ISSN (Online) No:

INTERNATIONAL JOURNAL OF RESEARCH REVIEW IN ENGINEERING AND MANAGEMENT (IJRREM)

RECONFIGURATION OF DISTRIBUTION NETWORK CONSIDERING LOOP CLOSING CONSTRAINTS

S. KAMALAKANNAN*
PG Scholar, Department of EEE,
Adhiyamaan College of Engineering,
Hosur - 635109, Tamilnadu, India.
kamalakannan29.92@gmail.com

V. TAMIL SELVAN
Professor, Department of EEE,
Adhiyamaan College of Engineering,
Hosur - 635109, Tamilnadu, India.
tamil2210@gmail.com

Abstract

Loop closing operation is an important measure for the power dispatching center to adjust distribution network operation mode without power interruption. However, the traditional method for the reconfiguration of the distribution network usually doesn't consider the loop closing constraints. In this paper builds a distribution network reconfiguration method considering the loop closing operation. In this model, the objective function takes minimum losses of the network and considers the constraints of node voltage and line power during loop closing operation. The greedy randomized adaptive search procedure algorithm a heuristic method to solve the new model without power interruption. The proposed new model and algorithm are validating to the numerical results of the 14-bus system.

Keywords -- reconfiguration network distribution, loop closing, power interruption, greedy randomized adaptive search procedure algorithm

I. INTRODUCTION

Reconfiguration of the distribution network is a method to change the topology of the network by operating interconnection and sectionalizing switches [1]. The feeder of the distribution network is usually radial topology to simplify the overcurrent protection [2]. The primary objective of the reconfiguration of the distribution networks is to minimization of the losses of the network. The station and transmission line power flow are reallocated according to the reconfiguration results [2]- [4].

Feeder reconfiguration is performed by the interconnection and sectionalizing switches by their operation of the open and closing operation of these switches. The interconnection switches are closed to link the two it may be a whole feeder or the part of the feeder or it may be another feeder while the appropriate sectional switch is opened to maintain the radial structure of the network [7]. The adjustment in the operation mode without power interruption is a great advantage of the loop closing operation [5].

In this paper, the traditional distribution network reconfiguration method by considering the loop closing operation. Section II defines the traditional network reconfiguration. Section III presents the loop closing operation of the reconfiguration network. Section IV presents proposed an algorithm for the reconfiguration model for reduces the losses. Section V gives test results for the IEEE 14 bus system for proposed algorithm

II. RECONFIGURATION OF THE NETWORK BY TRADITIONAL NETWORK

The mathematical model of the traditional distribution network reconfiguration is combined with the objective function and constraints

A. Objective Function

The reconfiguration model objective function is referred to the minimization of the total power losses:

$$P_{loss} = \sum_{ij=1}^{N_f} r_{ij} \left(\frac{P_{ij}^{\;2} + Q_{ij}^{\;2}}{V_k^{\;2}} \right) \tag{1}$$

B. Constraint

$$\sum_{j=1}^{k} \left(p_q + jq_q \right) = p_{df} + jq_{df} \tag{2}$$

$$v_i - v_f = z_{if} i_{if} \tag{3}$$

$$\sqrt{\left| p_{if}^{\;2} + q_{if} \right|} = s_{if\,max} \tag{4}$$

$$v_{i,\,min} \le v_i \le v_{i,max} \tag{5}$$

$$N_b = N - 1 \tag{6}$$

Where N_l is the number of branches, N_b is the number of the electrical nodes, k is the number of connecting lines in the bus j. P_{ij} is the reactive power of the branch ij, q_{ij} is the reactive of the branch ij, s_{ij} is the apparent power of the branch ij, z_{ij} is the impedance of the branch ij, p_{ij} and q_{ij} are the active and reactive load in the bus j, v_i,$v_{i\ max}$,$v_{i\ min}$ the current and voltage, upper and lower limits of the voltage at the i bus.

In the mathematical model above, Kirchhoff's law is representing from the constraints (2) and (3). Constraints (4) and (5) represent the power flow in the branches and voltage in nodes should keep within the limits. Constraints (6) are the system radial configuration constraints. The number of connected buses and the number of the connected branches minus one should be equal in the radial configuration.

III. RECONFIGURATION OF THE DISTRIBUTION NETWORK CONSIDERING LOOP CLOSING OPERATION

In the loop closing operation, the mathematical model of the traditional distribution network is added some new constraints of the network during the whole reconfiguration process.

