Reliability Analysis of Electric Human Factors Based on Grey Correlation Analysis

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Abstract. On the basis of the analysis of power safety accidents by using the improved Human Factors Classification and Analysis System (HFACS) model, due to the large proportion of the cause of power safety accidents and the typical gray system characteristics, Grey correlation analysis was conducted for each factor of electric safety accident to determine the relationship between them. Using the results of gray correlation analysis of power safety accidents can provide theoretical support for the prevention of power safety accidents.

1. Introduction
Human factor reliability analysis is an indispensable part of probabilistic safety evaluation. Good human factor reliability analysis is helpful for more accurate evaluation of system safety and prevention and reduction of human factor accidents in large-scale complex man-machine systems. Human factor reliability analysis refers to the qualitative and quantitative evaluation of the impact of human behavior on system reliability and security. In modern society, as an important part of large-scale complex man-machine system, man plays a very important role in the overall reliability of the system. In recent years, safety accidents caused by human factors account for more than 80% of the total accidents in China [1]. Therefore, it is of great significance to improve the safety management level and reduce the occurrence rate of power safety accidents to analyze the correlation of human factors in power safety accidents. In the existing human factor accident analysis model, the human factor classification and analysis system (HFACS) [2] is most widely used. In order to analyze power safety accidents more effectively [3], this paper proposes an improved HFACS model suitable for power safety accidents. The safety accident in power a few information, most of the information is known, has the characteristics of a typical grey system [4], so you can key in the electric power safety accidents are due to factors in grey relation analysis [5], you can get people due to factors related, so that targeted corresponding preventive measures are taken, thereby reducing the occurrence of electrical safety accidents.

2. Improved HFACS model
In 1990, James Reason proposed the "Swiss cheese model" [6], which described four levels of human failure. In 2002, d.w. iegmann and Shappell proposed the human factor classification and analysis system (HFACS) based on Swiss cheese model and American civil military aviation data, which has been widely used in aviation, navigation, coal mine, nuclear power, etc. [7].

HFACS model is proposed for the analysis of maritime aviation accidents of the us navy. Although it can be well applied to the analysis of power safety accidents, some factors are not applicable to the power industry. Therefore, an improved HFACS model applicable to the power industry is proposed, as shown in figure 1.
3. Grey relational analysis
The grey relational analysis method is an improvement of the mathematical statistics method. Its basic idea is to judge whether the correlation is close or not according to the similarity degree of the geometric shape of the sequence curve. The closer the curve, the greater the correlation between the sequences, and the smaller the inverse. Grey relational analysis can overcome the shortcomings of large sample size and calculation required by traditional mathematical statistics methods, and it is a commonly used system analysis method at present. The main steps of grey relational analysis are as follows:

1) Determine reference sequence \( X_0(k), k = 1, 2, \ldots, m \).
2) Determine the comparison sequence \( X_i(k), k = 1, 2, \ldots, n \).
3) The reference and comparison sequences are normalized.
4) Find the correlation coefficient between reference sequence and comparison sequence $\xi_i(k)$:

$$
\xi_i(k) = \frac{\min_l \min_k |X_0(k) - X_i(k)| + \rho \max_l \max_k |X_0(k) - X_i(k)|}{|X_0(k) - X_i(k)| + \rho \max_l \max_k |X_0(k) - X_i(k)|}
$$

Among them $\rho$ is the resolution coefficient, and $\rho \in (0,1)$, usually take $\rho = 0.5$.

5) Strives for the correlation $\gamma_i$, $\gamma_i = \frac{1}{n} \sum_{k=1}^{n} \xi_i(k)$, Among them $\gamma_i$ Is the correlation between reference and comparison sequences, $\gamma_i$. The closer the relationship between the sequences, and the rank of correlation, the main causes of accidents can be analyzed.

3 Grey correlation analysis of human factors in power safety accidents

3.1. Selection of grey relational analysis indexes

According to the human factor analysis and classification system (HFACS) model, the human factors causing the accident can be divided into four levels: organizational factors, supervision of unsafe behaviors, preconditions of unsafe behaviors and unsafe behaviors. These four levels basically include all human factors involved in power safety accidents. This paper proposes an improved HFACS model for power safety accidents based on the HFACS model, and forms an indicator system of grey relational analysis.

