Research on Personal Risk Management and Control Model for Intrinsic Safety of Power Grid Enterprises

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Abstract. Safe production is the basis for the smooth development of all work of power grid enterprises, and has played a great role in the development of power grid enterprises. However, there are great potential safety hazards in its production, which is easy to cause personal safety accidents. Intrinsic safety refers to the inherent function of equipment or technology, which can fundamentally prevent accidents. Therefore, a personal risk management and control model is established for the intrinsic safety of power grid enterprises. Analyze the intrinsic safety concept of power grid enterprises, establish the mathematical model of personal safety hazards, set the probability value of personal risk, and use the principal component analysis method to reduce the dimension to deal with the key factors of personal risk. On this basis, according to the personal risk management and control measures taken by the power grid enterprise's intrinsic safety concept, a personal risk management and control model is constructed and solved by Pareto ant colony algorithm. The experimental results show that the proposed method can effectively improve the efficiency of personal risk management and control.

Keywords: Power grid enterprise · Personal risk · Intrinsic safety · Pareto ant colony algorithm · Risk control model · Principal component analysis

1 Introduction

As the pillar industry of the national economy, the safety of the electric power industry is related to the economic and social development of the country and the production and life of the people. Safe production is the lifeline of various production units and the key to safe operation of power grid enterprises [1, 2]. At present, the working environment of power grid security is constantly changing, and power grid enterprises are facing a severe safety production situation with long-term power grid security risks, increasing equipment security risks and increasing personal injury risks. Therefore, it is particularly important to prevent all kinds of electric power safety, human casualties and major equipment safety accidents. The intrinsic safety of power grid enterprises refers to that under normal or abnormal conditions, even if there is unsafe behavior, the safety of people and property can be guaranteed, so as to achieve the "zero accident" intrinsic safety of power grid enterprises [3, 4]. Therefore, research on the intrinsic safety of power grid

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enterprises, establish a personal risk management and control model, effectively improve the personal safety risk management and control ability of production and operation personnel of power grid enterprises, and play a very important role in preventing the occurrence of personal safety accidents.

At present, scholars in relevant fields have conducted research on personal risk management and control models. Reference [5] proposes the safety evaluation and risk control methods for human error of railway maintenance personnel. Starting from the current situation of railway locomotive maintenance work, it is pointed out that human error is the main cause of failure. It is necessary to strengthen the safety assessment and risk control, and take effective measures to improve its maintenance quality and give full play to its utilization value. Reference [6] proposes a substation personnel safety monitoring method based on YOLOv4. Based on whether substation personnel wear safety helmets or not, this paper monitors the wearing of safety helmets by personnel entering high-risk areas to effectively distinguish between workers and non-workers. And through the detection technology of YOLOv4, the management personnel can clearly monitor the situation of the dangerous area, achieve the effect of predicting the occurrence of the danger in advance and minimizing the danger. The feature fusion part based on YOLOv4 is simplified, and the target monitoring effect is achieved by using a lighter feature extraction backbone network. The experimental results show that the method has strong robustness. However, the above methods still have problems of poor effectiveness and low efficiency in personal risk control.

In view of the above problems, a personal risk management and control model for the intrinsic safety of power grid enterprises is constructed. Analyze the intrinsic safety concept of power grid enterprises, and reduce the dimension to deal with the key factors of personal risk by setting the probability value of personal risk. According to the personal risk management and control measures adopted by the power grid enterprise's intrinsic safety concept, the personal risk management and control model is constructed and solved. This method has good personal risk control effect and high personal risk control efficiency.

2 Personal Risk Control Method

In order to effectively realize the personal risk management and control of power grid enterprises, first, analyze the intrinsic safety concept of power grid enterprises, then set the probability value of personal risk, and then reduce the dimension to deal with the key factors of personal risk, and finally, build a personal risk management and control model.

