

Application of Variable Weight Coefficient Method in State Evaluation of AC Contactor

Yuze Su¹, Zichun Liu^{2,a}, Kai Gao³, Guangyu Na³, Shuxin Liu²

¹ Northeast Electric Power University, 132012, Jilin, China

² Institute of Electrical Apparatus New Technology and Application, Shenyang University of Technology, 110870, Shenyang, China

³ Liaoning Provincial Electric Power Co., Ltd. Electric Power Research Institute, 110006, Shenyang, China

Abstract. AC contactor state evaluation is a challenging problem. This paper proposes an AC contactor state assessment method based on variable weight coefficient. Firstly, the characteristic indicators that have a great influence on the state of the AC contactor are selected, and the state evaluation index system is established. Secondly, using the subjective and objective combination weighting method combined with the analytic hierarchy process and the grey relational analysis method, the constant weight coefficient is obtained, and the variable weight coefficient method with the equalization function is introduced to obtain the variable weight coefficient of each characteristic parameter. Finally, the fuzzy comprehensive evaluation method is used to evaluate the running state of the AC contactor. The experimental results show that the state evaluation method proposed in this paper can accurately reflect the real state of the AC contactor operation and effectively improve the reliability of the power system.

1 Introduction

AC contactors are widely used in various electrical control circuits. They are mainly responsible for connecting and disconnecting AC circuits. Their working status directly affects the reliability of the power system. The mechanical life of the AC contactor is more than one million times, but the electrical life is much less than the mechanical life. Therefore, the evaluation of the operating state of the AC contactor mainly considers its electrical life[1-3]. Accurate assessment of the electrical life of the AC contactor can make maintenance decisions for the equipment at a minimum cost, and the development of optimal management measures is significant for improving the reliability and safety of the power system.

In recent years, the evaluation of contactor status has become a research hotspot for scholars at home and abroad. Escribano et al. [4] analyzed the response of AC contactors under different electrical loads in detail through a large number of experiments. RK Panda et al[5] studied the contactor electrical life test system to make the electrical life test more reliable and accurate. Zheng Shumei et al. [6] studied the erosion of AC contactor contact system and established a mathematical model of electrical life distribution characteristics. Li Kui et al[7] used cumulative arc energy and pick-up time as model input parameters, and analyzed the prediction error of AC contactor electrical life under different neural network models.

The evaluation of the state of the AC contactor involves multiple factors and multiple levels. If the life

state assessment is performed only according to the constant weight coefficient, since the state weight is not large, the overall evaluation result of the AC contactor may still be normal, which causes a great safety hazard. Therefore, using only the static weight coefficient does not accurately reflect the true operating state of the AC contactor. The fuzzy comprehensive evaluation method based on fuzzy mathematics has a better evaluation effect on multi-factor and multi-level complex problems. So, this paper introduces a variable weight coefficient method based on the constant weight coefficient. In the evaluation process, as the various indicators change, the weights also change, combined with the fuzzy comprehensive evaluation model, so that the evaluation results reflect the real-time status of the AC contactor more realistically.

2 Fuzzy comprehensive evaluation principle based on variable weight coefficient

In this paper, the fuzzy comprehensive evaluation method is used to judge the electrical life state of the AC contactor. The weight of the AC contactor is firstly obtained by principal and objective weighting, and then the variable weight formula is introduced to obtain the variable weight coefficient. Fuzzy comprehensive evaluation method is a method that uses fuzzy theory to comprehensively judge a variety of indicators and multiple factors, and has advantages in dealing with

^a Corresponding author: liuzichun241@163.com

multi-factor and dynamic complex networks. The main calculation process of this paper is shown in Figure 1.

