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An Electric Power System Fault Diagnosis Method Based On Time Series Petri Net

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Abstract

Timing information of the alarm signal is rich after the electric power system goes wrong. It will diagnose the fault quickly and accurately if it can be made full use of. The failure alert collected by the dispatch center contains the timing information, thus constitutes the time sequence. In this paper, the concept of time series and Petri net are introduced into the fault analysis of electric power system. An electric power system fault analysis method based on time series Petri net is proposed. First, the concept of time series Petri net and its method are presented. Subsequently, the method is improved and applied to fault diagnosis of electric power system. The time series Petri net model is constructed. The fast correction method is presented, which fully utilizes the time sequence attribute of the circuit breaker action information. The proposed method make use of the timing characteristics of alarm information sequence and still can quickly identify the false alarm in complex situations. Finally, the process of fault analysis is explained.

Keywords*: electric power system; fault diagnosis; time series; Petri net*

1. Introduction

Electric power system fault diagnosis is making the use of the electric power system fault process of the generation of telemetry, remote information and the sequence of event information, judging fault components and fault types, identify the protection and breakers for incorrect actions, assist scheduling or running personnel dealing with the fault, in order to shorten handling time of accident, avoid the fault to be extended, accelerate recovery of the electric power system. Over more than 30 years hard working, a variety of methods are presented in the field of fault diagnosis of power system at home and abroad, mainly includes: Expert System, Analytic Model, Artificial Neural Network, Petri net, Rough Sets Theory and etc.

Power system fault diagnosis method based on Expert System uses the action rules of protective equipment to establish the knowledge base, activate the corresponding rule with an alert signal, and the fault elements are identified by inference, the applicable scope is wide, and it has been used in some electric power system, but the Expert System requires that the knowledge base is complete and the maintenance of the knowledge base is difficult, so it is very difficult to guarantee a good fault tolerance ability, moreover, the diagnosis speed is not fast enough. The method based on Analytic Model considering the fault components and protection, the logical relationship of the circuit breaker action will describe the power system fault diagnosis problem for 0-1 integer programming problem and the optimal algorithm for solving this method has been the application in some practical power system, however, the use of the timing characteristics of the alarm signal is not enough. The performance of power system fault diagnosis method based on

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artificial neural network depends on whether the training sample is complete or not, this is generally not guaranteed, in addition, the power system running state changes very quickly, so we need to update the neural network regularly, and the training process is time-consuming, so far, this method has not been applied in the practical power system. Petri net uses the matrix to solve the model by constructing directed graph's combination model, and the speed is faster, but this method has not yet been systematically calculated the timing characteristics of the alarm. The basic ideas of Rough Sets Theory and Expert System are similar, but the ability to describe heuristic expert knowledge is stronger.

How to make full use of all kinds of alarm information, especially its time sequence characteristics, to improve the accuracy and fault tolerance of fault diagnosis, has become an important problem in the field of power system fault diagnosis. In the paper [12], an analytic model of the timing information is constructed by introducing a timing constraint network. The paper [13] which use the timing constraint network further developed fault diagnosis model of multisource information delay constrained weighted fuzzy network based on electric quantity criterion, the protection criterion and the circuit breaker criterion，however, the use of timing information is limited to data selection, and the correlation between the standard deviation and the accuracy of the information is not fully utilized.

Time series exist in science, engineering, economy, society and so on, there will be plenty of time series to produce all the time. Data mining technology is a comprehensive research field in the middle and later period of 1990s. It aims to extract potential and valuable knowledge or even rules from large amounts of data, as a common and important data type, data mining and analysis of time series is one of the most significant problems in data mining. With the development of power system dispatching automation system based on modern information technology, more and more information is collected by the dispatch center, the whole network time synchronization of the SOE information based on global positioning system (GPS) contains the unification benchmark alarm timing information, forming a more accurate time sequence. If we can effectively use the implication of the information, it will be able to improve the accuracy and efficiency of fault diagnosis.

