Research on Reliability for Electrical System

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Abstract. Specific to the electrical system protection unit, a weighting coefficient method to predict the reliability of the protection unit was proposed. Take the power system as an example, the predicting result for the failure rate of the protection unit was given. The result illustrated that the failure rate of the protection unit predicted with weighting coefficient method is only about one third of traditional prediction method, the reliability prediction of the protection unit based on weighting coefficient method is expected to be a reasonable modification for the traditional component counting method, and the result is more scientific and accurate.

Introduction

Reliability prediction is a predicting process based on the reliability model of products, it is a prediction of the reliability level for the product and its components through the existing failure rate data [1]. Reliability prediction is one of the most important ways to improve reliability.

The correct reliability prediction is the primary prerequisite for ensuring the quality of products, for this reason, researchers at home and abroad have conducted a lot of research on it.

In terms of the standards for reliability prediction, a lot of countries have developed corresponding standard documents. Document [2] is a widely used mainstream reliability prediction manual, document [3] is the reliability prediction manual for electronic equipment in China. Reference [4] summarizes the development history of reliability prediction for electronic products, and the existing reliability prediction methods for electronic products were classified, analyzed and compared. Reference [5] summarizes the latest methods of reliability prediction abroad.

The Characteristic of Electrical System Protection Unit

The protection unit of a general electrical system has two running states: working or ready. When the system appears some failures, the protection unit should be in working state, if it can act normally and play a protective role, which indicating the protection unit has performed correct action. If the protection unit should have acted but it did not, then the protection unit is defined as "miss trip". If the system operates correctly, the protection unit should be in the ready state and should not be activated, if it acts due to its own fault, then the protection unit is defined as "misoperation". If analyzing the impact of protection unit on the system, the "miss trip" only affects the security of the system, but it does not affect the reliability, only "misoperation" could cause the system to add a fault, which has an impact on the reliability. Therefore, when modeling the reliability of electrical automation system, the misoperation failure rate should only be counted as the failure rate of the protection unit.

In this way, considering the specificity of the protection unit, only the misoperation failure rate should be taken into account when predicting the reliability of the protection unit. That is to say, it is more scientific to predict the reliability of the protection unit by replacing its general failure rate with the misoperation failure rate.
Predicting the Reliability of the Protection Unit with Weighting Coefficient Method

Component counting method is suitable for the demonstration and the preliminary design of electrical equipment scheme. The method requires information about the type and quantity of the generic components, the quality level of the components and the equipment environment and so on. The general mathematical model of component counting method given in document [2] is:

$$\lambda_S = \sum_{i=1}^{n} N_i \pi_{Qi} \lambda_{Gi} \cdot$$

(1)

For a given system, $\lambda_S$ is the total failure rate of the system; $n$ is the number of different generic components; $N_i$ is the quantity of the $i$-th general component; $\pi_{Qi}$ is the quality coefficient of the $i$-th general component; $\lambda_{Gi}$ is the failure rate of the $i$-th general component.

Predicting the Reliability of the Protection Unit with Weighting Coefficient Method

For the particularity of the protection unit, in order to get the optimum failure rate data, this paper applying the weighting coefficient method to modify the mathematical model of traditional component counting method (1). The modified mathematical model is:

$$\lambda_S = \sum_{i=1}^{n} \alpha_i N_i \pi_{Qi} \lambda_{Gi} \cdot$$

(2)

For a given system, $\lambda_S$ is the total failure rate of the system; $n$ is the number of different generic components; $N_i$ is the quantity of the $i$-th general component; $\pi_{Qi}$ is the quality coefficient of the $i$-th general component; $\lambda_{Gi}$ is the failure rate of the $i$-th general component.

In the formula, $\alpha_i$ is the weighting coefficient of the $i$-th general component.

For general system components, $\alpha_i = 1$.

For the components in "miss trip" mode for system protection unit, $\alpha_i = 0$.

