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A New Brute-Force Attack Method for Power System Restoration and Reconfiguration

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Abstract: This study approaches the problem of restoring a faulted area in an electric power distribution system after locating and isolating the faulted block. Through this study we are going to explain the power system restoration technique using brute-force attack method. This is a new technique based on the possible combination in mathematical analysis. For example, suppose for three digit number we have possible thousand combination (000-999) and there is only one solution so by taking all the possible combination and arranging them we can get the required one solution. In the same way in the power system if a node has fault than its near by agents will make all the possible combination with the near by node starting (1st) to end (nth) and than will go up to the end load and the best solution path out of these combination will be used for the restoration. Although, this solution is little bit time consuming for big system but main advantage of this method is that it will give the 100% efficient result for the restoration of node considering the power availability of the feeders. Here due to fault in the system near by agent will be affected and become useless and will go in the non-working mode. Now in order to restore these near by load we will give a new connection called NO (Normally Open). These connections work in such a way so that the switch will be in open state as long as there is no fault. But it will close with the load of near by feeder as soon as fault is there and they will restore the system by taking the only available power (extra power) from the feeder through bus connection. The effectiveness of the proposed brute force attack method is demonstrated by simulating tests in a proposed distribution network and verified the results using the c programming.

Key words: Brute-force attack method, power systems restoration and reconfiguration, node, feeders, connection, India

INTRODUCTION

The primary concern in the power industry is the customer satisfaction and service reliability and continuity. Power system is a system which is still under investigation. So up to 99% we can say that the system will be in continuity. But due to fault (one of important parameter in power system) we cannot give assurance to the customer that their system is 100% efficient. So in order to overcome this problem and system reconfiguration we go through a process called restoration. Restoration is nothing but a process of maintaining power balance after the fault. The main aim of system restoration is to restore as many as load possible which are being affected from the faulted load. Although, they are in good condition but still due to fault they are unable to receive the power. Hence the aim is to restore there load taking the various factor consideration like time, amount of power available to feeder, system continuity (Momoh and Feng, 2009).

For the above system we have some constraints that we have to always keep in mind and they are:

- The restoration plan must find the new configuration in the efficient time and path in order to avoid inconveniences for the customers and without violating the constraints (block voltages and load sections). Of course, it is expected that the response time will be proportional to the magnitude and complexity of the area under analysis. Results may provide optimal and sub-optimal configurations that reflect an improvement in the operators decision making
- The plan has to minimize the number of operations involved in each configuration. An increase in the number of operations in large centres increases operating costs and the time to restore the faulted area and decreases the life of switches

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- Restore as much load as possible within the out-of service area with the available feeder power
- The plan must not overload any equipment or system component
- The system's radial structure must be maintained
- The configuration of the restored area should be as close to the original configuration as possible
- In this system block and node are equivalent term for the load and the path of the system refers to the medium or buses through which we are achieving the restoration

In this study we will solve a problem with the brief overview of solution of the problem with the required algorithm and finally a conclusion will be given.

PROBLEM FORMULATION

In this study we have formulated a power system so that we could study on this system after the fault. For the above system we have some important parameter that is important to understand. Feeder is one of the parameter of the system which supply the power to the system and hence it can be a power generation part of the system which has the demand power and extra power. Load is also a one of the important parameter of the system which consumes the power supplied by the generating part of the system. Now all the load and feeder are connected through the buses which transmit the power to the various loads. In addition, we are going to consider a three feeder system for simplicity. In actual system will be very large and we can generalized this system for a large system also. Beside these parameters there is one more special connection between the loads of feeder one to the load of other feeder. This special connection is working in such a way that connection is NO (normally open) condition when there is no fault in the system but it will be closed as soon as the fault is there in the feeder. The switch D will close according to the requirements of restoration in the different feeder (Sakaguchi and Matsumoto, 1983).

In Fig. 1 the status of a 3 feeder network having 5 loads in each feeder is shown. In general the feeder will work normally and each feeder will provide the necessary amount of power to each load depending upon there requirement and extra amount of power will be there as in reserve mode. Now initially the switch D will be in NO (Normally Open) condition as there is no fault in the system. Now as soon as there is a fault in the system the whole of the system status will change.

