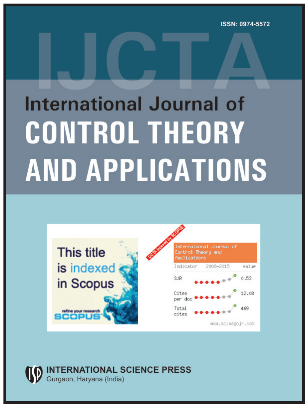

International Journal of Control Theory and Applications

ISSN : 0974-5572

Volume 10 • Number 16 • 2017

LSF Based Network Reconfiguration for Loss Reduction in Radial Distribution System

G. Sasi Kumar[a], S. Sarat Kumar[b] and S.V. Jayaram Kumar[c]

[a]*Assoc. Professor, Dept. of EEE, VNR VJIET, HYD, India. Email: sasikumar_g@vnrvjiet.in*
[b]*Professor, Dept. of EEE, M.V.G.R.C.E, VZM, HYD, India. Email: sahu.sarat@gmail.com*
[c]*Former Professor, JNTUH, Professor GRIET, Dept. of EEE, HYD, India. Email: svjkumar101@rediffmail.com*

Abstract: Network reconfiguration is one of the methods for loss minimization of Radial Distribution System. In this paper Forward/Backward sweep Algorithm (FBSA) is used for Distribution Load Flow analysis. Loss Sensitivity Factor based Network Reconfiguration Algorithm is proposed to decide the switching combinations and to find the best combination of switches for minimum active power loss. The proposed algorithm has been implemented on 33-node Radial Distribution System. The obtained results have been compared.

Keywords: Network reconfiguration; Loss Sensitivity Factor; Forward/Backward sweep Algorithm; Loss minimization.

1. INTRODUCTION

The key factor in any electrical power system is the power loss due to resistance during transmission and distribution networks. However the power loss in the distribution network is more than in the transmission network because of high R/X ratio. To minimise these losses in the distribution system, different methods were applied for the past two decades.

Distribution systems are normally configured radially for effective coordination of their protective systems. Most distribution networks use sectionalizing-switches that are normally closed, and tie-switches that are normally opened. From time to time, modifying the radial structure of the feeders by changing the on/off status of the sectionalizing and tie switches to transfer loads from one feeder to another may significantly improve the operating conditions of the overall system.

A branch exchange type heuristic algorithm proposed in [1] for determination of change in power loss due to a branch exchange. A method to identify the branches to be exchanged is proposed by [2,12].The branch and bound type optimization technique to find the minimum loss configuration is used in [3]. A heuristic algorithm is developed in [4,5,13] by Closing all the switches, which are then opened one after another so as to establish the optimum flow pattern in the network. Quadratic loss function and multiple switching pair operation method is proposed in [6,7] to solve the minimum loss reconfiguration problem. Switch-exchange and sequential switch opening methods are proposed by [8] for reconfiguration of the network. Global search switching Algorithm proposed in [9] for reduction of power loss. A Meta-heuristic Fire works Algorithm (FWA) used in [14] to optimize the RDS while satisfying the operating constraints. Genetic Algorithm and redefined Genetic Algorithm proposed in [16,17] for best combination of switches for power loss minimization, ITS Algorithm is used in [18] for loss reduction.

In this paper, LSF based NR Algorithm has been proposed to identify the optimum switching configuration for active power loss minimization. The algorithm is tested on 33-bus Radial Distribution System using MATLAB and comparative study is made.

2. PROBLEM FORMULATION

Feeder reconfiguration is performed by selecting, among all possible configurations, the one that incurs the smallest power losses and that satisfies a group of constraints.

The objective function of the problem is formulated so as to get maximum power loss reduction in distribution due to reconfiguration.

$$\text{Maximize } f = \max \Delta P_{Loss}$$

subjected to current, voltage and power loss constraints

(a) Branch current constraint $I_b \leq I_{b\,max}$

Where I_b is the branch current $I_{b\,max}$ is the maximum permissible branch current

(b) Node voltage constraint: $V_{i,\,min} \leq V_i \leq V_{i,\,max}$

Where V_{min} and V_{max} are the minimum, maximum permissible node voltages

(c) Total power loss: $P_{Loss} < P_{Loss\,b}$

where, P_{Loss} power loss after reconfiguration and $P_{Loss\,b}$ base case power loss

3. PROPOSED ALGORITHM

3.1. Load Flow Analysis for Radial Distribution System

The critical step in designing an electrical power system requires load flow analysis which involves planning, scheduling and operation control stages of power system. Forward/Backward sweep based algorithms used in [15] for load flow analysis of the distribution networks have major computational advantages such as low memory requirements, high convergence and efficiency.

