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Operation State of the Wind Turbine Pitch System Based on Fuzzy Comprehensive Evaluation

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ABSTRACT

To ensure wind turbine (WT) safe operations and improve the utilization rate of wind energy, effective evaluation of the operation state of the pitch system is critical. Therefore, a new method was proposed to evaluate the operation state of the pitch system of WT based on fuzzy comprehensive evaluation. Firstly, based on SCADA data, the working state of the pitch system under rated power state and power state of WT were analyzed. Secondly, through the analysis of characteristic parameters and physical mechanism of the pitch system, the consistency principle of characteristic parameters, the stability principle of power under rated state, and the stability principle of blade angle underpowered state were obtained. Next, based on the aforementioned principles, the evaluation indexes were established, and the fuzzy comprehensive evaluation method was used to establish the operation state evaluation model of the pitch system under rated power state and under power state of the WT. Finally, an example was provided to verify the effectiveness of the method. The evaluation model established in this study can be used as a technical reference for the online monitoring of WT pitch systems to ensure the safe and stable operation of WTs.

1 Introduction

Wind energy is a clean energy source and has attracted considerable attention for satisfying the ever-increasing demand for energy [1]. Wind turbines (WTs) are used for conversion of wind energy into electricity and provides stable electricity to the grid effectively. To achieve efficient wind energy efficiency and ensure safe operation, adjusting the blade attitude through the WT pitch system is critical to realize blade pitch control [2,3]. Therefore, the operating status of the pitch system directly affects the state of the WT. Thus, evaluation of the operating status of the WT pitch system is needed.

Studies on WT operation status evaluation is mainly focused on the evaluation of the WT and the evaluation of key components. WTs have been evaluated using the mathematical model [4], regression model [5], neural network [6], and machine learning [7]. Ouyang et al. [8] proposed a support vector machine (SVM) method based on data partitioning and data mining to achieve state evaluation. The method contained three kernel functions, and a power curve model was established to analyze the

deviation degree of the actual model from the normal model by fitting a normal distribution curve. The performance of the turbine was predicted using multiple linear regression and an artificial neural network in a wide range of duct opening angles [9]. Sun et al. [10] proposed to use the long short-term memory and weighted evaluation method to determine the health level of the WT. A sparse vector is obtained by the orthogonal matching pursuit algorithm, and subsequently the fault feature vector was extracted. The fault feature vectors were input to the improved AdaBoost-SVM classifier to realize WT condition assessment [11].

The pitch system, which is the core control component of WTs, has been investigated extensively.Khurshid et al. [12] proposed the Kalman filter to estimate the blade pitch angle and valve spool position of the blade pitch system for state evaluation. In response to the unbalanced sample categories and complex sample distribution of the operating data of the pitch system of the WT generator system, Tang et al. [13] proposed a method for the fault detection of the pitch system of the WT generator system based on the multiclass optimal margin distribution machine. Zhu et al. [14] proposed multiple model adaptive estimation model based on an extended Kalman filter to estimate the states of the pitch system. Fang et al. [15] proposed a neural network-based condition assessment method for the pitch system based on the characteristic parameters related to the operation status of the pitch system extracted from the SCADA system.

Expert systems and other methods are typically used for evaluating critical components of WTs [16]. In the expert system, historical experience and expert knowledge are used to evaluate the system, and updating the knowledge base is typically slow and difficult to maintain, which affects the feasibility of the method. VIKOR is a multi-attribute decision-making method based on ideal points by maximizing the group utility and minimizing the individual regret value for the trade-off ranking of finite decision options, and is mainly applied to the evaluation and selection of multi-attribute decision options in management science and socio-economic fields [17]. LINMAP is based on a two-by-two comparison of solutions given by the decision-maker and is a useful method used to determine the attribute weights and the optimal solution closest to the positive ideal point. The non-consistent model based on weighted Euclidean distance can be transformed into a linear programming model for solution, but the solution is still complex due to the presence of unconstrained variables in the model, especially in the case of a large number of objectives, and the solution will be high-dimensional [18]. WT system is a complex comprehensive system, which is affected by many factors, the number of system parameters is large, and the effect of each factor on the system is fuzzy. The evaluation method based on fuzzy theory not only overcomes the shortcomings of complexity, but also does not need to rely too much on experimental data, and better process uncertain information. At the same time, it also has a better processing mechanism for the fuzzy and random characteristics of index factors on system state, which makes this method more suitable for the state evaluation of important components of WT in complex operating environment.

In the aforementioned study, 10-min data were used for the analysis of the WT pitch system. However, the 10-min average data cannot reflect the real state of the pitch system satisfactorily. Therefore, this study analyzed the working state of the pitch system in the rated power state and the underpowered state of the WT based on the second-level data obtained from the SCADA data sample library. The characteristic parameters and physical mechanism of the pitch system were analyzed, and the principle of consistency of characteristic parameters, the principle of stability of power under rated state, and the principle of stability of blade angle underpowered state were proposed to evaluate the operation state of the pitch system. Most of the WT operating states are in the rated power state and under power state. Therefore, the evaluation indexes were established and the fuzzy comprehensive evaluation method was applied to establish the evaluation models of the operating status of the pitch

system under rated power state and the operating status of the pitch system to realize the evaluation of the operating status of the pitch system of the WT.

2 Introduction of the Pitch System

2.1 Working Principle of the Pitch System

The WT pitch system converts wind energy into electricity by controlling the generator speed to obtain the maximum wind energy utilization [19]. The pitch angle is the included angle between the fan blade and the plane of the wind wheel. When the wind speed is less than the rated wind speed, the pitch system maintains the blade angle at the minimum pitch angle so that the WT is in a state of maximum wind energy absorption. When the wind speed is greater than the rated wind speed and less than the cut-out wind speed, the turbine retains the output power near the rated power by adjusting the blade angle. When the wind speed exceeds the wind speed of the WT cut out, the pitch system accepts the command from the main controller to realize safe WT pitching [20]. The relationship between wind speed, pitch angle, and power are illustrated in Fig. 1.
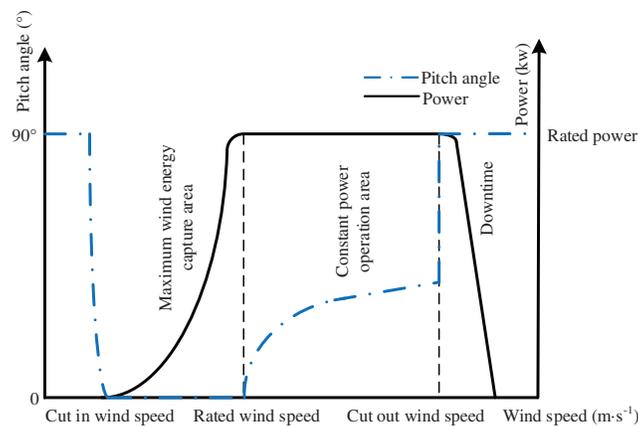
Figure 1: Variation curve of pitch system characteristics

2.2 Working State of the Pitch System

The pitch system is a key part of the WT control system. The pitch system behaves differently for different WT operating states.