Petri net is an effective modeling tool for discrete event systems, has achieved a variety of practical applications, such as object-oriented software modeling, flexible manufacturing systems, communication protocols, etc.. It is used in Topology analysis, fault diagnosis in power system. Using Petri net technology to solve the problem of fault recovery has a series of advantages: The graphical description of the Petri network makes the complex recovery process easy to describe; The problem of fault recovery usually presents the characteristics of concurrency, and the Petri network has the ability to deal with the problem; Petri network can easily analyze the system in the specific initial conditions of the reachability, security and conflicts and other issues. Petri net technology also has very obvious shortcomings, The network size increases exponentially with the increase of system dimension so as to make the system analysis more difficult.

According to the actual situation of the transmission system, this paper presents a model of power system fault diagnosis based on time series Petri net, fully and reasonably apply the temporal attributes of the alert message. Uncertainty information such as protection and circuit breaker malfunction and loss is processed. A fast correction method is proposed for the change of topology structure of power network. The remodel problem when topology changes is effectively improved.

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2. Mathematical Description of Time Series Petri Net

2.1. Concept of Time Series

Time series is an ordered set of record value of a physical quantity and elements of time nodes, can be written as:

$$X = \{x_1 = (v_1, t_1), x_2 = (v_2, t_2), ..., x_n = v_n, t_n\} \quad (1)$$

In the formula: $x_i = (v_i, t_i)$ shows the recording information of time series is v_i at time t_i , n is the potential of time series X , it is written as $|X| = n$,that is $i \le j \Leftrightarrow t_i \le t_j, i, j = 1,2,...,n$.

In narrow time series, v_i , generally refers to a real valued. In generalized time series, v_i , not only limited to the value, but also can be multimedia data, discrete symbols, custom model data and other information.

2.2. Definition and Operation Rules of the Basic Petri Net

A basic structure of the Petri net is a four tuple: $S(P,T,I,O)$, among them, $P = \{P_1, P_2, ..., P_n\}(n \ge 0)$ is a finite set of all nodes of the library; $T = \{T_1, T_2, ..., T_m\}(m \ge 0)$ is a finite set of transition nodes; They do not intersect, which means $P \cap T = \Phi$. $I: T \to P^\infty$ is a input function; $O: T \to P^\infty$ is a output function; Input function and output function are used to describe the relationship between the library and the transition. In fact, Petri net can be seen as a directed graph, $C = (A, B)$ which $A = P \cup T$, $B = I \cup O$, Therefore, the basic Petri net can be represented as a five tuple: $S(P,T,I,O,C)$. One of the most important components is the node P and the node T . Generally node P is used to represent state of the system, node T is used to represent the changing operation of the state of the system, node E is a directed arc that connects the node P and the node T .

The change of system state is represented by the change rule of node T , Petri net is controlled by Token distribution and the Number of cases, Token resides in the library to control the change of node operation. The firing of the transition node is removing the input library token, the new token will distribute to its each output library.

2.3. Definition of the Time Series Petri Net

Time series Petri net has Basic Petri net theory, also the ability with time constraints. In the modeling of real system, it can be used to model and analyze the structure of time related conflict. Time series Petri net uses weak trigger rule. There are two ways to show the duration of the event. One is to mark the duration of events next to the library. The other way is to mark the time next to the changes, which means that when the transition has a condition, it can be delayed for some time, or remove the corresponding token from the corresponding input library immediately when the change occurs, but it will produce the corresponding tokens from the corresponding output library after some time delay, more accurate diagnosis results can be obtained according to the reasoning of the decision.

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3. Modeling

3.1. General Model of Protection Configuration in Power System

When the electric power system goes wrong, the alarm information of the protection and circuit breakers constitute the alarm time series, according to the setting of protective device, it can construct a series of alarm hypothesis time series, As shown in figure, using E to represent the end point of time series.