2.1 Analyze the Intrinsic Safety Concept of Power Grid Enterprises

Intrinsic safety refers to the functions of the equipment or technology itself, which can fundamentally prevent accidents, rather than rely on additional safety systems. The essential safety of power grid enterprises is to minimize the unsafe behaviors of operators and eliminate the unsafe factors of power grid equipment. The intrinsic safety of power

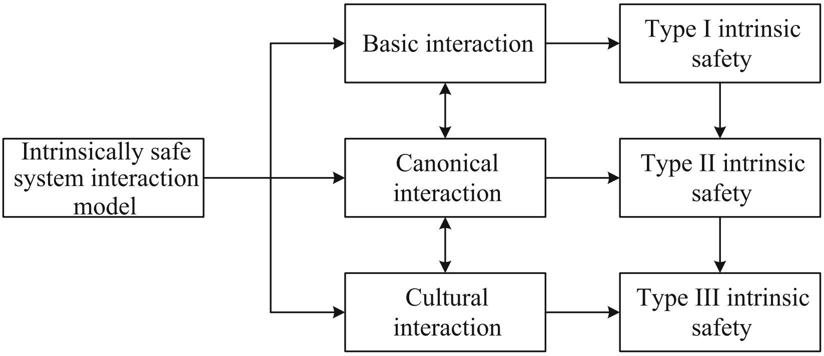

Fig. 1. Intrinsic safety system interaction model

grid enterprises can improve the safety of grid structure, equipment and environment, and improve their intrinsic safety through continuous improvement.

The basic safety of enterprises is the ultimate goal of modern safety management. From the perspective of people's understanding of the cause of the accident, intrinsic safety can be divided into category I intrinsic safety period, that is, basic safety period; Category II intrinsic safety period, namely normative safety period, its main indicators include: behavior, technology, management and legal norms; Category III intrinsic safety period, that is, cultural safety period, its main indicators include: human safety concept, production, safety, management and coordination of information transmission system. From this point, we can see that there is a complex interaction between basic safety, normative safety and cultural safety. The interaction model of the intrinsically safe system is shown in Fig. 1.

In Fig. 1, the intrinsic safety system of power grid enterprises is a system with the safety culture of the enterprise as the core and the mutual influence of safety management and material form.

2.2 Setting the Probability Value of Personal Risk

Before each power grid enterprise operation, the personal risk is unknown. It is necessary to establish a mathematical model of personal safety hazards, and set the probability value of personal risk through formula calculation.

The mathematical model formula of personal safety hazard will quantify the consequences of personal hazard, and calculate the probability value and hazard value of personal risk in power grid enterprises. The statistical model of personal hazard factors in power grid enterprises is established here, and the calculation formula is as follows:

$$R_s = W_{\max} \times P_f \tag{1}$$

In Formula (1), R_s refers to the value of personal risk, and $W_{\max}$ refers to the value of personal risk hazard. P_f is the probability value of personal risk, which is the product of the values of various influencing factors. The calculation formula is as follows:

$$P_f = P_1 \times P_2 \times \cdots P_n \tag{2}$$

In Formula (2), $P_1 \times P_2 \times \cdots P_n$ represents the corresponding probability of various personal risk factors.

2.3 Key Factors of Human Risk Reduction

In order to facilitate the construction of the personal risk management and control model, this paper uses the principal component analysis method [7, 8] to reduce the dimension of the key factors of personal risk, thus laying a data foundation for the construction of the personal risk management and control model.

First, determine the input matrix Q, where i is the number of input operation samples of power grid enterprises, and j is the total number of characteristics, q_{mn} is the n characteristic of the m sample, and w_n is the covariance of the n characteristic:

$$Q_{i\times j} = \begin{bmatrix} q_{11} & q_{12} & \cdots & q_{1n} \\ q_{21} & q_{22} & \cdots & q_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ q_{m1} & q_{m2} & \cdots & q_{mn} \end{bmatrix} = [W_1, W_2, \cdots, W_n] \tag{3}$$

Secondly, the covariance matrix W is calculated according to the Q input matrix:

$$\text{covmatrix} = \frac{1}{m-1} \begin{bmatrix} \text{cov}(w_1, w_1) & \text{cov}(w_1, w_2) & \cdots & \text{cov}(w_1, w_n) \\ \text{cov}(w_2, w_1) & \text{cov}(w_2, w_2) & \cdots & \text{cov}(w_2, w_n) \\ \vdots & \vdots & \vdots & \vdots \\ \text{cov}(w_n, w_1) & \text{cov}(w_n, w_1) & \cdots & \text{cov}(w_n, w_n) \end{bmatrix} \tag{4}$$

where, the covariance is:

$$\text{cov}(Q, P) = E(Q - \alpha)(P - \beta) \tag{5}$$

Thirdly, after obtaining the covariance matrix W, the eigenvalues are decomposed to obtain the eigenvalues corresponding to the original features, and the eigenvectors corresponding to the largest five eigenvalues can be obtained and extracted to form 26×5 transformation matrix.

