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Distribution Network Fault Diagnosis Method Based on Granular Computing-BP

Chen Zhong-Xiao, Cui Ke, Chen Xing-Yu, Li Yan-Fang
Xi'an Technological University
Weiyang Campas of Xi'an Technological University Shaanxi Province
*Corresponding author, e-mail: lyf_xiang@163.com

Abstract

To deal with the complexity and uncertainty of distribution network fault information, a method of fault diagnosis based on granular computing and BP is proposed. This method uses attribute reduction advantages of granular computing theory and self-learning and knowledge acquisition ability of BP neural network. It put granular computing theory as the front-end processor of the BP neural network, namely simplify primitive information making use of granular computing reduction, and according to the concepts of relative granularity and significance of attributes based on binary granular computing are proposed to select input of BP, thereby reducing solving scale, and then construct neural network based on the minimum attribute sets, using BP neural network to model and parameter identify, reduce the BP study training time, improve the accuracy of the fault diagnosis. The distribution network example verifies the rationality and effectiveness of the proposed method.

***Key words**: granular computing; BP neural network; fault diagnosis; distribution network*

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1. Introduction

With the technology and the rapid development of the national economy and the improvement of power quality and reliability requirements, our distribution network infrastructure has become increasingly complex, and also increases the probability of failure. Due to the relatively high failure frequency of the distribution network equipment, it has the varied quality in operating modes and the corresponding topology structure. The system will obtain the error information because of the wide distribution of distribution network equipment that the device information collection is difficult and it is prone to signal distortion in the transmission process. How to conduct the fault location and handle it on the basis of the more and complex distribution network fault information, to ensure the security and reliable operation of the distribution network is a research focus to every power staff [1]. The hybrid system of granular computing and BP(Back Propagation) neural network can achieve not only the fault diagnosis of incomplete information but also to reduce the number of neurons which BP neural network inputs and improve the training speed, that is very suitable for use in the fault diagnosis of distribution grid [2].

2. Granular computing and BP neural network theory

2.1. Basic concepts of granular computing and BP neural network

Granular computing is the world outlook and methodology which we look at the objective world, information granules that widely exist in our real life that is an abstract of the objective world, information granulation is a reflection which the human process and store information. Granular computing contributes to analyze and solve problems more accurately by conducting the complex problems to the abstract and measuring and transforming it into multiple simple questions which has an important role in solving the complex problems to mankind. Its basic idea is that the particles are applied to the solution of the problem, the particle is the class, cluster or group of elements [3], a class of objects of the problem are divided into a series of particle by information granulation, according to the indiscernibility relation, similarity and functionality among the particles that gather to an object and then process the problems.

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The BP neural network is error back propagation algorithm learning process, including the information forward propagation and error back propagation two process. The BP neural network is the composition by the input layer, implicit layer and output layer, the input layer receive input information from outside world, hidden layer is the information processing layer that is responsible for transforming information, output layer output information processing results to the outside world. When the output value does not meet the expectations, they entered the error back propagation process. Error through the output layer is layer-by-layer back propagation to implicit layer and input layer, according to the error gradient descent way fixed weights of each layer. The BP neural network adjustment the layer weights continuously through the information forward propagation and error back propagation [4][5], which is the BP neural network learning training process, and this process has been arrived at the process which the output error reduced to acceptable range or pre-set number of learning.

2.2. Binary granular computing reduction algorithm

Binary granular computing reduction algorithm is a kind of effective knowledge attribute reduction algorithm. This algorithm is based on the importance of relative granularity attribute as a heuristic search method of measurement, which can quickly and efficiently find optimal or suboptimal reduction of the decision information system [6].

Binary granular computing reduction algorithm steps:

Input: the decision information system of questions is $S=(U,A,C\cup D)$, which U is the domain of discourse, A is the attribute set, and C is the condition and D is the decision attribute set.

Output: the minimum relative attribute reduction decision information system of problems.

