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Distribution System Reconfiguration for Power Loss Reduction under Fault Condition

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Abstract: **In today's era distribution system complexity is increasing day by day. Due to this the possibility of occurrence of faults has also been increased. DAOP is one of the algorithms to run the load flow by reducing the losses in the network. Reconfiguration algorithm followed by the backtracking is very helpful in finding the best combination of the switches which when closed gives the minimum power loss. The paper describes the same algorithm manually performed on a small distribution network shown in section 2 and the work is verified by using Open DSS software.**

***Index Terms*— Distribution System Reconfiguration, Discrete Ascent Optimal Programming (DAOP), Backtracking, Open Distribution System Simulator (DSS) tool.**

I. INTRODUCTION

Power Distribution System has been generally operated at low voltage levels with the aim of obtaining power from a high voltage bulk power source and then distributing it to the different users like residential users, industrial users and commercial users. Due to different situations loads may be outage or lines may be overloaded due to different internal and external forces, and these leads to loss of life, revenue and utility integrity [1]. In order to overcome this problem and to supply all the loads at the same time distribution network reconfiguration was proposed [2]. There are several algorithms from which we can reconfigure the network such as: heuristic nonlinear constructive method, Integer Interior Point Programming Technique, Discrete ascent optimal programming (DAOP) etc. Maximum losses in the network are in the form of I^2R. The distribution automation has made it possible to optimize the losses by loss minimization techniques [3]-[4].

The prescribed work has the motive to fulfill all the loads during normal as well as faulty conditions, by selecting the best combination of the candidate switches such that the power loss should be minimized. Manually calculated results have been verified by the software Open DSS. This software was mainly developed as the distribution system simulator tool.

In this paper there are seven sections describing about the paper. Section I contains the introduction part; this explains the need of the distribution network,

distribution network in the today's era and the motive of our work. Section II describes the circuit diagram of a 4 source, 6 load systems with constant current loads. Section III explains the complete algorithm (DAOP and backtracking) used in the paper. Section IV has the manually calculated and software programmed result details with different cases taken on the circuit explained in the section II. Section V shows the conclusion. Section VI has all the references used in the paper.

II. CIRCUIT DIAGRAM

Fig. 1 can be any small distribution network with four sources and six loads. The loads here are constant current loads and the distance of the line is represented by the resistances. Here only active power losses are taken in consideration during calculation. The parameters of the circuit in Fig. 1 have been shown in the table 4 in Appendix.

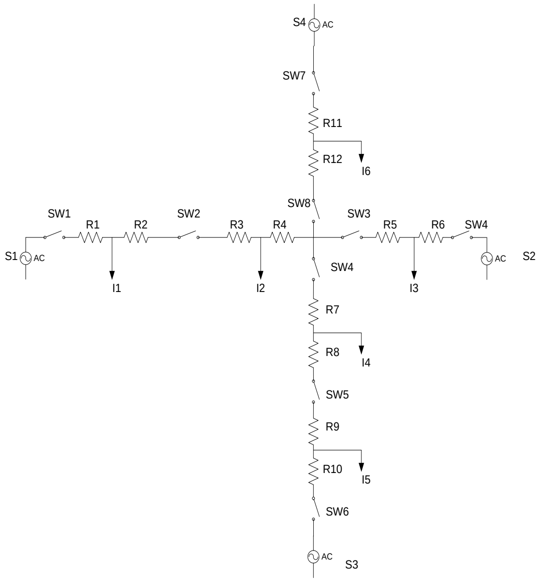


Fig. 1: 4 source, 6 load system with constant current loads

The circuit can have random switches connecting the loads to different sources such that whenever there would be fault between any two points no load should kept isolated. Every load should be supplied by selecting the best combination of the candidate switches such that the power loss should be minimized.

III. ALGORITHM DESCRIPTION

Optimal load flow and phase balancing for distribution systems has been carried out through discrete ascent optimal programming (DAOP). In DAOP the load increased with the step increases. When we added each step at the ending node this will create the smallest increase in the total losses. The loss increases with each step in discrete increments, hence called as “discrete ascent” optimal programming. DAOP is a greedy algorithm [7].

A reconfiguration algorithm based on DAOP is shown in Fig 2, full load flow evaluation with candidate switch operations is assumed. The types of switches to be used are mentioned by the user, and manually lock selected switches. More switches may be locked by the fault isolation process. At the end of preprocessing, the algorithm will contain a list of operable switches used for reconfiguration. The problem of benchmark losses and unserved load are solved using these operable switches in their current state. A network load flow can also be performed with all operable switches closed and a lower bound on the losses provided by this condition.