2.2.1 Rated Power Status

When the actual wind speed is greater than or equal to the rated wind speed, and the output power of the WT remains near the rated power, the WT is in the rated power state. To ensure the stable power output of the WT, the pitch system adjusts the blade angle and wind energy generation by the unit according to the feedback power signal. Fig. 2 reveals that when the wind speed of the WT is greater than the rated wind speed, the pitch system adjusts the blade angle according to the wind speed to ensure stable output power of the WT.
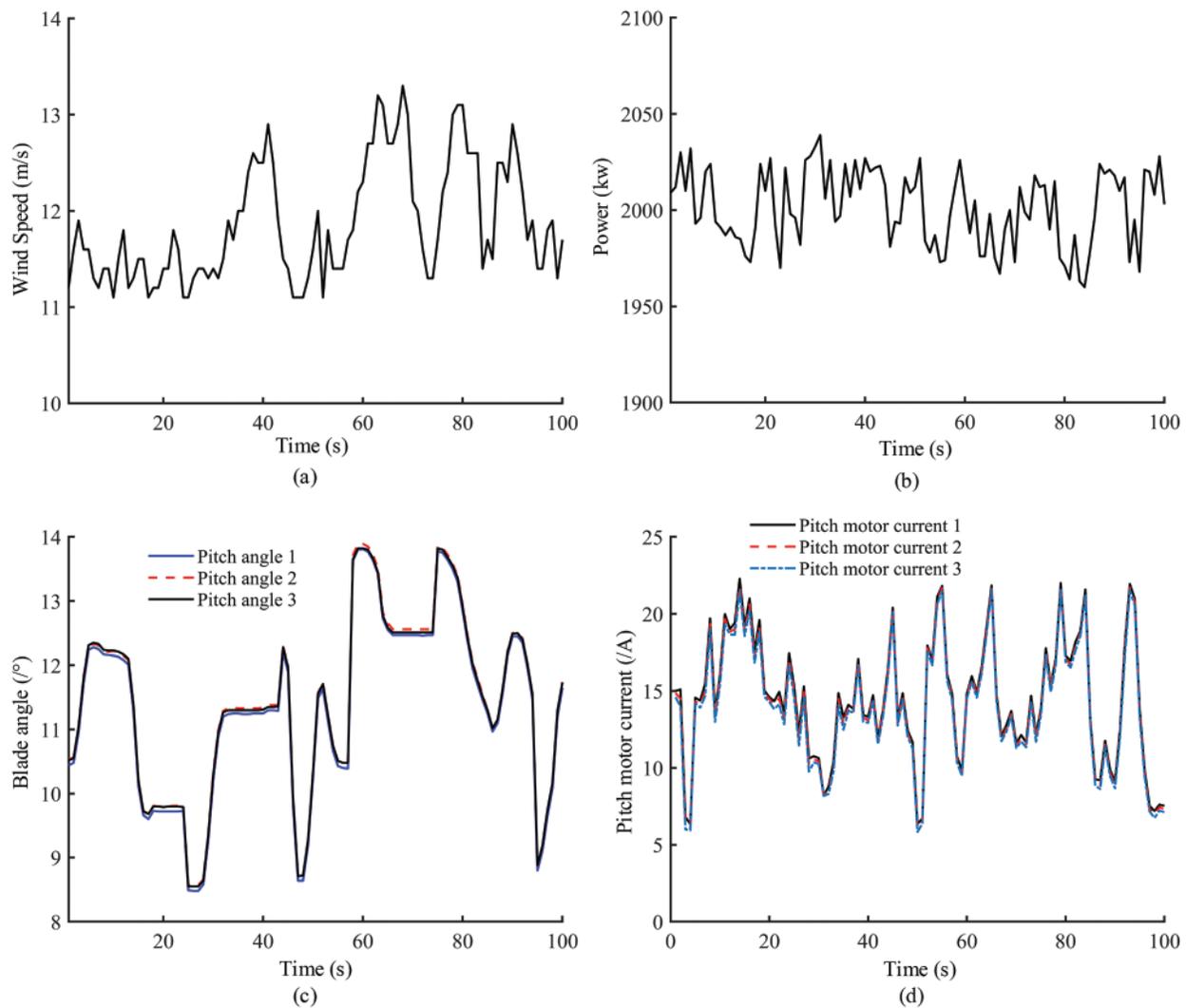
Figure 2: Rated power state, (a) Wind speed, (b) Power, (c) Blade angle, (d) Pitch motor current

2.2.2 Underpower State

The underpowered state refers to the operation state where the generator is connected to the grid, but the wind speed does not reach the rated wind speed; therefore, the WT is below the rated power. The output power of the WT does not reach the rated power, but the WT is in the power generation state, and the main purpose of the pitch system in this state is to ensure that the wind energy is captured to the maximum extent. Fig. 3 reveals that when the WT is in the underpowered state, the blade angle is kept near 0° to let the unit fully utilize the wind energy.
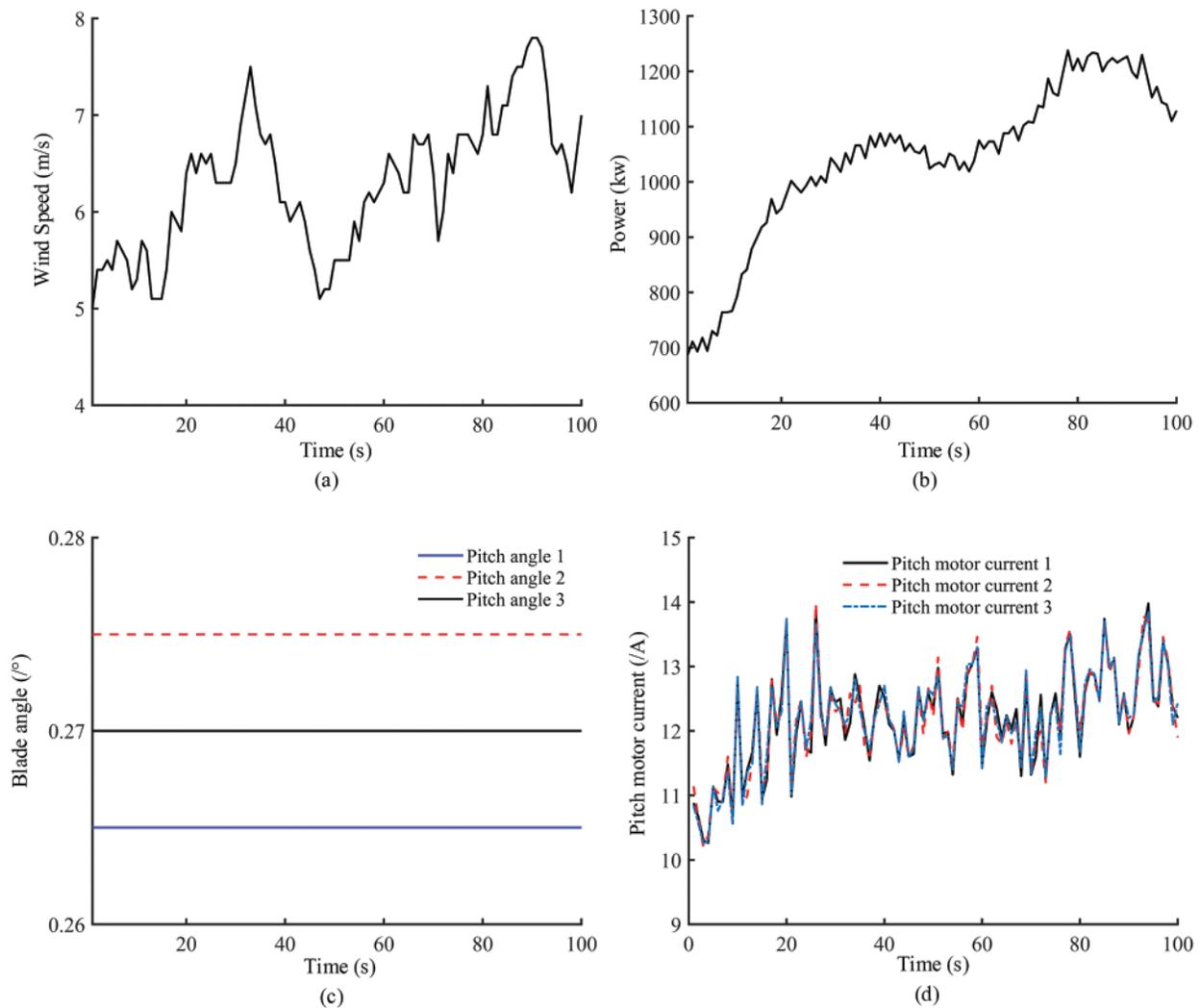
Figure 3: Underpowered state, (a) Wind speed, (b) Power, (c) Blade angle, (d) Pitch motor current