A. New constraints

The distribution network reconfiguration problem will be multistage optimization problem. In the whole process, first the interconnection switches and sectionalizing switches should be closed and open in order minimize the losses [7]. It can easily compute the change in the losses by the stimulate the two results of the load flow studies system configuration before and after the feeder reconfiguration [3]. This consideration just satisfied the terminal reconfiguration scheme. When only one interconnection switch is closed, the constraints (6) will be changed into (7):

$$N_{b=}N_l \tag{7}$$

Before closing the interconnection switches, the section switch should be opened. The safety constraints with loop connection with limiter should be considered in the actual process. So, the inequality constraints added in the reconfiguration process.

$$\sqrt{\left|p_{if}{}^{2}+q_{if}{}^{2}\right|}\le s_{if\max} \tag{8}$$

$$v_{i,\min}\le v_{it}\le v_{i,\max}\quad t=1,2,\ldots g \tag{9}$$

The variable in the formulation (8) and (9) include the subscript t which means the *l*th operation process. *g* is the number of all the operation during the whole reconfiguration process. In the whole reconfiguration process, the network safety constraints were satisfied by the loop closing operation of the above two constraints.

In this paper, the power flow equality constraints should be satisfied during the whole process. The formula can be written as follows:

$$\sum_{i=1}^{n}(p_{dj}+jq_{djt})=p_{dj}+jq_{dj} \tag{10}$$

$$v_{ii}-v_{ji}=z_{ij}i_{ij} \tag{11}$$

The variable with subscripts *t* represents the value of the variables the *t*th operational process.

B. Loop connection of distribution network power flow

In this, the safety of the reconfiguration process is verified by calculating the power flow of the distribution network. The thevenin's theory is adopted to solve the distribution network power with loop connection and the calculating method is illustrated in Fig. 1 [8].

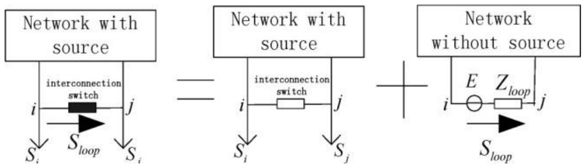

Fig. 1 Power flow calculation by the Thevenin's theory

Based on the traditional forward and backward power flow method [3], the power flow calculation procedure considering loop connection is explained as follows.

l) Calculate the distribution network power flow of current radial network before closing the interconnect switch. The voltages v_j ,v_i in extreme nodes of interconnect switch can be solved.

2) Calculate the Thevenin's equivalent impedance $Z_{loop} = \sum_{i=1}^{loop\ h} z_i$ from the interconnection switch, where is the number of branches in. Z_i is the impedance of the i_{th} branch.

3) Calculate the loop current by $I_{loop} = \frac{Vi - Vj}{Zloop}$. The loop equivalent input power in extreme nodes of interconnection switch can be calculated by $S_{loop\ =}= U_i I^*_{loop}$, $S_{loop} = U_j I^*_{loop}$. Add the equivalent input power to the extreme nodes i, j of interconnection switch illustrated in Fig.2.

4) Calculate the distribution network power flow for a current radial network with the new equivalent load.

5) Validate the safety constraints by the proposed power flow calculation method considering loop connection.

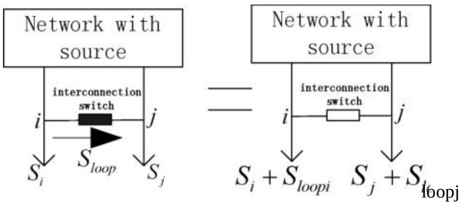

Fig.2 Power flow calculation equivalent circuit

From the calculation procedure mentioned above, two additional loads that are added to the extreme nodes of the switch is equal to the interconnection switch in the loop. From the above procedure of calculation, we can avoid modifying the traditional forward and backward power flow method. After closing interconnection switch, the power flow in the line can be calculated and the safety of the operation process can be verified. If the loop closing operation is feasible when the constraints (8) and (9) aren't violated in the above process. Otherwise, the loop closing operation can't be executed.

IV. PROPOSED ALGORITHM TO SOLVE THE RECONFIGURATION MODEL

There is mainly three kinds of the algorithm used for the solving distribution network reconfiguration model. They are 1. Constructive heuristic algorithm 2. Classical optimization algorithm 3. Intelligent algorithm. The constructive heuristic algorithm is simple but quite difficult to find the optimal solution [7]. The classical optimization algorithm [8] is easy to get the optimal solution for the model. But it takes more time to solve the problem with the big scale of the iteration process. In this algorithm, they used mostly the optimal power flow method. A third of algorithm is intelligent algorithm [9]. In the intelligent algorithm, broadly used in the power system optimization because it is mostly used for the mixed integer optimization problem.

In this paper uses an intelligent algorithm called Greedy randomized adaptive search procedure algorithm to solve the new reconfiguration model. The operation detail of the whole reconfiguration process is given by the GRASP is the biggest advantage of this algorithm. The GRASP is successfully being installed in the transmission expansion planning problem [8].

