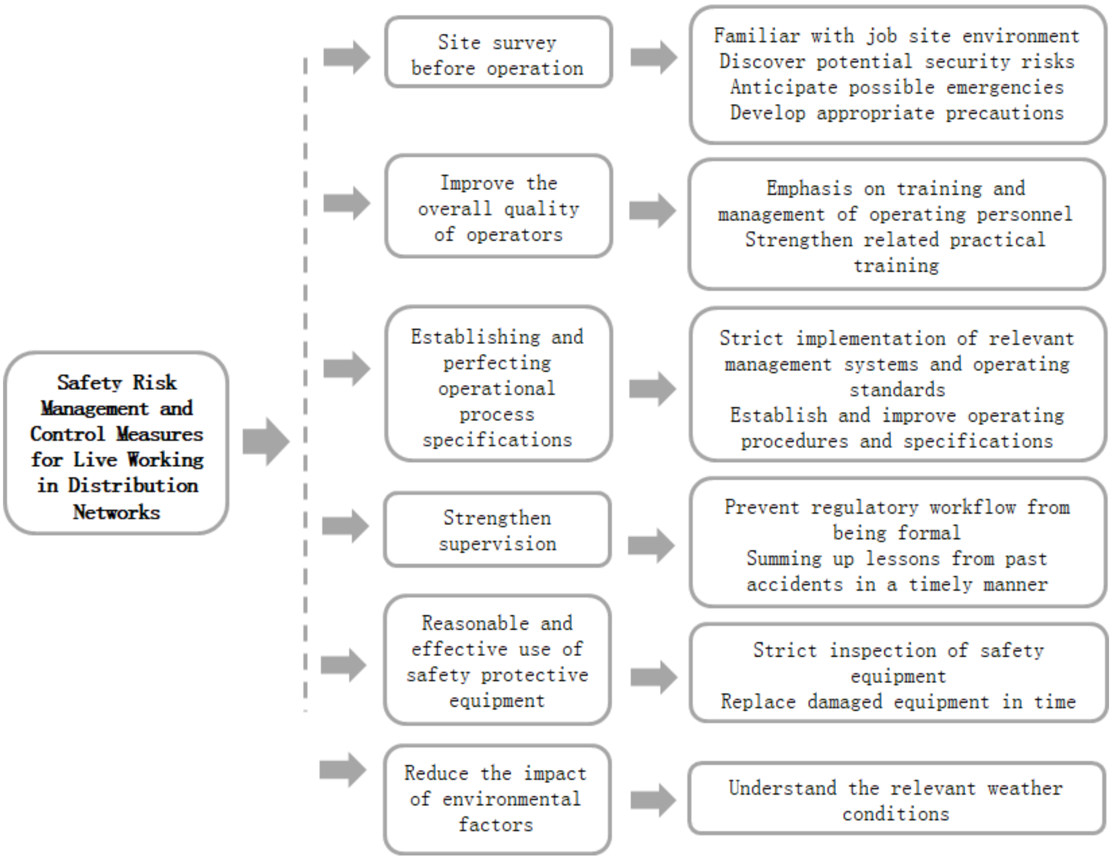

Figure 2. Security risk control measures

4. Safety management risk assessment

The safety risk assessment of the live operation of the distribution network is affected by various factors, and comprehensive analysis from multiple aspects is needed to determine the evaluation index weights [4-11]. At present, there are various methods, such as calculating index weights by the analytic hierarchy process. The advantage is that it effectively utilizes expert experience, and its evaluation index is clear [4-5]. Using the entropy weight method to calculate the index weight based on the characteristics of the index data has certain objectivity [6]. When the subjective and objective weight calculation method employed [7], the advantages of the analytic hierarchy process and entropy weight method are integrated. However, the above assessment methods have several shortcomings. For example, the establishment of an index system relies too much on theoretical analysis, and there are redundant indicators; The basic score of the indicator is fitted by the expert score standard curve, with a certain degree of subjectivity, making the evaluation result from subjective bias, and so on.

To fix these issues, this paper calculates the index membership of the index based on subjective and objective weights. It introduces the DS evidence theory fusion principle to fuse the index membership of the index and obtain the index membership of the evaluation index. The evaluation result is obtained based on the principle of maximum membership.

