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Cascading Failure Identification System of Transmission Network Based on GA Genetic Algorithm

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Abstract: Our country's power grids have been interconnected to form a super-large power grid. The scale and complexity of the power grid continue to increase, leading to an increasing risk of large-scale power outages, and the adverse impact of accidents on society and the national economy is also greater. Therefore, studying power system cascading failures and developing control theories and methods for such failures have important theoretical significance and application value. In this paper, the cascading failure identification system of transmission network based on GA genetic algorithm is studied. According to the related system structure, a cascading failure identification system structure based on GA genetic algorithm is proposed, and then the performance of the system is compared and analyzed on the basis. According to the experimental results, the system designed in this paper has only one group of faults with missed selection, and the correct rate of line selection is as high as 90%, while the traditional system has 2 groups of faults with missed and wrong selections, and the correct rate of line selection is 80%. Therefore, the simulation the results show that the accuracy of the system designed in this paper is higher than that of the standard system.

1. Introduction

Electric energy is the most convenient, cleanest, and most versatile secondary energy source. The electric power industry is a pillar industry of the national economy, and it plays a special role in the development of social economy and the improvement of people’s living standards [1-2]. The demand and dependence of human beings on electricity is increasing with the global economic integration and social development and progress [3-4]. Nowadays, the power grid has been interconnected to form a super grid, which effectively solves the imbalance of energy distribution and economic development. This has brought considerable benefits to environmental protection, resource optimization, and alleviation of power shortages. At the same time, it also brings many serious problems have been raised [5-6]. The most important of these is the wide geographical distribution of large power grids. After disturbances or failures occur, the spread will be larger, causing more severe economic losses and more damage to social life. This is important for the safety and stability control of modern power systems new requirements [7-8].

Regarding the identification of cascading failures of transmission grids, some researchers have proposed the macroscopic statistical law of blackouts. The existing conclusion is that the load loss caused by each blackout corresponds to the probability of this scale in a double logarithmic coordinate law distribution [9]. This means that the probability of smaller power outages in the system accounts for most of the entire power outage statistics, and as the scale of power outages slowly increases, the probability of a slightly larger power outage is slowly decreasing, when the scale of the fault gradually increases to a catastrophic blackout accident, its probability will decrease sharply in the double logarithmic coordinate [10]. The general power system itself has a certain ability to resist accidents, and small-scale blackouts will not cause a global negative impact; and large-scale blackouts cannot relax their vigilance because of their sudden decrease in probability [11]. Aiming at the self-organized criticality of the power system, some researchers combined with the hidden fault model to propose a model for judging whether the power grid enters the self-organized critical state. This model takes the load rate of the line as the core, and can be analyzed by this model. How the power flow is distributed under a specific load rate of a certain power flow can make the system enter a self-organized critical state. However, this article is not appropriate for how to obtain different specific power flow distributions under the same average load rate. It is simply a normal distribution under a certain variance to obtain a set of corresponding line load rate values. It may not match the actual system [12].

This paper conducts research on the cascading failure identification system of the transmission grid based on the GA genetic algorithm, and then has a general understanding of the cascading failures of the transmission grid based on the relevant literature data, and summarizes the basic structure of the related system, and then proposes based on the structure the overall framework of the system designed in this paper, and finally the system designed in this paper is tested, and relevant conclusions are drawn.

2. Research on Cascading Fault Identification System of Transmission Network

2.1 The Structure of the Cascading Fault Identification System of the Transmission Grid

(1) Knowledge base

The main function of the knowledge base is to store and manage knowledge in a dedicated system. The knowledge stored in the knowledge base is mainly divided into two categories: it is mainly divided into two parts: public knowledge in related professional fields and personal knowledge in related fields. Public knowledge mainly refers to the knowledge of theories, rules and definitions in certain professional fields. This kind of public knowledge is generally published in domestic and foreign magazines or in monographs and books, and has been recognized by everyone. It is very persuasive and is basically defined as correct knowledge. The so-called personal knowledge in related fields refers to some theories obtained by most experts through practice in related fields. Many of these theories are conjectures, and there is no complete theoretical system. Some knowledge is obtained through practice and has not been strictly tested by science. This type of knowledge is also called heuristic knowledge, because many formulaic theories are developed on the basis of personal knowledge, so personal knowledge is still very important. In the professional field, public knowledge and so-called personal knowledge form the basis of the knowledge base.