Finally, use $U = QR$ to get the U matrix with the size of 5 times the number of samples, which is the key factor of personal risk after dimensionality reduction.

2.4 Build a Personal Risk Management and Control Model

The goal of personal risk management and control is to minimize the personal risk level of power grid enterprises by designing personal risk management and control measures based on the concept of intrinsic safety of power grid enterprises with the minimum cost of personal risk management and control. In this paper, the personal risk control measures taken for the intrinsic safety concept of power grid enterprises are taken as decision variables.

Suppose z_{gh} represents the control measures taken for the personal risk of the g, and its calculation formula is as follows:

$$z_{gh} = \begin{cases} 1, a \text{ personal risk selection } s \text{ control measures} \\ 0, a \text{ no } s \text{ control measures are selected for personal risk} \end{cases} \quad (6)$$

In Formula (6), $g = 1, 2, ..., a$ and a are the number of personal risks of power grid enterprises, $h = 1, 2, ..., s$, s is the number of personal risk control measures.

Based on the above ideas, this paper constructs a personal risk management and control model that includes three objective functions: the personal risk evaluation value of power grid enterprises, the personal risk management and control cost of power grid enterprises, and the personal risk loss of power grid enterprises. The objective functions are as follows:

(1) Personal risk assessment value of power grid enterprises:

$$\min P_j = \sum_{g=1}^{a} \sum_{h=1}^{s} w_g \times \left[P_{jgh} \times z_{gh} + P_{jc}\left(1 - z_{gh}\right)\right] \quad (7)$$

In Formula (7), w_g is the personal risk weight of the g power grid enterprise, P_{jc} is the initial evaluation value of the personal risk g of the power grid enterprise, P_{jgh} is the evaluation value of the personal risk g of the power grid enterprise after being treated by the personal risk control measures h adopted by the power grid enterprise's intrinsic safety concept.

(2) Personal risk control cost of power grid enterprises:

$$\min C_b = \sum_{g=1}^{a} \sum_{h=1}^{s} z_{gh} \times \left(c_{gh} + c'_{gh}\right) \quad (8)$$

In Formula (8), c_{gh} is the cost of personal risk control measures designed for the intrinsic safety concept of power grid enterprises in advance to reduce the level of personal risk g of power grid enterprises, c'_{gh} is the treatment cost of the personal risk control measure h adopted by the grid enterprise's intrinsic safety concept after the occurrence of the personal risk g.

(3) Personal risk losses of power grid enterprises:

$$\min S_s = \sum_{g=1}^{a} \sum_{h=1}^{s} z_{gh} \times s_{gh} \quad (9)$$

In Formula (9), s_{gh} is the estimated loss after the treatment of the personal risk g of the power grid enterprise through the personal risk control measures h adopted by the power grid enterprise's intrinsic safety concept.

The constraints of the personal risk control model are: $S_s < C_b$.

Through the above process, a personal risk management and control model for the intrinsic safety of power grid enterprises is constructed, and the model is solved based on Pareto ant colony algorithm [9, 10]. The specific process is shown in Fig. 2.