2.3 Control Method of the Pitch System

The pitch angle variation is realized by controlling the current of the pitch motor and using the stalling torque and wind speed to achieve the pitch and ensure stable operation of the system. Current control exists in all states of the WT. The pitch motor current changes according to the actual wind speed condition. When the actual wind speed increases or decreases, the pitch motor current also increases or decreases to adjust the blade angle at the right position. The WT underpower condition and rated power condition were analyzed. Fig. 4 displays the pitch state under the underpower condition. In the underpower condition of the WT, the pitch system does not change angle, but the locked-rotor current still maintained to keep pitch system working. The current follows the wind speed variation. Therefore, the blade angle is kept near 0° so that the WT can capture the maximum energy.
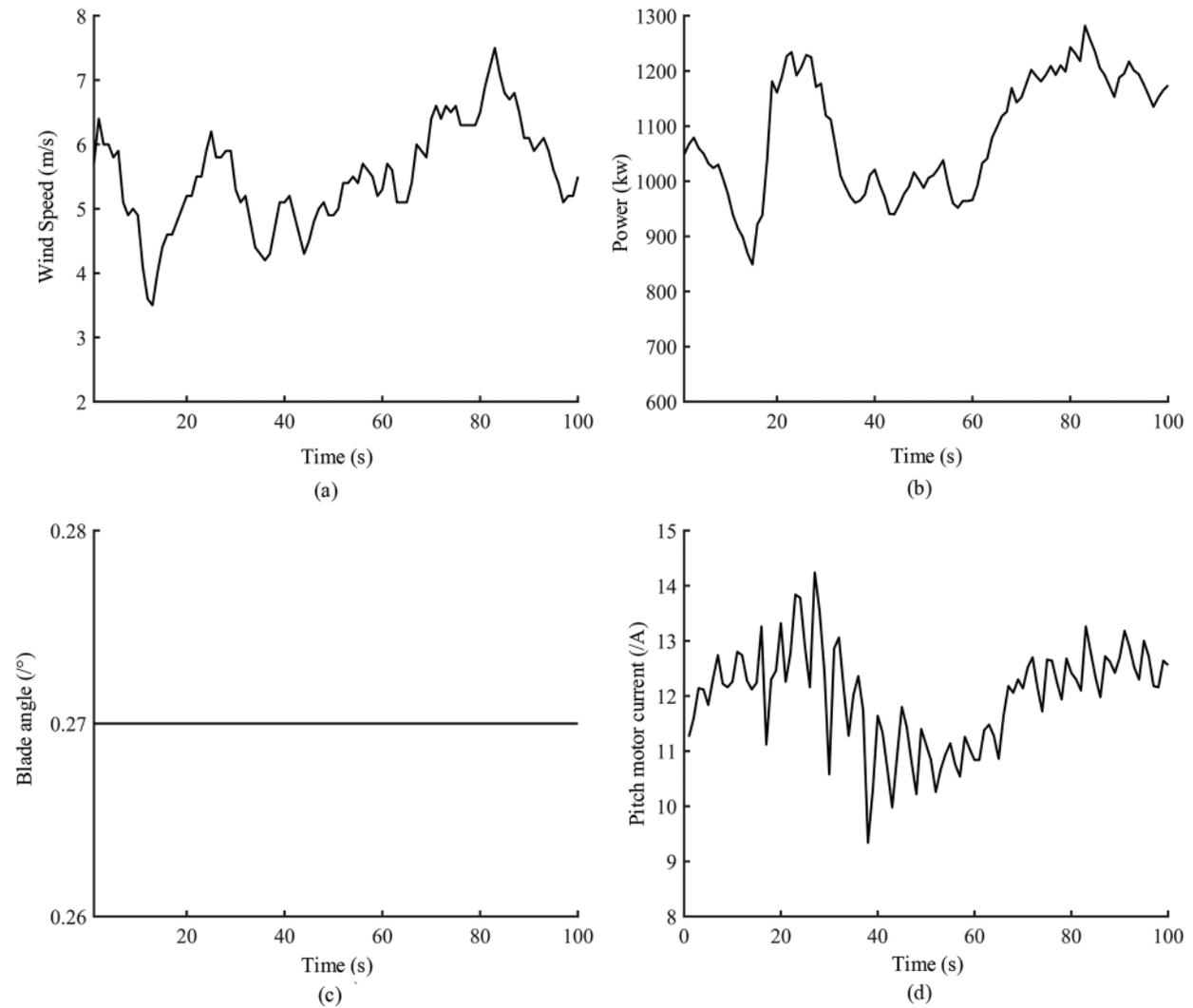
Figure 4: Pitch state in the underpowered condition, (a) Wind speed, (b) Power, (c) Blade angle, (d) Pitch motor current