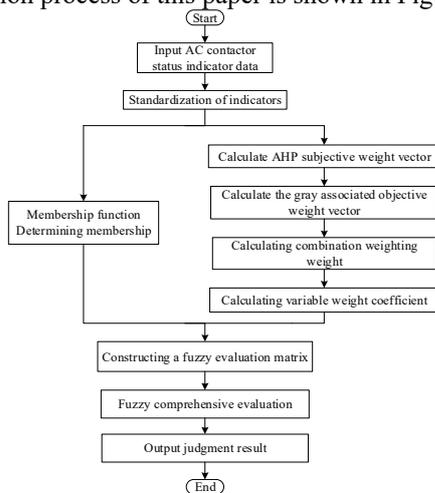


Figure 1. Fuzzy comprehensive evaluation process

3 AC contactor status evaluation index system

Among the many factors affecting the working state of the AC contactor, selecting the representative parameters as the evaluation factor for judging the working state of the AC contactor is the first step in establishing the evaluation model. As the AC contactor operates, the circuit is continuously turned on and off, the contacts gradually wear out, and the overall electrical performance of the AC contactor gradually decreases. In this paper, four characteristic parameters of contact resistance, pick-up time, release time and bounce time are selected. The state evaluation index system is shown in Figure 2.

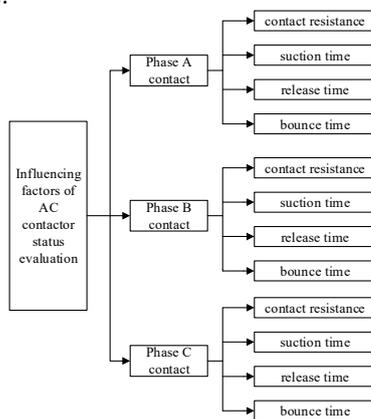


Figure 2. AC contactor status evaluation index system

4 Determination of variable weight coefficient in comprehensive evaluation

4.1 Determination of constant weight coefficient

Aiming at the advantages and disadvantages of the analytic hierarchy process and the grey relational analysis method, in order to solve this problem, the weight calculation method of AHP-gray correlation analysis combined weighting is proposed. At the same

time take the advantages of both to make up for their shortcomings, considering both subjective factors and customer observation factors, avoiding the shortcomings of the single assignment method. Let w_i be the subjective weight of the i -th indicator, and v_i be the objective weight of the i -th indicator, then the final weight of the i -th indicator can be determined by equation (1)

$$Q_i = \beta \times v_i + (1 - \beta)w_i \quad (1)$$

For the selection of the weight of the evaluation factor of the electrical contact state of the AC contactor, the role of subjective weight and objective weight is very important, that is, the choice of $\beta=0.5$ as the combination weight coefficient is more reasonable.

4.2 Determination of variable weight coefficient

Although the method of subjective and objective combination weighting avoids the disadvantage of single weighting to some extent. In this case of constant weight, when the evaluation index with a particularly small weight deviates significantly from the normal value, because the weight is small, the judgment result will still show the normal state, which is inconsistent with the state of the actual AC contactor. Considering the shortcomings of the constant weight coefficient, in order to evaluate the operating state of the AC contactor more accurately and accurately, the variable weight theory is introduced to adjust the constant weight coefficient in real time, so that the judgment result is more true and accurate.

Variable weight formula[8, 9]:

$$w_i^{v1} = \frac{w_i^{(0)}}{x_i} / \sum_{p=1}^n \frac{w_p^{(0)}}{x_p} \quad (2)$$

w_i^{v1} is the variable weight of the i -th characteristic parameter, $w_i^{(0)}$ is the static weight of the i -th characteristic parameter, and x_i is the i -th characteristic parameter. Select the equalization function

$$B(x_1, \dots, x_n) = \sum_{j=1}^n x_j^\alpha \quad (0 < \alpha \leq 1)$$

. Bring the equalization function into the expression, and its weighting formula is:

$$w_i^{v2} = w_i^{(0)} x_i^{\alpha-1} / \sum_{p=1}^n w_p^{(0)} x_p^{\alpha-1} \quad (3)$$

5 AC contactor state fuzzy comprehensive evaluation step

5.1 Establish a set of factors and evaluation sets for the evaluation model

It can be seen from the AC contactor state evaluation index system diagram of Fig. 2 that the operating state of the contactor is closely related to the state of each of the three-phase contacts. When the life of a phase contact is terminated, it represents the end of the life of the entire AC contactor. Taking one phase as an example, four characteristic parameters of contact resistance, pick-up

time, release time and bounce time of the AC contactor are selected to establish the factor set of the evaluation model. In this paper, the evaluation set is divided into 4 levels, namely {good (V1), general (V2), attention (V3), warning (V4)}.