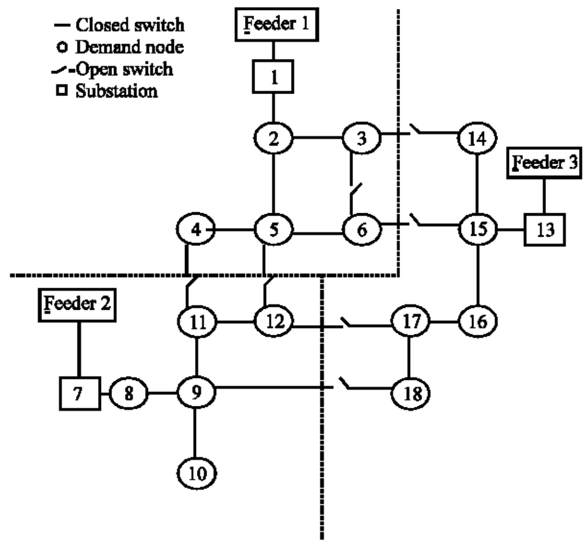

Fig. 1: The status of a 3 feeder net work howing 5 loads in each feeder

FAULT ANALYSIS

In the power system we cannot give the assurance that the system will work 100% efficiently. Even 0.1% irregularity in the system can lead to a big fault in the system. Now suppose any how a fault occurs in the system. As soon as fault occurs in the system the loads which are getting the power through the faulted load will also effects because of the fault. All the loads which are getting the power through this load will shut down. Hence we can see that because of the fault the healthy loads will be effecting. We can't restore the faulted load and we have to repair it manually that is the only option we have for the faulted load. For the effected load we have a different option that is if any how we give the same amount of power to these load through another way for example with the help of another feeder, we can restore these load and than we can maintain the continuity of the system. In the proposed system the feeder 1 and 2 are having extra 10-10 unit and feeder 3 is having 5 units and each block require 5 units (Kashem *et al*., 1998).

Now in the system suppose a fault occurs in the load 2. As soon as we came to know about the fault, the near by load of the faulted load will separate themselves from the faulted load in order to save from the fault. In the above case if fault is there in the load 2 than its near by agent 1, 3, 5 will separate themselves from the faulted load 2. Now for the load 3-6 power is transmitting through load 2. Because of the fault in load 2 the load 3-6 will become useless and they will go in off condition. At this stage the aim is to restore these loads through another way. Now those blocks which are in off condition will check the possible path starting from the initial block (1) to the end block (18) and than these block will check the power availability to the feeder and than blocks will be restored according to the power availability of the feeder if any how all the feeder don't have extra power for the blocks than in that condition the blocks can't be restored. After the separation of near by agent from the faulted load the special switch D will came in the existence. The switch D will be in close condition according to the requirement of load restoration. In the above system the switch D will close foe the load 3-6. Hence they will get required amount of from the near by feeder and can restore themselves. Hence load 3 connects himself from load 14 of feeder 3 and restored. Now feeder 3 is having 0 extra units, load 4 and 5 will connect itself from the load 11 and 12 of feeder 2 and restored. Now feeder 2 is having 0 extra unit, finally the load 6 will not be restored as no feeder is having extra amount of units. This approach we have taken initially for a small level but we can extend it for a very large system and can verify it for a very big system.

THE STEPS IN THE ALGORITHM

- Identify the block in which the fault has happened
- Open all switches connected to that block in order to isolate it. For each switch that is opened, a sub-tree is generated which will have to be restored, except for the switch that connects the faulted block to a block the substation is still feeding normally (a block that is before the fault)
- According to this make change in bus connectivity matrix and load status array. Put 0 in bus connection matrix for no connection between node and put 0 for unfed node in load status array
- If there is a connection between two unfed node (load (i, j) = 1) change it by loop switch (load (i, j) = 2)
- Create a list of the blocks still being fed and containing at this moment only the blocks the substation is still feeding, if any
- Check if there is a loop switch between a fed block and an unfed one (Possible connection are represented as 2 in bus-conn matrix)
- The unfed block which is only connected to fault block (node or load) can not be restored
- If there is a loop switch between fed and unfed block, check that from which feeder the fed block is getting power
- If that feeder has extra enough power for unfed block, connect the fed and unfed node and make necessary change in load connectivity matrix and load status array
- Now move to next unfed block and repeat from step 4
- After checking each unfed block and repeat again from step 4 for n times where n = no of fault node (block) at starting
- Check the load status and for which node load status value is zero that can not be restored

BUS CONNECTIVITY MATRIX

It is 18*18 matrix. In Fig. 1 node 2 and 3 are connected so element in row 1 and column 2 will be 1. In the same way element in row2 and column 1 will be 1. Now between node 3 and node 4 there is a loop switch so mat (2, 13) = mat (13, 2) = 2 (Papadopoulos *et al.*, 1997; Manjunath and Mohan, 2007).

```
1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 1 0 0 2 0 0 0 0 0 0 0 2 0 0 0 0
0 0 0 1 1 0 0 0 0 0 2 0 0 0 0 0 0 0
0 0 0 1 1 1 0 0 0 0 0 2 0 0 0 0 0 0
0 0 2 0 1 1 0 0 0 0 0 0 0 0 2 0 0 0
0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0 2
0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0
0 0 0 2 0 0 0 0 1 0 1 1 0 0 0 0 0 0
0 0 0 0 2 0 0 0 0 0 1 1 0 0 0 0 2 0
0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0
0 0 2 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0
0 0 0 0 0 2 0 0 0 0 0 0 1 1 1 1 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0
0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 1 1 1
0 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1 1
```

