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The Application of Rough Set Theory in Condition Assessment on Power Transformer

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Abstract: - Rough set theory is a relatively new soft computing tool to deal with vagueness and uncertainty. It has received much attention of the researchers around the world. Rough set theory has been successfully applied to many areas including pattern recognition, machine learning, decision support, process control and predictive modeling. Due to incompleteness and complexity of fault diagnosis for power transformer, a specific fault diagnostic model based on rough set theory is presented in this paper. After the statistic analysis on the collected fault examples of oil-immersed power transformer and using rough set theory to reduce result, diagnosis rules are acquired and they could be used to improve the condition assessment of power transformer.

Key-Words: Fault diagnosis; Rough set; Decision table; Reduction

1 Introduction

High-safety and high-capacity to deliver electric power energy are the basic requirements for modern power system. To achieve this target, the scale of the electric power system becomes more and more big, the construction of the power delivery network becomes more and more complicated, and this in a certain degree enlarges the scope of the break down. Since 1990s, some big power failures in China have made huge damage to the national economy[1]. How to guarantee the safety of the power system becomes an urgent problem to solve for power supply enterprises. There is an increasing need for electric utilities to employ assets to the fullest while maintaining system reliability. The large electrical power transformer which is one of the most important equipments, its condition affects the operation of the whole electrical system directly. To guarantee the safety of power system, we should make right judgment and take corresponding actions when the power transformer has some faults. The current diagnosis techniques of power transformer include the methods using temperature, vibration, partial discharge (PD) and dissolved gas analysis (DGA) signals. The method using DGA is a well-known diagnostic technique in the industry and several criteria have been established.

The complexity of power system has increased more with lots of equipments entering into, and people are paying more attentions to the reliability and economy of power system, because any failure of power equipment may cause the interruption of power in supply and even leads to high costs. Furthermore, large power transformers are the key equipment of power system, the more reasonable and effective fault diagnosis for it is always pursued. In general, the process of fault diagnosis is to search all the possible fault symptoms in feature space according to the membership of them, and then find out the best explanations for the faults inside a transformer, but there are so much uncertain factors in the fault diagnosis, which always behave stochastic and ambiguous at the same time .Taking into account these characteristics, probabilistic method or fuzzy mathematics utilized in diagnosis have got some achievements.

The diagnosis model for power transformer failure is set up in this paper, based on the Rough Set theory (RST). The strong ability of RST in data analysis and tolerance could help to achieve the goal of quick and accurate failure diagnosis. A decision table was formed basing on the recorded failure data of transformers, then by using the knowledge of RS, we got the reduction of the decision table. Taking into account the rough subordination of rule, an expert knowledge storage of failure diagnose system could be set up .The sample has proved the method being right and effective.

2 Rough Set Theory

Rough set (RS) theory introduced by Zdzilaw Pawlak[2] in the early 1980s is a new mathematics tool to deal with vagueness and uncertainty. RS provides a series of tools for data analysis and reasoning from imprecise and ambiguous data[3]. It has already found practical applications in many areas[4], including approximate classification, machine learning, process control, knowledge acquisition, expert system and data mining. RS has been successfully used for pattern classification of

patients based on medical data attributes. Recently, RS technique has been applied in power system to classify the operation point[5]. RS is a set theory that classifies objects based on the attributes of the objects. The fundamental notions of RS are reviewed in this section.

Basic conception of RS

A. Lower Approximation and Upper Approximation of Rough Set

Define 1: suppose $U \neq \Phi$ is universe, R is a group of equivalence relation of U 2-tuple $K = (U, R)$ constitute an approximation space. $X \subseteq U$ a is an object in U $[a]_R$ denotes a set that is composed by objects of indiscernibility with a that is an equivalence class decided by a.

The lower approximation of set X about R:

$$R_{\_}(X) = \{a \in U : [a]_R \in X\} \quad (1)$$

The upper approximation of set X about R:

$$R^{-}(X) = \{a \in U : [a]_R \cap X \neq \Phi\} \quad (2)$$

The boundary region of set X about R

$B_n = R^{-}(X) - R_{\_}(X)$ (3) $R_{\_}(X)$ is a greatest set composed by objects certainly belonging to X according to existed knowledge: $R^{-}(X)$ is a least set composed by objects likely belonging to X.

B. Decision Table and Reduction

The knowledge expression system S can be denoted as S=<U,At,Val, f> U is the domain, At is an attributes set, $Val = \cup_{a \in At} Val$ is a set of attribute value, $f : U \times At \rightarrow Val$ is an information function. The 'attribute-value' forms a 2-dimension table, and it is an information table. If $At = C \cup D$ C is condition attribute and D is result attribute, so a decision table is formed.

The decision table can be considered as a group of defined equivalence relation that is knowledge base. Not all the condition attributes in decision table are necessary. Some are redundant, and when these are eliminated, the expression effect is not changed.

Define 2: set R is a group of equivalence relation, $r \in R$ if

$$ind(R) = ind(R - \{r\}) \quad (4)$$

then r is omissible in R or r isn't omissible in R. if any $r \in R$ all are not omissible in R then R is independent.

