Personal safety risk analysis of power enterprises under the background of new power system

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Abstract. Personal safety risk management is one of the important components of power enterprise safety management. The key is to quantify the risk value. Based on the accident cause theory, combined with the particularity of the subject, object and environment of power supply operation, as well as the theory of human reliability and risk assessment, this paper studies the risk factors and logical analysis of personal safety accidents in power supply operation, and puts forward a quantitative assessment model of personal safety risks, which has an important reference value for the personal safety risk management of various operations in power supply enterprises.

Keywords: power safety; personal safety; risk analysis

1 Introduction

Through the study of safety psychology, safety behavior, accident cause theory, risk assessment and other safety theories, combined with the particularity of the subject, object and environment of power supply operation, as well as the theory of human reliability and risk assessment, the cause of personal safety risk in power supply operation and the model and method of its quantitative assessment are studied, and risk assessment indicators are formulated, It is of great value to provide quantitative indicators and instructions for the personal safety risks of various power supply operations in power supply enterprises and form a series of power supply operation behavior standards based on personal safety risk assessment[1].

In order to further improve the operation risk assessment and make the assessment results more consistent with the on-site work of power safety, the personal safety risk management and control model established in this study greatly enhances the accuracy of the risk assessment results by inputting the risk data of this operation into the model before each operation, and analyzing the output risk data and risk level in real time [2]. The main structure of the quantitative assessment model of personal risk is shown in the figure.

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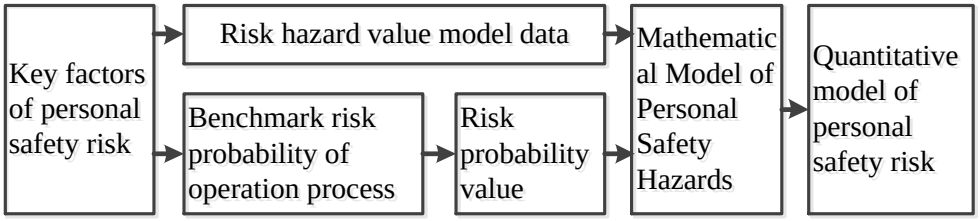

Figure 1. Structure of Quantitative Assessment Model of Personal Risk

2 Key factors of personal safety risk

2.1 Relationship between accident cause classification and risk factors

There is a certain law between the causes and results of accidents. Hazard factors involved in accident and event research and risk assessment are identified and classified through analytic hierarchy process and gray correlation method [3]. The causes of accidents and direct risks can be divided into direct causes and indirect causes.

The direct cause of an accident refers to the cause that directly causes the accident, also known as the primary cause. There are only two direct causes of the accident, namely, unsafe behavior of people and unsafe state of things.

The indirect cause of the accident refers to the indirect cause of the accident, but the existence of hidden dangers, involving and acting on the direct cause of the accident, indirectly leads to the occurrence of the accident.

2.2 Key factors of personal safety risk in power supply operation

Summarize and analyze the cause classification of various personal accidents and the work experience of each professional team [4]. By identifying the influencing factors of personal risk and combining the theory of "man, machine, material, method and environment" of quality control management, the "personal safety factor" in power supply operation is established by using the analytic hierarchy process:

(1) Personnel

The personnel factor is the biggest difficulty in the safety production management factors, and also the most complex and difficult to control link [5]. The factors surrounding "personnel" will bring different risks to the production process. Risk factors include: skills, age, working time of the post, familiarity with similar operations, work habits, health, mental status and work mood.

(2) Mechanical

It refers to the power grid equipment involved in production. Risk factors include: equipment type, equipment status, etc.

(3) Materials

It refers to tools involved in production. Risk factors include: allocation of personal protective equipment and tools.

(4) System

It refers to the type of work and rules and regulationsto be followed in the process of power safety production [6]. Risk factors include: type of operation, nature of operation, allocation of operators, operation duration, operation time, operation supervision, basis for operation guidance, grouping operation, cross operation, etc.

(5) Environment

It refers to the environment of power safety production site. Risk factors include: working weather, working area and working space.

3 Classification of work types involved in personal risk of electric power operation

The type of work involved in personal risk of electric power operation is the classification of professional operation activities in electric power production activities. The types of work involved in power production mainly include 22 disciplines, such as dispatching operation, transmission cable, live working, substation operation, substation maintenance, substation relay protection, etc.

