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Research on Fault Diagnosis Method of Wind Turbine based on CS and LS-SVM

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Abstract

This paper presents a fault diagnosis method based on CS and LS-SVM .Firstly, the main component analysis method is used to reduce the dimension of generator operation data, so as to reduce the complexity of parameter data and facilitate the acquisition of principal component features. Secondly, the least-squares support vector machine is used to construct training samples, obtain decision functions, and create a fault classifier model for the acquired principal component feature data to realize the classification of generator running state. Among them, the parameters c and g of the least squares support vector machine are optimized by cuckoo search algorithm. To verify the accuracy of the diagnosis model is created, two turbines were measured using a wind farm in Ningxia run data based on CS and LS-SVM validation of wind turbine fault diagnosis model, validated shows that after dealing with the dimension reduction of least squares support vector machine classifier can effectively identify generators of different fault, to verify the effectiveness of the design method.

Keywords

Wind turbine; Principal component analysis, least squares support vector machine; Data complexity; Fault diagnosis.

1. Introduction

Wind turbine fault diagnosis includes feature extraction and fault diagnosis.Among them, fault features are important indicators to judge the running state of equipment, and eliminating redundant features is an effective path to improve diagnostic efficiency [1-2].Principal component analysis (PCA) is an effective method to analyze data in multivariate statistics. In order to reduce the complexity of the original data samples, the sample information is described by replacing the original data description with the minimum feature quantity under the condition of ensuring the integrity of the information.PCA algorithm is adopted to extract fault features in literature [3], literature [4] and literature [5], which can simplify the model and maintain the information of original data, so as to facilitate calculation.In literature [3] and literature [4], PCA and neural network are used for fault diagnosis, which improves the accuracy. However, it is not easy to optimize the parameters of the constructed diagnostic model.LS-SVM algorithm is adopted in literature [6], literature [7] and literature [8], which has high fault classification accuracy and fast recognition and classification speed, and has been verified in practice and widely used.

As the core equipment of the wind turbine, the wind turbine is located in the engine room, and the wind turbine has been working in bad environment for a long time, and its stress condition is complex, and its operation condition is affected by many factors. Based on this, this paper proposes a fault diagnosis method of the wind turbine based on PCA and LS-SVM.The fault data were dimensionalized by PCA algorithm, and the sensitive feature, namely principal component, was

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obtained to replace the original information, which was used as the input quantity of the constructed LS-SVM classifier. The input classifier was trained to find the support vector of sample data and the optimal classification hyperplane, and finally the fault diagnosis was carried out on the test data.The effectiveness of the proposed method is verified by the actual fault diagnosis of the measured data of a wind farm in ningxia.

2. Cuckoo optimization ls-svm algorithm design

2.1 Cuckoo algorithm optimization of SVM parameters

Cuckoo Search (CS) is a heuristic optimization algorithm invented by Susah Deb of Cambridge university in 2009 according to the characteristics of Cuckoo.Later, scholars used a large number of examples to test and prove that this optimization algorithm is superior to common optimization algorithms in many aspects, such as particle swarm optimization and genetic algorithm.The advantages of CS lie in strong global search ability, good universality and robustness, fewer parameters and fast convergence, etc. Cuckoo search algorithm has been widely used.

Cuckoo search algorithm optimization of least squares support vector machine (CS-LS-SVM) parameters [9]c and g steps are as follows:

(1) Training samples were collected and preprocessed. In this paper, PCA algorithm was used to reduce the dimension of data, and the ls-svm model training samples were obtained.

(2) Determine the value range of parameters c and g according to experience and actual situation, as well as the maximum stride length $s_{\max}$, minimum step length $s_{\min}$ and the total iteration number N of cuckoo search algorithm.

(3) Set the initial probability parameter P_a as 0.25, randomly generate the position $P_i^{(0)} = [x_1^{(0)}, x_2^{(0)}, \cdots, x_n^{(0)}]^T$ of n nests, and each nest corresponds to a set of parameters (c, g). Calculate the fitting degree of training set corresponding to each nest position, and find the best nest position $x_b^{(0)}$ and the best fitting degree $F_{\max}$.

(4) Retain the best position of the previous generation of nests, calculate the step size of Levy's flight according to the step size adaptive adjustment strategy, and calculate the position of other nests according to the step size, obtain a group of new nests, and calculate the fitting degree F of the new nests.

(5) According to the fitting degree F, the new nest position is compared with that of the previous generation, and the position with better fitting degree is substituted for the position with poor fitting degree, so as to update the nest position and obtain a group of new nest position $P_t^{(0)} = [x_1^{(t)}, x_2^{(t)}, \cdots, x_n^{(t)}]^T$.

(6) The bird's nest position after the update, will be randomly generated a number of r, compared with random number r and Pa , retain probability of Pt was found to be smaller as the bird's nest, and the detection probability of the larger bird's nest is updated, the fit of the computation of the bird's nest, and comparing with the fit of the bird's nest in the location of the Pt with good bird's nest instead of the cross location, get a new set of the optimal position of the bird's nest Pt .

(7) Find the optimal nest position $x_b^{(t)}$ in (6), judge whether the fitting degree F meets the requirements, if so, stop the search, output the global optimal fitting degree F_{max} and the corresponding optimal nest position $x_b^{(t)}$;Otherwise, return to step (4) to continue the search.

(8) A set of parameters (c, g) corresponding to the optimal nest location are the optimal parameters sought, and ls-svm parameters are selected according to the optimal parameters c and g.

