Evaluation of Wind Turbine Operation Status Based on ACO + FAHP

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Abstract: Aiming at the shortcomings of the fuzzy analytic hierarchy process (FAHP) in the comprehensive evaluation of wind power projects, such as the difficulty of satisfying and modifying the consistency of the judgment matrix and the high computational complexity, a fuzzy analytic hierarchy process based on ant colony optimization (ACO+FAHP) is proposed. Firstly, the proposed fuzzy analytic hierarchy process based on ant colony optimization algorithm overcomes the disadvantages that the weight and consistency cannot be improved once the judgment matrix is given. The comparison chart of the consistency ratio calculated according to this method shows that the consistency ratio B, C1-C5 all have different degrees of reduction. Then, in view of the fact that various qualitative indicators cannot be accurately calculated, the wind turbine operating status evaluation model is established by using the fuzzy comprehensive evaluation method. In this paper, the evaluation score of a certain wind farm is 0.731, which means that the operators need to carry out high-level maintenance at this time.

Key words: wind power, fuzzy analytic hierarchy process, ant colony optimization, index system

1. Introduction

As a renewable and clean energy, wind energy has been paid more and more attention by the world. China is rich in wind energy resources and has unique development advantages. The evaluation model in this paper is constructed on the basis of the FAHP method that has been applied in various fields. In the electric power industry, FAHP has been applied to solar power station site selection decision , wind farm site selection decision , and evaluation of energy alternatives .

2. Evaluation model of wind turbine operating status

Evaluation Criteria for Wind Turbine Operation Status. The wind turbine operating status evaluation system is a criterion for multi-dimensional comparative analysis of different wind farms using the same scale. The evaluation index system of wind turbine operation status is shown in Fig. 1.

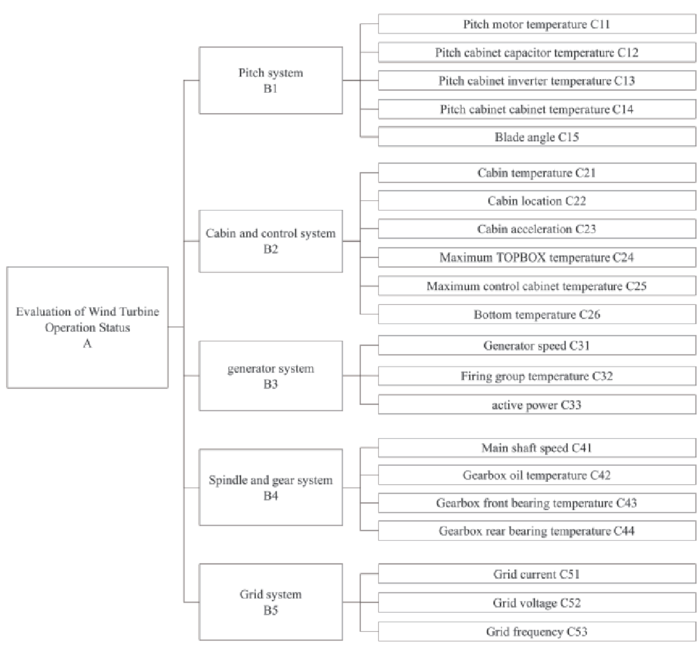

FIGURE 1: Comprehensive evaluation index system of wind power projects

FAHP Weight Optimization Based on ACO. In order to improve these problems, this paper proposes the ACO + FAHP model to optimize the weight calculated by the FAHP method and make the comprehensive evaluation results more scientific and reliable.

Consistency Ratio Formula for Computing Judgment Matrix:

$$CR = \frac{CI}{RI} \qquad (1)$$

Among them, CI is the consistency index, CR is the consistency ratio, and RI is the average random consistency index.It can be seen that the smaller the CI, the higher the consistency of the matrix, and the determination of the weight value of each index and the consistency test can be simplified as the following optimization problem:

$$\min CIF(\omega)=\frac{\lambda_{\max}-n}{n-1}=\frac{\sum_{i=1}^{n}\frac{\sum_{j=1}^{n}a_{ij}\omega_j}{\omega_i}-n^2}{n(n-1)} \quad (2)$$

Among them, λmax is the largest eigenvalue, the function CIF(ω) is the consistency index function, ω is the optimization variable, and the constraints are:

$$\sum_{i=1}^{n}\omega_i=1 \quad (3)$$

When the value of the function CRF(ω)=CIF(ω)/RI is less than 0.1, it is considered that the constructed judgment matrix has good consistency.

In the model, the population size is 50, the number of iterations is 200, the pheromone evaporation coefficient is 0.9, the transition probability constant is 0.2, and the penalty item threshold is 0.0001. The comparison chart of the calculation results and the results of the single FAHP method is shown in Figure 2.