According to the identification, there are two principles for the classification of work types of electric power enterprises involved in electric power operation personal risks and electric power personal casualty accidents:

First, non power field operation types, such as dispatching operation, dispatching monitoring, etc. The operation risks involve equipment, power grid, and social responsibility risks. There are few personal safety and occupational health risks involved in the operation process. This quantitative assessment model for personal risk of power operation does not involve such types of work;

Second, the types of work of personal risk in electric power operation can be classified into the following 6 categories according to the types of personal risk faced in the nature of the operation:

(1) Power transformation operation: the main feature of the operation type of substation is the type of work in which the operators have the longest contact/exposure time with the operating equipment [7]. The main personal risks include the operation risk in the operation of substation and the risk of equipment failure in the operation of substation. Especially in the operation and inspection of the operators, the production is not qualified because the quality of the substation equipment does not meet the national safety standards, With the passage of time, aging can not meet the needs of safe operation of the substation and other potential safety hazards, which brings more personal risks to the operation process of substation operators.

(2) Substation maintenance discipline is mainly responsible for regular maintenance and fault handling of the primary substation equipment, and its operation area is mainly the substation primary equipment area with power failure [8]. The main operation risk characteristics of the

overhaul professional operation are the hazards that the frequently used machinery, equipment, lifting machines and tools may bring to the operators or the abnormal equipment, and the tripping caused by improper use of lifting tools or damage of lifting belts may lead to equipment damage or casualties; There are risks such as entering the live space by mistake in the operation area with power failure.

(3) Power transformation test specialty is mainly responsible for the regular test and post fault treatment test of the primary power transformation equipment, and its operation area is mainly the power failure primary power transformation equipment area. The main operation risk characteristics of the test professional operation are the hazards that the machinery, instruments and equipment used in the high-voltage test may bring to the operators or the abnormal equipment, which may cause equipment damage or casualties due to the high-level test voltage [9]; There are risks such as entering the live space by mistake in the operation area with power failure.

(4) Substation automation is mainly used for maintenance and fault handling of substation secondary equipment. Its operation characteristics are that the operation area mainly exists in relay protection room, communication room, battery room, etc., and some work areas need to work in the primary equipment with power failure [10]. There is little or no live primary equipment contact, so the personal risk is small. The operation risk mainly includes the impact of misoperation on equipment, power grid, etc.

(5) Power transmission work mainly involves the operation of transmission line and transmission cable, and its operation characteristics and high risks mainly lie in the high altitude falling caused by damage to facilities and stepping on the ground when working up and down the tower.

(6) The operation area of distribution network operation types generally refers to high and low voltage distribution network operation below 10kV and household 220V operation. As the voltage level of distribution network and the important level of equipment are lower than the high voltage level of the main network, the operation risk of equipment [11]. The impact of social factors is small, so the results of job risk assessment are generally low.

4 Risk hazard value model

Risk hazard value refers to the result with the highest probability of accidents due to hazards based on historical electric power casualty accidents data. By analyzing the types and severity levels of electric power personal casualty accidents, the risk hazard value model data is assigned.

The personal level 4 event with the lowest severity (one minor injury event) is set as the reference value of the risk hazard value. The risk hazard value of minor injury, serious injury and death is increased in turn. The accident level score of multiple accidents/events is accumulated. The distribution of personal risk hazard value model of electric power operation is shown in the following table.

Table 1. Personal Risk Hazard Value Model of Electric Power Operation Risk Hazard Value

Accident level	Consequences of personal risk	Hazard severity	Score
extraordinarily serious accident	More than 30 people died or more than 100 people were seriously injured	Extraordinary death	500
Major accident	More than 10 but less than 30 people died or more than 50 but less than 100 people were seriously injured	Major personal death	300
Moderate accident	More than 3 but less than 10 people died or more than 10 but less than 50 people were seriously injured	More personal death	100
General accident	Less than 3 people died or less than 10 people were seriously injured	Ordinary personal death	50
Level IV to Level I events	1-5 people are injured	Serious injury Minor injury Slight injury	25 15 10

5 Mathematical Model of Personal Safety Hazards

5.1 Mathematical model formula of personal safety hazard

Before each operation, the personal safety hazards and risks are unknown, so a mathematical model needs to be established to calculate and predict the consequences of the personal hazards in the operation through the formula. The mathematical model formula of personal safety hazards will quantify the consequences of personal hazards, and calculate the risk probability value and risk hazard value involving the influencing sub factors. The statistical model of personal hazards in power supply operation is established here, and the calculation formula is as follows:

$$R = H_{\max} \times P \tag{1}$$

R means personal risk value (if one work causes two or more levels of personal risk at the same time, the risk assessment result shall be the highest level risk.)

H_{max} means risk hazard value: refers to the result with the highest probability of accidents due to hazards based on historical data.

P means risk probability value, which is the product of various influencing factors.

$$P = P_1 \times P_2 \times P_3 \times \cdots P_{25} \tag{2}$$

P_1, P_2, P_3, ... P_{25} are the corresponding probabilities of various risk factors.