3.2. Real Power Loss and Loss Sensitivity Factor

The real power loss which is function of α and β given by (1)

This line loss expression is named as "Exact Loss" formula describe in [10,11] has been used

$$P_{Loss} = \sum_{i=1}^{N}\sum_{j=1}^{N}\left(\propto_{ij}\left(P_iP_j + Q_iQ_j\right) + \beta_{ij}\left(Q_iP_j - P_iQ_j\right)\right) \tag{1}$$

where, $\alpha_{ij} = \dfrac{R_{ij}\cos(\delta_i - \delta_j)}{V_iV_j}, \beta_{ij} = \dfrac{R_{ij}\sin(\delta_i - \delta_j)}{V_iV_j}$

Sensitivity factors are evaluated at each bus, these values are obtained from base Distribution load flow analysis using forward backward sweep method algorithm

Loss sensitivity factor method is based on the principle of linearization of original nonlinear equation around the initial operating point, which helps to minimize the number of solution space.

Loss sensitivity factor is the real power loss variation with respect to real power at bus i and is given in [15] by (2).

$$\alpha_i = \frac{\partial P_{Loss}}{\partial P_i} = 2\alpha_{ii}P_i + 2\sum_{\substack{j=1 \\ j \neq i}}^{n} \left(\alpha_{ij}P_j - \beta_{ij}Q_j\right) \tag{2}$$

3.3. LSF based Network Reconfiguration Algorithm

A LSF based network Reconfiguration algorithm is proposed for distribution system which reduces the active power loss. The algorithm is considered as follows

Step 1: Read line data, bus data and set flag equal to zero for all tie switches

Step 2: Run the distribution load flow analysis using forward and backward sweep method and determine voltages, active power loss, current and LSF

Step 3: Check whether all the bus voltages are within specified tolerance limits or not.

$V_{i,\,min} \leq V_i \leq V_{i,\,max}$ if so go to step 10.

Step 4: Calculate LSF difference between the end nodes k and m tie switches with zero flag. Choose the tie switch with largest LSF difference.

Step 5: Check whether LSF at k^{th} node is larger than LSF at m^{th} node, If so, go to step 7

Step 6: Open the sectionalised switch between k and $k - 1$ and go to step 8

Step 7: Open the sectionalised switch between m and $m - 1$.

Step 8: Connect tie switch and set flag equal to 1.

Step 9: Check all the tie switches flag equal to 1 or not, if not go to step 2.

Step 10: Calculate power loss

If not $0 < P_L < P_{Lb}$ go to step 2

Step 11: Print V, I_b, LSF, and P_L

The proposed algorithm is shown as flow chart in Figure 1

4. RESULTS AND ANALYSIS

4.1. Test System Description

A Three phase balanced, 12.66kv, 100MVA, 33-bus Radial Distribution System shown in Figure 2 is considered for analysis. The converged values of voltage magnitude, phase angle and LSF are given in Table 2.