1) To calculate the binary particle matrix of decision information system that is $BGrM=\{Y_{m\times l}, X_{n\times l}, C_{m\times n}\}$;
2) Execute the compatible initial decision information system one after another, split incompatible decision information system and merge the same rules;
3) Calculate the nuclear C_0 which the condition attribute C conducts for the decision attribute D and the unimportant redundancy attribute among the reduction condition attribute set C. If the dependence degree $\gamma_{C-a}(D)=\sum C_{ij}/|U|\neq 1$, then $a\in C_0$;
4) The equivalence relation set $R=C_0$, knowledge $B=C-C_0$, then go to 10);
5) Execute 6) to 10) for every $b_i\in B$;
6) According to divide U/C_0, get $U/\{C_0\cup\{b_i\}\}$, $U/\{C_0\cup\{b_i\}\cup D\}$;
7) $GD(D|C_0\cup b_i)$;
8) Choose an attribute b_i that let $GD(D|C_0\cup b_i)$ the least, choose one if the attributes meet this condition is more then choose one and let $R=C_0\cup b_i$;
9) Obtained $f(b)=\gamma_R(D)$, if $f(b)\neq 1$ then $R=R\cup\{b_i\}$;
10) If $\gamma_R(D)=\gamma_C(D)$ then stop it ,or go to 8);
11) Get R that is the minimum relative reduction of the decision information system and then end the whole algorithm.

2.3. BP neural network algorithm

The BP neural network can conduct arbitrary precision approach to linear continuous function; can complete space mapping [7].

The BP neural network algorithm steps are below:

1) The BP network parameters initialization: set each weighted coefficient for minimum arbitrary number;

2) Choose good training sample set: provide input vector and expected output vector sets are respectively $x_1, x_2, \cdots, x_n$ and $y_1, y_2, \cdots, y_n$;
3) Calculate actual output according to the training sample: including each neuron node of the hidden layer and output layer.
4) Calculate the error $J = \sum_{p=1}^{N} J_p = \frac{1}{2}\sum_{p=1}^{N}\sum_{k=1}^{L}\left(y_k^p - o_k^p\right)^2$ between expectation and the actual output ,which N and L were sample of model and node number of network output;
5) Adjust output layer weighted coefficient w_{ki} according to the error: $w_{ki}(k+1) = w_{ki}(k) + \eta\delta_k^p o_i^p$;
6) Adjust hidden layer weighted coefficient w_{ij} according to the error: $w_{ij}(k+1) = w_{ij}(k) + \eta\delta_i^p o_j^p$;
7) If it is not reach the set requirements, return to 3) and continue to calculate until they reach the requirements.

3. The fault diagnosis methods based on granular computing and BP neural network

3.1.The basic ideas of fault diagnosis based on granular computing and BP

The fault diagnosis system based on granular computing and BP neural network acts the BP neural network model as a fault diagnosis model. First let the granular computing as the BP neural network input front-end processor [8], through the granular computing the reduction ability simplify the initial information system, get a optimal attribute set which is equivalent to the initial information system and then build BP neural network on the basis of the optimal attributes set, which handles the information system processing and reduces the information handling capacity and improves the system operation speed. The system structure is shown as shown in Figure 1.

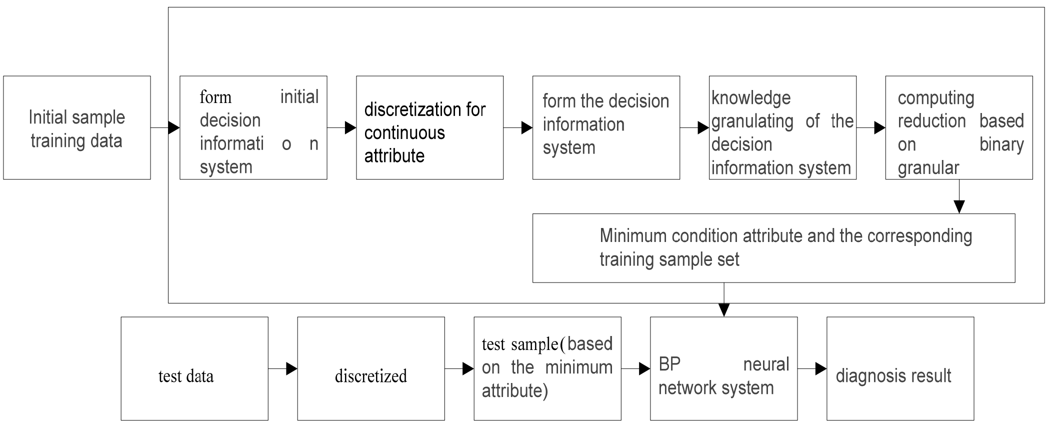

Figure 1. Structure of fault diagnosis system based on granular computing and BP

Basic idea of fault diagnosis:

