Application Research of Artificial Intelligence Technology in Power System Alarm Processing Method

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Abstract. The paper first introduces the principles of artificial intelligence and expert systems, and makes a detailed analysis of the application of expert systems in power systems. Secondly, the paper uses VC++ language to establish an expert system for judging power system fault areas and fault types. The system can identify power system bus faults, line faults, circuit breakers and relay malfunctions and refusal faults. Finally, the system simulation test shows that the fault diagnosis expert system established in this paper has certain theoretical and practical significance.

1. Introduction
The safe and stable operation of the power grid has always been one of the major challenges facing the modern power grid. The accidents such as the “8·14 US and Canada power outages” that occurred in 2003 are examples. In the past ten years, Chinese scholars have proposed and developed the grid security early warning technology [2] in response to large-scale blackouts [1], and have been applied in the actual power grid [3], which has become an important means to ensure the safe and stable operation of the power grid. This type of early warning technology is a "model-driven" "analytical" security alert. Based on the previous research, this paper puts forward a new method based on coverage set theory and Tabu search (TS) method. Based on the coverage set theory, this paper proposes a new index to describe the alarm processing problem for practical application. At the same time, the paper describes the alarm processing problem as an unconstrained 0-1 integer programming problem and proposes to use TS to solve the problem. Methods. TS is an efficient heuristic search technique suitable for solving combinatorial optimization problems and has been successfully applied to solve complex combinatorial optimization problems in many fields. Finally, the research on multiple numerical examples shows that the proposed method can find multiple global optimal solutions.

2. Tabu search and its application in alarm processing

2.1. Alarm Processing Mathematical Model
Alarm handling and fault diagnosis represent two different problems in the power system, but from an artificial intelligence perspective, alarm handling is a typical multi-fault diagnostic problem (MFD). In this way, the theory and method in MFD can be used to solve the alarm processing problem. Let's first examine what metrics are used in the MFD, and then define the appropriate metrics based on the characteristics of the alert handling problem.
MFD problems can be described by a four-tuple: \( \{D, M, C, M'\} \). Where \( D=\{d_1, d_2, \ldots, d_n\} \) denotes a set consisting of \( n \) faulty elements or locations ("system event set" in alarm processing); \( M=\{m_1, m_2, \ldots, m_k\} \), represents a set of \( k \) symptoms ("system alarm set" in alarm processing); \( C \) is an \( n \times k \) dimensional matrix used to describe the relationship between elements in \( D \) and \( M \) (for alarm handling problems, \( C \) reflects the “feature alarm set” associated with each event) [4]; \( M' \) is a subset of \( M \) that indicates what appears A collection of symptoms (a collection of "alerts that appear" in alert processing).

The relationship of an event to its signature alert set can be described as:

\[
e_i \rightarrow A_i, i = 1, 2, \ldots, n
\]

\[
e_i \in E_s
\]

\[
A_i = \{a_k | a_k \in A_s \land k \in N_A \}
\]

(1)

Where \( e_i \) represents event \( i \); \( A_i \) is the characteristic alarm set for event \( i \); \( n_e \) is the number of events contained in \( E_s \); \( N_A = \{1, 2, \ldots, n_e\} \); \( n_A \) is the number of alarms contained in \( A_i \).

2.2. Evaluation indicators for alarm processing

A reasonable solution to the alarm handling should meet the following three requirements: (1) its solution is the coverage of \( M' \). This is because the probability of false alarms is small. (2) The combination of the characteristic signature sets corresponding to the events contained in the solution should be as close as possible to the actual alarm pattern that appears. The indicators in [5] reflect only this requirement. (3) The solution should contain as few incidents as possible. The minimum indicator above reflects this requirement. An indicator that reflects the above three requirements is a modified minimum indicator that can be mathematically described as follows:

\[
\min f(E) = \omega_1 |\mathcal{V}A| + \omega_2 |\Delta A| + \omega_3 |E|
\]

(2)

Where \( E \) is an \( n_A \)-dimensional vector representing a possible solution to the alarm handling problem. Each element in \( E \) takes a value of 0 or 1, representing the state of the \( n_e \) events contained in \( E_s \), respectively, taking 0 and 1 respectively. The incident did not occur and occurred.

\( |\mathcal{V}A| \) is a \( n_e \)-dimensional vector and is determined by the values of the other two vectors, \( A_t \) and \( A_n(E) \). \( A_t \) is a \( n_e \)-dimensional vector, each of which takes a value of 0 or 1, representing the actual state of the B alarms contained in it (i.e., presence or absence). Taking 0 and 1 respectively indicates that the alarm did not appear and has occurred. \( A_n(E) \) is a B-dimensional vector that represents the alert pattern that should occur when an event represented by an element with a value of 1 in \( E \) occurs. Each element in \( A_n(E) \) takes a value of 0 or 1, indicating that the corresponding alarm should not appear or should appear.

2.3. Tabu search and its application in alarm processing

The idea of tabu search algorithm was first proposed by Glover in 1986 and is a global stepwise optimization algorithm. The solution process is to first find an initial solution, then search for a better solution in the neighborhood or move to a poor area to search for the best solution in the region, and record the path that was searched for, as the basis for the next search. To avoid falling into the local optimal solution. It introduces a taboo table to record the local bests that have been searched. In the next search, the information in the taboo table is used to no longer or selectively search for these points,
thereby jumping out of the local best, thus achieving global optimization. The idea of taboo search is organized, as described in Figure 1 below:

![Taboo algorithm calculation process](image)

