A New Approach for Break Points Determination for Relay Coordination Using Combination of Expert System and Graph Theory

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Abstract

Co-ordination of relay settings in interconnected power systems is one of the important study must be done by the electrical engineers.

The basic requirement for co-ordination study is finding the starting points which are called break points. Graph theory is the main tool has been used for break points determination, the authors of this paper developed an efficient computer program for determination of break points set based on graph theory. To consider the other parameters such as protective devices & locations of them etc, as well as network configuration the combination of graph theory and expert system is proposed.

Keywords: break point Set, protection, co-ordination, expert system

1. INTRODUCTION

Several methods have been proposed for the coordination of over current relays. Ordinary coordination algorithms consider different techniques, both for interconnected and industrial networks [1-5]. The selection of appropriate settings by the co-ordination procedures leads to disconnection of minimum parts of the network under consideration [6, 7]. The complexity of the problem increases with the number of loops presented in the system. A basic difficulty in setting relays results when one sets the last relay in a sequence, which closes a loop, it must coordinate with the one set initially in that loop. If it does not, one must proceed around the loop again. Of course, a given relay usually participates in more than one loop, so this procedure needs some organization. Indeed, for a given network we require 1) a minimum set of relays to begin the process with the break points 2) an efficient sequence for setting the remaining relays, i.e., determination of efficient primary and back up relay sets [2].

Therefore, finding the starting points, which are called break points, is the basic requirement. Graph theory is the main tool has been used for break points determination.

Dwarakanath and Nowiz developed a method based on graph theory for determination of break points, directed loop matrix and relative sequence matrix [5]. Damburg and Ramaswawi et al followed the previous work and obtained a method for all simple loops of network determination [2, 3]. In this methods, all the loops including simple and non simple are found using the whole network.

The break points chosen following the above procedure may not be the minimum set. Their procedure generates a minimal set, but not the minimum set. A minimal set is a set whose subset does not satisfy the minimal set with least cardinality [8]. Bapeswara Rao and Sanhara Rao [9] proposed a method for determining the minimum break points set of a power system network and manipulation of matrix L'. However, determination of the complete loop matrix L' can be time consuming for large power networks.

Prasad et a suggested a faster method for break point set (BPS) determination based on simple loop matrix. Although, this method has a good advantage compared to the previous ones, but there is a need for consideration of the whole system at the beginning

stage to compose a simple loop matrix [10].Recently, Madani and Rijanto have presented a new graph-theoretical approach for composition of minimum or near to minimum BPS [11].
The authors of this paper developed an efficient computer program for determination of break points set based on graph theory [12]. In this method network reduction is made first, and then the appropriate loops are composed, whilst in the traditional graph theory approach composition of the matrices loops are made on the original network [12]. This will be described in the next set.
These methods consider system configurations only, however many other parameters being influence break points. The kinds of protect devices, the location of power generation and short circuit level. In other words the kinds of protective devices & the location of them, the location of power generation and short circuit level can affect break points. As an example, if a fuse is used for protection or pilot system is used, the break points are totally different with the other protection.
Therefore, in this paper a new approach based on combination of the reduced graph theory approach & expects system is proposed.
Expert system uses the experiences of expert persons on protection area. The detail of the approach is given in the section 3. All the mentioned parameters are appeared as rules. Graph theory in this paper is used as a rule of the expert system. Indeed the graph theory plus other rules which posses protection configuration, fault level, the location of generating power etc give the break points.

2. REDUCED GRAPH THEORY

As mentioned in section 1, in the existing graph theory method all the loops including simple and non simple are found using the whole network. Although the methods are flexible, but because of creating extra large size matrices, solving the problem for real interconnected networks is difficult.
For example applying the existing method for a 400kv/230kv transmission networks with about 140 buses and 500 transmission lines, over 10,000 loops are obtained, In other word the matrix dimension will be over 500*10,000, therefore it is difficult to carry out mathematical calculations even with advanced computers.
The solution of this problem requires simplification of the power system network before loops composition. Fig.1 shows the flowchart of the procedure.
In this method the simplification network is made first. To do that some simplification rules are giving.