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2.2 Fault diagnosis model integrating CS and LS-SVM

LS-SVM uses radial basis function as kernel function, cuckoo search algorithm is adopted to optimize parameters c and g of LS-SVM, find the optimal parameters, and optimize the classifier model.PCA and LS-SVM fault diagnosis model [10] were used to analyze data and obtain feature vectors, which were used as training and test data of LS-SVM model for fault diagnosis.The fault diagnosis process based on PCA and LS-SVM is shown in figure 1.

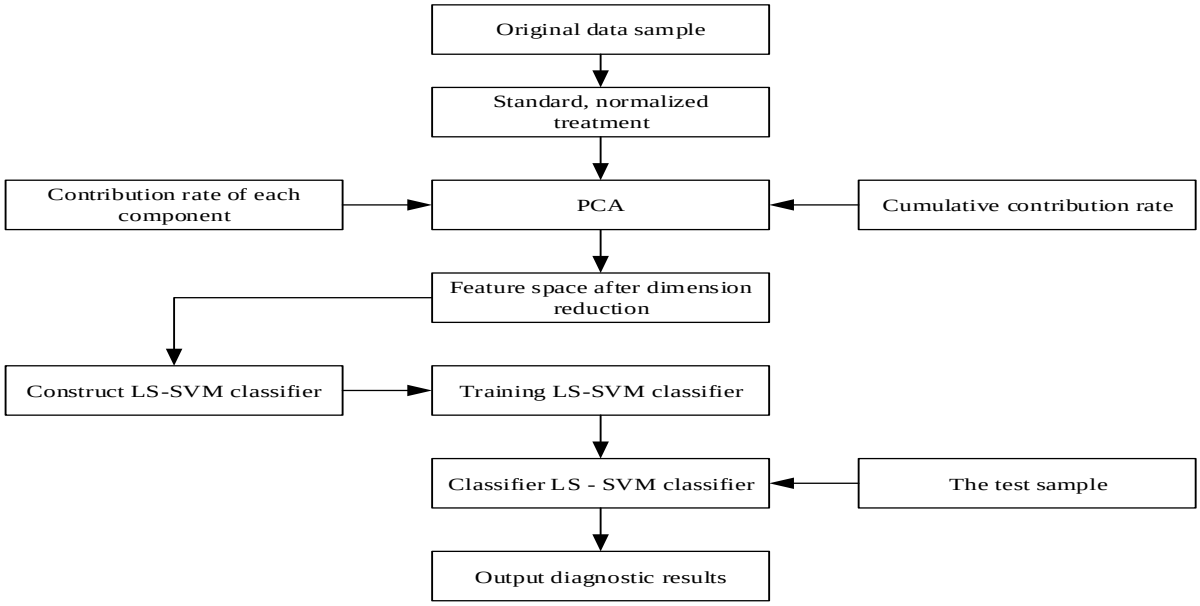

Figure 1. Fault diagnosis process based on CS and LS-SVM

3. Experimental results and analysis

The data set was extracted through dimension reduction processing of PCA algorithm to obtain ls-svm feature vectors, which were used as training samples of ls-svm model.RBF kernel function was used in LS-SVM model.Firstly, the parameters c and g of the model are optimized.Secondly, the fault classification model is constructed by training samples and corresponding support vectors are obtained.

After the cuckoo search algorithm optimizes the model parameters, the model is trained with the training samples of three kinds of faults, and the trained model is tested and diagnosed with the test samples to check the accuracy of the established model. The results are shown in table 1.

As can be seen from table 1, the fault diagnosis model constructed in this paper is 100% accurate in the diagnosis of temperature overrun of generator bearing and general fault of spindle, and the diagnosis of bearing wear fault has reached a high level, meeting the actual demand.

Table 1. Fault test and diagnosis results

Fault types	Generator bearing temperature exceeds limit	Bending of the crankshaft	Bearing wear
Sample number	1-60	61-120	121-180
Correct number of diagnoses	60	60	58
correct	100%	100%	96.67%

In fault classification and identification, different classifiers will have a great impact on the classification results, but the same classifier using different parameter optimization algorithms will also have a great impact on the classification results. The LS - SVM classifier, the PCA dimension reduction after nine characteristics of the vector is input into the LS - without the cuckoo tuning parameters and optimized the cuckoo parameters in SVM classifier of LS - SVM classifier, the results

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of the two, such as shown in table 2, the results showed that the cuckoo search algorithm of LS-SVM model parameters optimization for wind power generator fault identification, is practical.

Table 2. Comparison of classification effects of different optimization classifiers

Classification method	Classification accuracy
LS-SVM with unoptimized parameters	80.02%
Cuckoo algorithm optimization LS-SVM	100%

4. Conclusion

Aiming at the failure of wind turbine bearing such as temperature overlimit and bearing wear, a fault diagnosis method combining cuckoo algorithm and minimum support vector machine is adopted. Firstly, principal component analysis (PCA) is used to reduce the dimension of fault characteristic data, and the main components are extracted as feature vectors. Secondly, cuckoo search algorithm is used to optimize the parameters c and g of the constructed least-squares support vector machine classification model. Through the diagnosis and classification of the actual fault data, the results show that the accuracy of the identification of the temperature overlimit of the generator bearing and the bending crankshaft fault is 100%, and the identification rate of the bearing wear fault is not complete, but it can meet the actual demand of wind power plant. In order to further verify the effectiveness of the proposed method, different comparisons are made. The results show that the fault diagnosis method based on the combination of CS and ls-svm improves the efficiency of fault diagnosis of wind turbines and verifies the effectiveness of the method. It can be used for reference in the fault diagnosis of other wind turbine equipment.

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