A NOVEL FAULT DIAGNOSIS APPROACH OF SMART TRANSMISSION GRID BASED ON KNOWLEDGE GRID TECHNOLOGY

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ABSTRACT

There are some problems in current power grid fault diagnosis system based on expert system such as time-consuming diagnosing and difficulty in on-line expert knowledge maintenance especially in high level dispatching centre. A novel fault diagnosis approach of smart transmission grid based on knowledge grid technology was presented in this paper for solving problems mentioned above. Firstly, the knowledge grid technology was introduced to smart transmission grid fault diagnosis field. Then the knowledge map of fault diagnosis was designed according to the background of practical power system application. And the generation methods of each part in the knowledge map were analyzed in detail. Finally, a distinction between fault diagnosis system of power grid based on expert system and knowledge grid technology was contrasted with a power grid practical applications test, and the applicable conditions of two methods were described too.

INTRODUCTION

With the development of smart grid which is becoming more and more complex, power systems are being operated close to their stability limits. And recently, the serious unpredictable system cascading failure may cause system wide blackouts, which attracts the attention of researchers to the fault diagnosis and analysis of power system[1]. The need for the development of fault diagnosis system has been recognized since the 1960s.

Several fault diagnosis systems have been developed and are used now. The prevailing fault diagnosis systems are based on expert system [2], artificial neural network [3], fuzzy theory[4],information theory[5], complex event processing technology[6] and so on.

However, the method based on expert system is the most effective and widely used in practical systems, which provides reasoning and judgments according to the knowledge and experience of experts in the program system, and then simulates decision-making process of experts to solve problems in the grid fault diagnosis. Although expert system method's accuracy is directly proportional to sum of expert rules, how to improve the searching efficiency and on-line maintenance of expert knowledge is an important difficulty in applications of expert system.

Considering the current problems in power grid fault diagnosis method based on expert system such as slow searching speed of expert knowledge and difficulty in expert knowledge maintenance, a novel fault diagnosis approach of smart transmission grid based on knowledge grid technology is proposed in this paper, and the comparative analysis on aspects of searching efficiency and maintenance of expert knowledge is also presented.

KNOWLEDGE GRID TECHNOLOGY

Knowledge grid

Knowledge grid [7] is an intelligent interconnection environment that enables users or virtual roles to effectively capture, publish, share and manage knowledge resources. It also provides the required knowledge services for users and other services, and realizes knowledge innovation, collaborative work, problem solving and decision supporting. The natural combination of resource space and the semantic link network exiting among things helps people manage resources effectively.

Knowledge representation and storage

Knowledge representation is to study the feasibility and the validity of the general approaches of using the machine representing knowledge, which takes into consideration both the storage and the use of knowledge. It can be considered as a set of agreement describing things, to make the human knowledge represented as a data structure that machines can process. What this paper adopts is the knowledge grid representation based on Extensible Markup Language (XML).

Knowledge map

For intuitive representation of the knowledge grid generation process, we use knowledge map to illustrate, mainly including the knowledge nodes, the knowledge links and the knowledge description.

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Knowledge map of smart transmission grid fault diagnosis

According to the typical knowledge grid architecture [8] and the practical application background of power system, this paper builds a multi-level knowledge grid model of fault diagnosis knowledge in smart transmission grid,

which's the power system fault diagnosis knowledge map, shown in Fig.1, where knowledge dimension is used to store the fault diagnosis knowledge nodes, that are associated with each other through knowledge association.

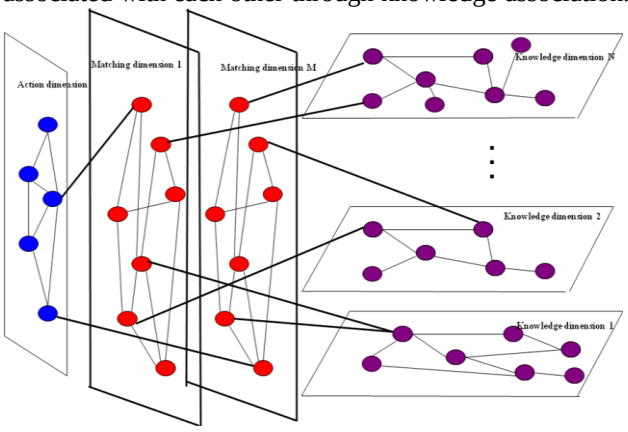

Fig.1 Knowledge map of smart transmission grid fault diagnosis

When the knowledge node within a knowledge dimension is successfully triggered, it will activate the corresponding diagnosis knowledge of power system, then give the corresponding diagnosis and control recommendations.

