Fault Diagnosis of Power Network based on Radial basis Function Neural Network

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Abstract. This paper proposed a fault diagnosis method based on radial basis function neural network (RBF), and this method could effectively solve the diagnosis problem of connection lines between interconnected regions. This method divides the large power grid into several regions through the network overlapping partition, and after the fault occurs, the RBF neural network diagnosis module corresponding to the area corresponding to the alarm information is selectively triggered according to the alarm information.

The simulation results show that this method can not only diagnose faults occurring in different regions, but also can effectively diagnose faults occurring in Interregional tie lines. This method is simple and effective, can make up for the shortcomings of the fault diagnosis method of the existing grid partition fault in the connection line fault diagnosis and handle all kinds of complex fault conditions, and has good fault tolerance ability.

1. Introduction
Fault diagnosis of power grids is the process to detect original fault through relay protection and the action information of breaker. Diagnosing grid failure quickly and accurately is important to reduce the time of fault power failure, prevent accident enlargement, and recover grid operation. Recently, different ways of fault diagnosis of power grid has been suggested, including the expert system, Petri grid [1], Bayesian network [2], optimization, data mining, etc. Since neural network has the characteristics of distributed line processing, self-adaptation, and recessive knowledge representation, it is applied in the field of fault diagnosis of power grids.

Methods of fault diagnosis of power grid based on neural network can be divided into centralized fault diagnosis and partition fault diagnosis [3]. Centralized fault diagnosis method sees the entire power grid as a whole, identifying fault component by constructing a neural network. This method’s principle is simple and is easy to be implemented. When the grid size increases, however, network dimension increased rapidly, neural network training becomes more difficult, easily falling into local extremum, even not being able to convergent effectively, restricting this method in small power grids.

Partition fault diagnosis, on the other hand, divides the whole power grid into several separate parts and establish a corresponding regional neural network diagnostic module for each area. Each subsection complete each diagnostic tasks in parallel which can increase efficiency. Therefore, partition fault diagnosis can be applied In larger power grids.

In this paper, two questions mentioned in the document, how to partition a large-scale grid and how to solve the problem of fault diagnosis inside the partition area, there is a third key question to consider to realize grid partition fault diagnosis, how to solve the fault diagnosis of the connection line between partitioned areas. Document [4] has solved the first problem. Document [5] mainly focuses on the second problem. Even though document [6] has mentioned the third problem, but when the
connection line fails, the main protection and near backup protection fail to cut off the fault effectively, requiring far backup protection action, the no-overlapping partition method restricts its application, make it unable to effectively diagnose contact line failure.

This article proposes a partition fault diagnosis method [7] based on radial basis function neural network and fuzzy integral fusion [8] for the problems of grid partition fault diagnosis mentioned in the previous paragraph. This method uses a network overlapping partition method to divide the large power grid into several areas with overlapping links. For each region, during the training phase, the regional diagnostic module is quickly and efficiently constructed through an accurate radial basis network. In the diagnostic phase, the regional diagnostic module of the corresponding region is selectively triggered according to the alarm information to improve the efficiency of fault diagnosis. For the diagnosis of the connection line between connected regions, the regional diagnostic module of the connected region is used to complete the respective diagnostic tasks independently and in parallel, and then the diagnostic output of the connected region on the connection line is fused by the fuzzy integral [9] correlation to achieve an effective diagnosis of the contact line. The simulation results of calculation examples show that this method is easy to construct and implement. It can effectively solve the fault diagnosis of fault diagnosis of power grids and can deal with complex fault situations correctly. It has high diagnostic accuracy and good fault tolerance.

2. Radial basis function neural network
Radial basis function neural network (RBF) is a feed-forward neural network whose structure is shown in Figure 1. RBF neural network consists of 3 layers of neurons, namely, input layer, hidden layer and output layer. And the input layer contains N neurons \((x_1, x_2, ..., x_n)\), Corresponding to the feature dimension of the input vector, the hidden layer contains H neurons, and the radial basis function is used as its excitation function \(\phi_i: R^n \rightarrow R\). The output layer contains M neurons \((y_1, y_2, ..., y_m)\).

![Figure 1. The RBF neural network structure](image)

![Figure 2. RBFs in various width and center](image)
General selection of Gauss function form for radial basis function:

\[
\phi_i(x) = \exp\left(-\frac{\|x - c_i\|^2}{q_i^2}\right)
\]

Where, \(x = [x_1, x_2, ..., x_n]^T\), \(c = [c_{i1}, c_{i2}, ..., c_{in}]^T\) is the center of the radial basis function of the \(i\)th hidden layer neurons.

3. Fault diagnosis strategy of power grid partition

3.1 Grid partitioning method

A suitable method of network partitioning is the premise for fault diagnosis of the grid. However, when the power grid is divided into several regions, how to handle the fault diagnosis of the connection lines between the connected regions is the key to completing the diagnosis task of the district fault diagnosis system. Since the power system relay protection system has an extended protection, that is, when the power grid fails and the non-enlarged protection of the faulty component fails to isolate the fault, the expansion protection will act to cut off the fault, resulting in the spread of the power grid fault area. If the fault of the tie line between the connected areas leads to the extended protection action, it is necessary to combine the alarm information of the two areas to accurately diagnose the fault of the tie line. In order to effectively solve this problem, this paper uses network overlapping partition method to partition the power grid, as shown in figure 3. The dotted line in the dotted line in Figure 3 is the inter-area tie line, which is shared by the two connected areas. For example, line L12 belongs to both area 1 and area 2, which is the overlapping part of the two areas.