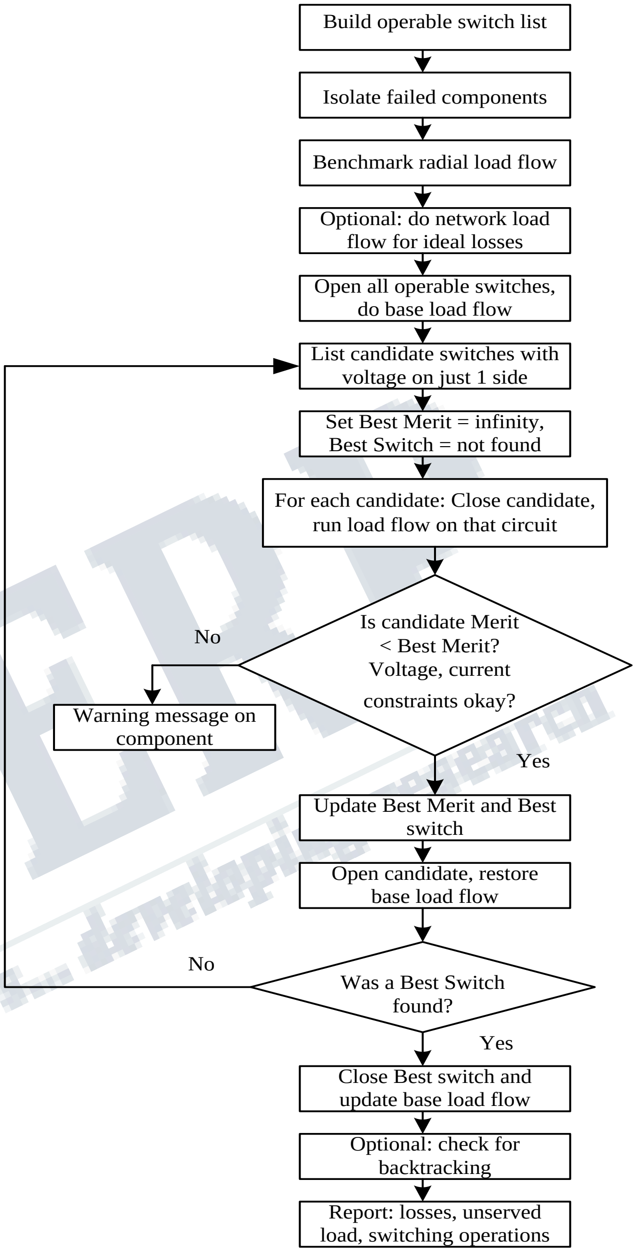


Fig. 2 Reconfiguration algorithm with full load flow analysis

In Fig.2 the algorithm’s main loop starts by opening the entire operable switch list. In the first step candidate switches are being selected and they must have voltage on just one side. All the candidate switches are closed one at a time and their respective merit figure is calculated. The switch having the lowest merit figure is closed and rest remains opened. In the next step again the same process is repeated until all the loads are fed or all the switch lists are checked. According to the discrete ascent optimal programming, the total loss increases with each step.

