An Expert System For Fault Diagnosis Using Alarm Information

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ABSTRACT

This paper deals with an application of an expert system to transmission line fault diagnosis using alarm information. The possible solution can be obtained even in case that the cause of alarms is due to relays, circuit breakers or alarm systems. The expert system diagnoses not only any possible fault element, but also normal or abnormal misoperations. Also, this system can give any possible answers only when the sum of appropriate error indices assigned to false operation of devices is less than the appropriate criterion specified in advance. This paper is written in Official Projection System-Version 5 (OPS-5) which is one of the AI languages.

1. Introduction

When a short circuit fault or a ground fault occurs, various protective devices are installed in power systems in order that the fault element may not affect the other areas of a power system ; A fault element means a kind of faults such as a short circuit fault, a ground fault at line or bus, generator outage, and so on, which is detected by relays or circuit breakers (C.B.'s). When a fault occurs, the fault section must be identified to protect the other area of the power system. Here, a section means a part of a line or a bus separated by C.B.'s from the rest of a power system. A fault element can be found effectively using alarm information from the operated protective relays and C.B.'s. Some misoperations of relays or C.B.'s related to any fault element make the fault section become larger than needed. In such case, it is difficult to diagnose a fault element. Consequently, it is desirable to introduce the expert system. The operation of protective relays and C.B.'s for any fault element can be described in detail as follows. In case any fault takes place, the first protective relays detect a fault element, and operate one or more C.B.'s, and then report alarms. But if the first protective relay fails to detect a fault element or the C.B. related to the relay does not operate, the second back - up protective relay detects a fault element and operates anothor C.B., and also reports alarms. The operated C.B. reports alarm through alarm system, too. It is fault diagnosis to judge the status of normal or abnormal operation of relays and C.B.'s with alarm information and to give possible fault element. The above-mentioned working mechanism of relays and circuit breakers related to any fault element is shown in Fig.1.

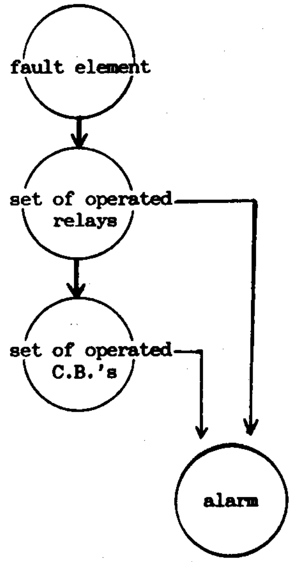

Fig.1. Working mechanism of protective devices on fault element.

Here are two alarms; one is a alarm related to relay and the other is to C.B.

2. Rule-Based language OPS-5

OPS-5, a kind of programming language, known as production system is used for applications in the areas of artificial intelligence, expert systems. In this paper, the interpreter for OPS-5 is written in Gclisp Version 2.1. A production system is a program which consists of conditional statements called productions. These productions operate by expressions stored in a global data base called working memory. The production is similiar to the IF-THEN statement. In other words, a production that contains n conditions Ci through Cn and m actions Ai through Am means "When working memory is such that C1 through Cn, then actions Ai through Am should be executed." The condition part of a production rule is usually called LHS (Left Hand Side), and the action part RHS (Right Hand Side). A production system interpreter executes a production system by performing a sequence of operations called the recognize-act cycle:

1) Match - Evaluate the LHSs of the production to determine which are satisfied given the current contents of working memory.
2) Conflict Resolution - Select one production with a satisfied LHS. IF no productions have satisfied LHSs, halt the interpeter.
3) Act - Perform the actions specified in the RHS of the selected productions.
4) Go to step 1.

The RHS of a production consists of an unconditional sequence of actions. OPS-5 set of action types includes actions to manipulate working memory, ones to perform input and output, ones to adds new productions to production memory, and others. The most important of the actions are the ones to manipulate working memory.

3. Rule-Based Knowledge Base

There are facts, and rules in knowledge Base. And they represent the relation of working mechanism. Their representations are as follows.

3.1 Fact Representation.

There are fault, relay, alarm-relay, and alarm-breaker in Facts. The expression is as follows.

```
( fault
      ^element <element>
      ^rlist <relayset>
      ^error <error> )
```

This is the representation for a fault element and set of the operated relays.

<element> is represented as f1, f2, f3,..., etc, and there are a short circuit fault, a line ground fault, a bus ground fault, on open circuit fault, generator outage, and so on.

