Fire detection and identification of wind turbines based on information fusion

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Abstracts: In this paper, the wind turbine operating environment studied, wind turbine fires detection method based on information fusion. The simulation tests proved the feature layer can be well judged the probability of fire, smoldering fire probability and no fire probability. And in the decision-making drawn the decision of fires probability. Can effectively reduce the probability of fires.

Introduction

In recent years, wind energy has become a very important part of therenewable energy development. At present, the domestic wind power industry is developing rapidly, more and more high-power wind turbines in operation, while wind power equipment accidents, particularly fire accident occurs frequently. Due to environmental and internal structure, etc., once the wind turbine fires, it is difficult to fight the blaze and it will result in huge losses. With the rapid development of China's wind power to solve the wind farm fire safety is especially important. With the increase requirement of the fire detection response sensitivity and anti-jamming capability,the complex multi-sensor fire detection technology has become a hot of the fire detection technology research.

About the cause and measures that should be taken for wind turbine fires ,in the reference [2] pointed out that as the internal wind turbine system may use a lot of natural, combustible materials, when these systems have any damages or temperature is high, can become a fire hazard. It pointed out that the fire fighting system of wind turbines generally include the following devices in reference[3]: temperature sensors, smoke sensors, flame detectors, air sampling detectors. In the reference[4], the authors proposed to combine wind power monitoring system to establish fire alarm and fire suppression linked control system to achieve early fire detection and control system. The reference[5]recommends setting automatic fire detection system in the nacelle and the tower of the wind turbine.

Wind power fire detection based on information fusion

For the issues raised above, we propose a wind fire detection method based on information fusion. Information fusion technology uses the characteristics of different types of sensors, to obtain more comprehensive information on different attributes, analysis, estimates and overall judgment of this information. Reasonable deal with some redundancy, complementary and multi-source information of each sensor provide synergistic.To obtain a precise estimate of the status and identity, as well as a complete assessment of the situation timely[6]. For the complexity of wind turbine structure, we should consider all aspects of wind power turbines that catch fire easily. Application of information fusion technology for fire detection signal processingachieve information integration at the data level, feature-level, decision-making level of the three levels. This method can reduce the data affected by the state of the environment and the characteristics of the sensor itself. Thus reducing loss of information in the data fusion process, and then you can more accurately determine the probability of occurrence of fire. And constantly optimization and integration in order to take more effective fire prevention measures to reduce the losses caused by wind turbines fire.

Information data layer fusion

Information fusion data layer is mainly on original data collected by the sensor is processed to extract feature vectors from the fusion of data. Comprehensive analysis of the data before the various sensors original observation information without pretreatment. Advantages of data layer is to keep as many as possible of original data, but because of the large amount of information, handle real-time worse. In this study, the main selection temperature, smoke density, CO gas concentration, three kinds of sensors to detect the value of original data of wind turbines for judging the probability of occurrence of fire. In order to meet the different seasons and different local environmental requirements, pretreatment of this article, is a dynamic time algorithm threshold, that is exceeds a threshold based on the detected signal , and by determining whether the time exceeds the threshold set by the dynamic ultrahigh time to determine whether further processing

Information feature level fusion

Feature level fusion refers to the observed data for each sensor for feature extraction in order to obtain a feature vector, and then integrate these feature vectors, and based on fusion feature vector for identity determination[6].Since the fire detection system mathematical model hard deterministic, we introduce the neural network algorithm.

It is characterized in dealing with and solving problems, accurate mathematical model does not require objects; It has a strong learning ability, features and characteristics for which data are distributed through a specific learning algorithm; As parallel computing, processing speed. Therefore, the use of neural network algorithm is very suitable for fire detection. When using BP neural network for function approximation, adjust weights used in a negative gradient fell method. This adjustment weights approach has its limitations. That is there is a slow convergence and local minima and other shortcomings, and RBF neural network capacity in terms of approach, classification ability and learning speed are better than BP neural network. So RBF neural network can be used to complete the integration of the characteristics of fire layer. Feature integration layer structure shown in Fig.1.

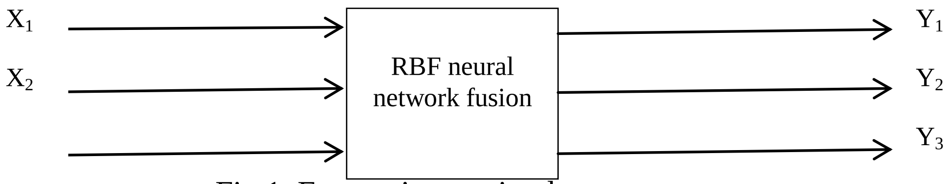

Fig.1. Feature integration layer structure

Which input parameters X_1、X_2、X_3denote the information layer after the pretreatment temperature signal, smoke concentration signal and CO concentration signal. After normalization fed into RBF neural network characteristic fusion. Draw fire probability Y_1, smoldering fire probability Y_2, non-fire source of interference probability Y_3.