The pitch state at rated power is displayed in Fig. 5. The figure reveals that when the wind speed increases or decreases rapidly under the rated power condition, the pitch system controls the blade angle by locked-rotor current. Therefore, the output power of the WT is still maintained near the rated power.
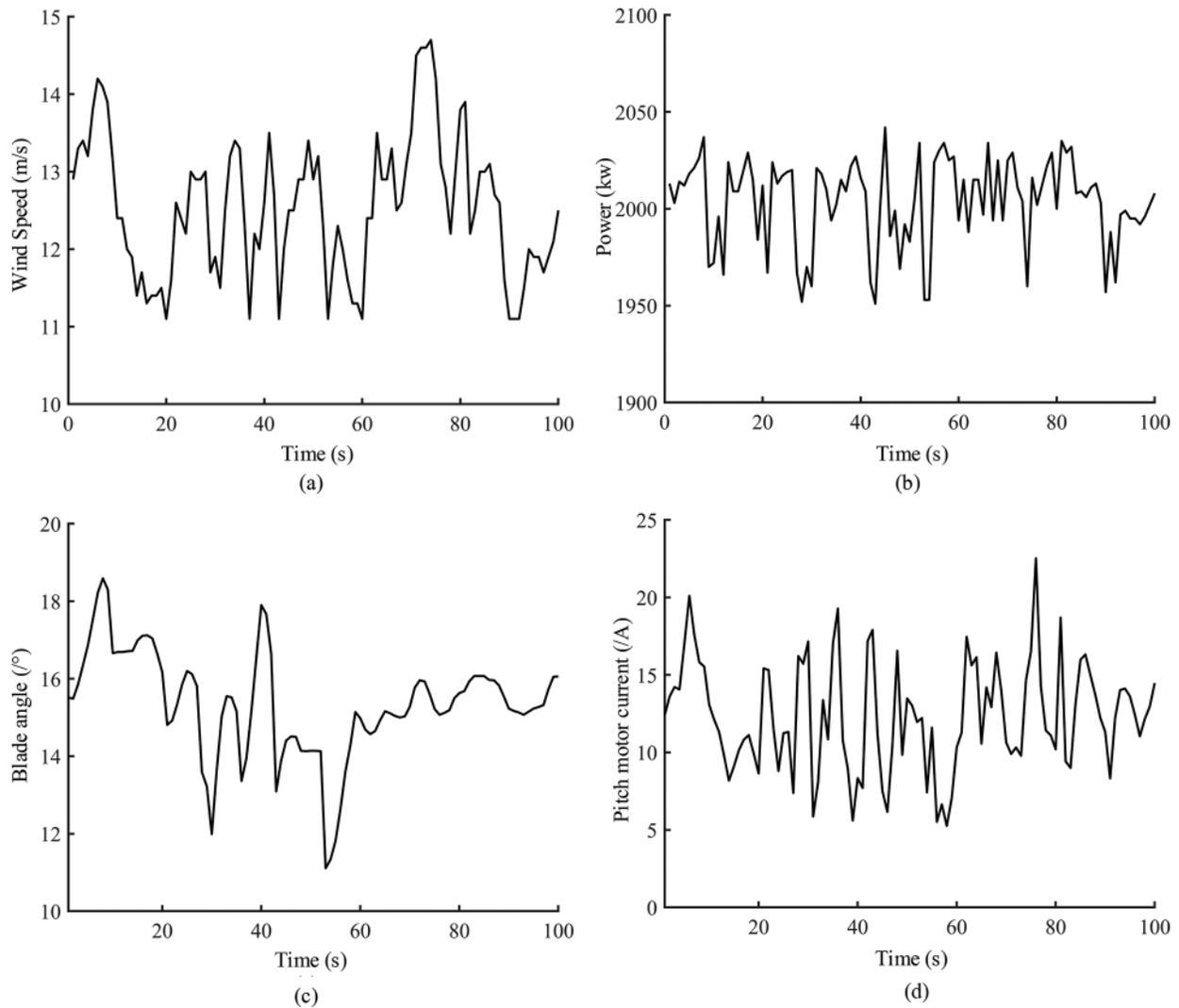
Figure 5: Pitch state at the rated power condition, (a) Wind speed, (b) Power, (c) Blade angle, (d) Pitch motor current

3 Pitch System Characteristic Parameters Analysis

3.1 Parameter Introduction

In this study, a 2-MW WT with a rated power of 2000 kW, cut-in wind speed of 3 m/s, rated wind speed of 11 m/s, and cut-out wind speed of 25 m/s, was investigated. The SCADA data selected were second-level data for July 2017. The SCADA system records the characteristic parameters corresponding to the pitch system, mainly including wind speed, power, blade pitch angle, and pitch motor current.

3.2 Characteristic Parameter Characteristic

(1) Consistency properties of feature parameters

Analyses of the pitch angle and pitch motor current data in the WT SCADA data and the physical mechanism revealed that the three pitch angles and pitch motor currents of the WT system should maintain similar trend and be close in value under normal operating conditions, as displayed in Figs. 2, 3 and 6.
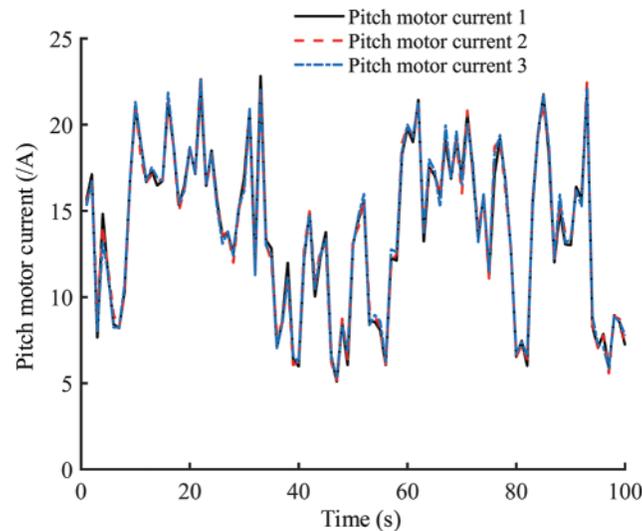
Figure 6: Pitch motor current

(2) Power stability under the rated state

When the WT is at rated power, the pitch system adjusts the blade angle according to the wind speed to ensure the stable output power of the WT as displayed in Fig. 2.

(3) Stability of the blade angle in the underpower condition

When the WT is in underpowered condition, the pitch system should stabilize the blade angle to work near 0° to allow the WT to obtain maximum wind energy, as displayed in Fig. 3.

4 Pitch System Evaluation Index

The power stability index, R_1, the angle stability index, R_2, the power residual index, R_3, and the pitch angle pitch motor current consistency index, R_4, were established by the analysis in the second and third parts of the paper. Because the power stability is closely related to the wind speed, the wind speed is introduced to establish the power residual index using the prediction model, and the state of the pitch system was analysed by calculating the ratio of the power residual to the theoretical power. In addition to the power residual, the working details of the pitch system should be considered. The details of the working of the pitch system were reflected by the pitch angle pitch motor current consistency index. The operating status of the pitch system was evaluated by organically combining these four indicators. Therefore, the power stability index R_1; the power residual index, R_3, and the pitch angle pitch motor current consistency index, R_4, were selected as the pitch system evaluation indexes under the rated power condition of the unit. The angle stability index, R_2, the power

residual index, R_3, and the pitch angle pitch motor current consistency index, R_4, were used as the evaluation indexes of the pitch system in the underpowered condition.