Analysis the fault information according the results of the system and form the initial information decision system; Preprocess the initial information, delete and pad the information in information system which can improve the decision information system. Proceed discretization attribute reduction to the data of the decision information system, handle the inconsistent rules in the decision information system [9], delete the repeat information in the decision information system, and then get the learning samples that can reflect the characteristics of the original data and the contained the least amount of the condition attribute; Structure fault diagnosis model according to the training of BP neural network; Input the data that pass the granular computing processing to BP neural network's input layer to test, and finally obtain the diagnosis.

3.2. The fault diagnosis algorithm steps based on granular computing and BP

1) Form the initial decision information system of fault diagnosis. When shaping the initial decision information system, which the fault information data that is the initial acquisition is missing or repeated phenomenon, need to supplement the missing characteristic parameters and delete repeated parameters;
2) Conduct continuous attribute discretization to the information system. Process the discretization to the information in initial information system, which the continuous attribute domain is divided into several discrete intervals, and then use different integral value for each interval corresponding attribute value;
3) Form the decision information system after the discretization. The attributes and attribute value form a two-dimensional form after the discretization, in which each column is object's properties, every line is an object [10];
4) Conduct the attribute reduction to the decision information system of fault diagnosis. Attribute reduction process is to delete the redundant condition attribute in the information system and get a most simple system decision rule;
5) Construct the BP neural network model and the test sample. Select the training sample and attributes from the reduction system decision rules to train BP network and test sample test according to the BP diagnosis mode;
6) Obtain the diagnosis. Use the test sample to train BP network model, until to receive the satisfactory results.

4. Form the Fault Diagnosis Model and the Decision Table for the Distribution Network

Under construct a fault diagnosis model shown in figure 2 that simulate the reality.

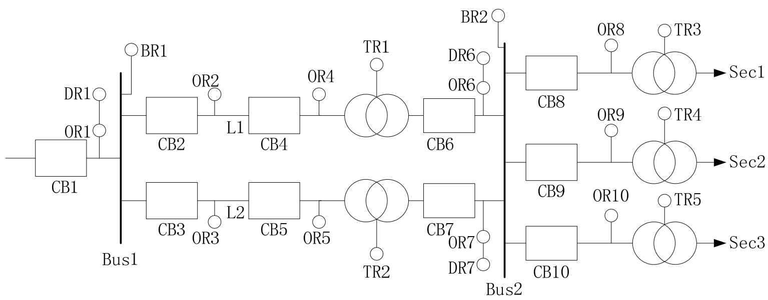

Figure 2. Sample map of distribution network

It shows the distribution network protection has short circuiter CB ,over-current protection OR, transformer protection TR ,backup distance protection DR and busbar protection BR in Figure 2.Signs information of fault diagnosis is mainly from the point voltage branch current and electric capacity in the distribution network, the protection action sinal can be used as the judgment basis of fault diagnosis, here choose the protection movement signal of each protection euipment as the failure signs information due to obtaining fault voltage and fault current is more difficult, form decision diagnosis information system according to the action signals, then form the fault diagnosis rules.

According to the protection equipment action principle in distribution network, protection equipment information constitute a condition attribute set of fault classification in figure 2, which possibly produces fault components, such as transformer [1], transmission lineand bus, which constitute the decision attribute of the decision information system, relay protection action principle determines the corresponding relation between the condition attributes and the decision attributes.

Table 1 lists the diagnosis system decision table including 18 samples, 29 condition attributes and one decision attribute, among them 1 said the breaker is disconnected or the protection action, 0 means no protection action or circuit breaker is closed.