RBF neural network consists of three layers. Input node just passes the input signal to the hidden layer, hidden layer neuron action functions most commonly used for the Gaussian function. Its expression is:

$$u_j = \exp\left[-\frac{(X - C_j)^T (X - C_j)}{2\sigma_j^2}\right] \quad j = 1,2,\ldots\ldots,N_h$$

Wherein u_j is the j-th hidden node output, X=（$x_1,x_2,\ldots\ldots,x_n$）^{T} is the input sample, C_j is the input value of the Gaussian function, σ_j is the normalization constant, N_h is hidden nodes. The output of the hidden layer RBF network is a linear combination of contact output. That is:

$$y_i = \sum_{j=1}^{N_h} W_{ij} u_j - \theta = W_i^T U \qquad i = 1,2\ldots\ldots, m$$

$$W_i = \left(W_{i1}, W_{i2}, \ldots, W_{iN_h}, -\theta\right)^T \quad U = \left(u_1, u_2, \ldots, u_{N_h}, 1\right)^T$$

RBF network learning process is divided into two stages. First stage, each node determines hidden layer based on all of the input sample values of the Gaussian kernel center C_j and the normalization constant σ_j. Second stage, after determining the parameters of hidden layer, according to the sample, using the least square principle, calculated output layer value W_i. After the completion of the second stage of learning, according to sample signals， parameters at the same time correcting the output layer and hidden layer, and further improve the accuracy of the network.

Information Decision-making Fusion

The basic function of the decision-making is to get the decision result in fire detection. Probabilities of different types of feature level fusion fire got, and on-site detection of information integration, the situation of a comprehensive analysis of fire fire. To obtain accurate and reasonable fire analysis. The decisions of fire decision-making information fusion are based on policy-making factors we selected. But these factors do not use the value determined to represent, but fuzzy nature of having a variable. Therefore, fuzzy reasoning in the decision-making. Input and output variables of fuzzy inference are all fuzzy variables, more suitable to solve some problems with the precise mathematical model is difficult to express.

Fuzzy logic control system usually consists of the fuzzy controller, input and output interfaces, actuators, controlled object and measuring device component. Fuzzy controller is the core component of the fuzzy logic control system. The basic structure of the fuzzy logic controller is shown in Fig.2. Its main component is a fuzzy process, knowledge base, reasoning decision logic and precision computing. The main function of its completion follows:

I Fuzzified: The measured value of the control object is converted from digital to fuzzy quantity, that is fuzzy process. Fuzzy interfaces and knowledge to complete.

After the feature layer processing we can get Open flames probability Y_1， smoldering fires probability Y_2 and the probability of interference non-fire source Y_3. They are inputs of the second design. In order to make better decisions, the fire signal duration T is added to the input. When the probability of fire or smoldering fire probability is greater than 0.5, start timing.

II Fuzzy Reasoning Decision: The amount of fuzzy measured being fuzzy inference by the fuzzy logic rules, obtained the output inference result of fuzzy controller. This part is done by inference decision-making and fuzzy base. Fuzzy inference rules adopted Mamdani Act. Fuzzy control rules are determined by the relationship between the actual signal characteristics. The establishment of 27 fuzzy control rules in this article.

III Precise: The amount of reasoning output fuzzy changed into practical systems acceptable precision digital. This part is done by precise calculation. In this paper, using the gravity method. The center of gravity of fuzzy membership function curve and the abscissa enclosed area as the final output value of the fuzzy reasoning

The realization of simulation in feature level

This paper selects the standard data in Chinese standard fire SH4， Standard smoldering fires SH1 and typical interference signal to the kitchen environment (Germany Duisdurg municipal hospital kitchen) to do simulate. Proved out the accuracy and feasibility of the fire detection system. Send normalized fire signal data into neural network characteristic fusion, and then the implementation of feature level fusion. The fire recognized as three forms: fire, smoldering fires and non-fire source of interference， and then output the probability of a fire under three forms.The value of goal is 500. The maximum number of neural elements 500. RBF neural network training results shown in Fig. 2.

