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Research of the fault location method of distribution network

Abstract. *The rough set theory is used to realize the automatic fault location method of the rural power distribution network. The decision table of the distribution network fault location is based on the fault complaints information. It is automatically formed by distribution network topology. Then the decision table is property reduced based on identifiable matrix. Finally improved value reduction method is used to form the fault diagnosis expert knowledge uniformly. Combined with the GIS platform, it designs the application program of the fault location and realizes the visual fault localization.*

Streszczenie. *W artykule zaproponowano wykorzystanie teorii zbiorów przybliżonych w tworzeniu metody lokalizacji awarii w sieci elektroenergetycznej na terenie wiejskim. Metoda bazuje na drzewie decyzyjnym, w którym zawiera informacja o zgłoszeniach awarii. Opracowany algorytm redukcji wielkości drzewa, w połączeniu z platformą Systemu Informacji Geograficznej (ang. Geographic Information System – GIS), pozwala na dokładne określenie miejsca awarii. (**Badanie metody lokalizacji awarii w sieci elektroenergetycznej**).*

Keywords: distribution networkt; non-measurement and control area; fault location; rough set; GIS
Słowa kluczowe: sieć elektroenergetyczna, rejon trudno dostępny, lokalizacja awarii, zbiory przybliżone, GIS.

Introduction

As the development of electronic technology, communication technology and computer technology, Many cities and rural departments have begun to implement power distribution management system (DMS) project, combining with Supervisory Control And Data Acquisition(SCADA) and Geographic Information System(GIS), make comprehensive monitoring and management to the distribution network, and have achieved some results. By installing the feeder terminal unit on the switch of the post outdoor, to get the real-time data which reflect the status of the distribution network, and through the fault information to do the fault location. However, due to constraints of construction cost and complexity, we generally only construct the Distribution Automation System. in the loan-up and important area. In the distribution network, only main feeder and long-branch have the Feeder Terminal Unit(FTU) on column. In rural power grid even install the RTU only in the substation, and considerable part of distribution lines are belong to the non management and control area of distribution net, they can not gain the real-time date because they do not have the FTU on column, only rely on customer telephone complaints messages(TCM) to help locate the fault. Therefore, relying solely on SCADA systems to provide fault information to distribution network fault location is actually not entirely feasible[1]. Based on the above situation, this article tries to apply rough set theory (Rough Sets) [2] to the non management and control areas of rural power grid for fault location, With a strong fault tolerance of rough sets and do not provide any prior information outside the processing date set. First use the telephone fault report in user area as condition attribute set for the fault location, consider all possible fault conditions and establish decision table. And then realize the automation simplification of decision table and the simplification of attribute values, to extract diagnosis rules and form a new knowledge library.

Fault location algorithm design

Mathematical description of the algorithm: In the non-measurement and control areas of distribution network, the fault site is determined according to the large number of complaints information received from different regions, that is the fault site can be inferred from the complaint calls. Because of the subjective factors and knowledge level of the user, the some of complaint information does not present the occurrence, some even contain uncertainty elements or error factor, so the complaints information is only a rough set. It will be more suitable to mathematically describe the distribution network fault location. Rough set (RS) [3] theory is proposed by a Polish scholars- z.pawlak in 1982. It is a new mathematical tool to characterize the incomplete and uncertainty. Algorithm design: In connection with a given distribution network topology, first, the telephone repair region is conducted as the fault classification condition attributes, considering all of the possible fault conditions, simplify the original information, find an equivalent reduction of the original information , then find the smallest reduction to further simplify, extract the decision rules, reveal the inherent redundancy of fault repair information, achieve the distribution system fault locating rapidly and accurately. The formation of decision table and the key Simple step are shown in Fig.1.

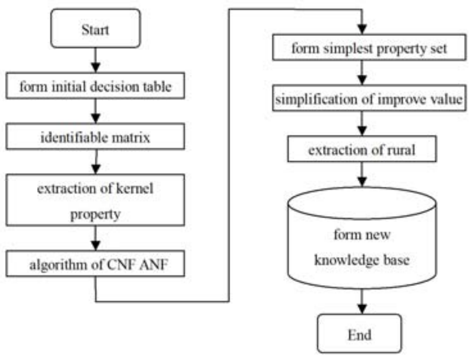

Fig.1. The simplification flow chart of the decision table of distribution network fault

Fig. 2 presents a typical distribution network, it illustrates the formation of decision table. In this network component S presents breakers drop switches, 11 totally. There are 10 power supply regions (T1-T10), 10 transformers (T).The fault occurred at the component S presents that the line containing S is fault, also if the fault occurred at T ,it presents that the transformer T is fault. The decision table is formed according to the analysis of distribution network topology. First of all, get the records set of transformer substation from geographic database, obtain the entire distribution network topology in accordance with the topology analysis algorithm in the GIS system map algorithm using breadth-first algorithm starting the cycle from the first record[4]. A breaker of the substation is assumed as the power point, it only corresponds to one line. Searches down from the circuit breaker using topology analysis algorithm, get the along switch, terminal transformers and the corresponding power supply region, and code them. The map 2 shows the distribution network, code the switching with S1, S2, ..., S11, transformer with T1, T2, ..., T10, the power supply area with T1 zone, T2 zone, ..., T10 Zone . Then search for the supply area line through all equipment components, the power supply area code is "1", other supply area code "0", thus the original fault decision table is formed in Table 1. "1" presents that the user dial the fault complaints telephone, "0" presents that the user does not dial.Fig.3 shows the dynamic coding process of distribution network.