Knowledge dimension

The reconstruction of the knowledge dimension nodes

The reconstruction of the knowledge dimension nodes is to extract different parts of the knowledge within a same dimension, and store them independently in the knowledge dimension. Thus, the knowledge matching within the same knowledge dimension would only need to match part of knowledge nodes, without matching all nodes of expert knowledge corresponding to the knowledge node, which greatly improves the matching efficiency.

Fig.2 shows an expert knowledge of fault diagnosis system, whose knowledge nodes in the specified knowledge dimension are stored as the way shown in Fig. 3. The action dimension mainly triggers the configuration properties in the expert knowledge shown in Fig.4. The matching dimension is the bridge between the action dimension and knowledge dimension, which is of great importance to design knowledge nodes of matching dimension. Known from action dimensional knowledge, the knowledge nodes in the same matching dimension have the same fault type, voltage level and wiring way, which are mainly generated by common parts of each knowledge dimension.

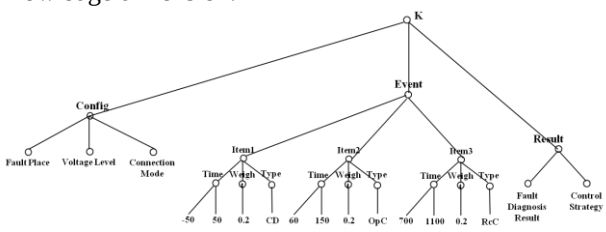

Fig.2 An expert knowledge of fault diagnosis

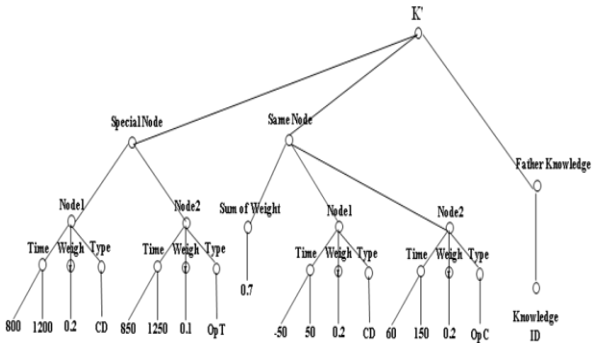

Fig.3 A knowledge node in knowledge dimension

The association relationship of knowledge dimension

Every knowledge dimension has a knowledge-dimensional association relationship XML, which mainly records the searching path of the reconstructed knowledge nodes within the knowledge dimension.

CASE ANALYSIS

The traditional diagnostic methods based on expert systems will be compared with the methods based on knowledge grid technology in this section, by analyzing their performances in aspects of diagnostic efficiency and on-line knowledge maintenance.

The power grid fault diagnosis method based on expert system

Traditional methods

Initially applied in Langfang, the diagnosis system only used 51 expert rules adopting a sequential searching method [9], with the maximum diagnosis time more than one minute, which had made the fault diagnosis system ineffective. To solve this problem, the searching algorithm should be optimized. If adopting the binary searching method, the maximum diagnosis time is about one minute. Based on binary searching, if we classify the faults according to the voltage level and the type of fault script, the maximum diagnosis time can be reduced to about 50 seconds. The corresponding relationship between sum of rules and diagnosis time of various methods shows in Fig.4, where t represents the diagnosis time cost, n represents the sum of rules.

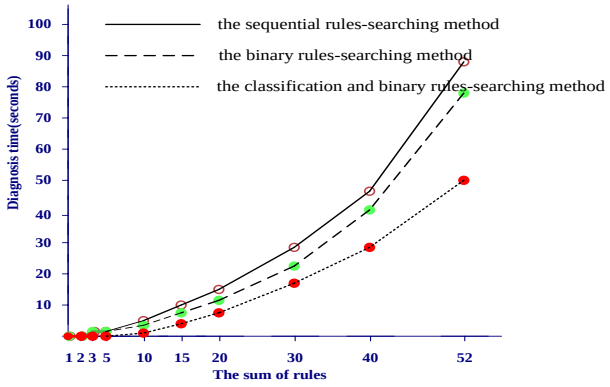

Fig.4 Relationship between sum of rules and diagnosis time cost of traditional method

As we can see, though the searching methods have been optimized in many ways, the diagnosis time retains still about 1 minute, which cannot meet the practical engineering needs. By analyzing we know the reason for long diagnosis time is not the long searching time, but the long matching time as a result that we need to match the rule after searching one.