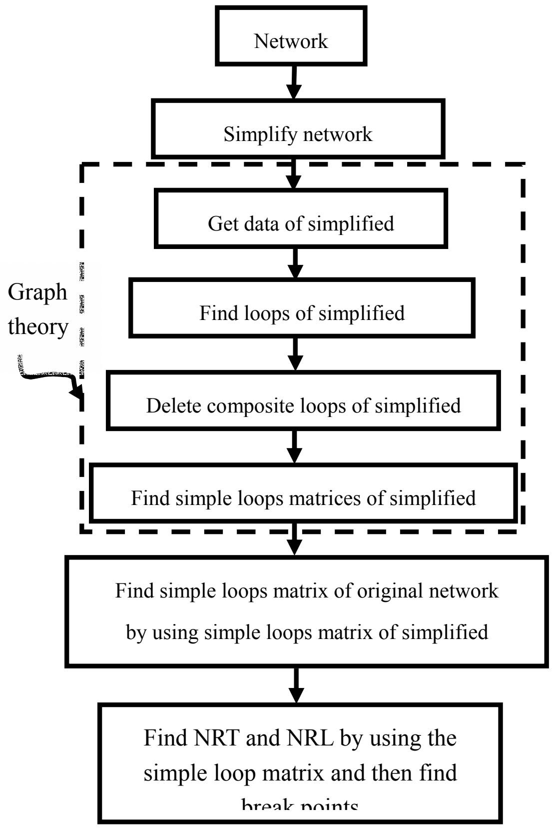

Figure 1. New method algorithm

Figure.2 shows a typical simple network and has two parallel lines 2 and 3.

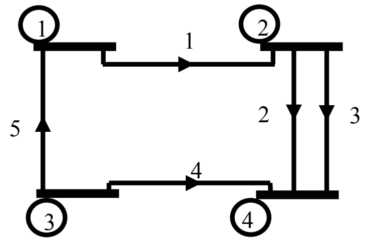

Figure 2. Simple network with two parallel lines

Table 1 shows the simple loops matrix with the direction of the loops of the network.
As it is shown in the table, the network includes six directional simple loops. Each row represents a simple loop. When the direction of a loop is the same as the direction shown on the line, the value of 1 is included in the table. Obviously, the value of a cell of the table,

which is -1 represents the loop direction is opposite to the relevant line direction. For example in loop no. 1 which includes four lines 1, 2, 4 and 5, the direction of the loop is the same as direction of the lines I, 2, and 5 whereas line 4 has opposite direction. The values of first row of Table 1 show this.

Table 1. C_{Sd} matrix of Figure 2

C_{Sd}		1	2	3	4	5
Directional Simple Loops	1	1	1	0	-1	1
	2	-1	-1	0	1	-1
	3	1	0	1	-1	1
	4	-1	0	-1	1	-1
	5	0	1	-1	0	0
	6	0	s-1	1	0	0

To find CSD a simpler method is suggested. Namely, one of the parallel lines, let us say line 3, is removed and for the simplified network, the relevant CSD are found (Table 2).

Table 3. C_{Sd} matrix of simplified network

C_{Sd}		1	2	4	5
Directional Simple Loops	1	1	1	-1	1
	2	-1	-1	1	-1

Now from the CSD matrix, the simple loop of the original network is found as follows:

First, a column called column 3 is added to Table 3 and the values of the matrix elements of this column arc set to zero. Then the rows of the new matrix which posses non zero elements in column 2 (because column two represents line no. 2, which is parallel to line 3) is added to the matrix. After that, the none zero elements of column 2 of the added rows are set to zero, instead, the zero elements of column 3 of the rows are replaced with relevant column 2 elements. Table 3 shows the new composed matrix.

Table 3. the composed matrix

C_{Sd}		1	2	3	4	5
Directional Simple Loops	1	1	1	0	-1	1
	2	-1	-1	0	1	-1
	3	1	0	1	-1	1
	4	-1	0	-1	1	-1

Finally, two new rows regarding the loops of two parallel lines 2 and 3 are added. The final table will be exactly Table 1, i.e., the table of the original network.

If a bus in a network is connected to a radial feeder and the next bus at the remote end of the feeder is also connected to an another radial feeder and this continued until the last feeder is connected to load, all buses belonging to the radial feeders can be joined to each other and become one bus. This cannot affect any Break Point Sets (BPS). In other words, if we compose the matrix, the relative columns consist of zero values.