4.1 Power Stability Index

The power generation capacity of WTs is directly reflected by the output power of the turbine; therefore, the stability of the output power is a critical measure of the power generation capacity of WTs. The ratio of WT power fluctuation to its own installed capacity is δ_i. In this study, the average value of δ_i is calculated as the power stability index R_1.

$$\delta_i = \frac{P_{i+1} - P_i}{P}, \quad i = 1 \sim n - 1 \tag{1}$$

$$R_1 = \frac{1}{n-1} \sum_{i=1}^{n-1} |\delta_i| \tag{2}$$

where P_{i+1} is the sampled value of WT power in the current period; P_i is the sampled value in the previous period; P is the installed capacity of WT; and n is the number of sampling points.

4.2 Angle Stability Index

The variance of the three pitch angles is calculated separately, and then the average value of the variance of the three pitch angles is calculated. Finally, the average value of the variance of the pitch angles is used as the angle stability index R_2 as follows:

$$s^2 = \frac{\sum_{i=1}^{n}(X_i - \overline{X})^2}{n - 1} \tag{3}$$

$$R_2 = \frac{s_1^2 + s_2^2 + s_3^2}{3} \tag{4}$$

where X_i is the pitch angle data; $\overline{X}$ is the average of the pitch angle data; and n is the number of sampling points.

4.3 Power Residual Index

Three thousand sets of data of WT in normal operation were selected to develop the BP prediction model. The wind speed, three blade pitch angles, and three pitch motor current data were used as model inputs and the output was power. Here, 70%, 15%, and 15% of the sample data were selected as training data, validation data, and test data, respectively. The power residual is the difference between the actual power value of the WT and the predicted power value of the model. The theoretical wind speed power data provided by the wind farm was used to obtain the theoretical power, P_q, using the interpolation method with the wind speed as the input. The average value of the WT power residual, that is, the theoretical power ratio was calculated as the power residual index R_3.

$$R_3 = \frac{1}{n} \sum_{i=1}^{n} \frac{\left| P_{actual} - P_{predicted} \right|}{P_q} \tag{5}$$

where P_{actual} is the actual power value; $P_{predicted}$ is the predicted power value of the BP model; P_q is the theoretical power value; and n is the number of sampling points.

4.4 Pitch Angle Pitch Motor Current Consistency Index

Dynamic time regularisation algorithm (DTW) is used to measure the similarity between two time series. In this study, we first calculate the three pitch angles and three pitch motor currents separately to obtain the corresponding DTW distances. Next, the average relative deviation values of the corresponding DTW distances are calculated, and finally weight the average relative deviation values of the pitch angles and the average relative deviation values of the pitch motor currents were calculated to obtain the comprehensive consistency index R_4.

$$DTW(x,y) = \sum_{k=1}^{p} \left(x(w_x(k)) - y\left(w_y(k)\right) \right)^2 \tag{6}$$

$$\omega_\lambda = \frac{\left|DTW(x,y) - \overline{D}\right| + \left|DTW(x,z) - \overline{D}\right| + \left|DTW(y,z) - \overline{D}\right|}{3\overline{D}} \tag{7}$$

$$R_4 = \gamma\omega_\lambda + \eta\omega_\zeta \tag{8}$$

where $w_x(k)$ is the subscript of the element in sequence x; $w_y(k)$ is the subscript of the element in sequence y; p is the length of the regularisation path; $\overline{D}$ is the average DTW distance value; ω_λ is the average relative deviation value of the three pitch angles; ω_ζ is the average relative deviation value of the three pitch motor currents; γ, η is the weighting weight, considering $\gamma = \eta = 0.5$.

5 Development of the Fuzzy Evaluation Model for the WT Pitch System

Fuzzy comprehensive evaluation is the process of using fuzzy mathematics to quantify all the factors and indicators related to the evaluated parameter. Next, a reasonable comprehensive evaluation of each evaluation object was used by the principle of fuzzy relationship synthesis. In this study, the evaluation index is established by analysing the operation status of the pitch system, and the fuzzy comprehensive evaluation model was used to evaluate the pitch system of WT, and the flow chart is displayed in Fig. 7.
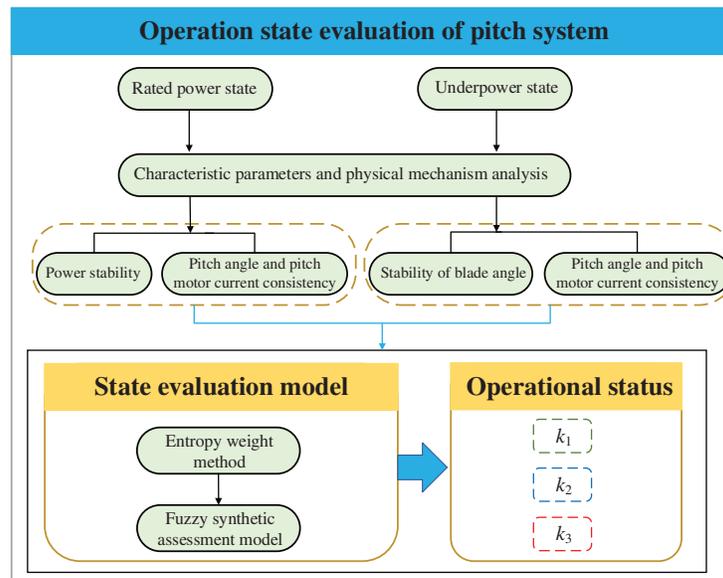
Figure 7: Flowchart of proposed in this study

5.1 Establishing the Appropriate Evaluation Set and Evaluation Criteria

The evaluation set is the set of comprehensive evaluation results of the WT pitch system, and the number of elements in the evaluation set is related to the complexity of the evaluation process [21,22]. To obtain reasonable evaluation results, the evaluation set of three elements was selected as the evaluation set for the evaluation of the WT pitch system in rated power state and under power state. Thus, the evaluation set was determined as $K = \{\text{Excellent, Good, Poor}\} = \{k_1, k_2, k_3\}$. The WT pitch system was evaluated using the evaluation index, and the affiliation of the state $k_i(i = 1, 2, 3)$ in the evaluation set $v_{ij}(j = 1, 2, 3)$. Next, the evaluation results of the index can be expressed by the affiliation set. This paper selects the widely used weighted average fuzzy operator $M = (\cdot, \oplus)$, where, $\cdot$ and $\oplus$ respectively represent algebraic multiplication and algebraic addition, that is, the sum of the product of weight value and evaluation value.

Power stability index R_1, angle stability index R_2, power residual index R_3 and pitch angle pitch motor current consistency index R_4 were considered as the evaluation indexes of WT pitch system. According to the relevant regulations and statistical analysis, the evaluation criteria of the WT pitch system in rated power state and underpowered state were obtained, as presented in Tables 1 and 2.

