A FAULT DIAGNOSTIC SYSTEM FOR INSULATION DIAGNOSIS OF POWER TRANSFORMER BASED ON MULTI ARTIFICIAL INTELLIGENCE

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ABSTRACT

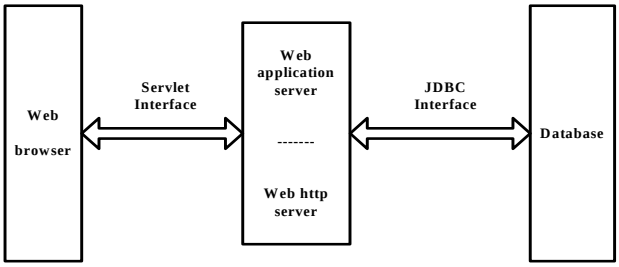
Among the development and application of artificial intelligence in fault diagnosis of power transformer, expert system using several AI methods is an effective technology that may help to finish the fault analysis. This paper presents an expert system for transformer fault diagnosis. Some algorithms such as expert system, artificial neural network, case-based reasoning and rough set theory are used in it. The advantages of each algorithm are assembled and the shortcomings of each single method are addressed, so a higher accuracy is offered. Furthermore, the successful conventional method was combined with the AI method, and based on the web technology it can be also used for the remote diagnosis. It had been used in power utilities and shows that the present system is effective.

INTRODUCTION

Transformer is one of the most important and costly equipment in the power system. The reliable and efficient fault-free operation of the high-voltage transformer plays a decisive role in the power system. At present, there were some effective methods for monitoring transformer already. But with each of these methods the correctness of diagnosis is not high, as the principle of each of these methods was only based on a limited sorts of data collected, for instance based on the oil-dissolved gas DGA data only. And mass case study show, many failures may be diagnosed and avoided by experienced stuff analysis. So it is important to analyze the DGA data, oil data, electrical test, thermal test and observation information synthetically. In the past, these analytic and diagnostic works mainly depended on experienced experts because it is difficult to create an accurate mathematical model for the diagnostic faults of transformer. Nowadays, using computer technology, statistical analysis and multi artificial intelligences, thinking process of human has been simulated, which may be combined into an expert system for fault diagnosis to accomplish analysis, reasoning and diagnosis. Nowadays based on the development of computer science, expert system is gradually used for the fault diagnosis of transformer and it has shown very promising results. But most of them only use one certain intelligent method and it cannot detail the fault analysis. In order to give a better way to solve this problem, a new expert system is presented in this paper, which using multi artificial intelligence, i.e. not only improving the correctness of diagnosis, but also mentioning the fault location.

HIERARCHY AND PLATFORM OF WEB APPLICATION

Based on aforementioned requirement, in the process of system development, not only effective methods should be possibly adopted, but also better results should be pursued. And it must be capable of update in the later. So a web application based on database has a multilayer structure. The web browser, web http server, web application server and database server is generally in this structure. In this system, a web application based on Servlet, JSP and JavaBeans architecture has been developed in the java application program environment, as shown in Figure 1. Its extensibility and transplant ability had been improved, and the system could run on the different platforms [1]. Database is the warehouse of data and diagnosis program [2]. Concretely, the test information, typical fault cases, modularized program, diagnosis standard, etc., are all stored in it. With the fast query and calculation ability of the database, some more complex analysis methods could be used in this diagnostic system.