Improved methods

According to the above analysis, we add checking items in the expert rules to reduce the matching time. We can know that the matching time T before improvement is the same as T_{Suc} which is the time successfully to match a rule after improvement, while bigger than T_{Fail}, the time failure to match a rule after improvement. As the sum of rules failure to match is much greater than the successfully matching ones, the improved rules-matching time will less than the time before improvement.

Analysis shows that using three or more checking items will increase the diagnosis time due to small knowledge rules. When adopting binary searching and classification and adding two checking items, the maximum diagnosis time is within one second, which can basically meet the requirements of practical engineering. As a result, this method is adopted in the practical application.

The power grid fault diagnosis method based on knowledge grid technology

The test case

In the test environment of the dynamic monitoring platform project in the State Grid Corporation, as the sum of applied expert knowledge is 260, the power grid fault diagnosis method based on expert system will be ineffective. If adopting the method based on knowledge grid technology, the computing efficiency will be improved significantly. For example, when line AB with current differential protection goes failure at time 0, the action of the protection switch has been generated as XML event, shown in Fig.5.

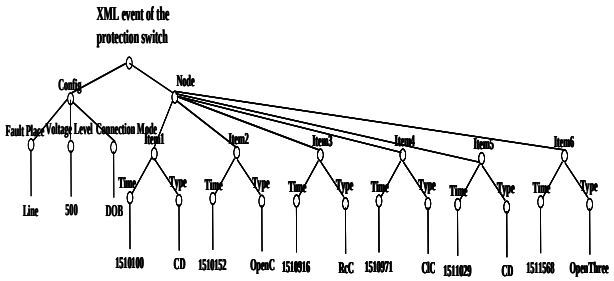

Fig.5 XML event of protection and switch action information

The diagnosis flow

The diagnosis flow of smart transmission grid fault diagnosis system based on knowledge grid technology is shown in Fig.6.

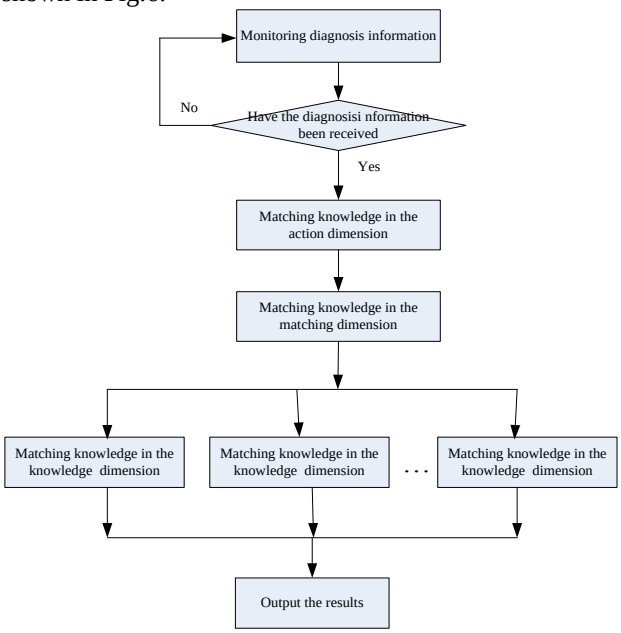

Fig.6 Diagnosis flow of smart transmission grid fault diagnosis system based on knowledge grid technology

Fig.7 shows the knowledge node 3 successfully matched with action dimension, it activates matching dimension 2.

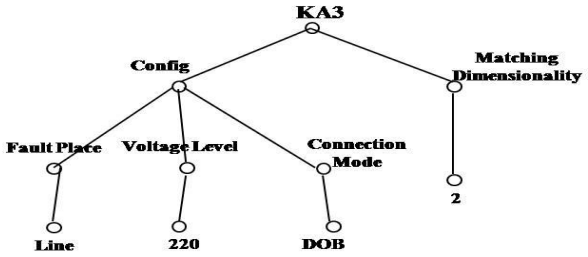

Fig.7 The matched knowledge node in action dimensionality

The knowledge node 1 successfully matched with matching dimension 2 shows in Fig.8, it activates knowledge dimension 1 and while the knowledge relationship of matching dimension 2 updates correspondingly.