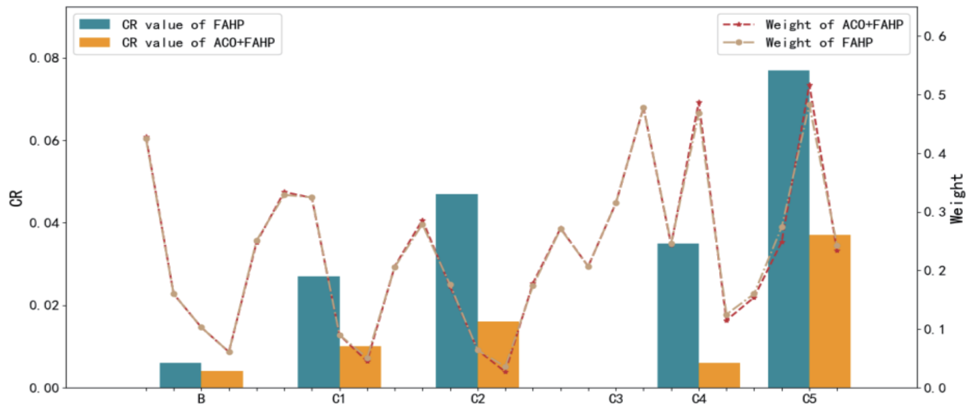

FIGURE 2: Calculation results of the weights and consistency ratios of each index in the ACO+FAHP model

It can be seen from the figure that CR value of the function of the above judgment matrix is less than 0.1. Among them, except for C3 which has complete consistency, CR values of the ACO+FAHP method are obviously lower than CR values of the FAHP method.

In order to demonstrate the effectiveness of the ACO algorithm in improving the consistency of the AHP judgment matrix, this paper uses the PSO algorithm and the GA algorithm as the control group. The comparison results of the change curves of the ACO algorithm iteration and other algorithm iteration processes are shown in Figure 3.

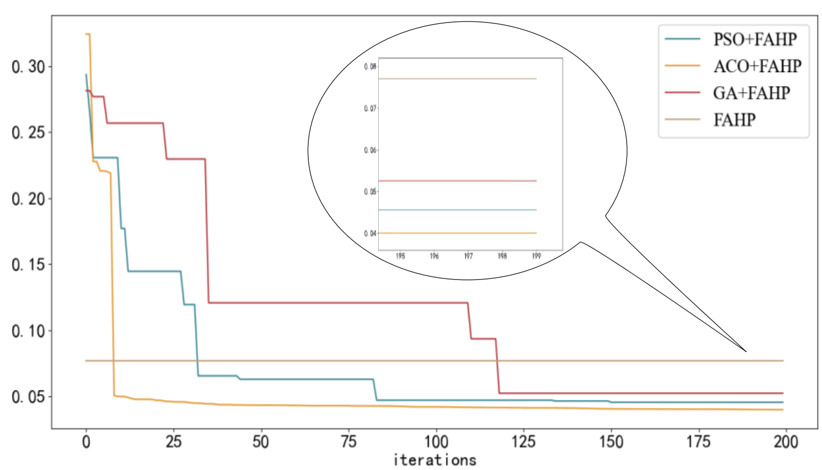

FIGURE 3: Iteration Curves of ACO+FAHP and Other Algorithms

It can be seen from Figure 6 that the ACO algorithm can obtain better consistency results with fewer iterations.

Calculation of results by fuzzy evaluation. Fuzzy evaluation can assign multiple indicators according to the same interval (0,1) .

Select the daily online monitoring operation data of 10 1.5MW wind turbines in a wind farm for 2 years, and some results are shown in

Table 1.

TABLE 1: Membership function parameters of each index

Index	Function type	xmin	xmax	[xa ,xb]
Pitch motor temperature/℃	decreasing	-9.4	653.6	-
Pitch cabinet capacitor temperature/℃	decreasing	0.8	45.3	-
……	……	……	……	……

According to the expert scoring value and fuzzy evaluation, Figure 4 can be obtained:

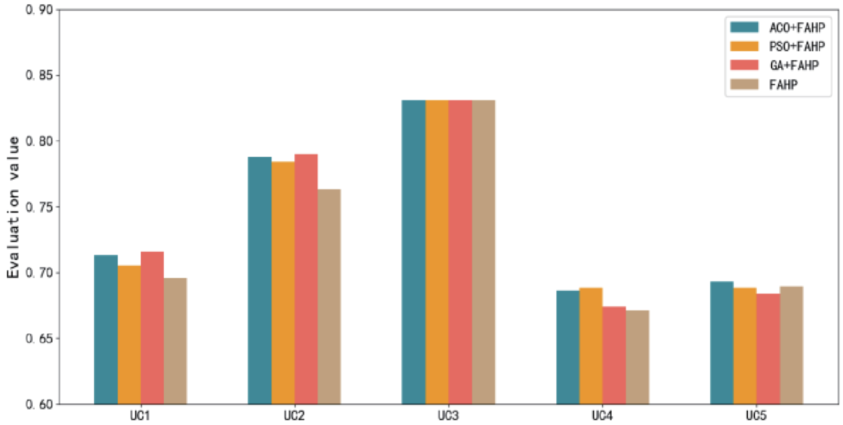

FIGURE 4: The evaluation results of each algorithm at the criterion level

It can be seen from the above table that the ACO-based FAHP wind turbine operating status evaluation has more accurate evaluation results.

Conclusion

In order to comprehensively and accurately evaluate the comprehensive performance of wind power projects, this paper uses ACO to optimize the weight vector of FAHP method. The idea is to define the indicators of various performances of wind power projects. Then the weight vector optimized by ACO is multiplied with the blurred representation value. Finally, the comprehensive evaluation of qualitative indicators and quantitative indicators is realized.

Data Availability

data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

authors declare that they have no conflicts of interest.

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