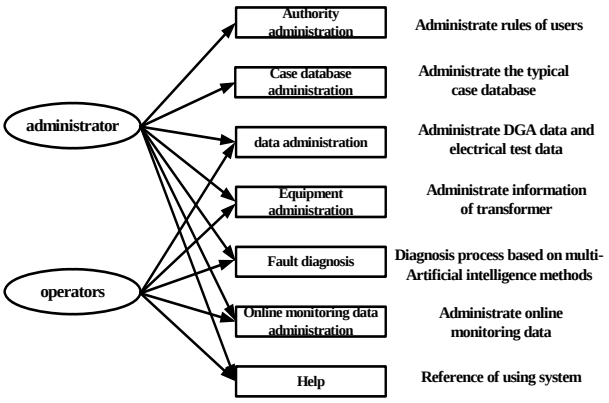


Figures 1 Brief structure of the system

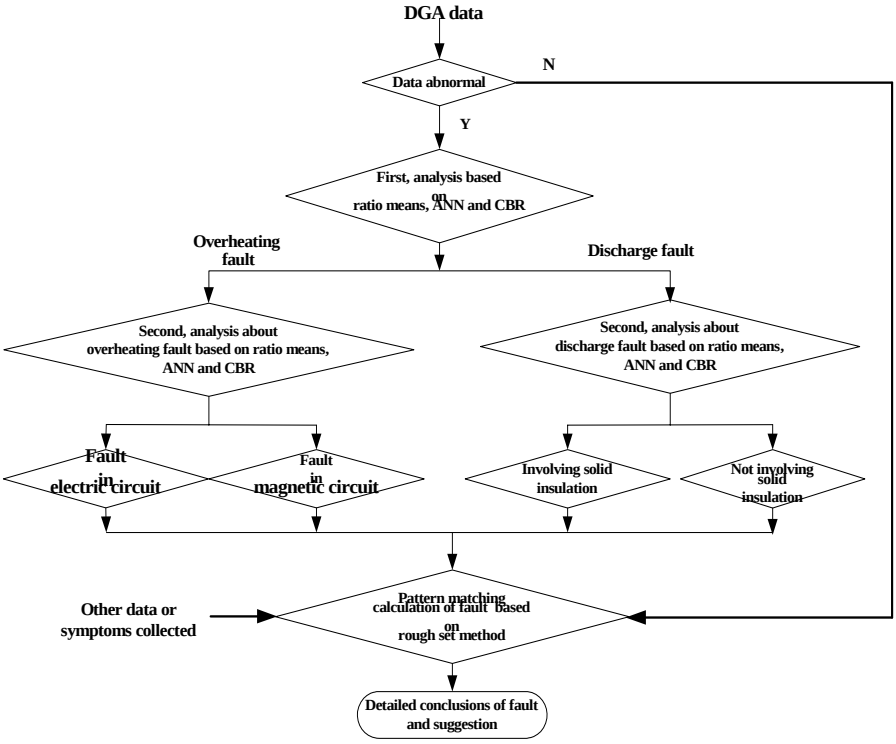
SYSTEM FUNCTIONS

System information may include many sources, i.e. inspection, operating parameters (from SCADA), test data, faulty and maintenance record, on-line monitoring data, etc. There are seven main function modules in the system, i.e.: authority administration, case database administration, data administration, equipment administration, fault diagnosis, online monitoring data administration and help document, as shown in Figure 2. The system uses a strategy with layered diagnosis, analyzing and detailing step by step in order to achieve a more delicate and accurate fault diagnosis. In addition, it also has certain effect for locating the fault parts. The diagnosis includes several main processes, as shown in Figure 3: at first, analyze the DGA data by using such

methods as ratio means, Artificial Neural Network ANN and Case Based Reasoning CBR; and if it is an overheating fault, it should be distinguished whether it is within the magnetic circuit or within the electric circuit; and if it is a discharge fault, it should be distinguished whether it involves in the solid insulation or not; secondly, based on above analysis, system will obtain the most possible fault parts and reasons by the method of rough set combining the tested data of the electrical, thermal or chemical tests as well as other appearance. By the means of considering the information of many ways and experience of lots of cases, and even more applying artificial intelligence methods, the diagnosis efficiency of system is enhanced obviously. Considering the effect of incompleteness these information, the rough set theory is introduce, which even may finish diagnosis with insufficient data. At last, detail diagnostic result is given, and the most three similar cases are retrieved from case base for the reference.



Figures 2 Sketch map of fault diagnosis system



Figures 3 The flow chart of fault diagnosis

FAULT ANALYSIS AND DIAGNOSIS METHOD

Fault diagnosis is a experienced task, and special physic or mathematic model is still absent till now, so the accumulated experiences and cases are very valuable. Some related guidelines in China have summarized several universal rules, with which condition based maintenance may be carried on. After considering these factors, this system is developed. With the progress of computer and intelligence, expert system could get some inherent rules through automatic learning process from mass accumulated faulty cases, and then put forward more valuable assistant diagnosis for new case.

Artificial neural network

As one branch of the AI, the ANN is suitable for the issues of pattern recognition in the field of fault diagnosis, thanks to the capability of non-linear mapping between its input and output. It has been a long period since the DGA analysis by ANN came into a hotspot in the field of fault diagnosis of power transformer. With the ANN, it is not necessary to create a certain physical model of transformer diagnosis. To some extent, the task of fault diagnosis for power transformer is to find some certain

relationship between the acquired data, the malfunction and the cause of defect. The ANN has been proved to be a useful and powerful tool for fault diagnosis [4].
The decision tree method is presented using the DGA data. As the method of ratio means, ANN and CBR was used together. As an example, the first ANN identification order is divided the faults into 2 categories (overheating, discharging). And each of them corresponds to another ANN, thus a multi-resolution identification of transformer malfunction can be constructed (shown in Figure 4). Convergence of ANN and accuracy of diagnosis are both improved.