Table1. The Decision Table of Fault Diagnosis

sample	CB1	CB2	CB3	CB4	CB5	CB6	CB7	CB8	CB9	CB 10
1	0	0	0	0	0	0	0	0	0	0
2	1	1	1	0	0	0	0	0	0	0
3	1	1	1	0	0	0	0	0	0	0
4	0	1	0	1	0	0	0	0	0	0
5	0	0	1	0	1	0	0	0	0	0
6	0	0	0	1	0	1	0	0	0	0
7	0	0	0	1	0	1	0	0	0	0
8	0	0	0	0	1	0	1	0	0	0
9	0	0	0	0	1	0	1	0	0	0
10	0	0	0	0	0	0	0	1	0	0
11	0	0	0	0	0	0	0	1	0	0
12	0	0	0	0	0	0	0	0	1	0
13	0	0	0	0	0	0	0	0	1	0
14	0	0	0	0	0	0	0	0	0	1
15	0	0	0	0	0	1	1	1	1	1
16	0	0	0	0	0	1	1	1	1	1
17	1	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	1	1	0	0	0

sample	OR1	OR2	OR3	OR4	OR5	OR6	OR7	OR8	OR9	OR 10
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	1	1	1	0	0	0	0	0	0	0
4	0	1	0	1	0	0	0	0	0	0
5	0	0	1	0	1	0	0	0	0	0
6	0	0	0	1	0	1	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	1	0	0	0
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	1	0	0
11	0	0	0	0	0	0	0	1	0	0
12	0	0	0	0	0	0	0	0	1	0
13	0	0	0	0	0	0	0	0	1	0
14	0	0	0	0	0	0	0	0	0	1
15	0	0	0	0	0	1	1	1	1	1
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0

TR1	TR2	TR3	TR4	DR1	DR2	DR3	BR1	BR2	fault
0	0	0	0	0	0	0	0	0	nothing
0	0	0	0	0	0	0	1	0	Bus1
0	0	0	0	0	0	0	0	0	Bus2
0	0	0	0	0	0	0	0	0	L1
0	0	0	0	0	0	0	0	0	L2
0	0	0	0	0	0	0	0	0	T1
1	0	0	0	0	0	0	0	0	T1
0	0	0	0	0	0	0	0	0	T2
0	1	0	0	0	0	0	0	0	T2
0	0	1	0	0	0	0	0	0	T3
0	0	0	0	0	0	0	0	0	Sec1
0	0	0	1	0	0	0	0	0	T4
0	0	0	0	0	0	0	0	0	Sec2
0	0	0	0	0	0	0	0	0	Sec3
0	0	0	0	0	0	0	0	0	Bus2
0	0	0	0	0	0	0	0	1	Bus2
0	0	0	0	1	0	0	0	0	L1/2

5. Distribution Network 'S Fault Diagnosis Example

5.1. Abtain the Distribution Network Fault Information Based on Binary Particle Calculation

Granular computing treats the distribution network's fault diagnosis as the pattern classification and using granular computing can excavate distribution network information, which can quickly and accurately find fault element and judgment fault area after that appears failure [2]. Here we adopt the improved granular computing reduction algorithm, from the decision information system we can find out the optimal reduction according to the importance of the granular degree attributes. The structure in this method is shown in figure 3.

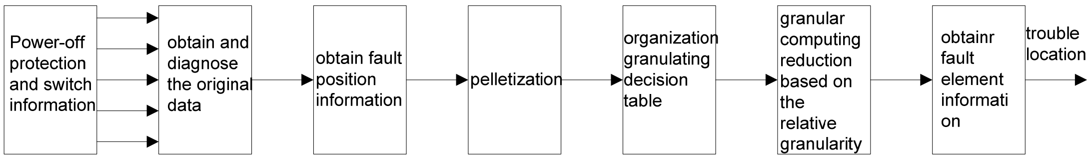

Figure 3. Structure diagram of diagnosis information acquisition model based on binary granular computing

5.2. The Distribution Network Fault Diagnosis Based on BP Neural Network

Here choose function S as BP network's transfer function, the BP network's input and output data are the continuous quantities between 0 to 1, but the actual input and output data are not between 0 to 1, so the input data of the BP network should be normalized, through BP network operation outputs the data and it becomes the actual output value after inverse normalized processing.

The specific steps based on BP neural network's distribution network fault diagnosis is below: First train the distribution network's decision information data that conducts it as BP network learning sample, obtain each neuron connection weight value and threshold value [3]; Secondly construct the knowledge library according to the BP network's corresponding connection weight value; Last use the trained BP network model to conduct the fault diagnosis. The diagnosis model is shown in figure 4.