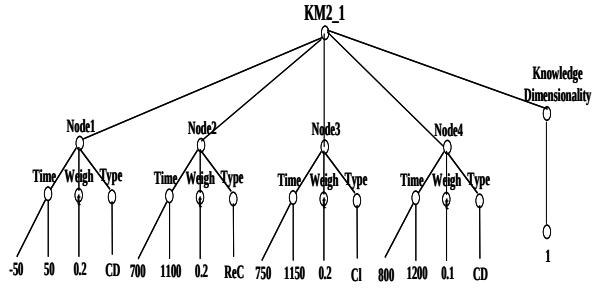

Fig.8 The matched knowledge node in matching dimensionality

The knowledge node 1 successfully matched with knowledge dimension 1 is shown in Fig.9, it activates diagnosis knowledge 15, and output the corresponding fault diagnosis results and scheduling recommendations,

while the knowledge relationship of knowledge dimension 1 updates accordingly.

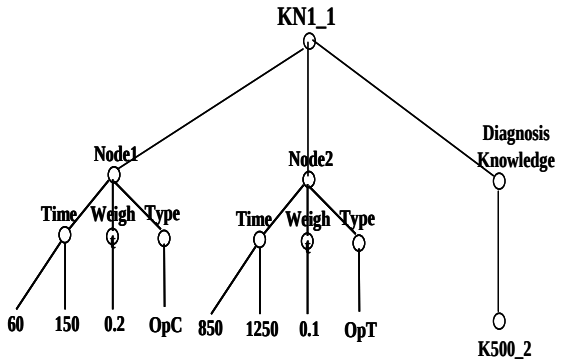

Fig.9 The matched knowledge node in knowledge dimensionality

The diagnosis time

The relationship between sum of rules and diagnosis time cost using knowledge grid technology in the smart transmission grid shows in Fig.10, from which we can see that the maximum diagnosis time is about 3 seconds, and with the use frequency increasing, the diagnosis time cost will be further reduced when the knowledge relationship amends continually, which can meet the demand of engineering practice.

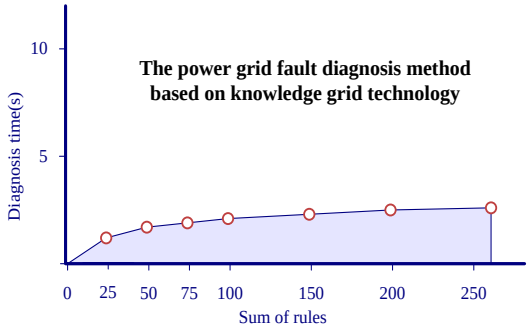

Fig.10 Relationship between sum of rules and diagnosis time cost using knowledge grid technology

Comparative analysis

The diagnosis efficiency

The practical case analysis shows that when the sum of knowledge rules is small, the efficiency of methods based on expert system and grid technology are nearly the same, or the former is even more efficient. But with the sum of knowledge rules increasing, especially reaching to hundreds or more, the efficiency of the latter is obviously better than that of the former.

Knowledge maintenance

In practical applications the expert rules must firstly be write in the method based on expert system [7], which are compiled as .h and .cpp files by the compiler; followed by stopping the application program, putting the compiled files into the main program; finally recompiling the main program and running the diagnosis system.

The expert knowledge in the method based on knowledge grid technology is stored in the form of XML. When revising the diagnosis knowledge, the original file can be replaced online. When modifying knowledge nodes within the knowledge map, it only need to generate new knowledge node XML file, then replace the existing XML file without pausing diagnosis system.

CONCLUSIONS

A power grid fault diagnosis method based on knowledge grid technology is presented in this paper, which solves the problems in current fault diagnosis system based on expert system such as time-consuming diagnosis and difficulty in on-line maintenance of expert knowledge. The case analysis shows the high accuracy and practicality of the method, which can be applied not only in power grid fault diagnosis, also in other industries and fields based on expert knowledge.

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