Here researchers have written code is written taking the fact in consideration that we already know the initial status of the system (Liu *et al.*, 2004). Coding is done in C language because it is easy to understand (One can use matlab also).

```
/* This program is based on system shown in Fig. 1 loadstatus1[18]:- this
will show that the particular node is fed (1) or unfed (0).
    Load [][]:-this is bus connectivity matrix. If node 2 and 3 are connected
then load [1] [2] = load [2][1] = 1
    a[18]:- It is carrying the unfed node's number
LOAD STATUS (int p,int k):- it is a function to deduce that a node can be
restored or not. */
#include<stdio.h>
#include<conio.h>
int
loadstatus1[18] = {1,0,0,0,0,0,1,0,0,0,0,0,1,0,0,0,0,0};
int
load [18] [18] = { {1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0},
{1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0} ,
{0,1,1,0,0,2,0,0,0,0,0,0,0,2,0,0,0,0} ,
{0,0,0,1,1,0,0,0,0,0,2,0,0,0,0,0,0,0} ,
{0,1,0,1,1,1,0,0,0,0,0,2,0,0,0,0,0,0} ,
{0,0,2,0,1,1,0,0,0,0,0,0,0,0,2,0,0,0} ,
{0,0,0,0,0,0,1,1,0,0,0,0,0,0,0,0,0,0} ,
{0,0,0,0,0,0,1,1,1,0,0,0,0,0,0,0,0,0} ,
{0,0,0,0,0,0,0,1,1,1,1,0,0,0,0,0,0,2} ,
{0,0,0,0,0,0,0,0,1,1,0,0,0,0,0,0,0,0} ,
{0,0,0,2,0,0,0,0,1,0,1,1,0,0,0,0,0,0} ,
{0,0,0,0,2,0,0,0,0,0,1,1,0,0,0,0,2,0} ,
{0,0,0,00,0,0,0,0,0,0,0,1,0,1,0,0,0},{0,0,2,0,0,0,0,
0,0,0,0,0,0,1,1,0,0,0},{0,0,0,0,0,2,0,0,0,0,0,0,1,1,1
,1,0,0},{0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,0},{0,0,0,
0,0,0,0,0,0,0,0,2,0,0,0,1,1,1},{0,0,0,0,0,0,0,0,2,0,0
,0,0,0,0,0,1,1}};
```

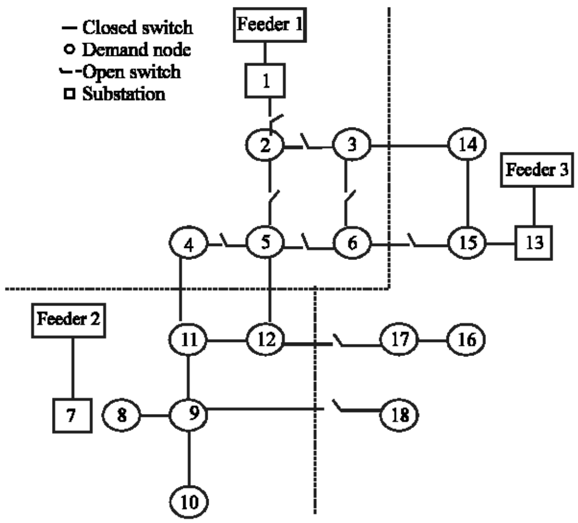

Fig. 2: The output when the fault is in load 2

For the code we can see the output keeping in mind all the constraints. The output for the above system will be different for fault in different loads. Now in the above case if fault is there in load 2 than output will be as follows:

Enter the no of fault load = 2
Demand node 1 is separated from 2
Demand node 3 is separated from 2
Demand node 5 is separated from 2
Demand node status is : 1 0 0 0 0 0 1 1 1 1 1 1 1
1 1 1 1 1
Demand node 3 is connected to demand node 14
Demand node 3 is restored.
Extra power Feeder1 = 10
Feeder2 = 10
Feeder3 = 0
Demand node 4 is connected to demand node 11
Demand node 4 is restored.
Extra power Feeder1 = 10
Feeder2 = 5
Feeder3 = 0
Demand node 5 is connected to demand node 4
Demand node 5 is restored.
Extra power Feeder1 = 10
Feeder2 = 0
Feeder3 = 0
Demand node 6 can not be restored
Demand node 2 can not be restored (Fig. 2)

CONCLUSION

In this study we presented a Brute-force attack method to solve the problem of restoration in a distribution network. We show that this method is adequate to solve restoration problems and may be used in real-size networks. The B-R attack procedure that was presented is able to considerably reduce the magnitude of the problem by using the local network concept (considering only adjacent feeders) in a very objective approach to the problem. This way, the B-R attack procedure offers substantially fast solutions, usually with times that are smaller than one second. Besides providing solutions in a very short time, the method presents a list of possible solutions that can be implemented in a prioritized order.

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