Table 1: Evaluation criteria at rated power

Evaluation index	Excellent	Good	Poor
R_1	0.010	0.015	0.020
R_3	0.01	0.03	0.04
R_4	0.2	0.3	0.4

Table 2: Evaluation criteria in underpowered condition

Evaluation index	Excellent	Good	Poor
R_2	0.010	0.15	0.30
R_3	0.050	0.080	0.12
R_4	0.2	0.3	0.4

5.2 Membership Function

Because calculating the distribution function of the triangular and semi-trapezoidal combination is easy and does not differ considerably from the results calculated by other complex affiliation functions [23]. In this study, this function is used to establish the affiliation functions of each indicator corresponding to various state levels.

For smaller, the membership function is calculated as follows:

$$g(x) = \begin{cases} 1, & x < \alpha \\ \dfrac{\beta - x}{\beta - \alpha}, & \alpha \leq x \leq \beta \\ 0, & x > \beta \end{cases} \tag{9}$$

where $g(x)$ is the membership function of the evaluation index; x is the measured value of the evaluation index; α is the allowable value of the index; and β is the limit value of the index.

For Intermediate type, the membership function is calculated as follows:

$$g(x) = \begin{cases} 0, & x < \alpha_1 \\ \dfrac{x - \alpha_1}{\beta_1 - \alpha_1}, & \alpha_1 \leq x < \beta_1 \\ 1, & \beta_1 \leq x < \alpha_2 \\ \dfrac{\beta_2 - x}{\beta_2 - \alpha_2}, & \alpha_2 \leq x < \beta_2 \\ 0, & x \geq \beta_2 \end{cases} \tag{10}$$

where $g(x)$ is the membership function of the evaluation index; x is the measured value of the evaluation index; α_2, β_1 is the allowable value of the index; α_1, β_2 is the limit value of the index.

For larger, the membership function is calculated as follows:

$$g(x) = \begin{cases} 0, & x < \alpha_3 \\ \dfrac{x - \alpha_3}{\beta_3 - \alpha_3}, & \alpha_3 \leq x \leq \beta_3 \\ 1, & x > \beta_3 \end{cases} \tag{11}$$

where $g(x)$ is the membership function of the evaluation index; x is the measured value of the evaluation index; α_3 is the allowable value of the index; and β_3 is the limit value of the index.

5.3 Determination of Evaluation Index Weights

The key link in fuzzy comprehensive evaluation is the value of the weights, which directly reflects the degree of influence of various assessment indicators on the evaluation results [24]. The value of the weights is generally determined by expert experience, which is typically highly subjective and not conducive to reflecting objective facts. To reduce the subjectivity present in determining the weights and ensure the evaluation results become reliable, the entropy weight method is used to determine the index weights. The entropy weighting method is based on the principle that the smaller the variability of an indicator, the less information it reflects, and the lower its corresponding weight should be [25]. Assuming that m evaluation indicators and n objects exists, for the j-th indicator, its calculation formula is as follows:

$$e_j = -\frac{1}{\ln(n)} \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \tag{12}$$

Let the information utility value and the weight of the j-th indicator be g_j and w_j, respectively.

$$g_j = 1 - e_j \tag{13}$$

$$w_j = \frac{g_j}{\sum\limits_{j=1}^{m} g_j} \tag{14}$$

6 Application and Analysis

To verify the effectiveness and accuracy of the evaluation method of the WT pitch system proposed in this study, two sets of data in the underpowered condition and three sets of data under the rated

power condition of the WT were selected for analysis. Here, 300 data points were obtained for each set of data. Each evaluation index obtained by calculating each group of data is presented in Table 3. In this paper, the distribution function of triangle and semi trapezoid combination is selected to establish the membership function of each index corresponding to different state levels. As shown in Fig. 8.

Table 3: Value of each evaluation index

Wind turbine status	Group number	R_1	R_2	R_3	R_4
Underpower status	1	—	0	0.0554	0.181
	2	—	0.3895	0.1064	0.417
	3	0.00880	—	0.0124	0.105
Rated power state	4	0.0131	—	0.0320	0.327
	5	0.0231	—	0.0466	0.375
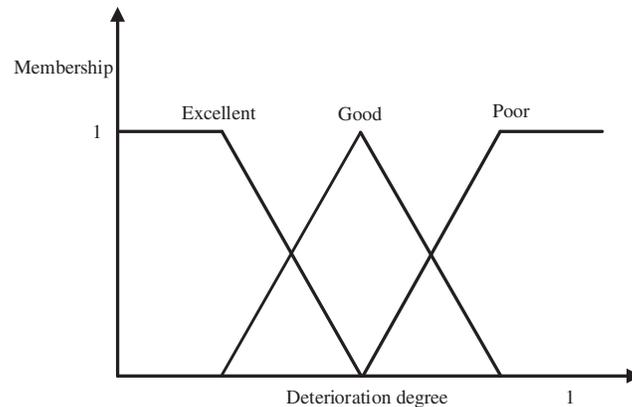
Figure 8: Distribution map of half-ladder-shaped and triangular membership function

Because the pitch system of WT in rated power state is primarily used to maintain the stability of power, the pitch system of WT in under power state is primarily to maintain the stability of pitch angle. Therefore, the evaluation index weights of these two states are not the same. By using the entropy weighting method, the evaluation index weight of the pitch system in the underpowered state is $A_1 = [0.483\ 0.223\ 0.294]$, and the evaluation index weight of the pitch system in the rated power state is $A_2 = [0.441\ 0.275\ 0.284]$. According to the subordinate function determination method introduced in the study, the evaluation matrices of the pitch systems in the underpower and rated power states were obtained as follows:

$$V_1 = \begin{bmatrix} 1 & 0 & 0 \\ 0.82 & 0.18 & 0 \\ 1 & 0 & 0 \end{bmatrix} \tag{15}$$

$$V_2 = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0.34 & 0.66 \\ 0 & 0 & 1 \end{bmatrix} \tag{16}$$

$$V_3 = \begin{bmatrix} 1 & 0 & 0 \\ 0.88 & 0.12 & 0 \\ 1 & 0 & 0 \end{bmatrix} \tag{17}$$

$$V_4 = \begin{bmatrix} 0.38 & 0.62 & 0 \\ 0 & 0.8 & 0.2 \\ 0 & 0.73 & 0.27 \end{bmatrix} \tag{18}$$

$$V_5 = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 0.25 & 0.75 \end{bmatrix} \tag{19}$$