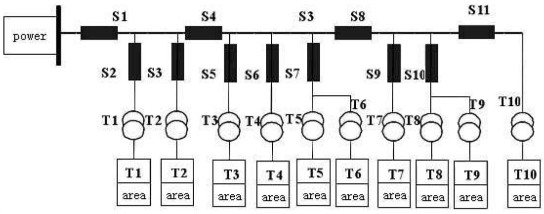

Fig.2. Simple distribution network

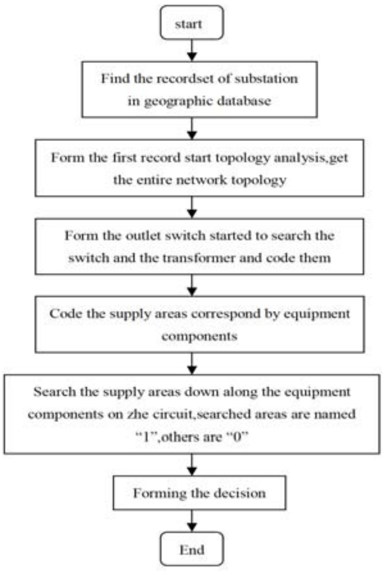

Fig.3. Flow chart of dynamic coding process of distribution network.

Identification matrix is an important concept in rough set theory. It accommodates arbitrarily complex information in a matrix, without the affecting of the original system. Thus the analytical ability is improved greatly. The simplification of information system is started on identification matrix. $S=(U,A)$ is an information system, U is discuss domain and $U=(x_1,x_2,\cdots,x_n)$,A is condition attribute set, D is decision attribute $a\ (x)$ records the value of x on a, C_{ij} presents the element in the i row and j column. Identification matrix can be defined as (i, j = 1, 2, 3, ···, n):

$$(C_{i,j})=\begin{cases}\{a\in A:a(x_i)\neq a(x_j)\},D(x_i)\neq D(x_j)\\0,D(x_i)=D(x_j)\\-1,a(x_i)=a(x_j)\text{且}D(x_i)\neq D(x_j)\end{cases}$$

Three kinds of value consist of the elements of the identification matrix. If the decision attribute of two records are different and the conditions attribute are different, the element value shall be the property combination of different attribute values; If the decision attribute of two records are the same and the conditions attribute are the same, the element value shall be 0; If the decision attribute of two records are different but the conditions attribute are the same, the two record are conflict, the element value shall be -1.

The decision table is simplified according to the identification matrix, the following steps: (1) Change the decision table into identification matrix, find the kernel property which the property combination is 1 and property combination which does not contain kernel property. (2) The condition attribute set which does not contain kernel attribute expressed as ANF, and calculate, that is P=∧{∨bi,k(i=1,2,….,s;k=1,2,…,m)},change it into ANF, and simplify. (3) All ANF and kernel attribute compose of reduction set.

In order to remove redundant information in the decision table, the property value reduction is introduced. In this paper, an improved value simplification algorithm is adopted [5]. It inspects the records in the table one by one, deletes all the redundant condition attribute values which do not affect the expression of rules. It follows these steps: (1)Delete all duplicate records of reduction combination. (2)Delete the conditions attribute of reduction combination to get a new information system T. If there are conflict records in T, recover its original property value, if there are duplicate records in T, marker "*" to the original property value, if there is either conflict records or duplicate records in T, marker"?" to the original property value. (3) If the record containing all the terms of property value are marked "*" or "?", recover all "?" to the original value. (4) If all of the property value of a record are marked "*", delete it. (5)Check all "?" records. If the decision can be inferred from the un-marked attribute value, change "?" to "*". Or, change "?" to the original property value. (6) First, delete the duplicate records. If some condition attribution in two records are the same, the remaining are specific value in one record and marked "*" in the other. Considering the latter record, if the decision can be made only by the un-marked attribute value, delete the record containing fewer "*", or, delete the record marked "*".