A. GREEDY RANDOMIZED ADAPTIVE SEARCH PROCEDURE ALGORITHM

Greedy Randomized adaptive search procedure algorithm is a multi or multi-iterative algorithm to solve the optimization problem. Each iteration of the GRASP basically consists of two phases a) construction phase b) local search phase. A feasible solution is built from the construction phase until a local minimum is found during the local search procedure. In this phase, each iteration has a set of candidate elements that can be incorporated into the partial solution without disturbing the feasible solution.

The main planning procedure for the GRASP algorithm is illustrated is as follows:

1) Initialize the optimal solution OP with a very big value. Set the current iteration times 0.
2) Construction phase.
3) Local Search phase. Suppose the solution after this phase is LP.

4) If LP<OP, OP=LP. K-K+I.

5) If K<MI, go to step 2); else go to step 6).

6) Termination, output the optimal solution OP.

The procedure in construction phase to solve the proposed reconfiguration model is illustrated as follows:

1) Calculate the power flow in the distribution network for radial topology.

2) Calculate the voltage difference of all interconnection switches and arrange them in descending order. The first CL switches are selected as the candidate set.

3) Choose one interconnection switch randomly in the candidate set and close it.

4) Calculate the power flow with loop connection using the algorithm proposed in section Ill. If the safety constraints can be satisfied, go to (5). Otherwise, go to (3).

5) Simulate all the neighbor topologies created by opening a sectional switch in the loop and choose the best one according to the loss changing index formula (12) derived in reference [9].

$$\Delta P = \mathrm{Re}\left\{\sum_{i=1}^{k} I_i \left(E_m - E_n\right)'\right\} + R_{loop} \sum_{i=D} I_1^{2} \tag{12}$$

6) Calculate the distribution network power flow and validate its feasibility. If it satisfies the safety constraints, reserve opening the switch and go to (7). Otherwise, go to (5) to choose another switch to open.

7) If the loss changing index AP is a plus, stop and output one candidate reconfiguration scheme. Otherwise, discard the scheme.

In this construction phase, a feasible solution is constructed in an element at a time. In each iteration of the construction phase, the choice of the next element is decided by the ordering of all candidate elements in a candidate list C with respect to the greedy function. In each iteration of the construction phase, the benefits of each element are get updated to brought changes on the selection of the previous elements. The best candidate list is called is called a restricted candidate list (RCL). The above choice technique allows for different solution obtained at each iteration of GRASP. In the GRASP, the solution generated in the construction phase is not guaranteed to be locally optimal with respect to the simple neighborhood. And the local search is to attempt to improve the solution of the construction phase. The pseudo code for the construction phase of the GRASP is as follows:

```
Solution ← ∅;
form the incremental costs of the candidate elements;
while Solution is not complete solution
    construct the restricted candidate list (RCL);
    randomly select an element s from the RCL;
    Solution ← Solution∪ {s};
    Re-form the incremental costs;
end;
return to the Solution;
end Greedy Randomized Construction
```

The procedure for the local search phase for the proposed reconfiguration model is explained as follows:

1) Choose one candidate scheme generated in the construction phase.

2) Select one pair of switches exchanged in current scheme and cancel the exchange operation temporarily.

3) Calculate the power flow in the distribution network and validate if the ant changes in the network losses.

4) If there is no loss increasing, cancel the switch exchange operation and go to (2). Otherwise, reserve it and go to (5)

5) If all pairs of switches exchanged in the current scheme have been tried, stop and output one candidate reconfiguration scheme. Otherwise, go to (2).

A local search algorithm works in an iterative fashion method. In the local search, the current solution is replaced by better solution from neighbourhood solution. The best solution is called as a locally optimal solution. The starting solution, a suitable choice of the neighbourhood structure, efficient search technique is a key to success of the local search procedure algorithm. The pseudo code for the local search phase is as follows

```
Procedure Local Search (Solution)
    While Solution is not locally optimal do
        Find s0 ∈ N(Solution) with f(s0) < f(Solution);
        Solution ← s0;
    End; return Solution;
End Local Search
```

V. TEST RESULTS

The data for IEEE14 bus system can be found in [9] and the value of the $V_{min} = 0.95$ p.u is used in the tests. The capacity of the line is specified as 10MV. The IEEE 14 bus system data load is shown in the table I. In this system, we include the capacitor of the size 100 kvar. The initial topology of the reconfiguration distribution network is shown in Fig 6.

TABLE.I. LOAD DATA OF 14-BUS SYSTEM

Node	Active power(MW)	Reactive power(MVAR)
1	0	0
2	2	1.6
3	3	0.4
4	2	-0.4
5	1.5	1.2
6	4	2.7
7	5	1.8
8	1	0.9
9	0.6	-0.5
10	4.5	-1.7
11	1	0.9
12	1	-1.1
13	1	0.9
14	1.3	-2.5

All the safety constraints in the topology are satisfied. In the reconfiguration scheme, the whole active power losses are 504.75 KW.