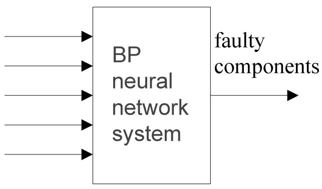

Figure 4. Structure diagram of distribution system fault diagnosis model based on BP neural network

Use the fault diagnosis model to simulate the above distribution network model, which gets the training mean square error is 3.4176 e-004, the training time is 18.578000 s, the diagnosis results are {0.0767; 0.0027; 0.0026; 1.0000}.

5.3. Distribution Network Fault Diagnosis Based on Granular Computing and BP Neural Network

The fault diagnosis methods have the following key process:

1) Conduct the information into binary grains and transform the fault diagnosis system which is the initial formation into the binary grain table;

2) Proceed the binary granulating decision information system doing the attribute reduction according to the binary granular computing reduction algorithms, nuclear attributes are {TR3, TR4} after reduction;
3) Add the redundant attributes for the decision table and complete the decision information system, then get the minimum condition attribute set is {CB1, CB3, CB4, CB6, CB7, CB8, CB9, CB10, TR3, TR4} through calculating f (b) and get the decision table as shown in Table 2 through merging the same rule set;

Table 2. Fault Component Diagnosis Table after Reduction Based on Granular Computing

sample	CB1	CB3	CB4	CB6	CB7	CB8
1	0	0	0	0	0	0
2	1	1	0	0	0	0
3	0	0	1	0	0	0
4	0	1	0	0	0	0
5	0	0	1	1	0	0
6	0	0	0	0	1	0
7	0	0	0	0	0	1
8	0	0	0	0	0	1
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	1	1	1
13	1	0	0	0	0	0
14	0	0	0	1	1	0

sample	CB9	CB10	TR3	TR4	fault
1	0	0	0	0	nothing
2	0	0	0	0	Bus1
3	0	0	0	0	L1
4	0	0	0	0	L2
5	0	0	0	0	T1
6	0	0	0	0	T2
7	0	0	1	0	T3
8	0	0	0	0	Sec1
9	1	0	0	1	T4
10	1	0	0	0	Sec2
11	0	1	0	0	Sec3
12	1	1	0	0	Bus2
13	0	0	0	0	L1/2
14	0	0	0	0	Sec1/2/3

4) Design the BP neural network. First determine the layers are 3 layers; Then determine the number of node in each layer which has 10 input feature vectors after reducting the model, so there are ten nodes in the input layer and the output information uses the 4 dimensions coding way, then the output layer neuron number is four and determine the number of panel points in hidden layer according to the empirical formula that is $m = \sqrt{n+l} + \delta$, in which n is the number of node in input layer and l is the number of node in output layer and δ is the constant between $0 \sim 10$;
5) Diagnose according to the specific fault information. The deflected information has $CB1 = 1, CB3 = 1, TR3 = 0, TR4 = 0$ and the rest did not change, if the information that has $CB3, CB4$ is not received and the system can still determine the fault element is $Bus1$, then it proves that the diagnosis result is correct. Simulate the distribution network model and get the mean square error is 2.8813e-004, the training time is 5.985000 s, the total training times are six, the diagnosis result is {0.0064; 0.0064; 0.0214; 0.9858}.

6. Fault Diagnosis Examples Analysis

Distribution network fault diagnosis model simulate 30 times, get the average results shown in Table 3.

Table3. Comparison of Simulation Result

algorithm	accuracy rate	Quasi square error	Running time	Error to 0.001 steps
BP algorithm	88.9%	4.7088e-004	12.7985s	17
Granular computing and BP	94.4%	3.6192e-004	4.1813s	6

It can be seen that using granular computing and BP neural network from the table 3 for fault diagnosis can improve the speed and accuracy of fault diagnosis, reduce the training time and improve the stability of the system, which is suitable for now more and more complex distribution network.

7. Conclusion

In this paper, it can accurately and effectively conduct the fault diagnosis to distribution network based on granular computing and BP fault diagnosis methods. By comparison, it is known that use the granular computing to reduce the distribution network information, which reduces the complexity of the BP network structure and shortens the time of fault diagnosis, because of granular computing can eliminate the omission and misstatement information in the fault diagnosis, it can improve the accuracy of the fault diagnosis and the anti-interference ability of the system, which is suitable for the requirements of the distribution network now.

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