Remote monitoring system of environmental variables in distribution room based on fuzzy neural network

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ABSTRACT

Aiming at the problems existing in the operation and maintenance of distribution network at present, this paper studies the design of remote monitoring system of environmental variables in distribution room based on FNN(Fuzzy neural network). A remote monitoring system of environmental variables in intelligent power distribution room is established. Aiming at the fault problem of distribution system, a fault diagnosis method of low-voltage distribution system based on FNN is proposed. The combination of fuzzy reasoning and BPNN (BP neural network) is adopted, that is, the output of fuzzy system is used as the input of neural network. First, the collected fault signal is processed by fuzzy set theory, then the fault signal is diagnosed by three-layer BPNN, and the adaptive learning rate is used for learning. The research results show that the diagnosis accuracy of the method based on fuzzy reasoning and BPNN is obviously improved compared with the method based on neural network alone. The diagnosis error is greatly reduced, the situation of misjudgment and missed judgment is basically eliminated, and the overall performance of the system is improved. The research results show that the system is reliable and can meet a wider range of needs.

Keywords: Fuzzy neural network; Distribution room; Environmental variables; Remote monitoring

1. INTRODUCTION

With the increase of nonlinear, aperiodic and impact loads (variable frequency motors, switching power supplies, etc.) in power system, harmonics, voltage flicker, voltage fluctuation and three-phase load imbalance occur in the operation of distribution equipment [1]. In addition, the thermal effect and closed environment caused by the operation of electrical equipment make the operating environment of electrical equipment very bad. High temperature, humidity, dust and noise, poor ventilation, toxic gas accumulation and other environmental problems are eroding all kinds of equipment all the time, restricting the efficiency of equipment. With the in-depth development of intelligent distribution network construction, higher requirements are put forward for the operation reliability and informatization level of distribution room. However, at present, the level of operation and maintenance management of distribution room is relatively low [2-3].

The electrical equipment in the distribution room is a complicated system. The reliability of the system is directly related to the stable operation of the whole unit. Therefore, ensuring the good performance of the electrical system plays an important role in the long-term and safe operation of the whole unit. When the low-voltage distribution system fails, some components will fail, which will cause the protection circuit to act, thus affecting the normal operation of the distribution network [4]. Traditional fault diagnosis methods often fail to guarantee the timeliness and accuracy of fault diagnosis, which leads to the expansion of faults. The environment monitoring platform of the power distribution room is a set of system developed to help ensure the normal operation of the power distribution room equipment [5-6]. In the past, when power enterprises managed the distribution room, they usually relied on manual timing to test all kinds of power equipment and instruments, and manually drew them into tables and reported them. However, this management mode is extremely inefficient in practical application, and it has been unable to adapt to the scale of most intelligent distribution networks and the needs of power users [7].

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This paper explores the value of various monitoring data, reduces the operation and maintenance cost of the distribution room, and improves the management level of the distribution room, so as to better cooperate with the construction of smart grid [8]. The proposal of this topic is based on the environmental monitoring system of power distribution room, which is set up to improve the operation reliability of power supply system, and is specially developed for the operation and environmental monitoring of power equipment in small power places such as power distribution room and switching station. Based on the principle of neural network and fuzzy reasoning, this paper takes the low-voltage fault of distribution network as the diagnosis object, and applies FNN(Fuzzy neural network) to the low-voltage fault diagnosis of distribution system in order to improve the diagnosis speed and eliminate the situation of misjudgment and missed judgment.

2. RESEARCH METHOD

2.1 System overall design

The environmental monitoring degree and monitoring scope of the distribution room are insufficient, so it is impossible to carry out effective fault location analysis; Lack of real-time effective monitoring of equipment status and online visual data support, unable to operate remotely, and difficult to improve the level of automation; At present, the functional structure, equipment conditions and safety settings of the distribution room are difficult to meet the needs of emerging business expansion such as microgrid, distributed energy and charging piles. In this paper, the FNN-based remote monitoring system for environmental variables in power distribution room is applied in practical needs, and the hardware equipment of the system is selected according to the system design cost, power consumption and application performance.