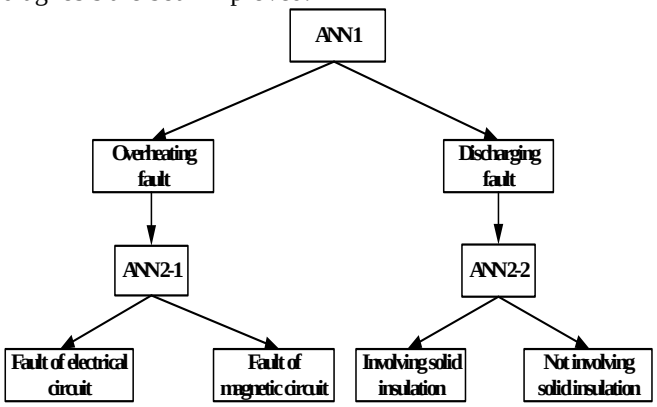


Figure 4 Structure of combined ANN

Case-base reasoning

CBR is a new approach to help solving problems based on previous cases which had been tested and overhaul. As the CBR accumulated the reasoning results obtained in the past cases, so when a new problem to be diagnosed, a pertinent case close to the problem concerned is selected from the case database [5]. In this system, the DGA data and some ratio of different gas contents have been chosen as the character parameters of the case database used here. For instance, C_2H_2/C_2H_4 is chosen to be the parameter for judging the fault overheating or discharge. And $C_2H_4/(CO+CO_2)$, $CH_4/(CO+CO_2)$ and $CO_2/(CO+CO_2)$ are chosen to be the parameter for judging the overheating fault in electric circuit or in magnetic circuit.

Rough set theory

Researchers have proposed many methods of faults diagnosis of power transformers, such as, ratio method, ANN, CBR, Expert System and Fuzzy Mathematics. In general these methods get satisfying results in the conditions with a lot of accurate and full data and symptoms information collected. Actually, some data is often imperfect and imprecise. This system employs the rough set theory RST to deal with this problem. As rough set is a mathematic method to process imperfect, imprecise and abhorrent data and it does not need any transcendental knowledge and effective dealing with the imperfect, imprecise and deficient datum, and some connotative knowledge can be picked up with this method. Based on the corresponding relationship between the faults and its symptoms, rough set theory is adopted in the system. Diagnostic model of insulation faults in power equipment based on rough set theory is shown in Figure 5. It takes fault symptom as the condition attribution set and takes fault as the decision attribution set. As the decision table is formed, we can compute the reduction of it and then calculate the rough membership function; finally the rule set of diagnosis can be set up.

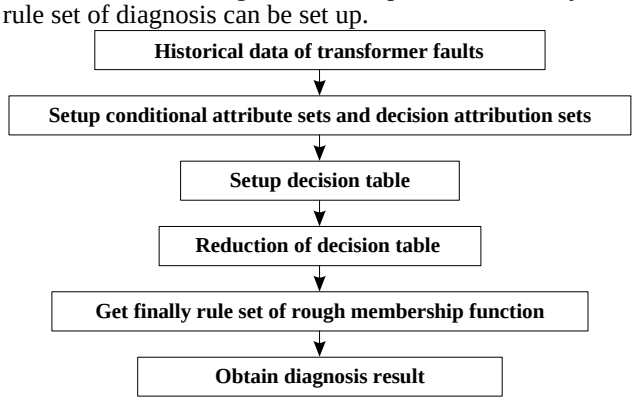


Figure 5 Flowchart of RS diagnostic model

FEATURES OF FAULT DIAGNOSIS SYSTEM

Because different AI methods are applied to analyze different information, layered structure is used in the system to avoid confusion of all methods. Comparing with the expert system used before, some character of this system could be derived as following:

Combining DGA data with other test data and observation information

DGA method is a common practice in power transformer diagnosis and a lot of experience had been gotten [3]. But this method is only effective for a lot of faults in the oil immersed transformer. And the electrical test, oil test, thermal test and observation information are also important for transformer fault diagnosis. As more information has been used in the fault diagnosis, more accurate conclusion could be derived and more detailed fault categories could be point out. And this will also be convenient for the equipment maintenance.

Using multi-AI methods for diagnosis

By using multi artificial intelligence methods in diagnosis, not only the correct rate of judgment is enhanced, but also the locating of faults is possible. Especially by using the rough set theory, the system has the ability to get proper diagnosis when lack of information.

A fault tree helpful for back tracing

Comparing with the fault tree model in the past which may leads result to be a mistake if the judgment at any node of the fault tree happened to be wrong. After adopting rough set theory to verify the result at its first step (divided into four categories as shown in Fig.3), this system avoided such instance: it may avoid some misjudgment occurred in the upper node, and effectively improve the validity and practicability of fault diagnosis.

