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A RULE_BASED APPROACH for AUTOMATIC CONTINGENCY SELECTION in POWER SYSTEMS

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Abstract

This paper presents a rule-based approach for automatically selecting critical contingencies in electric power systems.

The rules required to perform the task are derived from inspection about results of simulation and expertise of operators. And inherent information of system, for example, topology of system configuration, and flow direction in a line by compensation theorem, etc., which are independent of operating point of system, is stored in the database using the off-line calculation.

The approach was investigated using the study of a sample test system. Since it is based on the knowledge engineering technique, efficiency of selection can be improved by updating and adding the rules.

1. Introduction

The objective of steady state security analysis is to determine whether, if contingency occurred, the state of system remained in the acceptable range of component capacity and then to take a measure against the critical contingency. For large systems, full AC analysis of each contingency could be so time-consuming and costly that the result of analysis has not meanings any more.

Therefore in practice, it is appropriate to select the critical contingency which is expected to badly affect the state of system, to analyze the selected contingencies and to take a measure.

The methods of contingency selection have been investigated continuously. A performance index method, a DC loadflow method and an approximate network solution method are examples of them. [1,2,3]

And another approach of study is on the threshold. Recently application of AI(artficial intelligence) methodology to power system study is being actively investigated in Japan and U.S.A.. [4,5]

This study presents a new approach for contingency selection based on the knowledge engineering technology.

The followings are assumed:

a. The state of power system is characterized by the quantity and direction of each line flow.

b. Load and generation of each bus does not change after line outage.

c. The outage of single line is only considered.

The rules used to select the critical contingency are derived from results of simulation. The result of selection is presented as an example. Prolog is used to implement the approach.

2. Power System Modelling

A model represents the present state of system so adequately that it provides the information about system for the rules. From the viewpoint of the aforementioned, the model may be modified in accord with the rules modified and added afterward.

In Prolog, the state of system is represented as follows:

```
branch(Code,Sb,Eb,Flow1,Flow2,Capacity)
where
 Code : number of line
 Sb : the starting bus of line Code
 Eb : the ending bus of line Code
 Flow1 : the line flow from Sb to Eb
 Flow2 : the line flow from Eb to Sb
 Capacity : the tolerance of line about
            active power
```

The above predicate branch represents the present operating point which is monitored on-line. Nextly, the rules must be informed of the electrical characteristics of the given power system i.e., the impedance of each line, which determines the relative potential of each bus. And accordingly the increse or decrese of line flow at specific line outage is determined.

Compensation theorem is employed to determine the post-contingency state. The state of post-contingency is a result of the base-case conditions and the conditions of an adjoint network.

The adjoint network is constructed:

first, remove the source and load of each bus and, the concerned line,

second, a unit source is attached to the starting bus of it and a unit load the ending bus of it.

The results of simulation of the adjoint network is used to determine the direction of the post-contingency flow of each line and it is stored in the database. The pattern of it is as follows:

```
adbranch(Code1,Code2,From,To)
where
 Code1 : number of contingency line.
 Code2 : number of concerned line at outage of
         line Code1.
 From : starting bus of line flow of line Code2
        on the adjoint network.
 To : ending bus of line flow of line Code2
      on the adjoint network.
```

The above two predicates branch and adbranch is used to characterize the power system wholly.

3. Structure of System and Rules

A. Structure of system

(1) Inference Engine

The inference engine consists of the processes that work the knowledge base, do analyses, and audit the processes according to some strategy that emulates the expert's reasoning. It provides overall control. Inference facility of Prolog is employed in the proposed system.

(2) User Interface

Menu-driven user interface is constructed in order for the user to watch the overall process of problem-solving. A user can use the menu to call the routine of loadflow calculation and to display the result of selection graphically or in the form of table as he wants.

(3) Rules of Selection

a. facts

The aforementioned predicates branch and adbranch is used to represent the facts. They are stored in the database to later use.

b.rules

The rules are classified four groups.

The first group determines the direction of line flow at the pre-contingency.