The results of the state evaluation of the pitch system in the underpowered and rated power states according to the fuzzy judging principle are as follows:

$$B_1 = A_1 \times V_1 = [0.960 \quad 0.0400 \quad 0] \tag{20}$$

$$B_2 = A_1 \times V_2 = [0 \quad 0.0758 \quad 0.9242] \tag{21}$$

$$B_3 = A_2 \times V_3 = [0.967 \quad 0.0330 \quad 0] \tag{22}$$

$$B_4 = A_2 \times V_4 = [0.167 \quad 0.701 \quad 0.132] \tag{23}$$

$$B_5 = A_2 \times V_5 = [0 \quad 0.0710 \quad 0.929] \tag{24}$$

According to the principle of maximum affiliation, the affiliation degrees of B_1, B_2, B_3, B_4 and B_5 are 0.960, 0.9242, 0.967, 0.701 and 0.929, respectively, which leads to the evaluation results of group 1 and group 3 data as excellent, the evaluation results of group 4 data are good and the evaluation results of group 2 and group 5 as poor respectively. The data timing diagram of group 1 data is displayed in Fig. 9, which reveals that when the WT is in the underpowered state, the pitch motor current changes with the wind speed, the stability of the blade angle is good and remains basically unchanged, and the consistency of the pitch motor current is good, which is consistent with the evaluation results of this paper.
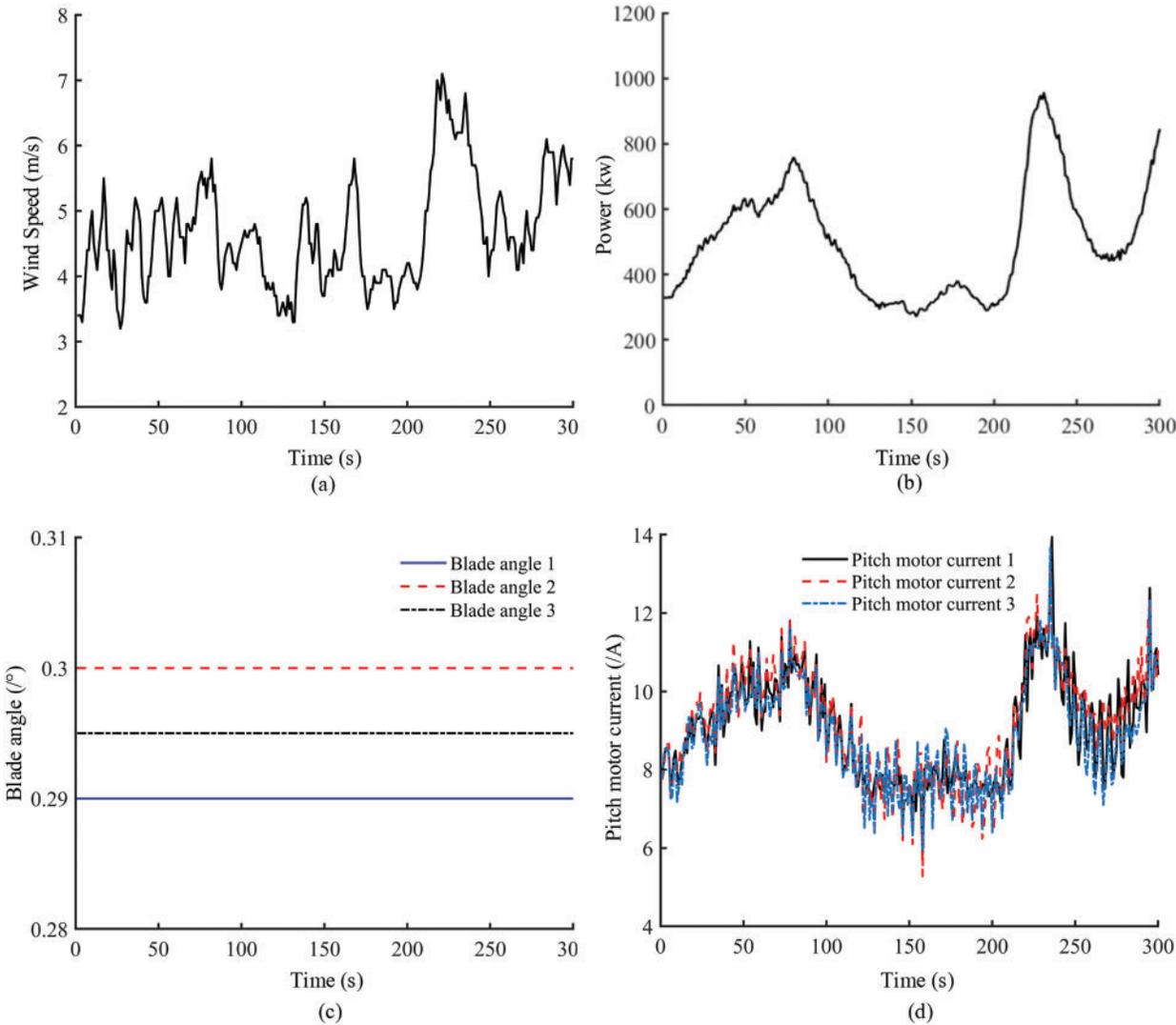
Figure 9: First set of data underpowered state, (a) Wind speed, (b) Power, (c) Blade angle, (d) Pitch motor current

The data timing diagram of group 2 data is displayed in Fig. 10. It can be seen that when the WT is underpower state, the fluctuation of blade angle is large, and the consistency of pitch motor current is poor, which is basically consistent with the evaluation results in this paper.
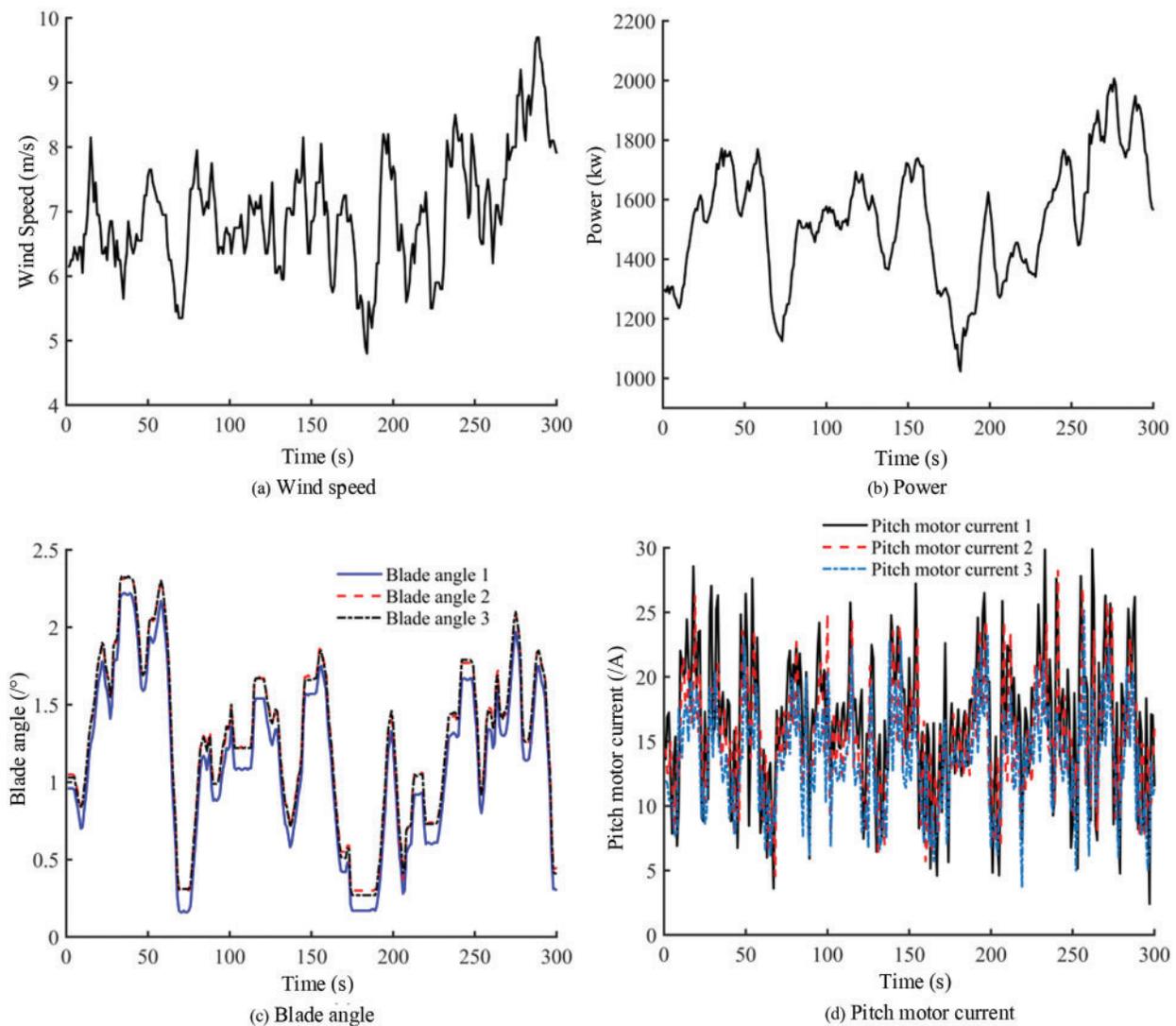
Figure 10: Second set of data underpowered state, (a) Wind speed, (b) Power, (c) Blade angle, (d) Pitch motor current