In this paper, 302 power safety accidents were taken as samples from 2010 to 2017, and the improved HFACS model was used for analysis.

3.2. Correlation analysis between human factors and primary indicators

The total number of accidents occurred in each year from 2010 to 2017 was taken as the reference sequence $X_0$. The organizational factors, the supervision of unsafe behaviors, the preconditions of unsafe behaviors and the number of unsafe behaviors are the comparison sequences $X_1, X_2, X_3, X_4$. MATLAB can be used to calculate the organizational factors, the supervision of unsafe behavior, the precondition of unsafe behavior and unsafe behavior and the accident related degree of the total people in each year are respectively $r_1 = 0.5428, r_2 = 0.6503, r_3 = 0.7326, r_4 = 0.4731$, clearly $r_3 > r_2 > r_1 > r_4$. It can be seen from the above calculation results that the main reason for the occurrence of accidents is the premise of unsafe behavior, followed by the supervision of unsafe behavior.

3.3. Correlation analysis between primary indicators and secondary indicators

Tissue factors were taken as reference sequences $X_1$. The comparison sequences are poor organizational atmosphere, inadequate resource management, unreasonable management organization process and inadequate training education $X_{11}, X_{12}, X_{13}, X_{14}$. You can get $r(X_1, X_{11}) = 0.8764, r(X_1, X_{12}) = 0.7426, r(X_1, X_{13}) = 0.4305, r(X_1, X_{14}) = 0.5439$. It can be seen that, among organizational factors, poor organizational atmosphere is the most important influencing factor.

Take the surveillance of unsafe behavior as the reference sequence $X_2$. The sequence of inadequate supervision, inappropriate operation plan, no problems found and violations of supervision is comparison $X_{21}, X_{22}, X_{23}, X_{24}$, available $r(X_2, X_{21}) = 0.8749, r(X_2, X_{22}) = 0.4294, r(X_2, X_{23}) = 0.7864, r(X_2, X_{24}) = 0.6206$. Therefore, inadequate supervision plays a major role in the supervision of unsafe behaviors.

Take the precondition of unsafe behavior as the reference sequence $X_3$. Physical environment, technical environment, poor quality and ability, poor physiological state, poor mental state, poor Psychological state, inadequate work preparation, weak safety and protection awareness, poor communication and coordination are the comparison sequences $X_{31}, X_{32}, X_{33}, X_{34}, X_{35}, X_{36}, X_{37}, X_{38}, X_{39}$. You can get $r(X_3, X_{31}) = 0.6239, r(X_3, X_{32}) = 0.4896, r(X_3, X_{33}) = 0.6509, r(X_3, X_{34}) = 0.5748, r(X_3, X_{35}) = 0.5748, r(X_3, X_{36}) = 0.5810, r(X_3, X_{37}) = 0.6234, r(X_3, X_{38}) = 0.7108, r(X_3, X_{39}) = 0.4224$. It can be seen from above that in the premise of unsafe behavior, weak safety and protection awareness is the most common problem.
Take unsafe behavior as the reference sequence $X_4$. The random and habitual violations are the comparison sequences $X_{41}, X_{42}$. You can get $(X_4, X_{41}) = 0.5467, r(X_4, X_{42}) = 0.5203$. Therefore, among the unsafe ACTS, the most important is accidental violations, followed by habitual violations, but the difference is not significant.

3.4. Correlation analysis between secondary indicators

According to the improved HFACS model, the people causing the accident can be divided into four levels, namely, organizational factors, supervision of unsafe behaviors, preconditions of unsafe behaviors and unsafe behaviors. There is a strong correlation between adjacent levels. Using the grey relational analysis method, we can effectively analyze the influence relations among different levels. The specific calculation data are shown in table 1, table 2 and table 3.