5.2 Assignment of mathematical model of personal safety hazards and determination of its level

(1) Determination of benchmark risk probability value in operation process

In the risk assessment for a specific operation, the value of each corresponding risk factor has been determined. At this time, the risk assessment is the probability of personal accident under

the condition that each risk influencing factor is determined. This also requires statistical calculation of the probability of occurrence of a factor in the power supply operation, that is, event A, P_c, so as to calculate the conditional probability P_b. Under a benchmark condition, A probability value that will appear in the benchmark situation corresponding to each risk factor is the reference value of personal risk probability value of electric power operation.

According to Bernoulli's law of large numbers, when the sample size is large enough, the frequency of events is approximately equal to the probability of events. The probability value P_n corresponding to each risk factor and the probability Pc that the corresponding probability value of each risk factor may occur. Based on the normal distribution principle, the risk probability value of 25 key factors of personal safety risk is established. The calculation method is as follows:

$$P_b = P_{n1} \times P_{c1} + P_{n2} \times P_{c2} + \cdots P_{nn} \times P_{cn} \tag{3}$$

$$P_{c1} + P_{c2} + \cdots P_{cn} = 1$$

P_b is the reference value of personal risk probability value of electric power operation;

P_{n1}, P_{n2},... P_{nn} are the corresponding probability values of each risk factor;

$P_{c1,}$ P_{c2},... P_{cn} are the probability that the corresponding probability value of each risk factor may occur.

According to the formula, comb and calculate the risk probability value to establish the risk probability value model database. The risk probability value is calculated as follows:

$$P_b = P_{b1} \times P_{b2} \times P_{b3} \times \cdots P_{b25} \tag{4}$$

P_b is the reference value of personal risk probability value of electric power operation;

P_{b1}, P_{b2},... P_{bn} are the reference values of corresponding probability values of each risk factor;

According to the formula, the reference value P_b of personal risk probability value of electric power operation is 98.78, which is approximately 100.

(2) Determination of hazard level of quantitative model of personal safety risk

Establish a personal safety hazard matrix according to the risk value, and set five risk levels.

Level I risk (red): consider giving up and stopping;

Level II risk (orange): corrective measures need to be taken immediately;

Level III risk (yellow): corrective measures need to be taken immediately;

Level IV risk (blue): need to pay attention;

Level V risk (green): tolerance.

(3) Risk hazard value model

In case of minor injury and minor injury, it is a tolerable risk level when it is lower than the reference value of personal risk probability of power operation. The risk level value is 15 * 100=1500.

When serious injury occurs, it is the risk level of concern when it is lower than the reference value of personal risk probability of electric power operation. The risk level value is 30 * 100=3000.

When an ordinary personal death accident occurs, it is the risk level that needs to take corrective measures when it is lower than the reference value of the personal risk risk probability of electric power operation. The risk level value is 50 * 100=5000.

When a relatively serious personal death accident occurs, when it is lower than the reference value of personal risk probability of electric power operation, it is an intolerable risk level that requires immediate corrective measures. The risk level value is 100 * 100=10000.

In case of major or higher level personal death accident, if it is the reference value condition of personal risk risk probability of electric power operation, it is the risk level of non work. The risk level value is greater than 10,000.

5.3 Assignment and grade results of mathematical model of personal safety hazards

According to the model comparison, the assignment and grade results of the mathematical model of personal safety hazards are as follows:

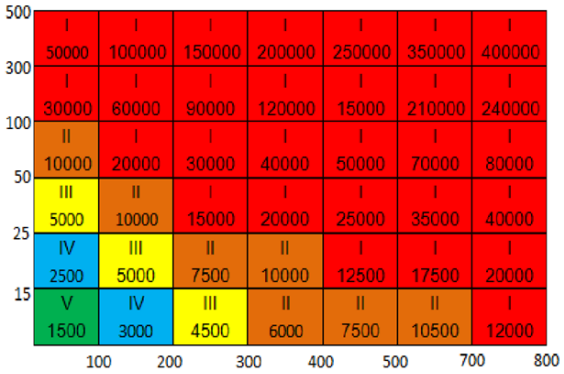

Figure 2. Assignment and Grade of Mathematical Model of Personal Safety Hazards

Level I risk (red): risk value > 10000, consider giving up and stopping;

Level II risk (orange): 5000 < risk value ≤ 10000, and corrective measures need to be taken immediately;

Level III risk (yellow): 3000 < risk value ≤ 5000, corrective measures need to be considered;

Level IV risk (blue): 1500 < risk value ≤ 3000, which requires attention;

Level V risk (green): risk value ≤ 1500, tolerable.

6 Conclusions

Closely combining with the field operation practice of power grid enterprises, this paper analyzes the key factors of personal safety risks in power supply operations, proposes a

quantitative assessment model and application method system of personal safety risks, develops risk assessment indicators and design grading thresholds, gives quantitative indicators and instructions for personal safety risks in various power supply operations in power supply enterprises, and establishes a quantitative assessment model of personal risks.

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