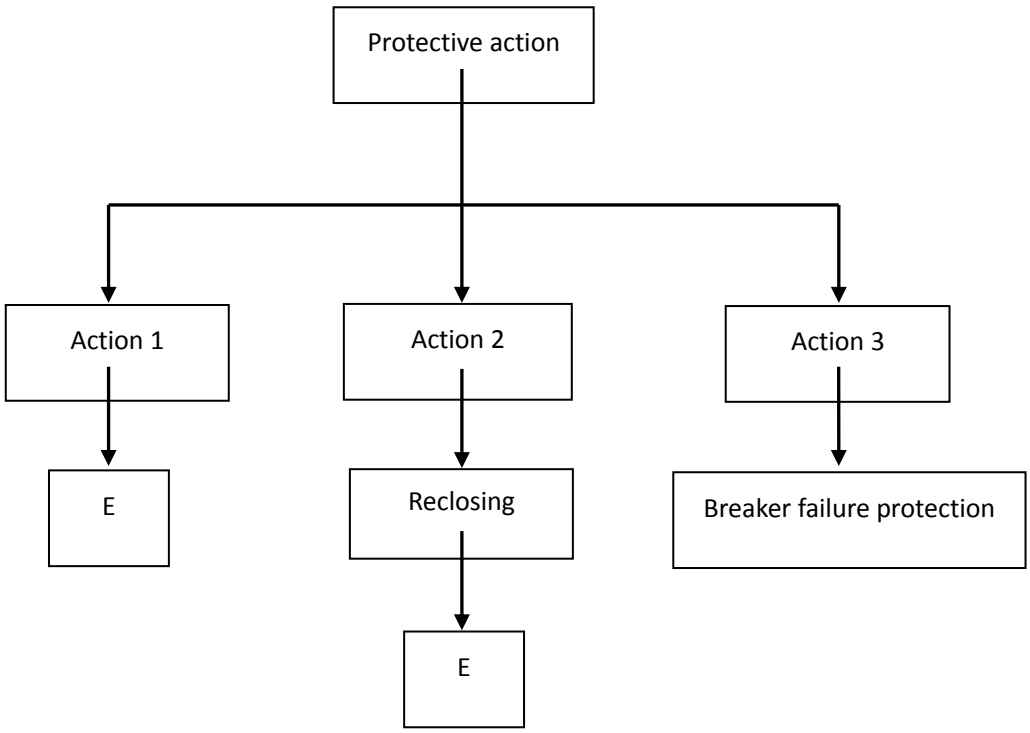

Figure 1. Common Configuration Model for Protective Device

It can be seen from Figure 1, each time series generated by the protection device configuration will be ended with "E" or another set of protective equipment.

For any of the elements related time series G_1 , event occurring time set by the setting of protective device with time length Δt , then set it according to the allowable event time error. When the protective device acts, time series happen one after another in the related time series, enter dispatching center after information collection, to form accurate time series.

When the power system has faults, relay protection will act and isolate the fault elements. The real time information of circuit breaker can be used to identify the fault area. The identification of fault components can be limited to the components contained in the fault area so that the speed of fault diagnosis can be greatly improved. Fault area identification is generally in process after the accident, at this point, the dispatch center has received the full alert information which can form an alert information time series. That is, the alarm information has been reached in the order of time, and no more change. Operation process of the method of electric power system fault diagnosis based on time series matching is simple, and fast, also can satisfy the requirement of on-line fault diagnosis.

The steps are as follows:

Step 1: Get the Suspicious fault elements by searching the passive region in system.

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Step 2: According to the setting of protective equipment, build a general model for protection device for suspicious fault components involved. All of the time series build in this model will be ended with “E” or second action of protective equipment; For the time series ended with second action of protective equipment, Complete time series of alarm hypothesis can be got by opening the second general model for protection device to form time series of alarm hypothesis.

Step 3: To each one of the time series of alarm hypothesis, the distance between the time series of alert information received by the dispatching center is calculated by sub time series matching method

Step 4: Covert the distance of time series into confidence degree of elements action to get the fault elements.

Step 5: Analysis of fault process. Explain the development of fault process, and the accuracy of the alert information and the action status of relay protection and circuit breaker are evaluated.

3.2. Power System Fault Diagnosis Model Based On Time Series Petri Net

The relay protection device in the power grid is set with the fixed action time limit, merge it in the Petri net according to the power system fault diagnosis model based on time series Petri net in chapter 1.3. When a fault occurs in the power system, the action of main protection triggers the action of corresponding circuit breaker. The action of backup protection after a period of time delay is related to the state of the circuit breaker at the end of the time delay. In order to simplify the model, this paper only considers the relationship between the time of protection and circuit breaker. Then more accurate diagnosis results are obtained.