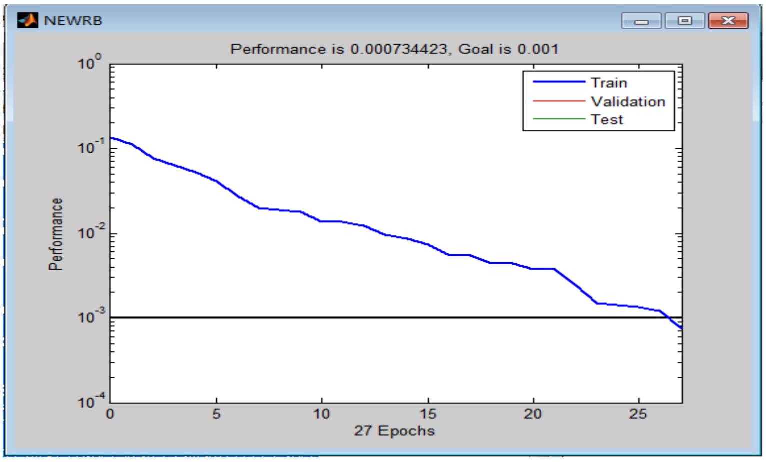

Fig.2 RBF neural network training results

Get the comparison of predicted and actual output value. The simulation results shown in Table 1..

Serial number	Desired probability of fire	Desired probability of smoldering fires	Desired probability of non-fire source	Actually probability of of fire	Actually probability of of smoldering fires	Actually probability of of non-fire source
1	0.0504	0.1011	0.8496	0.05	0.1	0.85
2	0.7999	0.0988	0.1001	0.8	0.1	0.1
3	0.2000	0.1002	0.6988	0.2	0.1	0.7
4	0.0502	0.0994	0.8504	0.05	0.1	0.85
5	0.8502	0.0991	0.0504	0.85	0.1	0.05

Table.1 Predicted and actual output values compare simulation results

We can see that RBF simulation works well,basically consistent with predicted and actual output values.

The realization of simulation in decision-making level

Feature layer output fire probability, smoldering fire probability and fires signal duration, as the three decision factors of the decision-making integration. After fuzzy logic to give a final decision output. The fires were divided into four classes namely PN (no), PL (small), PM (medium) and PB (large). Fuzzy inference structure shown in Fig.3.

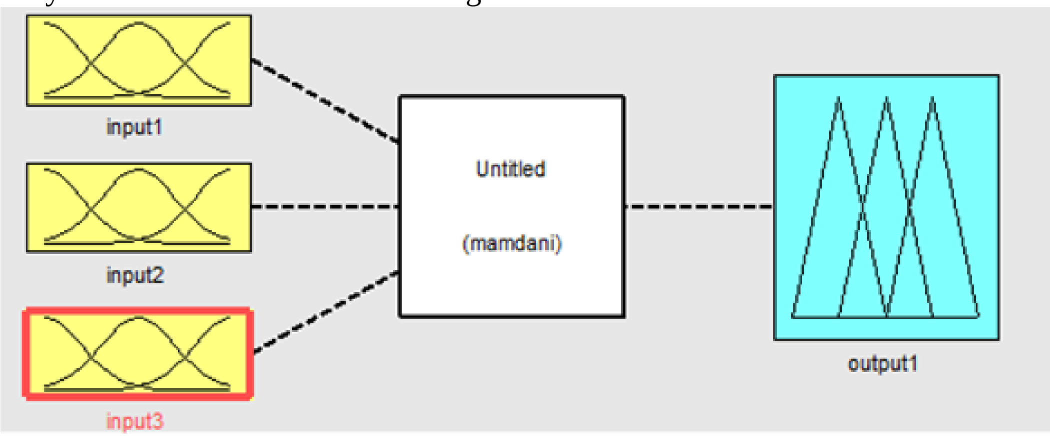

Fig.3 Fuzzy inference structure

Open flames and smoldering fire probability is the value [0,1]. The duration of the fire before entering the fuzzy inference system normalized to [0,1]. Therefore, the upper limit of the amount of input is 1 and the lower limit is 0, as the domain U. To fuzzy into three levels:PB,PM,PS, Gaussian function as the membership function. Output U of decision-making for domain [0,1].Fuzzy into three fuzzy sets: No fire (PS), high temperature (PM), has a fire (PB). Triangle function as membership function.

Conclusion

Wind turbines fire protection is an important and complex work. A variety of measures automatic fire prevention systems, wind turbine operation state, fire-fighting equipment configuration required in order to effectively curb the wind turbine fires. In this paper, the wind turbine operating environment studied, wind turbine fires detection method based on information fusion. The simulation tests proved the feature layer can be well judged the probability of fire, smoldering fire probability and no fire probability. And in the decision-making drawn the decision of fires probability. Can effectively reduce the probability of fires.

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