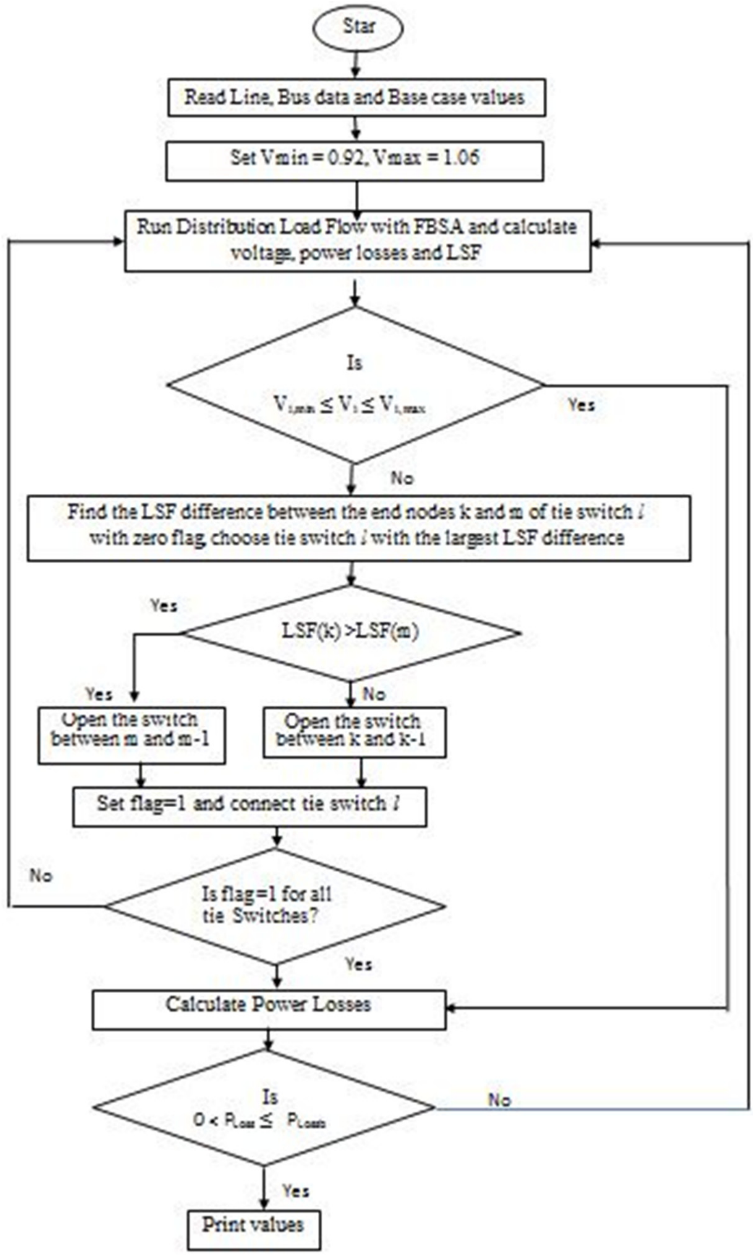

Figure 1: Flow Chart for Network Reconfiguration of RDS

4.2. Assumptions and Constraints

(a) The load model is used with a constant power for simulation and voltage of primary bus is 1.0p.u.

(b) The upper voltage limit is 1.05p.u and lower voltage limit is 0.9p.u

4.3. Power Loss Analysis

The proposed algorithm is applied to 33-bus Radial Distribution System using MATLAB™ programming and for the same system simulated results are validated with other techniques found in literature for achieving the reduction in power loss for effectiveness.

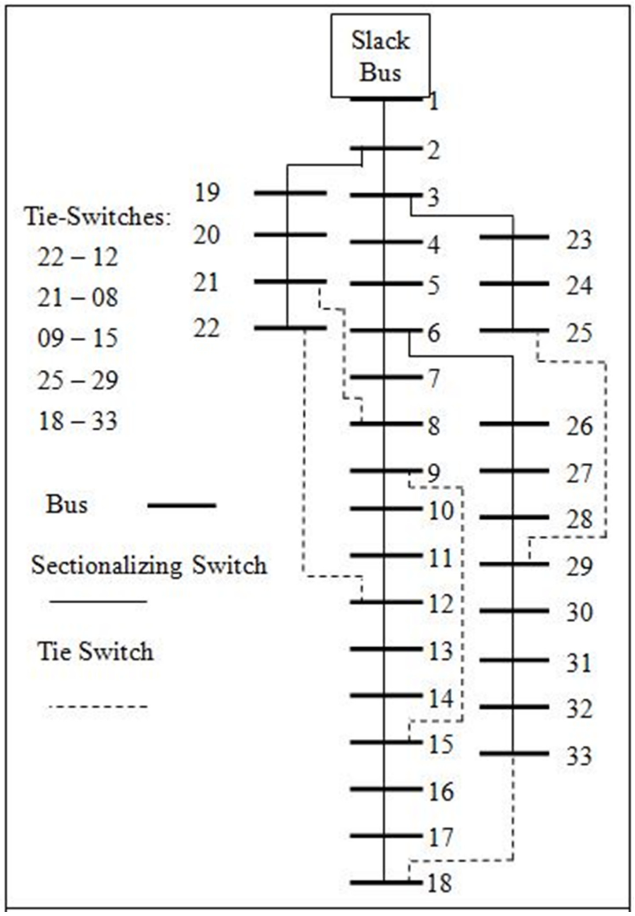

Figure 2: Line diagram of 33-bus Radial Distribution System

The base case configuration of real power load of 3.72MW and reactive power load of 2.3MVAR with real power loss of 202.38 kW.