(2) System database

The database is the storage used to store fact data in the expert system. The data in the database generally refers to the facts that have been known, and the conclusions obtained after reasoning. The data obtained from the database can be analyzed very well, and the status and characteristics of the problems to be processed by the system can be well displayed. In the process of reasoning, the facts often appear as intermediate conclusions, so the entire data It changes during the operation of the system. Moreover, the database of the expert system stores fault information and fault rules, and it needs to make some changes in real time. Therefore, the expert system has higher requirements on the storage capacity of the database, and generally requires a larger database system.

(3) Inference engine

The inference engine is a very important part of the entire expert system. It can also be regarded as a kind of computer program, which can ensure the normal operation and use of the expert system, and can coordinate and protect the entire expert system. The main function of the inference engine is to answer the questions raised by the user based on the known knowledge to ensure that the system can operate reasonably.

2.2 Ga Genetic Algorithm

(1) Initialize the population, determine the initial population size, and use the real number method to encode individuals. Each individual real number string in the population includes the weights and thresholds of each node of the neural network. A set of weights and thresholds of the neural network are randomly generated in the solution space.

(2) Use training samples to train each individual in the population. If the error requirements are not met, continue to train the network, otherwise, calculate the fitness value of each individual.

(3) Determine whether the algorithm has reached the prescribed evolutionary algebra, if not, perform genetic algorithm operations. Selection operation refers to selecting good individuals from the old population to form a new population according to the probability. The fitness value of the i-th individual is shown in the following formula:

$$F(x)=\begin{cases} f(x)-\overline{F}(x) & g_j(x)\geq 0 \\ f_{\max}+\sum_{j=1}^{n}(g_j(x))-\overline{F}(x) & g_j(x)\prec 0 \end{cases} \tag{1}$$

Among them, f(x) represents the objective function value of individual x, F(x) represents the average fitness value of the previous generation population, fmax represents the objective function value of the worst individual in the population, and gj(x) represents the output value of node j.

The probability Pi of individual i being selected is:

$$p_i=\frac{f_i}{\sum_{j=1}^{n}F_j} \tag{2}$$

(4) Crossover operation: randomly select the intersection of two individuals x1 and x2 according to the adaptive crossover probability Pc to perform the crossover operation to obtain two new individuals.

(5) In the mutation operation, the individual x is mutated according to the adaptive crossover probability Pm to obtain a new individual. The selection of the mutation point in x is also random. The mutation point in the mutation operator in this paper is randomly selected. For any individual x; there is an interval [x1, x2], and each real value in the interval can be used as a variation value, the interval [x1. x2],

(6) Combine the individuals obtained by genetic evolution, and these recombined individuals form the next generation group. The evolutionary generation number is increased by 1, and the steps (2) ~ (5) are repeated until the evolutionary generation number is reached. After the iteration is completed, the fitness value of all individuals in the last-generation group is calculated again, and the individual with the best fitness is selected for output.

(7) Decoding the individual with the greatest fitness in the new population, and the neural network weight and threshold are the optimal weight and threshold of the BP neural network.

(8) Use the obtained optimal weights and thresholds to predict the neural network.

3. Design of Cascading Fault Identification System for Transmission Network Based on Ga Genetic Algorithm

3.1 Overall System Architecture Diagram

Since the previous section briefly studied the structural characteristics and principles of the cascading fault identification system of the transmission grid, the design of this system mainly includes the power grid fault knowledge base, the management system of the knowledge base, the man-machine interface interface, the inference engine, the interpreter and the fact base of the failure phenomenon, the specific system framework composition is shown in Figure 1.