EXAMPLE OF SYSTEM

A new case may be added into system, as shown in

Figure 6.

Figure 6 DGA example of expert system

According to Figure 3, first synthetic diagnosis may be finished, whose result is shown in Figure 7. And the second diagnosis and case retrieved are shown in Figure 8 and Figure 9, respectively.

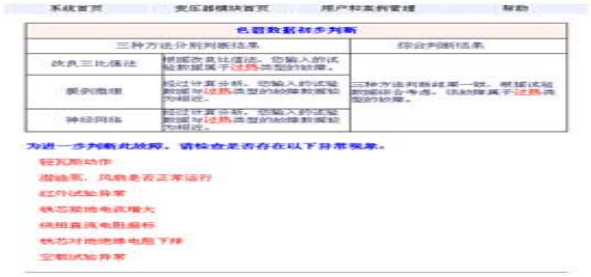


Figure 7 The result of first synthetic diagnosis

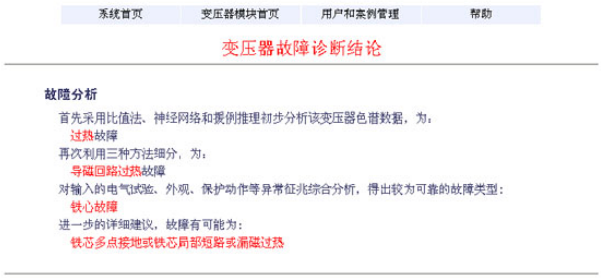


Figure 8 The result of second synthetic diagnosis

Figure 9 The result of similar case retrieved

EXAMPLE OF DIAGNOSIS

To examine this diagnosis system, test it with several fault transformers. For example, the model of a transformer is SFSZ8-31500/110 and differential protective relay tripped after a short circuit occurred. Diagnosing based on this system; firstly the data of main DGA gas are shown in Table 1.

Table 1 Contents of dissolved gas in oil (unit: 10^{-6})

Gas	CH_4	C_2H_4	C_2H_6	C_2H_2	H_2	CO	CO_2
Value	18.9	9.4	3.67	5.58	33.9	1143	5068

Input these data into diagnostic system as Fig.3, analyzing it by ratio mean, ANN and CBR, the primary conclusion of this case is a discharge fault, and further it is suspected to involve solid insulation. And rough set method is used to detail fault part and reason. For this, the abnormal signs of electric test, appearance, etc., need to be input into system, including is there the acting of relay, unbalance of three-phase of DC resistance, abnormal DC resistance, abnormal winding ratio and increased discharge energy. After analyzing further by rough set theory based more information, a winding failure is diagnosed in company with a more detailed suggestion of turn-to-turn short circuit and the result credibility is high. The result got from the diagnostic system has a rather detailed fault location and suggestion and the effect of diagnosis is enhanced than other ES before. Beside fault analysis by the system, the similar fault cases in the past can be searched from the cases database.

Further more, the renewal ability of diagnosis system is also considered. For example, the ANN is trained base on lots of sample cases collected before; and if some new cases have been added into the database and it is thought to be worth retraining the network, the administrator can retrain it by calling the training procedures. As well as the ANN method, the result of CBR will be more accurate with the increasing of sample cases. In other words, the system has certain ability of self-study. The correct rate of judgment will be improved by the more typical case increased.

CONCLUSION

Fault diagnosis of oil immersed transformer is a complex task and demand more knowledge and expert experiences. This paper introduced an expert system based on multi artificial intelligence. Not only could using multi information for diagnosis synthetically, but also could get proper result when lack of information. The case studies had shown the validity and veracity of the system.

REFERENCES

[1] UeliWahli, et al. Servlet and JSP Programming with IBM WebSphere Studio and VisualAge for Java. Beijing: China Machine Press, 2001

[2] ScottUrman. Oracle8i Advanced PL/SQL Programming. Beijing: China Machine Press, 2001

[3] Zhenyuan Wang. A combined ANN and Expert System Tool for Transformer Diagnosis, IEEE Computer Applications in Power, January, pp.50-55, 2000

[4] Wensheng Gao, Zheng Qian and Zhang Yan, Fault Diagnosis of Power Transformer Using Neural Network of Decision Tree, Journal of Xi'an Jiaotong University, Vol. 33, No. 6, pp.11-15,1999

[5] S. Itakura, K. Okada and R. Yokoyama, Application of CBR approach for electrical equipment layout design. Fuzzy Systems, 1995. Proceedings of 1995 IEEE International Conference on Fuzzy Systems and The Second International Fuzzy Engineering Symposium, Vol. 4, pp. 2063-2068,199