An important link of smart grid is the construction of smart distribution network, and distribution transformer is the core equipment of the whole distribution station area. In the ideal ventilation situation of distribution room, various problems will be encountered in actual operation, such as the aging of fans and the increase of noise caused by pollution, and the existing noise reduction methods can not meet the actual requirements of residential areas. The environmental monitoring system of power distribution room is composed of power distribution room environmental control instrument, wireless remote communication, central operation control master station and power distribution room positioning search function software [9]. The system can be widely used in power distribution room, power communication room, switching station, box transformer and other power-related places.

The key to the design of the whole system lies in the adaptability under different monitoring conditions and the user experience of the interactive interface. When the number of monitored lines changes, on the one hand, the number of acquisition modules can be adjusted to complete the data acquisition task, and there is no need to design the hardware and software of the acquisition circuit again to realize plug and play; On the other hand, it is not necessary to redesign and upgrade the interface program to reset the number of human-computer interaction interfaces and realize the re-layout of interface controls. Automatically control the opening and closing and output of the fan; Adjust the air flow and the intensity of convection to match the dynamic characteristics of the heat source's calorific value change, so as to improve the efficiency of convection heat dissipation and achieve the efficiency of cooling, energy saving and noise reduction. In order to cope with various emergencies, corresponding measures are taken in power supply design and server design to ensure that the system can be restored to its original state when it resumes normal operation.

On the whole, the remote monitoring system of environmental variables in intelligent power distribution room should be based on the principles of advancement, reliability, safety and expansibility, and have the ability of information circulation and interaction with various monitoring execution subsystems, data transmission and storage systems, data analysis and management systems, etc [10]. The hardware and software of the system are in line with the mainstream direction of industry application, and the structural design meets the future development needs of intelligent distribution network. The structure of FNN-based remote monitoring system for environmental variables in power distribution room is shown in Figure 1:

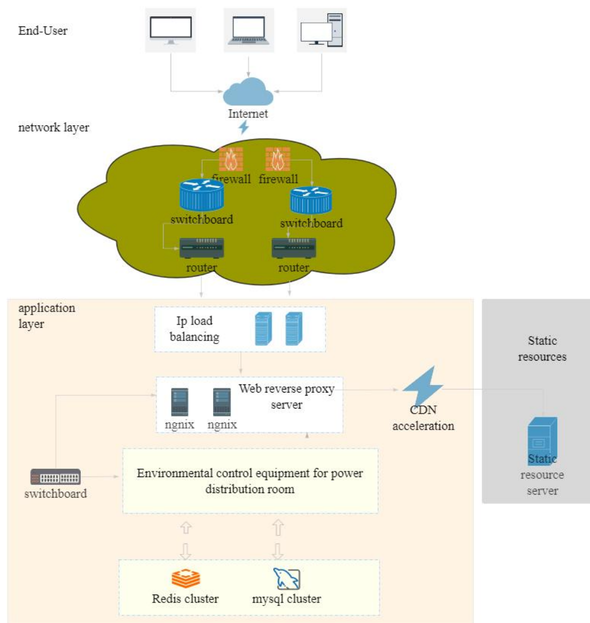

Figure 1. System structure

The system consists of field equipment, intermediate communication layer and system layer, in which the functions of the system layer and communication layer are provided by the existing intelligent distribution transformer monitoring system, and the communication layer can use optical fiber and short message communication to monitor the field environmental temperature in real time without any additional investment. When the temperature exceeds the limit, the fan can be turned on and turned off when the temperature drops to a certain temperature. Real-time monitoring of transformer winding temperature, when the overtemperature alarm, forced to turn on the fan, and immediately notify the power distribution management personnel.