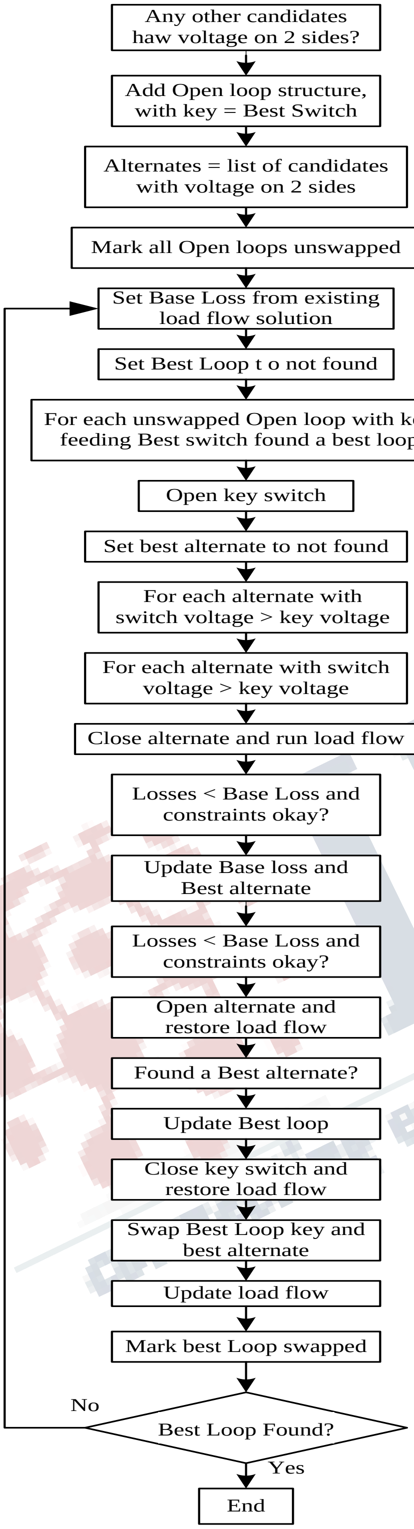


Fig. 3 Open loop backtracking scheme

$$M = \Delta P_{loss}/(\Delta S_{load} + 0.001\Delta Q_{cap}) \qquad \ldots\ldots\ldots \ (1)$$

Where, M = merit figure

$\Delta P_{loss} = \sum I^2R$ (incremental loss caused by closing the candidate switches)

ΔS_{load} = the load kVA picked up

ΔQ_{cap} = the utility capacitor bank kVAR picked up

Minimum loss increment normalized by the total apparent load picked up is favored by the merit figure. The only purpose of the factor 0.001 is to provide a non-zero denominator for switched segments with capacitors but no customer load.

When no candidate switches can be closed, the algorithm stops in the given steps. This can be occurring when:

- ❖ All load has been served - no more candidates
- ❖ Without violating voltage or current constraints no more switches can be closed

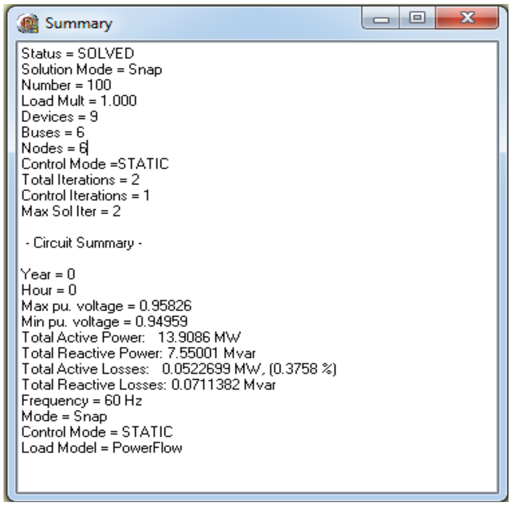
If under the criteria ii) some of the loads remained unserved then the voltage or current constraints can be modified reflecting the emergency condition and then repeat the loop.

At the end of the main loop in Fig. 2, the detail of an optional backtracking is shown in Fig. 3. When switch is closed completing an open loop, at least one of the other candidates present at that step will now have voltage on both sides. Subsequent steps in the algorithm one of the candidates can be make more attractive by adding load to that circuit. Whenever a selected candidate switch has one or more of the open loop key switches in its feeder path leading back to the source the algorithm checks alternate feeds. After the key switch opened, if the voltage magnitude of an alternate feed has a higher value than the key switch, then that alternate switch is closed by the algorithm and runs a load flow to see if the losses decrease. Then the key switch and best alternate are exchanged if the condition satisfied. An open loop may swap only once for each step, but may swap again in the next step.

IV. SIMULATION AND RESULT

Open DSS was released by EPRI in 2008. It is open source software. The software was developed to overcome the problem for simulating the large and complex networks. It provides flexibility, faster result as compared to the other software. There was a need for such software because existing software were having restriction in distribution network simulations. Through this software user can write their own network program and can get the real time values, also the harmonic analysis is possible without use of non-linear models. This has also helped in the distribution automation.

The circuit shown in the section II has been simulated using Open DSS software under the normal operating condition. Switches 3, 6, 9 are open under the normal condition therefore the network has been divided into four parts and each part we have calculated the active power loss, and the software results were verified manually. The circuit description is provided in the table1 and the verified results are provided in the table 2.