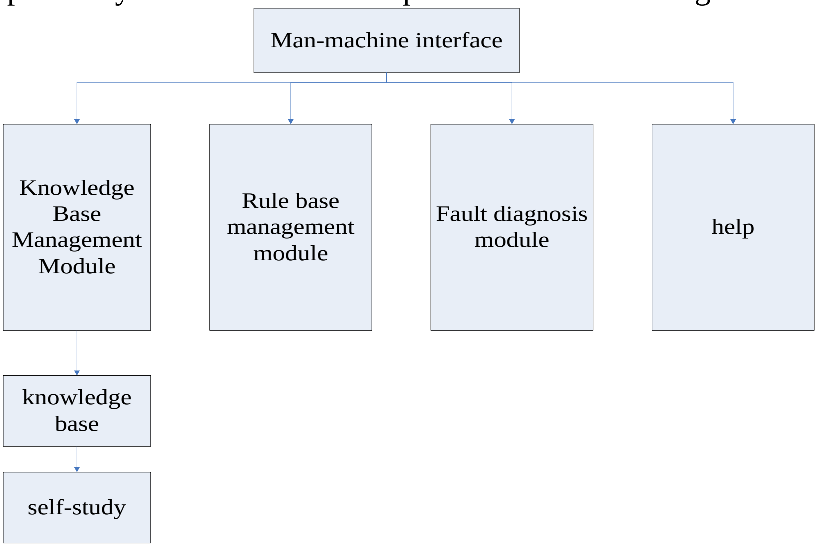

Figure 1: System overall architecture diagram

3.2 System Module Design

(1) Fault knowledge base

The knowledge base is one of the cores of the cascading fault identification system of the transmission grid. The establishment of the grid fault knowledge base of this subject combines self-learning methods to obtain fault knowledge, and SQL Server 2010 is used as the platform to create the knowledge base.

(2) Fault rule library

The function of the fault rule library is to store a large number of rules, use the obtained fault phenomenon to fuzzy match the rules, and obtain the final cause of the fault through the inference engine according to the matching result.

(3) Fuzzy inference engine

The inference engine is also a core of the cascading failure identification system of the transmission grid. The cascading fault identification system of the transmission grid will use C++ to write source programs to build an inference engine based on the forward reasoning strategy, and the inference engine will be applied to fuzzy inference, which can greatly improve the fault diagnosis ability and the accuracy of the fault.

(4) Man-machine interface

The man-machine interface is a platform for users to communicate with the system. This system adopts the form of C++ dialog box to realize the man-machine interface.

(5) Knowledge base management system

The knowledge base management system is also a very important part of the power grid fault diagnosis expert system. This system uses VC++ to create the knowledge base management system.

3.3 Grid Fault Extraction Method

The faults of the power system are more complicated. Here we briefly analyze the basic faults of the power grid as generator set faults, substation faults, transmission line faults, and power distribution system faults. In the event of a power grid failure, it is inevitable that excessive excitation current and various noise signals will appear. The system extracts the power grid fault through wavelet multi-resolution analysis of the noise signal.

3.4 Self-Learning Mechanism of the System Knowledge Base

Fault information can be said to be the source of fault diagnosis. How to obtain high-quality fault information is very important for a diagnosis expert system. In general, there are two main ways to acquire knowledge: one of which is to learn the knowledge and practical experience of experts in the field. This method sets the initial value of the fuzzy matrix completely based on the expert's personal experience, and the system worker part of the fault information can be modified directly through the knowledge base management system; the other method is to use the historical experience confirmed by the knowledge experts to conduct self-learning by the expert system itself. In this way, the fuzzy matrix is modified. Makes the matrix more accurate to simulate the correlation between failure causes and failure phenomena. Since the fault diagnosis system of this subject adopts the method of fuzzy diagnosis, the self-learning will be carried out through fuzzy GA genetic algorithm.

3.5 Fuzzy Matching Algorithm

In order to solve the problem in the actual fault diagnosis process, due to the uncertainty of expert knowledge acquisition and the inconspicuousness of fault symptoms, the system decided to adopt a fuzzy matching algorithm to fuzzy match the feature vector with the condition vector of the fuzzy rule, and then the matching degree obtained is compared with the rule threshold τ, and the obtained comparison result finally determines whether the rule should be used.

3.6 System Implementation

(1) The organizational structure of the system

The system adopts B/S architecture for design and development. The B/S (browser/server) structure is called the browser/server structure, which is based on a three-tier structure, namely, the browser, the Web server, and the database server. The browser is the interface between the system and the user, and is responsible for transmitting user requests and displaying the content that the user wants. The web server is responsible for retrieving the data that the user wants from the database, and accepting the data returned by the database for sorting. The database server provides data for the application.

(2) Development tools

Java is very suitable for the Internet or corporate network environment, so it has become one of the most popular and important programming languages on the Internet. Compared with C++, Java has deleted many unused features, including those whose advantages outweigh the disadvantages. Simple, object-oriented, distributed, structurally neutral, portability, high performance, interpretability, reliability, safety, multithreading, dynamics and other advantages. Clients of any processor are allowed to run and stream on the Internet, so this article chooses Java as the development tool.