The system can monitor the working state of the monitored equipment in real time, collect information such as environmental temperature and humidity, record and analyze relevant data, and timely alarm the abnormal situation on site. Through remote communication, centralized monitoring and centralized maintenance can be completed, which can improve the automatic adjustment ability of the power site and reduce the cost of manual inspection, thus improving the automatic management level and power supply ability of power supply enterprises and ensuring the safe operation of distribution systems.

2.2 Fault diagnosis of distribution system based on FNN

The normal operation of the distribution room is very important for ensuring power supply. However, the distribution rooms are numerous and scattered, which brings great workload to the operation and maintenance work. After the accident of low-voltage distribution system, a large amount of fault information will be transmitted to the control center in a very short time. Compared with neural network, the process of fuzzy reasoning is easy to understand [11]. It is not a black box that people can't understand directly like neural network, and it doesn't require a large number of high-quality training samples like neural network. On the other hand, fuzzy reasoning is not as accurate as neural network and its reasoning speed is relatively slow. It contains all kinds of basic facts, rules and other related information. The knowledge in the library comes from many experienced experts in the industry. The requirement for the collected electrical signal is that it must accurately reflect the accurate position and current state of the measured point.

Fuzzy reasoning includes five steps: fuzzification of input variables; Applying fuzzy operators in the antecedent of fuzzy rules; According to the fuzzy implication operation, the conclusion is deduced from the premise; Fuzzy synthesis is carried out by combining the conclusions of each rule; De-fuzzification of output variables. Fuzzy rules use fuzzy language to describe expert knowledge in various fields. Fuzzy rules are measures and means of fuzzy reasoning. After the input variables are fuzzified, it can be determined whether the propositions in the antecedent of fuzzy rules can be satisfied or to what extent. If the antecedent of fuzzy rules includes multiple propositions, the satisfaction degree of the antecedent can be obtained. However, the reasoning result in practical application is an accurate quantity, so it is necessary to determine an accurate quantity that best represents the distribution of its output possibility from the fuzzy output membership function, which is called anti-fuzzification of output variables.

Generally speaking, neural networks are not suitable for expressing rule-based knowledge. Therefore, when training neural networks, because the existing empirical knowledge cannot be well utilized, the initial weights can only be taken as zero or random numbers, thus increasing the training time of networks or falling into undesirable local extremum, which is the deficiency of neural networks. Fuzzy logic is also a useful tool to deal with uncertain and nonlinear problems. It is more suitable for expressing those vague or qualitative knowledge.

This chapter adopts the combination of fuzzy reasoning and neural network in series, that is, the output of fuzzy system is used as the input of neural network. First, the collected fault signal is processed by fuzzy set theory, then the fault signal is diagnosed by three-layer BPNN (BP neural network), and the adaptive learning rate is used for learning. The purpose of adopting this method is to combine the advantages of the two methods, foster strengths and avoid weaknesses, so as to achieve better diagnostic results. The fault diagnosis process is shown in Figure 2:

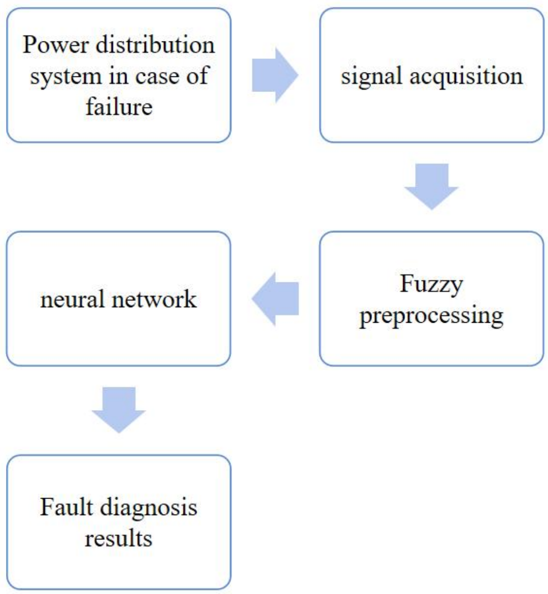

Figure 2. Fault diagnosis process

The learning process of the network consists of two parts: forward propagation and backward propagation. In the process of forward propagation, the state of each layer of neurons only affects the next layer of neural network. The parameters FNN needs to learn are mainly the connection weight ω_{dk} of the last layer, and the central value $\omega_{b_{ij}}$ and width value $\omega_{c_{ij}}$ of the membership degree. The error function is defined as:

$$E = \frac{1}{2}\left(Y_{di} - Y_i\right)^2 \tag{1}$$

Where i is the number of learning samples, Y_{di} is the expected output of the system, and Y_i is the actual output of the controlled object.

Because the fuzzy controller processes data based on fuzzy sets, it is an essential step to fuzzify the input data. The essence of fuzzification is to obtain the membership function of fuzzy sets in the corresponding numerical domain. The analytical expression of membership function is shown in Formula (2):

$$\mu(u)=\begin{cases}\frac{1}{a-b}(u-b), b \le u \le a \\ \frac{1}{a-c}(u-c), a \le u \le c \\ 0, \text{other}\end{cases} \tag{2}$$

According to the actual situation, the signals of ambient temperature, smoke concentration and carbon monoxide concentration are divided into: fire possibility, small fire possibility and no fire possibility, and the system adopts triangular membership function.

Let the connection weight between the rule layer and the deblurring layer be λ_{ij}, and here the weighted average method is adopted to calculate the output value V of FNN as follows:

$$V=\frac{\sum_i \sum_i \lambda_{ij}\mu_{ij}}{\sum_i \sum_i \mu_{ij}} \tag{3}$$

Reinforcement learning of objective function Y. Parameters in FNN are adjusted by reinforcement signal to minimize the mean square error function, and reinforcement learning signal r is defined:

$$r = Y^* - Y(k) \tag{4}$$

When adjusting the learning rate, we should pay attention to the difference between this learning error and the last learning error. If it is less than the last learning error, it shows that this adjustment is appropriate, that is, the current learning rate can adapt to the changes of fault diagnosis, and on this basis, the learning rate can be appropriately increased; If this learning error is greater than the last learning error, it indicates that this adjustment is inappropriate and the learning rate needs to be reduced [12].

3. RESULT ANALYSIS

The testing of distribution monitoring system mainly includes the testing of functional modules and data transmission reliability. Seven experimental installation points are selected in a power supply area for testing. In order to verify the universality of equipment use, the principle of geographical proximity is mainly adopted when selecting the installation location, and whether the distribution transformer load is overloaded or not is considered.

Run the monitoring interface and click "Device Selection" to send a device query instruction to the server. The server will return the connected online device ID to the client, and the client will display it. Now disconnect and reconnect individual devices, and observe whether the devices are displayed in the device management interface again. The test results are shown in Table 1.

Table 1. Test results of equipment disconnection and reconnection

Equipment number	Number of disconnection	Normal connection times	Percent of pass%
A	20	20	100
B	20	20	100
C	20	20	100
D	20	19	95
E	20	20	100
F	20	19	95
G	20	20	100

When the equipment is disconnected and reconnected, the standard for judging normal connection is that the connection time is less than 5s, and if this condition is met, it is normal connection. According to the test results, the loading performance of Android client on equipment meets the requirements of power distribution monitoring.