<relayset> is represented as the set of relays operated by <element>. The relays are represented as r1, r2, r3, ..., etc. There are relays for a short circuit fault, a ground fault, an open circuit fault, a bus ground fault, and so on.

<error> is assigned by error indice. If the first protective relays detect any fault element, 0 is assigned to <error>. If the second protective relay detects any fault element, 1 is given to <error>. The second protective relay works when the first protective relay fails to detect any fault element, or when the C.B. related to the first protective relay fails to operate.

```
( relay
      ^rname <name>
      ^bset <bset> )
```

The representation is for relay and set of C.B.'s operated by relay.

<Name> is the name of relay. The representation is a form of r1, r2, r3, ..., etc. as explained above.

<bset> is represented set of C.B.'s operated by relay <name> and the C.B. is represented as b1, b2, b3, ..., etc.

There is one to one relation between alarm of each relay and operated relay. The C.B. is such being the case; therefore representation for the relation of working relay and alarm, of operating C.B. and alarm is replaced by alarm information.

```
( alarm-relay
            ^rlist <rlist> )
```

The above is representation for the set of relays reporting alarms. Accordingly, <rlist> is the set of relays.

```
( alarm-breaker
            ^blist <blist> )
```

This represents the set of circuit breakers reporting alarms, so, <blist> is the set of C.B.'s.

Fig.2. is a simple example for forgoing fact representation.

Example)

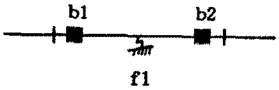

Fig.2. Example

```
( fault
        ^element f1
        ^rlist r1 r2
        ^error 0 )
( relay
        ^rname r1
        ^bset b1 )
( relay
        ^rname r2
        ^bset b2 )
( alarm-relay
        ^rlist r1 r2 )
( alarm-breaker
        ^blist b1 b2 )
```

Fig. 2. shows that operating relay for fault element f1 is r1, r2. The relay r1 and r2 results in the operation of C.B. b1 and C.B. b2, respectively. The <rlist> r1, r2 of alarm-relay indicate the relay alarms. The <blist> b1, b2 of alarm-breaker indicate the breaker alarms.

3. 2 Rules.

The following is some of important rules which are introduced in this paper.

<Rule 1>

```
( P test-fault-find
    ( alarm-relay
            ^rlist <r1> )
    {( fault
            ^element <element>
            ^rlist <r1>)
            ^error <error> ) <fault>}
-->
   ( make test-fault
            ^element <element>
            ^error <error> )
   ( remove <fault> ))
```

This is the rule of searching for the elements of the possible fault related to alarms. That is to say, "if any alarm-relay <r1> occurs, the possible fault element is <element>".

<Rule 2>

```
( p operate-of-breaker
    {( act-relay
            ^rname <ri>
            ^blist <blist> ) <relay>}
-->
   ( bind <one> (litval blist) )
   ( make operate-breaker
            ^breakerset
                (substr <relay>
                        <one> inf) ))
```

The above expression is the rule of searching for the C.B.'s operated by working relay, namely, "if any relay <r1> operates, C.B.'s <blist> are operated by relay <r1>".

<Rule 3>

```
( p error-count
    {( test-fault
            ^element <element>
            ^rlist <r1>
            ^error <error> ) <fault>}
    -( alarm-relay
            ^rlist <r1> )
-->
    ( modify
            ^error
              (compute <error> + 1) ))
```

The above description represents the rule summing up the error indices. In other words, "if there is no alarm-relay <r1> for working relay <r1> by detecting fault element <element>, then, error indice is increased by 1.

<Rule 4>

```
( p test-criterion
    (criterion
            ^number <crit>)
    {( test-fault
            ^element <element>
            ^error
              {<error> <= <crit>} )
                            <fault>}
-->
   ( make result-fault
            ^element <element>
            ^error <error>) )
```

The rule is to keep on searching only when the sum of error indices is less than the specified criterion, that is, "if error indice <error> summed up for a fault element is less than the specified criterion <crit>, the result-fault <element> is made."

On the basis of rules described above, A Problem Solving Strategy is used to give any possible answers.

4. Problem Solving Strategy

A chain of inference for OPS-5 is based on Forward-chaining. Forward-chaining systems progress from the given information to a goal. In a *forward-chaining*, the contents of working memory represent what is currently known. The possible goals is specified on the basis of alarms, and the forward-chaining is applied to get solutions. The search is continued under the condition that the summed-up error indice is less than the specfied criterion in each step. A step means the proceding from alarm to C.B., from C.B. to relay, or from relay to any possible fault element. In this case, the four important rules explained already are applied. This problem solving strategy is shown in Fig. 3.