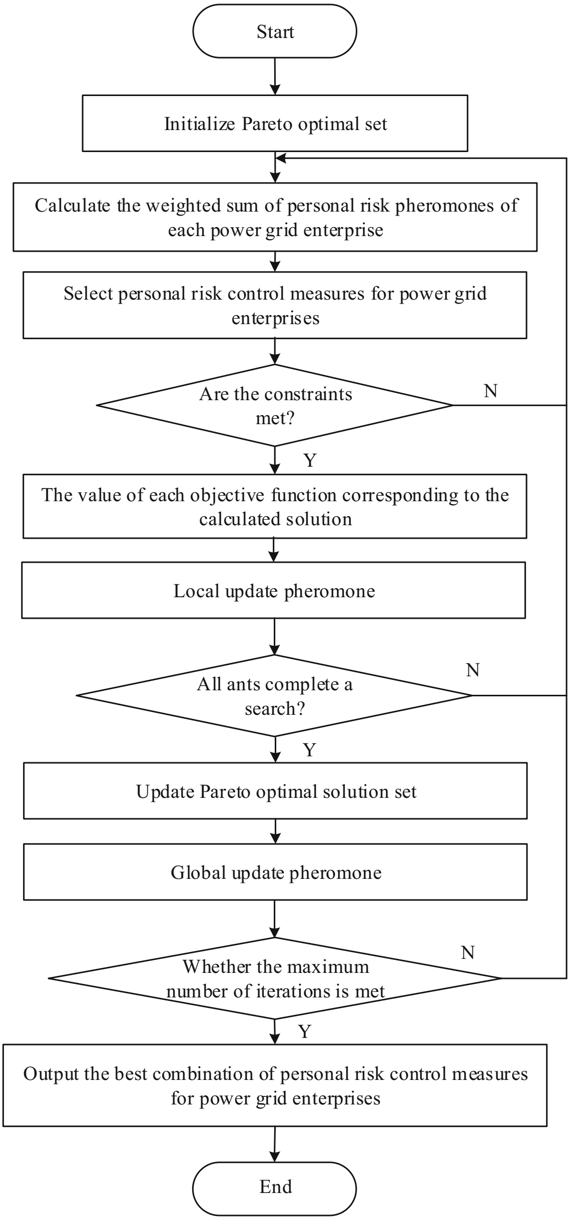

Fig. 2. Flow Chart of Model Solution

3 Experiment and Analysis

3.1 Experimental Environment Setting

In order to verify the effectiveness of the personal risk management and control model for the intrinsic safety of power grid enterprises, the personal risk of a power grid enterprise is analyzed by taking its production process as an example. Write and run in the Matlab simulation software environment. The method of reference [5] and the method of reference [6] are selected for comparison to test the effectiveness of the proposed methods.

3.2 Analysis of the Effect of Personal Risk Control

The Pareto Ant Colony Algorithm is used to solve the constructed personal risk management and control model for the intrinsic safety of power grid enterprises, and the Matlab program code is compiled and run to obtain five Pareto optimal solutions. The Pareto optimal solutions for the personal risk management and control for the intrinsic safety of power grid enterprises are shown in Table 1.

According to Table 1, there are effective control measures for each of the five personal risks of power grid enterprises. Take the Pareto optimal scheme combination of power grid enterprise's personal risk control cost and the minimum personal risk loss of power grid enterprise as an example. In this scheme, most power grid enterprise's personal risk adopts the personal risk avoidance strategy involved in the intrinsic safety concept of power grid enterprise. In this case, power grid enterprises can effectively reduce the loss of personal risk and have a better effect of personal risk control.

3.3 Efficiency Analysis of Personal Risk Control

On this basis, further verify the efficiency of personal risk management and control of the proposed method. Taking the time of personal risk management and control as the evaluation index, the shorter the time of personal risk management and control, the

Table 1. Pareto optimal solution of personal risk management and control for intrinsic safety of power grid enterprises

Pareto optimal solution	Optimal scheme combination	Personal risk assessment value of power grid enterprises	Personal risk control cost of power grid enterprises/yuan	Personal risk loss of power grid enterprises/yuan
1	$\{S_4,S_1,S_3,S_5,S_2\}$	85.73	3145.26	2543.12
2	$\{S_3,S_5,S_2,S_1,S_4\}$	89.05	1275.43	1104.86
3	$\{S_5,S_1,S_4,S_3,S_2\}$	91.54	1627.15	2973.25
4	$\{S_5,S_3,S_1,S_4,S_2\}$	92.58	814.56	534.12
5	$\{S_2,S_5,S_3,S_2,S_1\}$	88.42	2845.68	3157.86

Table 2. Comparison results of personal risk control time of three methods

Iterations/time	The proposed method/ms	The method of reference [5]/ms	The method of reference [6]/ms
10	5.2	7.6	9.5
20	8.5	9.9	12.3
30	10.8	13.3	16.9
40	12.3	16.7	18.7
50	14.4	18.1	21.4

higher the efficiency of personal risk management and control. The method of reference [5] and the method of reference [6] are used as comparison methods. The comparison results of safety classification time of the three methods are shown in Table 2.

According to Table 2, with the increase of the number of iterations, the time for personal risk control of the three methods will increase. When the number of iterations reaches 500, the personal risk control time of the proposed method is less than that of the method of reference [5] and the method of reference [6]. It can be seen that the proposed method has high efficiency in personal risk control.

4 Conclusion

This paper constructs a personal risk management and control model for the intrinsic safety of power grid enterprises. By analyzing the intrinsic safety concept of power grid enterprises, the probability value of personal risk is set, and the key factors of personal risk are reduced. In view of the personal risk management and control measures adopted by the power grid enterprise's intrinsic safety concept, the personal risk management and control model is constructed and solved, so as to effectively improve the efficiency of personal risk management and control, with a better effect of personal risk management and control.

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