It can be seen from table 1, $X_{12}$ is the main factor that affects the surveillance of unsafe behavior. The average correlation is 0.6779. The second is $X_{14}$, The average correlation is 0.6507. Failure of resource management is the most likely cause of unsafe behavior supervision.

| correlation | $X_{11}$ | $X_{12}$ | $X_{13}$ | $X_{14}$ |
|-------------|---------|---------|---------|---------|
| $X_{21}$    | 0.7893  | 0.7765  | 0.4769  | 0.5794  |
| $X_{22}$    | 0.4048  | 0.4903  | 0.6874  | 0.5236  |
| $X_{23}$    | 0.6739  | 0.8236  | 0.4563  | 0.6035  |
| $X_{24}$    | 0.5347  | 0.6212  | 0.5139  | 0.8963  |

It can be seen from table 2, $X_{24}$ is the most important factor influencing the secondary indicators of unsafe behaviors, and the average correlation degree is 0.7363. Therefore, the supervision violation is closely related to the occurrence of the premise conditions of unsafe behaviors.

| correlation | $X_{21}$ | $X_{22}$ | $X_{23}$ | $X_{24}$ |
|-------------|---------|---------|---------|---------|
| $X_{31}$    | 0.6792  | 0.6135  | 0.7206  | 0.8628  |
| $X_{32}$    | 0.5186  | 0.8886  | 0.5458  | 0.6147  |
| $X_{33}$    | 0.7197  | 0.5485  | 0.7657  | 0.9483  |
| $X_{34}$    | 0.6186  | 0.6736  | 0.6501  | 0.7520  |
| $X_{35}$    | 0.6186  | 0.6736  | 0.6501  | 0.7520  |
| $X_{36}$    | 0.6285  | 0.6639  | 0.6539  | 0.7589  |
| $X_{37}$    | 0.6649  | 0.6641  | 0.6782  | 0.7413  |
| $X_{38}$    | 0.7321  | 0.5374  | 0.7583  | 0.7401  |
| $X_{39}$    | 0.4286  | 0.6967  | 0.4315  | 0.4567  |

It can be seen from table 3, $X_{32}$ is the most important factor influencing the two secondary indicators of unsafe behavior, with an average correlation degree of 0.8032. Followed by $X_{31}, X_{34}, X_{35}$. Therefore, the technical environment is most likely to cause unsafe behaviors, followed by physical environment, physiological state and mental state. In general, the environment and own state of the operator are directly related to the occurrence of unsafe behaviors.
Table 3. The correlation between the preconditions of unsafe behavior and unsafe behavior

| correlation | $X_{41}$ | $X_{42}$ |
|-------------|---------|---------|
| $X_{31}$    | 0.7887  | 0.7041  |
| $X_{32}$    | 0.7546  | 0.8519  |
| $X_{33}$    | 0.7367  | 0.6751  |
| $X_{34}$    | 0.7598  | 0.7283  |
| $X_{35}$    | 0.7598  | 0.7283  |
| $X_{36}$    | 0.7472  | 0.7341  |
| $X_{37}$    | 0.6657  | 0.8001  |
| $X_{38}$    | 0.6764  | 0.6648  |
| $X_{39}$    | 0.5836  | 0.5843  |

4. Conclusion
Human factor reliability analysis refers to the qualitative and quantitative evaluation of the impact of human behavior on system reliability and security. One of its main objectives is to reduce the frequency of unintended consequences caused by human error in complex industrial operations. At present, the human factor reliability analysis has been quite mature in aviation, navigation, nuclear power, coal mining and other aspects, but there is a gap in the power industry related research. In this paper, on the basis of the traditional HFACS model, in combination with the practical situation of electric power safety accidents, construct improved HFACS model is applicable to electric power industry, and by using grey correlation analysis method of people due to factors and primary index, primary and secondary indicators, secondary index are analyzed, between can clearly show the relationship between each because of factors related, provide a reference for power safety accident analysis and prevention. The analysis of human factors reliability of power safety accidents is of great significance to improve the safety management level of power enterprises and reduce the occurrence rate of power safety accidents.

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