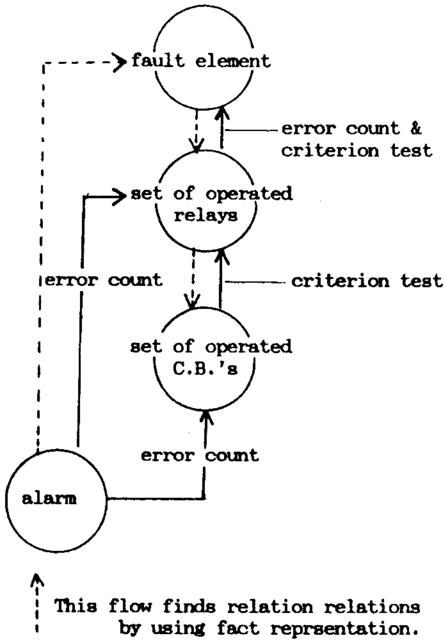

Fig. 3 Problem Solving Strategy. 1.

And also, when the cause of alarm is the misoperation of relay, the error indice is increased by 1, The final summed-up error is compared with error criterion, and the answer is what is less than the criterion.

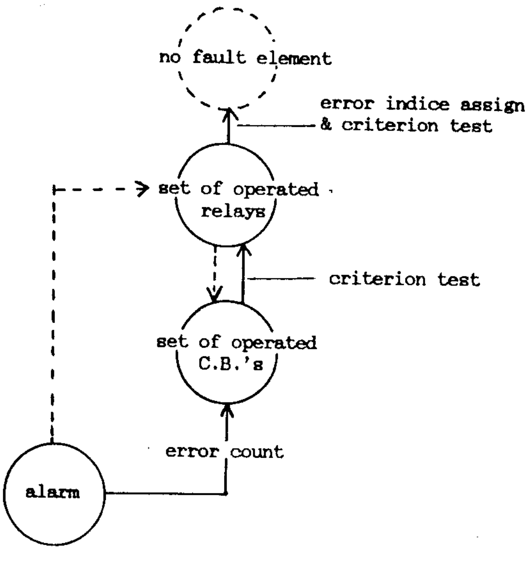

Fig. 4 Problem Solving Strategy. 2.

Even though the cause of alarm is misoperation of C.B. or alarm itself, the possible answer is given by comparing with criterion.

5. Case Study

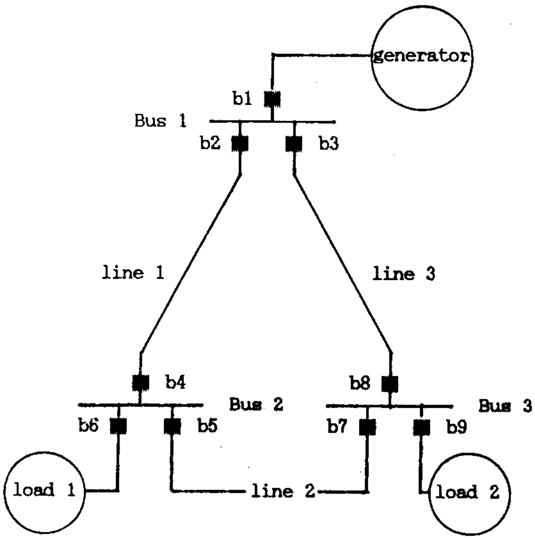

Fig. 5. Sample

Case 1.

<alarm information>

alarm-relay r2 r7
alarm-breaker b2 b7
critrrion 1

<solutions>

possible fault f1
(a ground fault at line 1)
operated relay r2 r7
operated breaker b2 b7
error indice 1

possible fault f1
(a ground fault at line 2)
operated relay r2 r7
operated breaker b2 b7
error indice 1

possible fault f8
(a ground fault at bus2)
operated relay r2 r7
operated breaker b2 b7
error indice 1

Case 2.

<alarm information>

alarm-relay r20
alarm-breaker b4 b5 b6
criterion 1

<solutions>

possible fault f8
(a ground fault at bus2)
operated relay r20
operated breaker b4 b5 b6
error indice 0

no fault
misoperating relay r20

operated breaker b4 b5 b6
error indice 1

6. Conclusion

This paper developed an expert system to diagnose a fault through the working mechanism of relays and C.B.'s by using the alarm information. Also, this system helps the exepert system to diagnose not only a fault section but also a fault element.

7. References

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