Table 1. Original fault decision table of distribution network

sample	T1 area	T2 area	T3 area	T4 area	T5 area	T6 area	T7 area	T8 area	T9 area	T10 area	Fault component
1	1	1	1	1	1	1	1	1	1	1	S1
2	1	0	0	0	0	0	0	0	0	0	S2, T1
3	0	1	0	0	0	0	0	0	0	0	S3, T2
4	0	0	1	1	1	1	1	1	1	1	S4
5	0	0	1	0	0	0	0	0	0	0	S5, T3
6	0	0	1	1	1	1	0	0	0	0	S6, T4
7	0	0	0	0	1	1	0	0	0	0	S7
8	0	0	0	0	1	0	0	0	0	0	T5
9	0	0	0	0	0	1	0	0	0	0	T6
10	0	0	0	0	0	0	1	1	1	1	S8
11	0	0	0	0	0	0	1	0	0	0	S9, T7
12	0	0	0	0	0	0	0	1	1	0	S10
13	0	0	0	0	0	0	0	1	0	0	T8
14	0	0	0	0	0	0	0	0	1	0	T9
15	0	0	0	0	0	0	0	0	0	1	S11, T10
16	0	0	0	0	0	0	0	0	0	0	none

Table 2. The result of improved value simplification algorithm

sample	T1 area	T2 area	T3 area	T4 area	T5 area	T6 area	T7 area	T8 area	T9 area	T10 area	Fault component
1	*	1	*	*	*	1	*	*	1	1	S1
2	1	0	0	0	0	0	0	0	0	0	S2, T1
3	*	1	0	0	0	0	0	0	0	0	S3, T2
4	*	0	*	*	*	1	*	*	1	1	S4
5	*	*	1	0	0	0	0	0	0	0	S5, T3
6	*	*	*	1	1	1	0	0	0	0	S6, T4
7	*	*	*	*	1	1	0	0	0	0	S7
8	*	*	*	*	1	0	0	0	0	0	T5
9	*	*	*	*	0	1	0	0	0	0	T6
10	*	*	*	*	*	0	*	*	1	1	S8
11	*	*	*	*	*	*	1	0	0	0	S9, T7
12	*	*	*	*	*	*	*	1	1	0	S10
13	*	*	*	*	*	*	*	1	0	0	T8
14	*	*	*	*	*	*	*	0	1	0	T9
15	*	*	*	*	*	*	*	*	0	1	S11, T10
16	0	0	0	0	0	0	0	0	0	0	none

Decision Table 1 is calculated according to the attribute reduction algorithm of decision table and improved value reduction algorithm, which infers Table 2. In Table 2, "*" has no effect on distribution network fault location, extracts decision rules from Table 2, form fault diagnosis expert knowledge base. Such as rule 4, T6 zone , T9 zone and T10 zone can make an inference that S4 has fault. Compared with the Rule 4 in the original decision table, 5 redundant condition attributes is deduced.

Use the distribution network shows in Fig.2 as an example to explain the availability of this algorithm. First example, One day the electricity sector received the outage complaint phone calls from the T5 and T6 users. Enter fault repair information through the fault location system, according to the expert knowledge library table two which has been generated to diagnose, found that the reason is the fault of the S7, it is the fault in the circuit of switch 7. This situation is matching the actual. Because sometimes base on the demand of repair from user does not necessarily mean the fault happen on the branch which directly supply power to the customers, but may occur in the branch on a long branch line or main feeders. Second example, One day the electricity sector received the outage complaint phone calls from the T4 and T5 users. Enter fault repair information, the expert knowledge library table two diagnose it is fault T5.After field testing, we found that the power outage of T4 user because the blown fuse overload in this area, all the floor outage.

The above example shows that the algorithm used for fault location is simple, fast and effective, when error complaint message is not the key information, it will not affect the localization results, it has strong fault tolerance. This algorithm can be applied to distribution network which have large, complex and radiation structure.

Fault location Implementation

Fault location Functions –Overview: Fault location is a prerequisite for fault repair. Through the implementation of fault location, the fault area can be determined to avoid relying solely on staff experience repair troubleshooting situation. Fault location of this study consists of three parts: the input fault message, fault location algorithm for rough set methods, GIS fault section highlighted.

Fault location Implementation: In this study, the fault location algorithm is applied to county-level distribution automation system. hen the fault repair telephone of power customers access, GIS on-line fault diagnosis based positioning function can be achieved with the resulting knowledge base on rough set, and be regard as the complement and supplement of using SCADA system Fault Location. In the process of positioning diagnosis, matching the repair telephone information and Failure Knowledge base Rules, by searching, if the repair information and knowledge base in line with a rule, then stop the search, output location results, and highlighted displayed in the power distribution circuit diagram. Therefore it can increase the speed of diagnosis, and won for the failure recovery time. Combined with GIS platform, using GIS technology features a powerful display of query statistics, visual fault region localization will be actualized. Fig.4 shows the distribution network of non-fault location monitoring area workflow.

Conclusion

In this paper, combining with the real situation of rural areas distribution network of non-measurement and control area, proposed fault location method based on rough set theory. Since rough set theory in dealing with imprecise question, it do not be required to provide any prior information outside of data collection that need to be processed when solving the problem, and be able to simplify the information systems under the premise of retaining critical information and obtain a simple form of information system, which does not require complicated calculations and own good fault tolerance. Combined with GIS platform, in the application of the actual distribution network, this method can be more objective for fault location, reflect the failure device information, reveal the inherent redundancy of fault repair information, find a new way to deal with incomplete repair information.

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