5.2 Determining membership function

There are many methods for determining the degree function. The membership functions used in this paper are triangle, lower half trapezoid and rising half trapezoid function, which is beneficial to simplify the model and will not cause too much error. The hierarchical diagram is shown in Fig. 3.

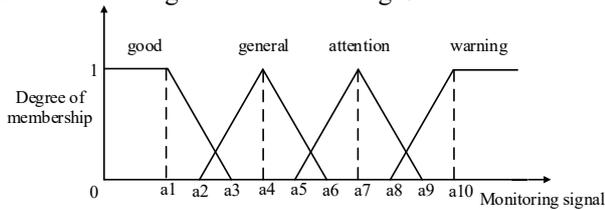


Figure 3. The membership function corresponding to each level of state

As can be seen from the figure, as the monitoring signal increases, the state is arranged by ‘good’, ‘general’, ‘attention’, and ‘warning’, indicating that the monitoring signal gradually becomes larger as the AC contactor operates.

5.3 Synthetic fuzzy comprehensive evaluation result

The evaluation model is obtained by different combinations between the weight set A and the fuzzy relation matrix R, namely $B = A \circ R$. In order to retain as much judgment information as possible, this paper uses the $M(\bullet, \oplus)$ model to synthesize. This model not only considers all the influencing factors, but also retains all the information of single factors, and the results can truly and accurately reflect the operating state of the AC contactor.

6 Example calculation

Figure 4 shows the AC contactor electrical life test platform. The test uses the CJX2-8011 AC contactor as the test object. Under AC-4 conditions, the main contact voltage and current signals and the voltage and current signals of the coil are monitored and collected. The life test data of the AC contactor was obtained, and a total of nearly 40,000 sets of raw data were obtained. Then, the characteristic parameters such as contact resistance, pick-up time, release time and bounce time are calculated from the collected data, taking the phase A as an example.

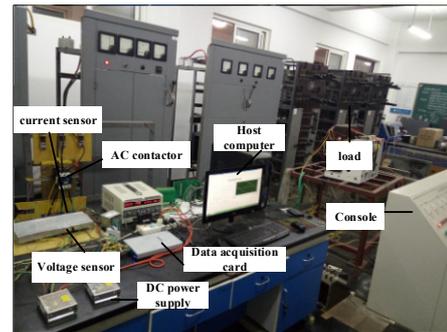


Figure 4. AC contactor electrical life test platform

The calculated waveforms of the various characteristic parameters are preprocessed to obtain a waveform as shown in Fig. 5.

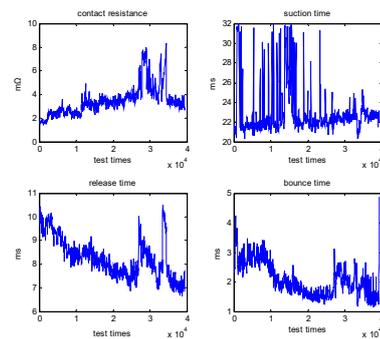


Figure 5. Characteristic parameter waveform

6.1 Establishment of AC contactor weight set

Firstly, the subjective weights of the four characteristic parameters are calculated by the analytic hierarchy process. Secondly, the objective weight is calculated by the grey correlation analysis method. Again, according to the combined weight formula, the combined weight is obtained. Finally, the variable weighting method that introduces the equalization function obtains the variable weight coefficient of each index as shown in Fig. 6.