An example is as follows:

```
flow_direction(Code,From,To):-
   branch(Code,Sb,Eb,Flow,_,_),
   Flow > 0.0
   From = Sb.
 This rule means that
     if flow of Code is positive,
     then direction of flow is from Sb to Eb.
```

The second group determines the increase or decrease of each line flow at the post-contingency of a specific line. It has two subgroups accordingly to direct or indirect connection between outaged line and concerned line.

```
direct_up(Code1,Code2):-
   Code1 <> Code2,
   flow_direction(Code1,From1,To1),
   flow_direction(Code2,From2,To2),
   From1 = From2.
This rule means that
    if Code1 and Code2 have the same direction of flows,
    then the outage of Code1 increases the flow of Code2.
```

The third group of rules actully predicts the possibilty of overload of a specific line at the another line outage.

```
cause_not_overload(Code1,Code2):-
  direct_connect(Code1,L1,_,Code2,F1,_,Cap),
  direct_up(Code1,Code2),
  abs(L1) + abs(F1) < Cap.
This rule means that
   if Code1 is directly connected with Code2,
      the outage of Code1 causes the flow of Code2
      to increase,and
      sum of flows of pre-contingency is less than
      the capacity of Code2,
   then the outage of Code1 does not cause Code2 to overload.
```

```
cause_not_overload(Code1,Code2):-
  indirect_connect(Code1,L1,_,Code2,F1,_,Cap),
  up(Code1,Code2),
  get_big(L1,L2,Big1),
  get_big(F1,F2,Big2),
  Big1 + Big2 < Cap.
This rule means that
   if Code1 is indirectly connected with Code2,
      the outage of Code1 causes the flow of Code2
      to increase,and
      sum of flows of pre-contigency is less than
      the capacity of Code2,
   then the outage of Code1 does not cause Code2 to overload.
```

The fourth group uses the pattern of overload to distinguish a non-critical contingency from a critical contingency.

(4) Routine of Loadflow Calculation

The AC loadflow routine is provided to determine the overall state of system, at an outage of line expected to cause severe damadge on the system according to the result of selection.

4.Test of Approach on Sample System

To inspect the viability of the proposed system, the author tested the method on the 14-bus/20-line power system. The result of application is shown in Figure 1.

The system is implemented on IBM PC.

The proposed system contains 13 main and auxilliary rules.The author thinks that the rules should be added and modified to improve the efficiency of selection.

5.Conclusion

This paper proposes the new approach of contin-gency selection using the knowledge engineering technology.And it demonstrates the viability of applying a rule-based system on power system contingency selection.The above prototype becomes more intellectual by acquiring rules and refining the inferencing function.

6.References

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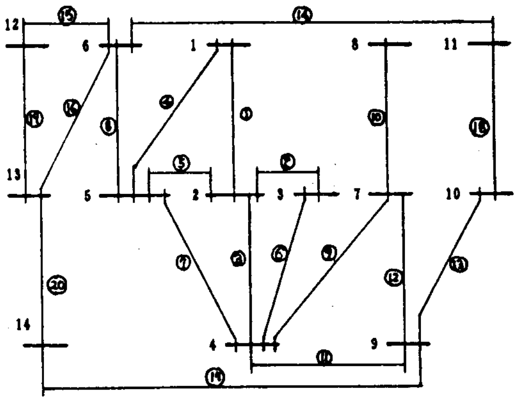

Figure-1,A diagram of a sample system

Table 1,Result of selection for 14-bus/ 20-line system

outaged line	possible overloaded lines	actual overload
1	4,6,7,11,14,15,16,17,18,20	4,7
2	3,4,7,11,14,15,18	7
3	4,7,11,15	7
4	10,11,17	
5		
6	11	
7	2,3,10,11,14,15,16,17,18	
8	10	
9	7	
10	3,4,6,7,8,11,15,17	
11		
12	4,11,14,15,16,17,18	11
13		
14	7	
15	7	
16	7,11,15,17	
17	10	
18	7,10	
19		
20	7	