If a bus of a power system network has only two nonparallel lines, the bus can be joined to one of its adjacent buses and simple loop matrix is composed for the reduced network. The more detail regarding this part is given in reference [12].

3. COMBINED EXPERT SYSTEM & GRAPH THEORY APPROACH

In this section the parameters which are used as the rules are described first. Then in section 3-2 the combination approach is explained.

3.1- Expert Rules

In this part, the rules of expert system are described. If the feeder under consideration is far from generating source, that feeder can not be a break point. In other word if the feeder closes to a generator, it is more probable that the feeder to be a break point. This is obvious from the radial networks. This is because the fault level of the feeder nearer to a generator is higher than the other. This can be considered as the first rule.

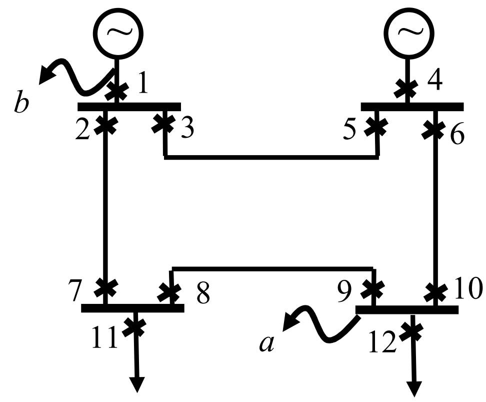

Figure 1. A sample network

In figure 2, relays no.2&3 posses the advantages of being close to the source, however the relay no.1 does not have the advantage of closing to the source. This can be understood by putting faults at a and b. The second rule is the amount of the fault level. The feeders with lower fault levels are considered as break points. The third rule is based on high set instantaneous elements of over current relays. The feeders on which the high set element has been installed can be considered as a break point. The reason for that is the high speed operation of high set element causes that relay can not support the other relays with lower speed as backup protection.

When a pilot protection is used, the feeder adjacent to the feeder protected by pilot protection is chosen as a break.

Loads can be classified into three categories. The first are very important loads and must not be disconnected, the second load type can be disconnected for short times & the last type can be disconnected for long time. Obviously the break point can not be the first type of load. This is because if the relay closes to this local considered as a break point, then that relay will be the first one to operate. The third type is more probable to be a break point.

3.2- Combination of Expert and Graph Theory

In this paper a new approach based on combination of the reduced graph theory approach & expects system is proposed. Expert system uses the experiences of expert persons on protection area. The explanation of the expert approach is given in the previous section. All the mentioned parameters are appeared as rules. Graph theory in this paper is used as a rule of expert system. Indeed the graph theory plus other rules which posses protection configuration, fault level, the location of generating power etc give the break points. The flow chart of the complete procedure is shown in Figure.3.