4. System Inspection

4.1 System Testing Design

This paper uses EMTP to simulate a single-phase ground fault in the distribution network, and obtain the zero sequence current signal of each line under the fault condition. Program each line selection method through MATLAB software, call various single-phase ground fault electrical quantities obtained by EMTP simulation, and obtain the characteristic components of different electrical quantities under fault conditions. Using these feature components as training samples, through the learning of training samples, the detection performance of the system designed in this paper and the traditional system are analyzed, and relevant conclusions can be drawn.

4.2 Result Analysis

Through the atp simulation method program, the resistance value under the following different situations is simulated: First, the two lines l2 and l4 are selected as the line where the fault occurs, and the total length of each resistance line is between 10%, 50% and 90%. Do a single-phase grounding experiment when the phases of the voltage and the voltage are 0° and 90°, and the transition resistances in various tests are 5ω, 50ω, 500ω, 1kω, 2kω. Since there are a total of 6 power lines in the entire system, a total of 360 identical zero-sequence current signals can be collected in this experiment. The original data obtained after extracting active components, 5th harmonic components and transient components of 12 zero-sequence current signals. Using these data as test samples, the system designed in this paper and traditional recognition were tested respectively, and the output results are shown in Table 1.

Table 1: System performance comparison results

	Text system	Standard system
1	0.020	0.004
2	1.034	1.010
3	0.024	0.008
4	0.015	0.003
5	0.053	0.012
6	0.018	0.002
7	0.026	0.010
8	0.027	0.012
9	0.018	0.008
10	1.044	0.997
11	0.018	0.002
12	0.024	0.004

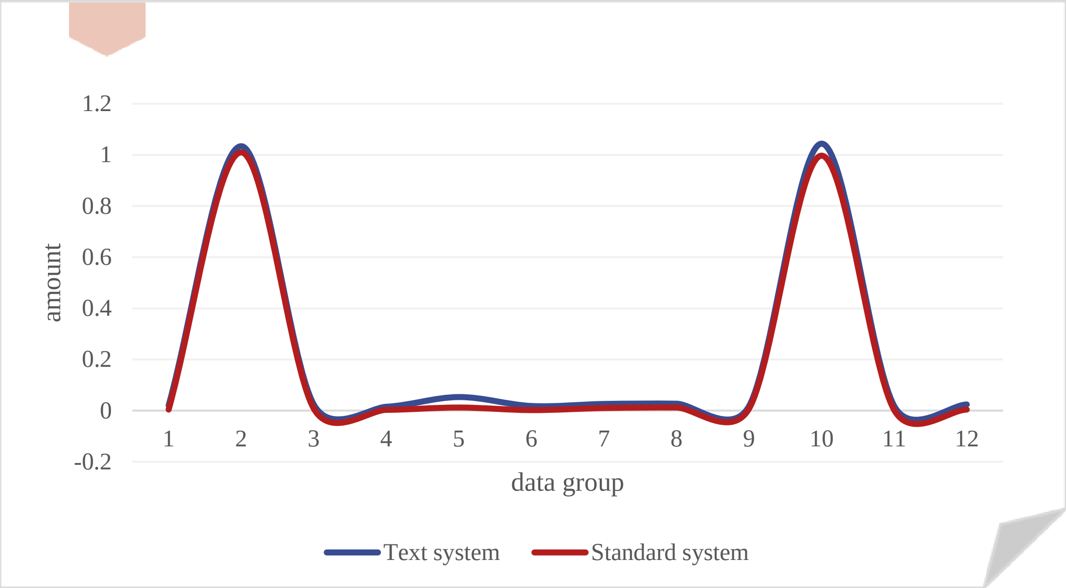

Figure 2: System performance comparison results

System output 1 is judged to be a faulty line, and close to 0 is judged to be a non-faulty line. As can be seen from Figure 2, for the faulty line, the system simulation result based on the design of this paper is closer to 1 than the result obtained based on the traditional system simulation; for non-faulty lines, the results of system simulation based on the design of this paper are closer to zero than those obtained based on traditional system simulation. Tested on 12 sets of test samples, the system designed in this paper has only one set of faults with missed selection, and the correct rate of line selection is as high as 90%, while the traditional system has 2 sets of faults with missed and wrong selections, and the correct rate of line selection is 80%. Therefore, the simulation results show that the accuracy of the system designed in this paper is higher than that of the standard system.

5. Conclusions

In the process of writing this article, when collecting data, it was found that the cascading fault identification system of the transmission grid is not yet fully mature; faced with the massive information resources of the network, it is easy to lose sight of one another, and at the same time, it may not be well in-depth due to limited knowledge, or put forward a relatively one-sided view, and will continue to study related issues in work and study in the future.

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