The data power time series plots of groups 3, 4, and 5 data are presented in (a), (b), and (c) in Fig. 11, the variance and coefficient of variation were selected as parameters to measure the stability of the three groups of power data in Table 4. Comparing the data in Fig. 11 and Table 4, the stability of the power of group 3 data is better than that of group 4 data, and the stability of the power of group 4 data is better than that of group 5 data, which is consistent with the evaluation results of the three groups of data at the rated power condition. This result also verifies the validity and accuracy of this evaluation method.
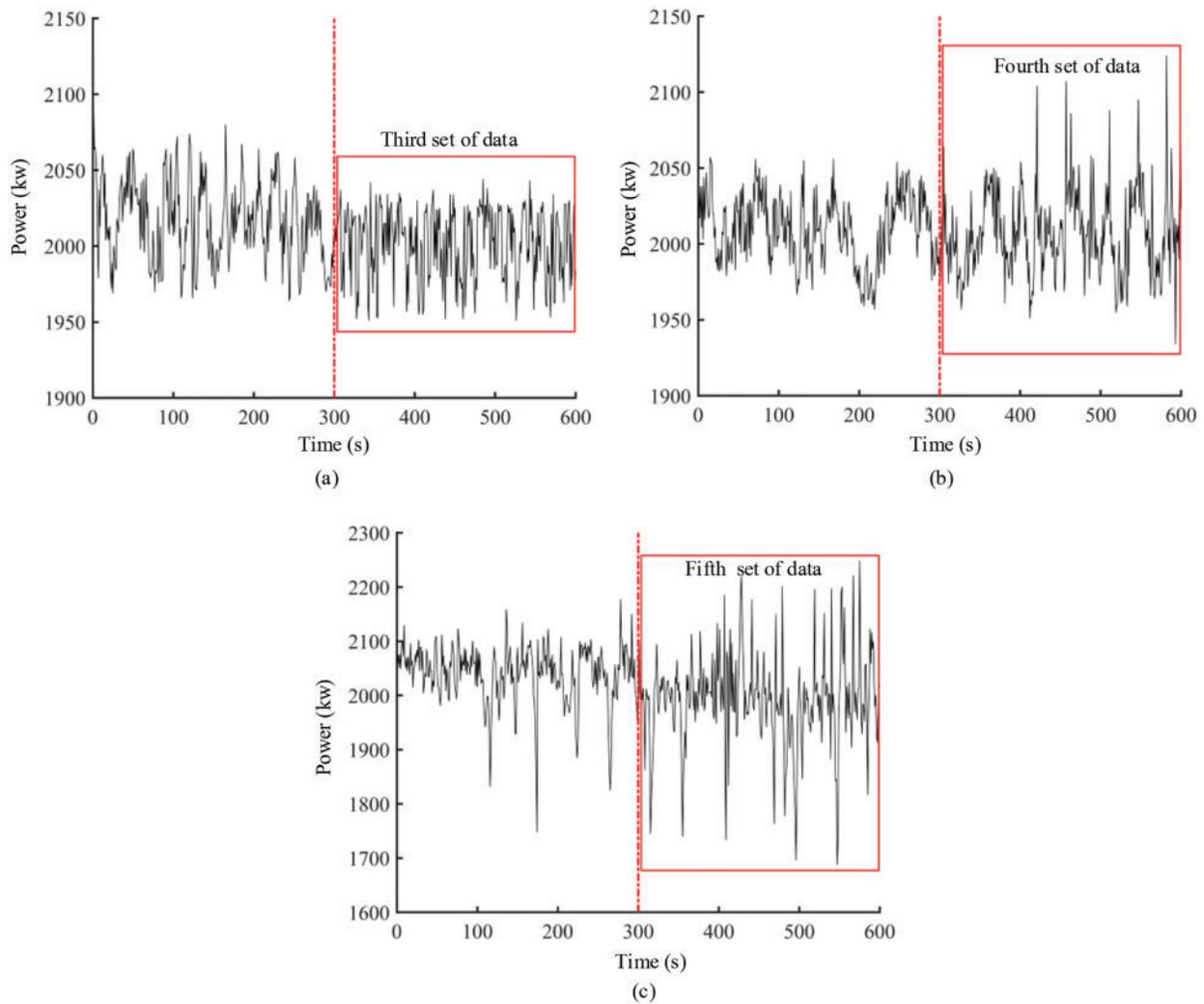
Figure 11: Rated power state timing diagram, (a) Third set of data, (b) Fourth set of data, (c) Fifth set of data

Table 4: Evaluation index value

Data	Variance	Coefficient of variation
Third set of data	545.27	0.0117
Fourth set of data	810.56	0.0142
Fifth set of data	3527.13	0.0428

7 Conclusion

A novel method for evaluating the operating condition of the WT pitch system was proposed in this paper. Five sets of actual data are analysed and compared with the actual operating condition

of the turbine to verify the effectiveness of the method. When the underpower condition is poor, the fluctuation of blade angle is large, and the consistency of pitch motor current is poor. The rated power condition is judged by the index variance and coefficient of variation. The new method proposed in this paper can better evaluate the operating condition of the pitch system, find hidden dangers in time, and avoid safety accidents.

This study proposed a pitch system condition assessment method to evaluate the operational status of the pitch system. However, identifying the specific type of fault should be considered in the future. This study focused on the pitch system to establish indicators by describing the operation status using the fuzzy comprehensive evaluation method to assess its operation status. In the future, the method will be extended to other aspects of the WT, such as generator, gearbox, yaw system, even the whole WT system.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

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