The reconfiguration of the distribution network method without considering looping constraints operation, the optimal reconfiguration scheme is solved. In this topology, all safety constraints are satisfied. The whole active power losses of this reconfiguration are 455.4 KW.

In this paper, GRASP proposed algorithm is used in the reconfiguration scheme in the distribution network considering loop operation can be solved.

In the reconfiguration scheme, four switches states are changed. Firstly, we consider the proposed algorithm for the reconfiguration scheme without considering loop closing constraints. The operation process for the closing the line 3-9, 6-8,11-13,13-14. The whole active power losses of reconfiguration are 392.01 KW In the reconfiguration scheme with loop closing operation the four switches states are changed. In this reconfiguration can be realized by closing the four lines in the topology. Closing the line1-11, 3-9, 6-8, 11-12. The active power losses in the reconfiguration scheme with looping constraints are 397.12 KW. In this GRASP the optimal solution is randomly changed because it is randomly choosing the best solution. All the safety constraints are not get violated and getting the feasible solution.

TABLE.II. COMAPRSION OF TEST RESULT OF 14-BUS SYSTEM

	Active power (KW)	**Interconnection switches**
Initial topology	504.75	3-9,6-8,8-12,13-14
Optimal topology without loop operation	392.01	3-9,8-12,11-13, 13-14
Optimal topology with loop operation	397.12	1-11,3-9,6-8,11-12

From the above test results in its shows that reconfiguration scheme solved by the proposed algorithm considers the safety constraints with loop closing operation. Although the power loss of the proposed algorithm is less than the traditional algorithm and it gives a feasible solution without power interruption.

VI. CONCLUSION

This paper proposes a new reconfiguration scheme for distribution network model considering loop closing operation. In this, new reconfiguration process considered as a multistage optimal problem. The proposed new algorithm GRASP is applied to solve new reconfiguration model. During the whole reconfiguration process safety, constraints are satisfied and solve the loop closing operation. In this scheme solved by proposed method in this paper is feasible and effective.

REFERENCE

[1] Yang Jianjunt, Zhan Hong. "Application of the improved genetic algorithm based on graph theory in distribution network reconfiguration". Power System Protection and Control, vol. 38, no 21, pp. 122-125, Aug. 2012.

[2] F. Gomes, S. Carneiro, J. L. R. Pereira, M. Vinagre, P. Garcia, and L. Araujo, "A new heuristic reconfiguration algorithm for large distribution systems," IEEE Trans. Power Syst., vol. 20, no. 3, pp. 1373-1378, Aug. 2005.

[3] J.Z. Zhu, "Optimal reconfiguration of electrical distribution network using the refined genetic algorithm," Elect. Power Syst. Res., vol. 62, pp. 37-42, 2002

[4] H. P. Schmidt, N. Ida, N. Kagan, and 1. C. Guaraldo, "Fast reconfiguration of distribution systems considering loss minimization," IEEE Trans. Power Syst., vol. 20, no. 3, pp. 1311-1319, Aug. 2005.

[5] XIA Xiang, XIONG Jun, HU Liexiang. "Analysis and control of loop power flow in the regional power network," Power System Technology, vol. 28, no 22, pp. 76-80, 2004.

[6] YE Qing-hua, TANG Guoqing, W ANG Lei, et al. "Development and application of the analysis system for closed loop operation of distribution network," Electric Power Automation Equipment, vol. 26, no 22, pp. 66-69,2002

[7] YE Qing-hua, TANG Guoqing, WANG Lei, et al. "Development and application of the analysis system for c10sed loop operation of distribution network," Electric Power Automation Equipment, vol. 26, no 22, pp. 66-69,2002

[8] F. Gomes, S. Carneiro, J. L. R. Pereira, M. Vinagre, P. Garcia, and L. Araujo, "A new distribution system reconfiguration approach using optimum power flow and sensitivity analysis for loss reduction," IEEE Trans. Power Syst., vol. 21, no. 4, pp. 1616-1623, Nov. 2006.

[9] Edgar Manuel Carreno, Ruben Romero. "An Efficient Codification to Solve Distribution Network Reconfiguration for Loss Reduction Problem," IEEE Trans. Power Syst., vol. 23, no. 4, pp. 1542-1551, Nov. 2008.

[10] S. Binato, G. C. Oliveira, and J. L. Araujo, "A greedy randomized adaptive search procedure for transmission network expansion planning," IEEE Trans. Power Syst., vol. 16, no. 2, pp. 247- 253, May 2001