**Figure 1.** Taboo algorithm calculation process

3. **Numerical simulation and results analysis**

The paper applies the power system distribution network model (Document 5) shown in Figure 2 for the simulation test of Tabu search alarm processing. This network system contains a total of 26 components and 26 alarms. Where \( P_i \) is the component and \( C_j \) is the alarm. Because it is a distribution network [6], it is relatively simple compared to the power system backbone network, so we only selected more than 40 cases to calculate, and all the results found the optimal solution. We only give some of the conditions listed in the table below: From the figure we can easily get the characteristic alarm set of each component, and the characteristic alarm set of some components is shown in Table 1.
Figure 2. Power system distribution network model

Table 1. Partial test results of power system distribution network

| Test sequence number | Alert that appears | Problematic component |
|----------------------|--------------------|-----------------------|
| 1                    | C1, C2, …, C26    | P1                    |
| 2                    | C2                | P2                    |
| 3                    | C4, C6, C7, C8    | P4                    |
| 4                    | C5, C9, C10, …, C26 | P5                |
| 5                    | C13, C14, …, C26  | P13                   |
| 6                    | C14               | P14                   |
| 7                    | C2, C3, …, C26    | P2, P3, P4, P5        |
| 8                    | C18, C19, …C26    | P18                   |

More examples can be found from this model. The examples are not listed here. The validity and efficiency of the Tabu search algorithm are further verified by this example. It is proved that the application of Tabu search algorithm is feasible in power system alarm processing. In the calculation process, the parameters related to TS are: $S_{\text{max}} = 26$, $K_{\text{max}} = 50$, and $T_{\text{max}}$. The value can be between 10 and 15.

4. Artificial intelligence and expert system establishment

4.1. Artificial Intelligence

The study of artificial intelligence began in 1956 and began with the so-called problem solving. Most of the early problems were limited to simple areas such as chess, guessing, and proof of mathematical theorems. At present, the research of artificial intelligence involves almost all disciplines, and it mainly includes the following aspects: 1) Expert system. Let the computer simulate the decision-making process of human experts, solve those who cannot establish mathematical models and must rely on expert experience to solve practical problems. 2) Decision support system. Through computer reasoning and judgment, assist decision-making on certain diversified, inaccurate or uncertain problems. 3) Natural language understanding system. Enable computers to understand human language and improve human-
machine connections. 4) Knowledge base system. The knowledge that human beings have mastered is expressed by certain rules, that is, it is stored in a computer through form comparison processing to provide users with knowledge sharing. 5) Intelligent robots. The robot has the functions of human hands, eyes and brain. It not only looks, does, but also thinks, and can determine its own behavior according to environmental conditions. Intelligent robots have been used in aerospace, nuclear industry, metallurgy, machinery, chemical industry, etc. The beginning of the field replaces the work of humans.

4.2. Establishment of expert system
The expert system is implemented in a computer. It consists of five parts: knowledge base, database, inference engine, knowledge acquisition part and interpretation part. The knowledge base and inference engine are the core parts of the expert system. The relationship between the parts is shown in Figure 3. Among the above components, the knowledge base and inference engine are indispensable components of the expert system. In some application areas, there may be a lack of explanation and knowledge acquisition, but a complete expert system should have the above five parts.

![Figure 3. The composition of the expert system](image)

4.2.1. Human-computer interaction interface. The human-machine interface of the expert system is mainly used for two-way technical communication between the system and the user. A friendly human-machine interface should have the following features:

1) The system can understand the information that the user enters in the specified language. The languages commonly used by expert systems are Lisp and Prolog (both languages will be introduced in related books). The common features of these two languages are very close to natural language, and they can be used directly to express expert knowledge and reasoning process. Using these intelligent languages, new knowledge can also be generated and thus is widely used in expert systems. The future human-machine interface will use natural language understanding technology, which allows the system...
to directly understand people's words, which is another important aspect of current artificial intelligence research [7].

2) The system can ask the user questions. In the process of starting and working, it is inevitable to ask the user for the purpose of further clarifying the user's request or obtaining sufficient evidence. Commonly used questions are: A. Test Table B. Project Selection C. Data D. Yes or No (Y/N). In addition, when the system finds a fault, such as during the reasoning process, it finds that the rules used are contradictory or incorrect, or the reasoning process enters an infinite loop, it can prompt the expert and request correction.

3) The system can display the results of the query and answer the user's questions. The basic method for implementing the system's explanatory function is backtracking, that is, the reason for the conclusion is reversed from the current conclusion until a reasonable explanation is given.

4) The system should be able to alert the user to the operating method of the system and how to use the peripherals (printer, screen display).

4.2.2. Database. The database is a part of the storage space in the computer. It is used to store some initial data and the intermediate results obtained during the inference process. It stores the facts provided by the user (including the information of the inquiry and the answer) and the middle of the reasoning process. Information. For example, in the power system fault diagnosis system, the database stores user-related fault phenomena (such as the displacement of the circuit breaker, the relay protection and the action of the automatic device, the indication of the measuring instrument, and other related Situation) and the fact that the user requires the system to diagnose the faulty component, as well as intermediate excess information that occurs during the diagnostic process. The difference between a database and a knowledge base is that the contents stored in the database are always dynamic and will not be stored forever. When the system is finished, its contents are automatically cleared.

5. Conclusion
The paper obtained the following research results: (1) based on the coverage set theory, a new indicator describing the alarm processing is given. Compared with other alarm processing, the index is more reasonable and practical. (2) Describe the alarm processing problem as an unconstrained 0-1 integer programming problem. (3) The TS method is an efficient heuristic search technique and is widely used to solve complex multidimensional combinatorial optimization problems. In this paper, TS technology is applied to the alarm processing problem of 0-1 integer programming as a model, and has achieved good practical results. The computer numerical simulation example shows that the integer programming alarm processing model based on TS method 0-1 is reliable and effective; the alarm processing method based on TS method can find the global optimal solution of the given model.

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