![Figure 3. Schematic of division overlapping network](image)

The network overlap partitioning method is characterized by the attribution of the tie line to two connected areas, rather than strictly belonging to a certain area. The advantage of this method is that when the connection line is faulty, the diagnostic system can simultaneously trigger the interconnected two zone diagnostic modules to complete their respective diagnostic tasks in parallel, and then use the fuzzy integral correlation to fuse the diagnostic results of the two regions to complete the fault of the contact line diagnosis.

3.2 Partition fault diagnosis system structure

The scale of power grids has become increasingly complex and huge, making centralized fault diagnosis unable to effectively adapt to this development. In the event of a grid fault, the faulty components tend to be concentrated in a certain local area, so that the distribution of the warning signals of the protection system is characterized by locality. Because the partition diagnosis uses a local diagnosis strategy, it can effectively overcome the shortcomings of centralized fault diagnosis,
thereby improving the diagnostic efficiency. Assuming that the given grid is divided into N regions, the partition fault diagnosis system used in this paper is shown in Figure 4. After the grid fails, the first task is to preprocess the fault alarm information received by the monitoring center, mainly to complete the task of information grouping, consolidation, and conversion. The fault alarm information is processed by the pre-processing system and enters the RBF neural network diagnosis module. The regional neural networks selected for triggering are concurrently diagnosed. After the diagnosis by the regional neural network module, the fault conclusions of some components will be obtained. If there are two or more regional neural network modules connected to each other that are selected to trigger, the diagnosis output of the contact line elements in the connected area must be fused by fuzzy integration to achieve fault diagnosis of the tie line. Finally, through the fault conclusion comprehensive processing module, the neural network and fuzzy integral output results are summarized, and the complete diagnostic report is sorted out and output.

It is worth noting that the triggering mechanism of the regional RBF neural network diagnostic module is that as long as the neural network has an alarm information input, the module will be triggered. That is, as long as the alarm information appears in a certain partitioned area, the corresponding neural network will be triggered, while the triggering mechanism of the fuzzy integral fusion module is that the fusion module is triggered as long as the two regional neural network diagnosis modules are triggered.

![Figure 4. The system of the divisional fault diagnosis](image_url)

4. Simulation Analysis
The system used in this paper is composed of 14 buses and 20 transmission lines. And the main protection of the bus bar is B01m–B14m, the main protection of the line is LXm, the line near backup protection is LXp, the line far backup protection is LXs (and the X is the number of the circuit breaker. The structure and parameters of neural network have an important influence on the generalization ability of neural network. The center and the expansion constant of the radial basis function determine the characteristics of the function. In order to improve the training speed of the network and enhance the approximation ability of the network, the radial basis function network is used as the neural network module.

In training, the network can ensure that the actual output is approximated to the desired output with zero error, so that the error free design can be realized. The only need to determine the expansion constant of the radial basis function before training. The larger the expansion constant, the more smooth the RBF network, but the larger expansion constant leads to the lack of selectivity. The smaller the expansion constant, the worse the approximation effect of the radial basis function. In the...
simulation process, the relevant parameters of the neural network and the final determination of the expansion constant are shown in Table 1.

| Neural network | Training sample | Test sample | Input layer | Output layer | Extension constant |
|----------------|-----------------|-------------|-------------|--------------|--------------------|
| NN1            | 151             | 181         | 56          | 10           | 4.2                |
| NN2            | 248             | 296         | 84          | 14           | 4.0                |
| NN3            | 182             | 210         | 68          | 11           | 3.8                |

The simulation results are shown in Figure 7. And it is shown that the diagnostic accuracy of each neural network is very high, with the accuracy of 95.63%, 94.63% and 97.17% respectively.

The simulation results show that the RBF neural network has good fault tolerance for different types of faults. It can be seen that the effects of different regions are mainly reflected in the structural parameters of the diagnosis model itself, but the impact on the diagnostic ability of the diagnostic model is very small.
5. Conclusion
The main content of this paper is based on RBF neural network to put forward a method of partition fault diagnosis which can effectively adapt to large power grid. The core of this paper is to solve the fault diagnosis problem of the contact line between different partitions. In the training process of RBF neural network, each area can be carried out independently. The accurate radial basis network can be used to construct the model quickly and effectively, and there is no convergence problem. The diagnosis process can trigger the regional neural network diagnosis module based on the alarm information collected by the monitoring center, and the neural network which is triggered is triggered. The modules independently and parallely accomplish their respective diagnostic tasks, thereby improving the efficiency of fault diagnosis. And in this paper the "divide and conquer" strategy is used to handle all kinds of complex faults, such as the existence of protection/circuit breaker rejection, misoperation or alarm information loss, even multiple faults, and the results shown that it has high diagnostic accuracy and good fault tolerance ability.

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