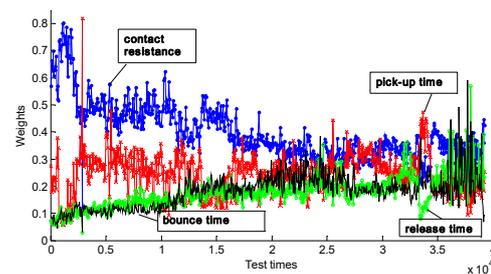


Figure 6. Variable value of each index

6.2 Establishment of fuzzy relation matrix

Each set of influencing factors corresponds to a fuzzy relation matrix, and the introduced membership function is used to bring each set of characteristic parameters into the membership function to obtain the fuzzy relation matrix.

6.3 AC contactor fuzzy comprehensive evaluation result

Using the $M(\bullet, \oplus)$ model, the comprehensive evaluation results of the AC contactor state under the constant weight and variable weight coefficients of the evaluation model $B = A \circ R$ are shown in Table 1.

Table 1. Evaluation results

Test times	The set of evaluation results is B (constant weight).	Constant weight state	Judging result set B (variable weight)	Variable weight state
2000	[0.6493,0.2981,0.0526,0]	I	[0.7359,0.2198,0.0443,0]	I
6000	[0.7751,0.2249,0,0]	I	[0.8107,0.1893,0,0]	I
12000	[0.2183,0.5686,0,0.2131]	II	[0.2100,0.6749,0,0.1151]	II
16000	[0.2085,0.5784,0.0734,0.1397]	II	[0.1586,0.6244,0.0748,0.1422]	II
22000	[0,0.3055,0.5184,0.1761]	III	[0,0.1174,0.5412,0.3414]	III
26000	[0,0.0864,0.5246,0.3890]	III	[0,0.0760,0.4966,0.4274]	III
32000	[0,0.2580,0.4095,0.3325]	III	[0,0.0842,0.1477,0.7681]	IV
36000	[0,0.2126,0.2924,0.4950]	IV	[0,0.1358,0.1978,0.6664]	IV

According to the principle of maximum membership degree, the final result is determined. Due to the limited space, the results of eight groups of AC contactors in different periods are listed. In the 2000th time, the membership of the AC contactor state from the constant weight coefficient is state state I is 64.93%, and the state I membership degree obtained by the variable weight coefficient is 73.59%. The evaluation results are all in a good state, and the state membership degree obtained by the variable weight is greater than the constant weight. The condition of the 2000 contactor dynamic and static contacts is as shown in Fig. 7(a), and the state is good and the result is accurate.

At 32000 times, the AC contactor state obtained by the constant weight coefficient belongs to state III. The result obtained by changing the weight coefficient is state IV, and the dynamic and static contact condition is as shown in Fig. 7(b). At this time, although the AC contactor is in a general state as a whole, the performance state of some characteristic parameters becomes a state of attention. When the constant weight coefficient is used for evaluation, since the characteristic parameters of the change are often small, the evaluation result is still not in the state III. By using the variable weight coefficient method, the weight coefficient is increased, so that the evaluation result is closer to the real running state of the AC contactor, and the accuracy of the state evaluation is improved.

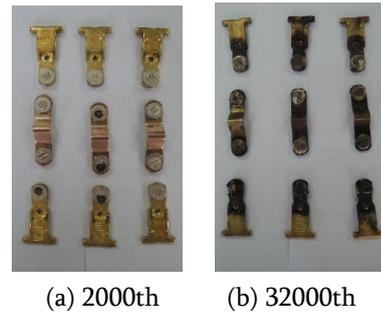


Figure 7. The movement and static contact situation

It can be obtained from the example analysis that the variable weight coefficient method described in this paper can accurately reflect the true state of the AC contactor and improve the safety and reliability of the power system.

7 Conclusion

(1) From the many influencing factors affecting the electrical life of the AC contactor, the characteristic parameters that have a great influence on the state of the AC contactor are selected, the set of evaluation factors is established, and the fuzzy relation matrix is established by the membership function.

(2) Research on the method of determining the constant weight, and on this basis, the variable weight coefficient method with equalization function is introduced to carry out fuzzy comprehensive evaluation of the state of the AC contactor. The example shows that the results obtained by variable weight coefficient can better reflect the true state of the AC contactor and improve the accuracy of the state assessment.

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