Define 3: if exist $Q = P - r \quad Q \subseteq P$ Q is independent, and meet $ind(Q) = ind(P)$ and then Q is a reduction of P denoted as $red(P)$.

Define 4: a group of equivalence relation P may has many-reductions, and the intersection of all reductions is core of P denoted as $core(P)$.

$$core(P) = \cap red(P) \quad (5)$$

The reduction of decision table is that reducing condition attributes, namely eliminate redundant attribute. The process of reduction of decision table is as follows:

(1) Eliminate redundant condition attributes, namely delete one column of table;

(2) Eliminate repeated row;

(3) Eliminate redundant attribute of decision rules;

The final decision table after reduced is much simpler than primary decision table; it only contains necessary condition attributes needed when making decision.

The table contains information about some objects in its rows. Its columns contain the values of attributes describing the objects. Two kinds of attributes are distinguished in RS theory: condition and decision. The data table is represented as a decision table (also called information table), which is a key tool used in the RS method. A decision table contains rules specifying what decisions should be made when certain conditions are satisfied. Each row of the decision table contains a production rule of the form:

If {set of conditions) Then {set of decisions)

It is one of the most common approaches to get knowledge from expert. The process is also called Case Based Learning (CBL). The method of reduction can be shown using algebraic developments or based on logical relations. The algorithm that provides the reduction of conditions has been proposed in [1], and can be represented by the following steps:

Step 1: Build a decision table describing the example cases of the interested domain.

Step 2: Eliminate identical attributes and cases

Step 3: Compute the reduction of the decision table.

Step 4: Merge possible cases.

Step 5: Generate the final set of rules.

3 The Diagnosis Method of Power Transformer Base on RS

The fault diagnosis of power transformer can be described as a pattern classify problem, so it is very suitable to be dealt with RS. The basic rule is using the fault parameters as condition attributes and using the fault signals as decision attributes to set up decision table. Then find the minima reduction. In practice, the power transformer can be diagnosed using the Rules derived from RS.

The faults of power transformer are too complex, so the paper just discusses the main fault attribute of the power transformer.

Fault attribute N is presented in table 4, the types and the characters of each fault of power transformer are present in table 5. So the decision table of the fault diagnosis is gained in table 6. U is the examples, ni(i=1 2 … 9) is the condition attribute and D is decision attribute. The value of the ni : 1 means the fault sign appeared and 0 means not.

CODE	Fault Symptom
n_1	Hot Fault, DGA
n_2	Water in the Oil
n_3	Core earthing
n_4	PD
n_5	Resistance Unbalance of 3 Phase
n_6	Winding Insulation Resistance
n_7	Winding Ratio
n_8	Gaseous Relay Action
n_9	Charging Fault, DGA

Table.4 The symptom of set N

CODE	Fault types
	Insulation Moistening
	OTLC fault
	Charging Fault
	Core earthing or Short Circuit
	Discharge on barrier
	Turn Insulation Fault
	Winding Distortion
	Hot Fault
	Others

Table.5 Fault types of set D

U	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	D
1	0	1	0	0	0	1	0	0	0	
2	1	0	0	0	1	0	0	1	0	
3	0	0	0	1	0	0	0	1	1	
4	0	0	1	1	0	0	0	1	1	
5	0	0	0	1	0	0	0	1	1	
6	0	0	0	1	0	0	1	1	0	
7	0	0	0	1	0	0	1	1	0	
8	1	0	0	1	0	0	0	0	1	
9	0	0	0	0	0	0	0	0	0	

Table.6 Decision Table

Eliminate redundant condition attributes, 9 reductions can be found out. These 9 reductions preserve classify ability as the decision table but decrease the condition attributes. Eliminate the redundancies of these 9 reductions, the minima reduction can be gained in table 7.

U	n_1	n_2	n_4	D
1	*	1	0	
2	1	*	0	
3	0	*	1	
4	1	*	*	
5	*	1	1	
6	0	0	*	
7	*	*	*	
8	1	*	1	
9	0	0	0	

Table.7 The Minima Reduction

Using the minima reduction, the fault diagnosis of power transformer can be done. Taking a power transformer in a 220kV substation as an example:

A power transformer in a 220kV substation broke down shortly after the maintenance. The DGA values are:

CH4 151.1 C 2H2 10.3 C2H4 56.2 C2H6 318.4. The PD value is:220pc

Basing the rules 2 and 4, the Core earthing or Short Circuit Fault and OTLC Fault could be judged. This power transformer was returned to the factory later, and the fault was shown in Fig.1.

Fig.1 The fault of the 220kV power transformer was found after returned to factory

4 Conclusion

The reduction method of the decision table of Rough Set Theory can handle missing or wrong failure symptoms of transformer. In the condition of imperfect data, it can also gain correct diagnose results and has certain tolerance. So this method is very suitable for fault diagnosis of power transformer.

Using the fault symptoms as the condition attributes and the fault types of power transformer as the decision attributes, we can get the decision table. By eliminating redundant condition attributes, we get the minima reduction of the decision table. Basing on the minima reduction, the fault diagnosis model of power transformer could be obtained.

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