For the components in "misoperation" mode for system protection unit, $\alpha_i = \alpha \cdot \alpha$ is the relative frequency of failure mode, which indicating the proportion of a failure mode in components failure. Generally, the sum of $\alpha$ values in all kinds of failure modes for a component should be equal to 1, and the reference $\alpha$ values can be seen in table 1.

An Example of Application

The Under-Voltage Protection Unit of Diesel Automatic Control Subsystem SDA-22

Take the under-voltage protection unit of diesel automatic control subsystem SDA-22 for marine power station as an example, as shown in figure 1. When the grid voltage of the marine power station is normal, the relay J is released and won’t take action; when the grid voltage appears under-voltage failure, the relay J will act and send out an under-voltage protection signal.

If there appears under-voltage failure in marine power station, the input voltage $V_{IN}$ is low level, however the output voltage $V_{OUT}$ is high level, the relay J is released without action, which indicates the protection unit is in the "miss trip" state; When the grid voltage of the marine power station is normal, but the output voltage $V_{OUT}$ is low level, the relay J acts and sends out an under-voltage protection signal, which illustrates that the protection unit is in the "misoperation" state.

The main factors that cause the misoperation of protection unit are: the auxiliary contacts of relay J fail; short circuit of transistor T; and the high output voltage of amplifier $N_1$. 

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The main factors causing the high output voltage of amplifier N1 are: the short circuit of resistance R_{27} and R_4; the open circuit of resistance R_{15} and R_1; and the low input voltage V_{IN}.

The main factors that cause the low input voltage V_{IN} are: the short circuit of capacitor C_{10}; open circuit of resistance R_{16} and R_7; the short circuit of resistance R_8 and R_{17}; the open circuit of diode V_{19}; the short circuit of voltage stabilizer V_{11}; and the open circuit of transformer B_m.

The failure rate, the major failure mode and its relative frequency a(%) of each component in the under-voltage protection circuit of diesel automatic control subsystem SDA-22 are shown in the table 1 (Note: The major failure mode in the table refers to the one used in this paper).

Among them, the misoperation failure rate $\lambda_M$ is equal to the general failure rate multiplied by the percentage of misoperation failure mode (relative frequency a(%)). The working environment of the system is in the cabin of ship, and the environmental coefficient N_S is used.

**Predicting the Reliability of the Protection Unit with Component Counting Method**

Without considering the particularity of under-voltage protection unit, according to the principle of regular reliability prediction, the reliability model of the under-voltage protection unit consists of a total of 19 reliability series models. The predicting failure rate of the under-voltage protection unit SDA-22 $\lambda_S$ for diesel engine automatic control system with component counting method is:

![Under-voltage protection circuit of diesel automatic control subsystem SDA-22.](image-url)
\[ \lambda_S = \sum_{i=1}^{n} N_{i} \pi_{Qi} \lambda_{Qi} = \sum_{i=1}^{19} N_{i} \pi_{Qi} \lambda_{Qi} = 22.4924 \times 10^{-6} / \text{h}. \]  

**Predicting the Reliability of the Protection Unit with Weighting Coefficient Method**

Considering the particularity of the under-voltage protection unit and adopting the weighting coefficient method, the failure rate of the under-voltage protection unit should only consist of the misoperation failure rate, and replace the general failure rate \( \lambda_G \) of the protection unit with its misoperation failure rate \( \lambda_M \). The predicting failure rate for the under-voltage protection unit of diesel automatic control subsystem SDA-22 is as follows:

\[ \lambda_S = \lambda_{SM} = \sum_{i=1}^{n} \alpha_i N_{i} \pi_{Qi} \lambda_{Gi} = 6.18619 \times 10^{-6} / \text{h}. \]  

In the above example of the under-voltage protection unit of diesel automatic control subsystem SDA-22 for marine power station, the misoperation failure rate is used to instead of the general failure rate, and the failure rate with weighting coefficient method is only about one third of traditional component counting method. The weighting coefficient method is more scientific and accurate in predicting the reliability for marine power station compared to the traditional one, and it also provides a more reasonable and accurate basis for the further development of reliability modeling for marine power station.

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