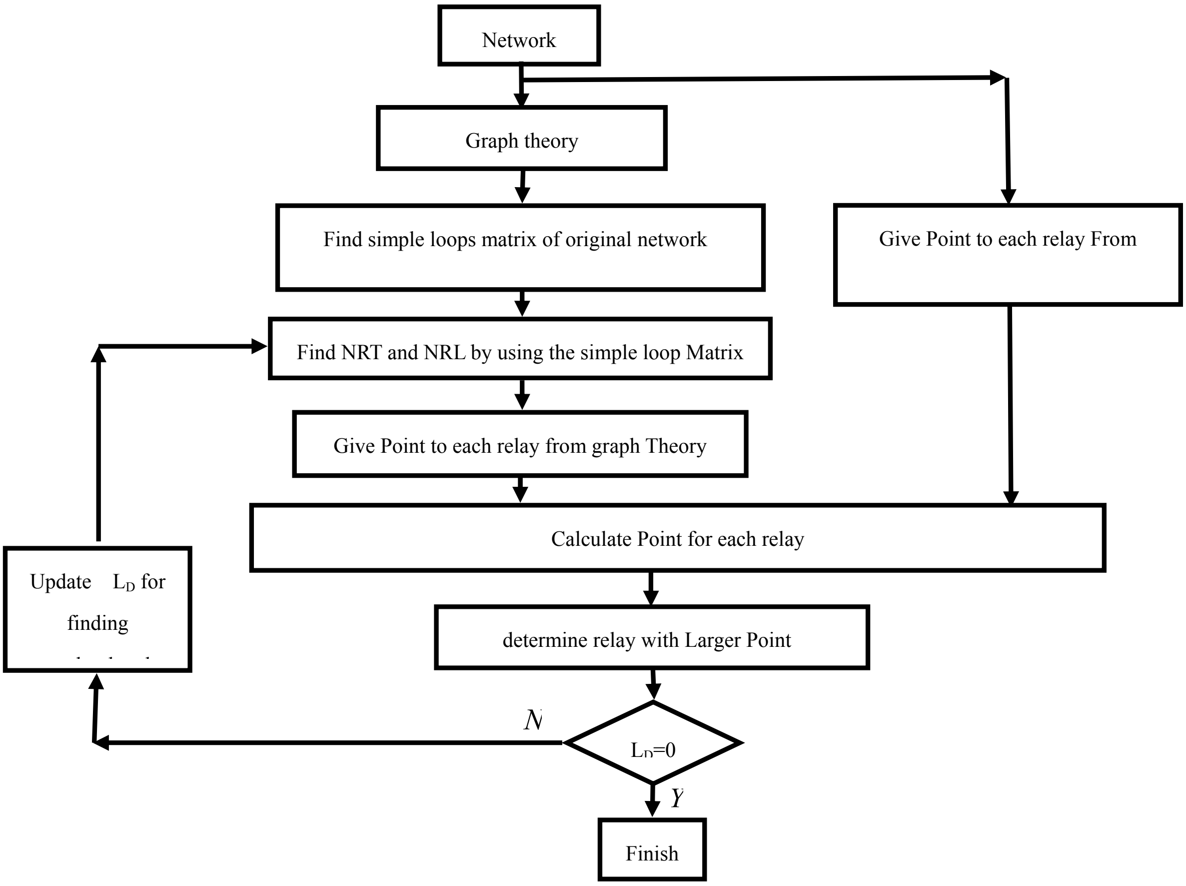

Figure 1. Flowchart of the Combined Approach

4. TEST RESULTS

The computer program has been tested on the network shown in Figure.4.

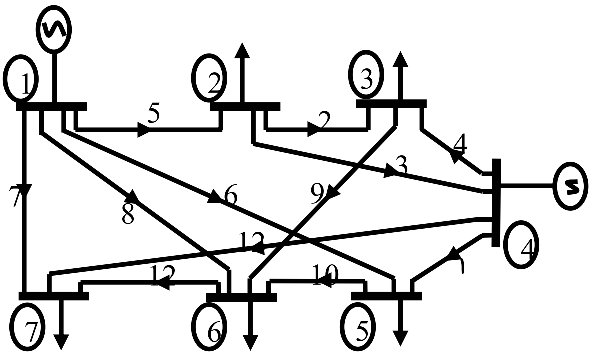

Figure 4, Power system Network

The network includes 12 transmission and lines 6 busses. The information of the network is given in Table 4.

Table 4. Information of the network

Branch No.	Sending bus	Receiving bus	H.S in sending bus	H.S in receiving bus	S.C.L of sending relay	S.C.L of receiving relay	Pilot protection	Connection of sending bus to source	Connection of receiving bus to source	Bus importance
1	*4*	*5*	*0*	*0*	*4000*	*6000*	*1*	*1*	*0*	*0*
2	*2*	*3*	*0*	*1*	*2000*	*6000*	*0*	*1*	*0*	*0*
3	*2*	*4*	*0*	*0*	*4000*	*7000*	*1*	*1*	*1*	*0*
4	*4*	*3*	*0*	*0*	*4000*	*6000*	*0*	*1*	*0*	*0*
5	*1*	*2*	*0*	*0*	*1000*	*5000*	*1*	*0*	*1*	*0*
6	*1*	*5*	*0*	*1*	*5000*	*5000*	*0*	*0*	*0*	*0*
7	*1*	*7*	*0*	*1*	*8000*	*8000*	*1*	*0*	*0*	*0*
8	*1*	*6*	*1*	*0*	*4000*	*2000*	*0*	*0*	*0*	*0*
9	*3*	*6*	*1*	*0*	*4000*	*5000*	*0*	*0*	*0*	*1*
10	*5*	*6*	*1*	*0*	*5000*	*5000*	*0*	*0*	*0*	*1*
11	*6*	*7*	*0*	*0*	*5000*	*4000*	*0*	*0*	*0*	*0*
12	*4*	*7*	*0*	*0*	*7000*	*5000*	*0*	*1*	*0*	*0*