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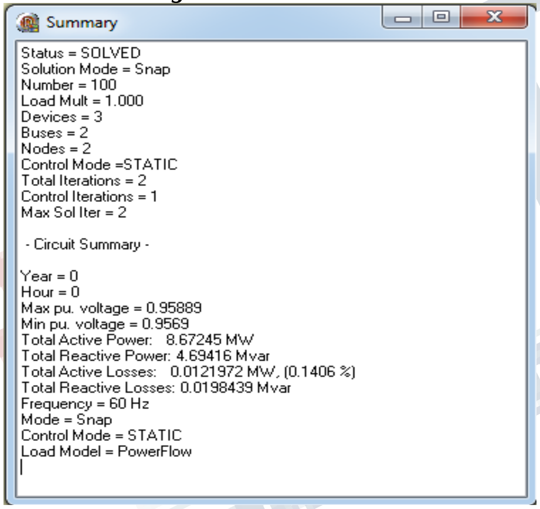
Status = SOLVED
Solution Mode = Snap
Number = 100
Load Mult = 1.000
Devices = 9
Buses = 6
Nodes = 6
Control Mode =STATIC
Total Iterations = 2
Control Iterations = 1
Max Sol Iter = 2

 - Circuit Summary -

Year = 0
Hour = 0
Max pu. voltage = 0.95826
Min pu. voltage = 0.94959
Total Active Power:   13.9086 MW
Total Reactive Power: 7.55001 Mvar
Total Active Losses:   0.0522699 MW, (0.3758 %)
Total Reactive Losses: 0.0711382 Mvar
Frequency = 60 Hz
Mode = Snap
Control Mode = STATIC
Load Model = PowerFlow
```

Fig.4 Circuit 1 results



```
Status = SOLVED
Solution Mode = Snap
Number = 100
Load Mult = 1.000
Devices = 3
Buses = 2
Nodes = 2
Control Mode =STATIC
Total Iterations = 2
Control Iterations = 1
Max Sol Iter = 2

 - Circuit Summary -

Year = 0
Hour = 0
Max pu. voltage = 0.95889
Min pu. voltage = 0.9569
Total Active Power:   8.67245 MW
Total Reactive Power: 4.69416 Mvar
Total Active Losses:   0.0121972 MW, (0.1406 %)
Total Reactive Losses: 0.0198439 Mvar
Frequency = 60 Hz
Mode = Snap
Control Mode = STATIC
Load Model = PowerFlow
```

Fig.5 Circuit 2 results

Table 1

Circuit No.	**Description**
1	S1, R1, R2, R3, R4, R7, I1, I2, I4
2	S2, R6, I3
3	S3, R10, I5
4	S4, R11, I6

Table 2

Circuit No.	**Power Loss (Software Result)**	**Power Loss (Manual Result)**
1	52.2699 kW	53.019 kW
2	12.1972 kW	12.51489 kW
3	17.031 kW	17.459 kW
4	12.2399 kW	12.5586 kW
Total	93.738 kW	95.5515 kW

The circuit diagram shown in the section II is simulated by using discrete ascent optimal programming (DAOP) with different cases as shown in the table 3 below.

Table 3

S. No.	**Cases**	**Switches Open**	**Switches Close**
1	Normal Operating Condition	3,6,9	1,2,4,5,7,8
2	Fault at load between switches SW3 & SW4	3,4,6,9	1,2,5,7,8
3	Fault at load between switches SW5 & SW6	3,5,6,9	1,2,4,7,8
4	Fault at Source 3	4,6,9	1,2,3,5,7,8
5	Fault at Source 2	3,7,9	1,2,4,5,6,8

V. APPENDIX

Table 4

Parameters	**Values**
S1, S2, S3, S4	13.8 kV
R1, R2	0.285 Ω
R3	0.527 Ω
R4	0.627 Ω
R5	0.284 Ω
R6	0.286 Ω
R7	0.570 Ω
R8, R9	1.71 Ω
R10, R12	0.399 Ω
R11	0.287 Ω

I1, I3, I5, I6	209.185 A
I2	41.637 A
I4	83.674 A

VI. CONCLUSION

This algorithm is very much different from others because we need not to perform the switch exchanges or the sequential switch openings. The reconfiguration algorithm is clubbed with the backtracking scheme which helps in avoiding the local minima. Screening of the candidate switch closing is done by an approximate loss formula. At the end of the algorithm we get the best combination of the switches during the load flow. Modification of the merit figure can also be done to obtain the objective function other than loss minimization.

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