In the study, we learned that there are many factors that affect the operating environment temperature of the distribution room. According to the load measurement data of the distribution room, the correlation curve between the load rate and the environment temperature is obtained, as shown in Figure 3 below:

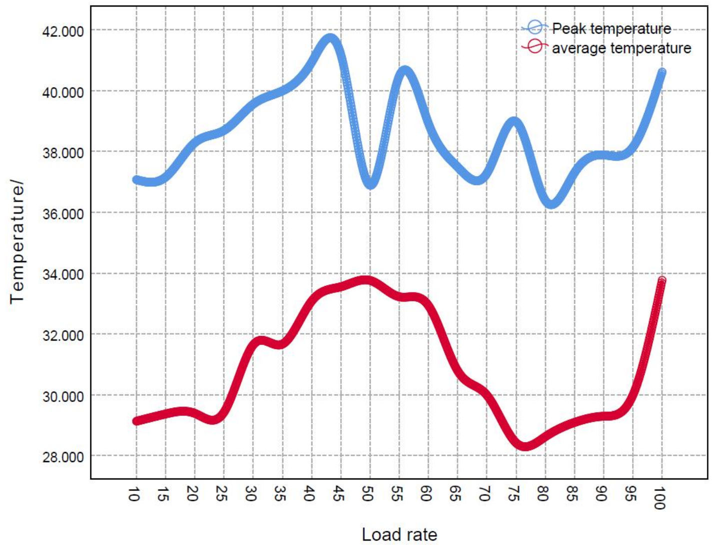

Figure 3. Relationship between load rate and ambient temperature

We can see that both the average temperature and the peak temperature have a slightly upward slope, which shows that there is a positive correlation between the load rate and the ambient temperature.

The structure of this neural network is three input layer neurons, each representing the output of the fuzzy system, that is, each phase fault, seven hidden layer neurons and four output layer neurons. 30 groups of fuzzy reasoning system outputs are randomly selected as training samples. Fig. 4 shows the diagnosis output of the system for a fault phase of low voltage fault.

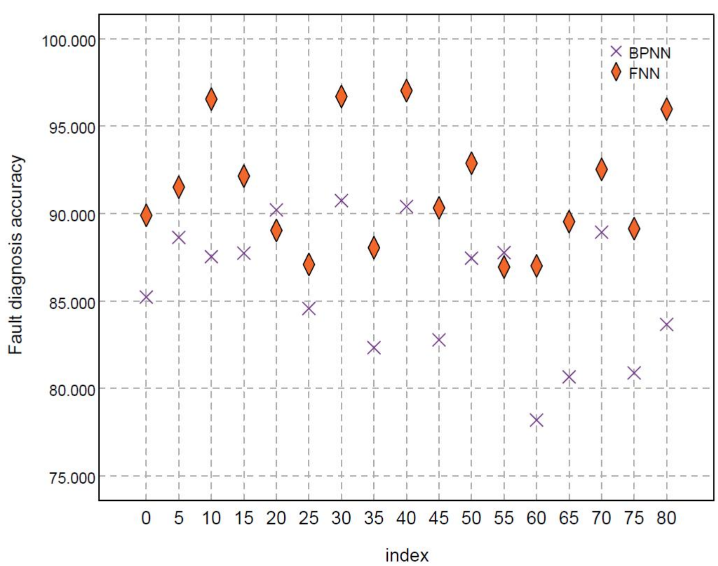

Figure 4. Test results of fault diagnosis

Through the comparison of test results, it can be seen that the diagnosis accuracy of the method based on fuzzy reasoning and BPNN is obviously improved compared with the method based on neural network alone. Because the fuzzy reasoning system is the pre-processing part of the signal, it also simplifies the model of neural network, which can improve the diagnosis speed of the neural network of the system.

Compared with using one method alone, the combination of fuzzy reasoning and BPNN greatly reduces the diagnosis error, basically eliminates the situation of misjudgment and missed judgment, and improves the overall performance of the system.

4. CONCLUSION

In this paper, the design and research of remote monitoring system of environmental variables in distribution room based on FNN are carried out. The remote monitoring system of environmental variables in intelligent power distribution room and the fault diagnosis model of intelligent electrical system based on FNN are established. The research results show that the diagnosis accuracy of the method based on fuzzy reasoning and BPNN is obviously improved compared with the method based on neural network alone. The diagnosis error is greatly reduced, the situation of misjudgment and missed judgment is basically eliminated, and the overall performance of the system is improved.

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