Then, by using the reverse manner, LD matrix is composed. Now each relay is given a point. The way of giving the points to the relays are given in Table 5. in this Table

Table 5, The simplification of the network

Relay No.	1	2	3	4	5	6	7	8
First Parameter Point	3	3	1	3	0	2	2	2
Second Parameter Point	4	2	4	4	1	5	8	4
Third Parameter Point	0	0	0	0	0	0	0	1
Forth Parameter Point	98	103	86	86	111	93	93	69
Fifth Parameter Point	0.16	0.16	0.2	0.2	0.16	0.16	0.2	0.2
Sixth Parameter Point	1	0	1	0	1	0	1	0
Seventh Parameter Point	11	10	10	11	12	12	12	12
Eighth Parameter Point	4	5	5	4	5	5	5	5
Conclusion	8.77	8.36	8.8	8.3	8.21	8.63	10	9.08

Relay No.	9	10	11	12	13	14	15	16
First Parameter Point	4	2	0	3	0	2	1	2
Second Parameter Point	4	5	5	7	6	6	7	6
Third Parameter Point	1	1	0	0	0	0	1	0
Forth Parameter Point	111	93	93	98	98	103	86	86
Fifth Parameter Point	0.1	0.16	0.16	0.16	0.16	0.2	0.16	0.16
Sixth Parameter Point	0	0	0	0	0	0	0	0
Seventh Parameter Point	10	11	12	11	11	10	11	10
Eighth Parameter Point	4	4	4	4	4	4	4	4
Conclusion	9.08	9.3	7.97	8.14	8.27	8.44	10.2	8.13

Relay No.	17	18	19	20	21	22	23	24
First Parameter Point	3	2	2	0	0	0	2	0
Second Parameter Point	5	5	8	2	5	5	4	5
Third Parameter Point	0	1	1	0	0	0	0	0
Forth Parameter Point	111	93	93	69	111	93	93	98
Fifth Parameter Point	3	4	4	4	3	4	4	3
Sixth Parameter Point	0.16	0.1	0.16	0.16	0.16	0.2	0.16	0.16
Seventh Parameter Point	10	11	11	12	12	12	11	11
Eighth Parameter Point	5	4	6	4	4	4	6	6
Conclusion	9.13	9.3	11	7.16	7.54	7.97	8.51	7.47

In Table 5, each relay no. represents tow relays. For example the relay no. 1 is used for two relays, 1 and 1', the relay no.2 for relays 2 and 2' etc.

To show how the points are given to the relays, again consider Table 5 and concentrate on relay 1, the points given in the row shown by first parameter point is 3. This means relay no.1 is in the third distance stage to the two sources. The second parameter point is 4. This means the short circuit level for a fault close to the relay no.1 is 4 per unit, base of 1000MVA. The third parameter point is zero. This no. means the relay no.1 does not include high set instantaneous element. The forth parameter point is 98. This means relay no.1 installed on the feeders of some loops which poses 98 relays. The fifth parameter is 3 which means, the relay installed on the feeders of the loops in which the maximum difference relays of the shortest and largest loops are 3. The point of sixth parameter is 1. Point 1 here shows that the pilot protection exists. The two last parameters are 11 and 4 respectively. 11 means relay no.1 posses 11 backup relays exists in the backup feeders directly connected to the main bus. The next parameter i.e. 4 means relay no.1 is four steps far from unimportant loads.

If the reduced graph theory is used only the network configuration is considered only, in other word the numbers of fourth and fifth parameters of Table 5 are only taken into account. However in the new combined method eight rows parameter are considered. This means the new method is more accurate than the graph theory methods. In Table 5, by comparing the values of the last row, relay no.19 which posses highest point value is the best break point. After simplification and repeating the process by comparing the results of the new points in the last row, the break points set are 19, 7, 15, 18, 10, 14, 9 and 23.

5. CONCLUSION

A computer program has been developed in which the rules of expert system and graph theory are included. In the method the reduced graph theory is considered as a rule. The computer program has been tested on an interconnected power system possessing the different protection systems & power system configuration. The results obtained from the running of the program for the network under consideration are given and from the way of obtaining them, it has been conducted the approach is successful.

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