4.1. Construction of Evaluation Index System

The construction of the evaluation index system needs to meet the five principles of systematicness, independence, scientificity, comparability, and simplicity to ensure that the evaluation is comprehensive and objective. Based on the above principles, the establishment of assessment indicators includes personnel risk assessment indicator D1, electricity risk assessment indicator D2, management risk assessment indicator D3, and environmental risk assessment indicator D4. D1, D2, D3, D4 are qualitative indicators, corresponding to the quantitative indicators X11, X12, X13, X14, X15, X21, X22, X23, X24, X31, X32, X33, X34, X35 and X41, X42, X43, such as shown in Figure 3.

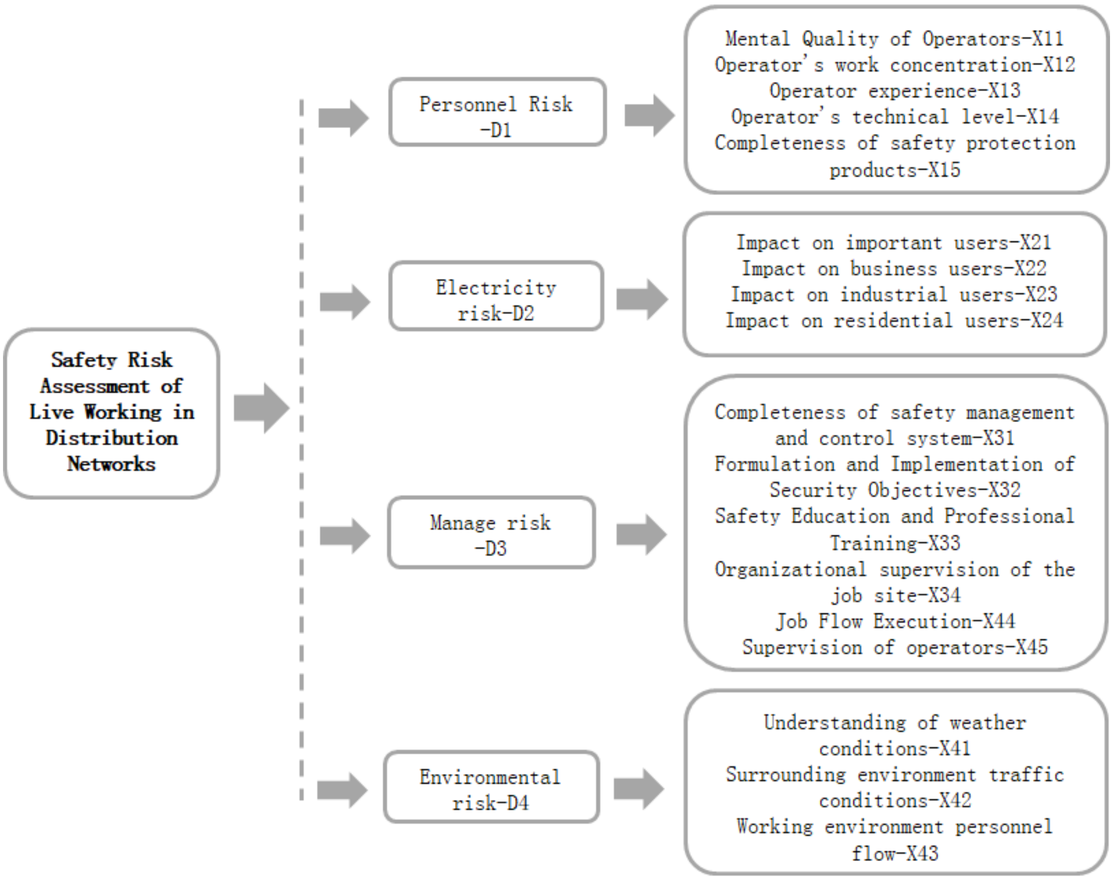

Figure 3. Evaluation index system

4.2. Calculation of subjective and objective index weights

Each quantitative indicator is different in importance and therefore needs to be weighted. The entropy weight method is a commonly used weight calculation method [19]. The entropy value represents the objective weight of the evaluation index in the comprehensive evaluation result. The entropy weight method is simple to calculate, but the sensitivity is too high, which easily leads to the imbalance of the index weight. The analytic hierarchy process is an improvement on the gray correlation model. It is subjective based on expert experience and user judgment. In this paper, the analytic hierarchy process and the entropy weight method are used to assign index weights, which improves the impact of sensitivity and subjectivity. To better obtain the assignment effect, the Lagrange multiplier method is used to obtain the combination weight closest to the subjective and objective weights:

$$\mathbf{r}(i)=\frac{\sqrt{\mathbf{v}(i)\boldsymbol{\omega}(i)}}{\sum_{i=1}^{m}\sqrt{\mathbf{v}(i)\boldsymbol{\omega}(i)}} \tag{1}$$

In the formula, ν (i) and ω (i) respectively use the weight of the index Xi obtained by the analytic hierarchy process and the entropy weight method, and r (i) represents the weighing result after the combination of the two methods.