A major problem to be solved for fault diagnosis of complex net is automatic correction of diagnostic model for topology change. In this paper, we take the electric power system element as the object, build up the model of power system fault diagnosis based on time series Petri net. It has the following characteristics:

The models of the two ends of the line are established separately, for line or transformer, the main protection acts due to its fault, it will cut all the circuit breakers which are connected. The rejection of each circuit breaker will lead to the expansion of the scope of the fault, so we need to establish a model for each connection; In this paper modeling, adopting the traditional protection configuration principle line or transformer has no near backup protection. Take the protection of adjacent lines as a backup protection, the line itself has the main protection and near backup protection. Take the adjacent lines as a remote backup protection. From the first characteristics of the model, the structure of several models associated with a particular element is the same. According to this characteristic, the reference model can be set up.

In the problem of power system fault restoration, the process of recovery can be expressed by the state change and the recovery step of the power element. If we view the state of the components in the grid as node P and view the recovery step as node T, directed arcs in time series Petri net indicates the state transition of the system. Through the changes of time Petri nets system state, The initial state of the system after the fault can be gradually change to the steady state. Then the target node is pushed back to the beginning. At last, the time of the operation and each step of the recovery operation of this path are obtained.

Dynamic model of power system fault diagnosis based on time Petri net can further describe the time required to restore the power system to the end of the fault. Time series Petri net assumes that any system has a unified global time. Mark the time next to the change. It means that when the transition has a condition, it can be delayed for some time or after the change, remove the corresponding token from the corresponding input library immediately. But the corresponding tokens are produced in the corresponding output library after a time delay. The time series Petri net model of power system fault diagnosis

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can be obtained from this. Taking the three bus system shown in Figure 2 as an example, the time series Petri net model is established. This model has 34 nodes P, 24 nodes T and 109 directed arcs. Because the model is quite complex, this paper only gives a part of the model as shown in Figure 3.

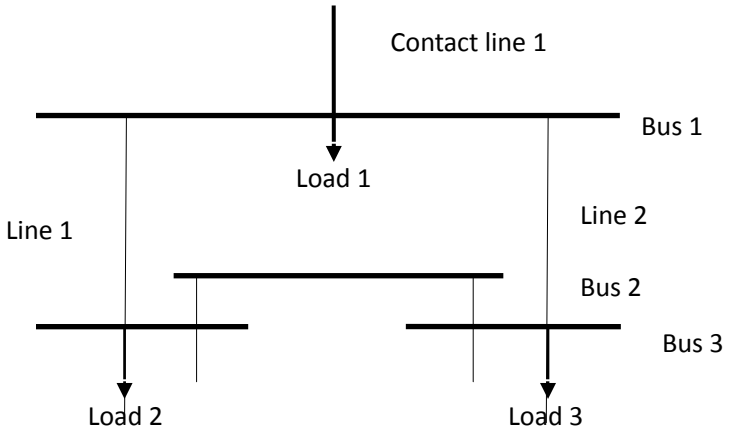

Figure 2. Three Bus System

4. Fault Diagnosis Process

The node P and the node T in Figure 3 represent: indicates the contact line 1 is no fault; indicates the contact line 1 is not connect to the system; indicates the bus 1 is not charged; indicates the line 1-2 is not charged; indicates the line 1-3 is not charged; indicates the contact line 1 is connect to the system; indicates the bus 1 is not charged; indicates the line 1-2 is charged; indicates the line 1-3 is charged; indicates the load 1 is no power; indicates the load 1 is with power; indicates the load 2 is with power; indicates the bus 1 and the line 1-2 are not connect; indicates the bus 1 and the line 1-3 are not connect; indicates connecting to the link line 1; indicates delivering power from the link line 1 to the bus 1; indicates delivering power from the line 1-3 to the bus 1; indicates delivering power from the line 1-2 to the bus 1; indicates delivering power from the bus 1 to the line 1-2; indicates delivering power from the bus 1 to the line 1-3; indicates delivering power to the load 1; indicates paralleling the bus 1 subsystem and the line 1-2 subsystem.

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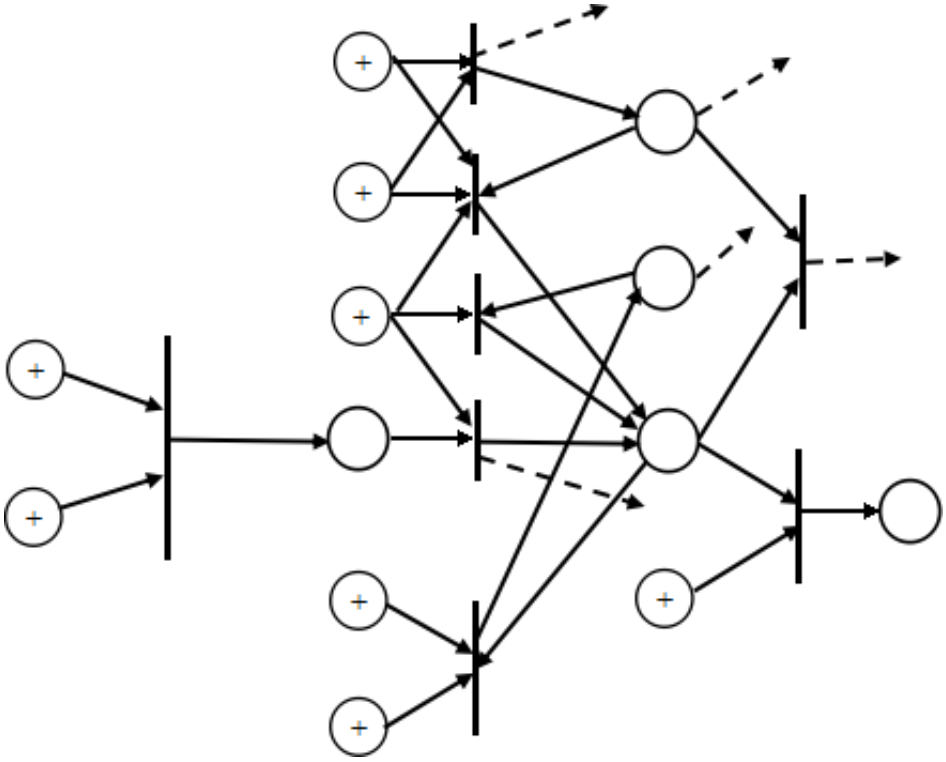

Figure 3. Time Series Petri Net Model of Three Bus System

All of the initial nodes P are marked (*i.e.*, token number equals to 1) in the initial state, the other nodes P are not marked(*i.e.*, token number equals to 0). According to the implementation rules of the Petri net, the mark in the initial node P will be moved: If all the input P of a node T are marked, the node T is executable, in other words, the recovery operation that the node T represents will become the next possible operation. In Figure 3, in the first step of the mark movement, only is available. In the second step, becomes an executable node, and in the third step , , and are executed, according to the implementation rules, if a transition is executed, the mark of the PN model will change according to the rules, we call the phenomenon as the movement of the mark. If the time stamp is added to each node P, and time valued for each node T, this time value corresponds to the time of the recovery operation that the node T represents. At the same time, each node T is added with the time stamp, which represents the cumulative time to complete the operation. The initial time of all the nodes P in Figure 3 is 0 minutes. Assuming the time required for the recovery of is 25 minutes, the time stamp of the will be 25 minutes. has two input nodesand , the time stamp of the is 25 minutes, and 0 minute for , In this algorithm, we take the maximum value of two input nodes, that is, 25 minutes, Assuming the time required for the recovery of is 5 minutes, the time stamp of the will be 30 minutes. In the actual situation, the cost of each node T that represents the recovery operation can not be accurately determined, in this case, we take the time period as the time to complete the operation. According to this analysis, the spending time of the ultimate goal will also be a time period.

5. Conclusion

In order to make full use of the figure the alarm signal after power system faults, and improve the efficiency and accuracy of fault diagnosis, in this paper, the concept of time series Petri net and related technologies are introduced into power system fault diagnosis. Compared with the fault diagnosis method of transmission system

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proposed in recent years, this method makes full use of the connection between the alert information and the accuracy of the information. With the help of Petri net the situation of the false alarm still can be identified in complex conditions. Accurately it can diagnose the fault components and fault types, and the action of protective device is evaluated. So this method has great feasibility and validity.

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