4.3. Security Risk Assessment Based on D-S Evidence Theory

D-S evidence theory is a method of uncertainty reasoning, which provides a powerful tool for handling the representation and fusion of uncertain information [20-21]. Because qualitative indicator data cannot be obtained directly, it is necessary to give weight to quantitative indicators to obtain evaluation level membership. Qualitative indicators have ambiguity and uncertainty, so based on evidence theory, a reliability function is used to characterize this type of "randomness" and "uncertainty." Think of qualitative indicators as sub-evidence bodies:

$$\mathbf{B}_i = \begin{bmatrix} K_{11} & \cdots & K_{15} \\ \vdots & \vdots & \vdots \\ K_{j1} & \cdots & K_{j5} \end{bmatrix} \tag{2}$$

In the formula, i = 1, 2, 3, 4, j is the number of quantitative indicators corresponding to qualitative indicators; Bi is the grading matrix of qualitative indicators. Combining the weights to obtain the evaluation level evaluation matrix Di of the child evidence body:

$$\mathbf{D}_i = \mathbf{r}_i \cdot \mathbf{B}_i = [d_{i1}, d_{i2}, d_{i3}, d_{i4}, d_{i5}] \tag{3}$$

In the formula, i = 1,2,3,4; j is the number of quantitative indicators corresponding to each qualitative indicator; Di represents the sub-evidence body relative to the evaluation level Hg (g = 1,2,3,4,5) Membership matrix. Set the risk level of live work to five levels of excellent, good, medium, passing, and poor, and the corresponding limits are: H1 = Excellent [0.9,1], H2 = Good [0.8,0.9], H3 = Medium [0.6.0.8], H4 = Passing [0.4,0.6], H5 = Poor [0,0.4]. The composition of the evaluation framework is Θ = {H1, H2, H3, H4, H5}. Let m (H) be the reliability function, that is, the degree of membership of the safety risk of live work at each evaluation level. The reliability function must meet the following conditions:

$$\begin{cases} \mathrm{m}(\varnothing) = 0 \\ \sum\limits_{x \subseteq \Theta} \mathrm{m}(H) = 1 \end{cases} \tag{4}$$

The principle of D-S evidence theory fusion is:

$$\begin{gathered} \mathrm{m}(U) = \begin{cases} \dfrac{1}{k} \sum\limits_{\cap Hi = U} \prod\limits_{1 \le j \le n} m_j(Hi) & Hi \ne \varnothing \\ 0 & Hi = \varnothing \end{cases} \\ k = \sum\limits_{\cap Hi = \varnothing} \prod\limits_{1 \le j \le n} m_j(Hi) \end{gathered} \tag{5}$$

The assessment result of the safety risk level of live work is U:

$$\mathbf{U} = [m(H1), m(H2), m(H3), m(H4), m(H5)] \tag{6}$$

According to the principle of maximum membership, the assessment level of the safety risk of live work is determined. For example, if m (H3) is the largest in U, the risk assessment result is "medium."

5. Summary

This paper systematically studies the safety management and control of the live working in the distribution network, analyzes the safety risks in the live working process, and proposes corresponding safety protection measures. Existing risk assessment methods are based on the index's basic scores given by experts, and the final scores of the indexes are obtained through curve fitting and weighted processing, subjective errors exist. To solve the above problems, based on the advantages of subjective and objective weights combined with the entropy weight method, the rank member of the index is calculated, and the D-S evidence theory fusion principle is introduced to fuse the rank member of the index to obtain the rank member of the evaluation index. The evaluation results were obtained according to the principle of maximum membership. Based on the theory of evidence theory fusion and the use of reliability functions, it can effectively overcome the ambiguity and randomness of evaluation indicators and give reasonable evaluation results. The method in this paper is feasible and advanced.

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