The LSF differences of all tie switches are calculated. For the Tie switch in between 25-29, LSF difference is maximum with respect to LSF NRA given in Figure 2, this tie switch is to be closed first. As LSF of 25 is more than LSF of 29, the switch in the branch 28-29 is opened and now total active power loss is reduced to 172.02kw.

Next, tie switch between 9-15 is closed by opening the switch between 14-15, with total active power loss is reduced to 166.14kw. Next, tie switch between 18-33 is closed and switch between 32-33 is opened, with total active power loss reduced to 155.62kw. Next, tie-switch between 22-12 is closed and switch between11-12 is opened with total active power loss reduced to 139.58kw.

The procedure is repeated until final optimal configuration is achieved. The final optimal configuration is shown in Figure 3 and the converged values of voltage magnitude, phase angle and LSF are given in Table.3. Thus, final active power loss is 137.53kw.

4.4. Comparison of Voltage Magnitudes and Power Loss

Comparison of voltage magnitudes and Power loss for the base case and Network Reconfigured of 33-bus RDS is shown in Figure 4 and Figure 5.

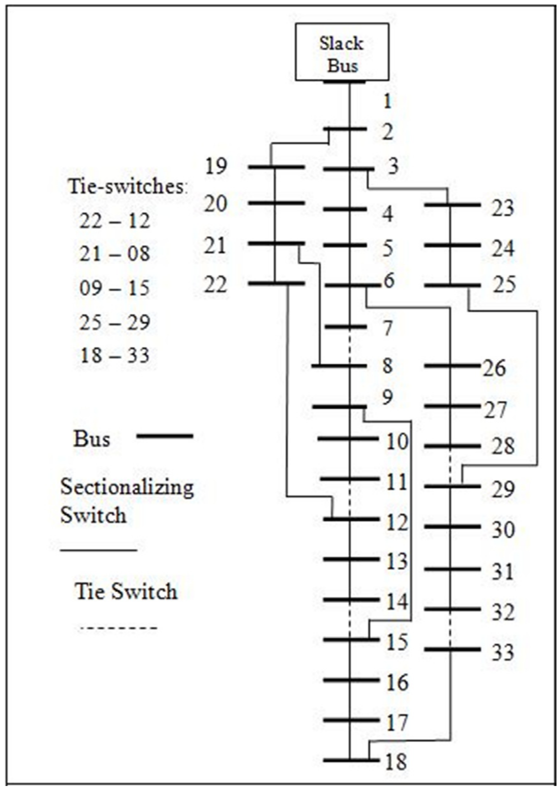

Figure 3: Line diagram of Reconfigured 33-bus Radial Distribution System

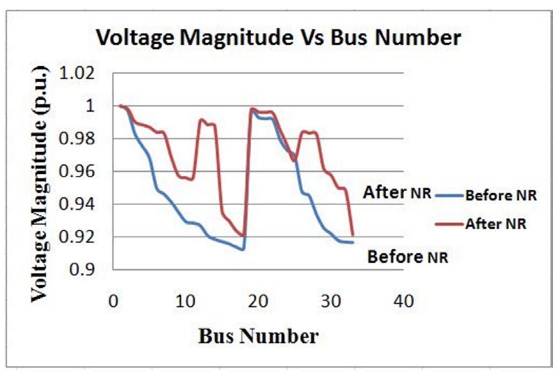

Figure 4: Comparison of Voltage magnitude before and after Network Reconfiguration

Figure 5: Comparison of Power loss before and after Network reconfiguration

4.5. Comparison of Active Power loss

Comparison of active power loss with various methods available in literature is given in Table.1

Table 1
Comparison table of Power loss

Item	*Initial Configuration*	*Final Configuration*				
		GA [16]	*RGA [17]*	*ITS [18]*	*HSA [13]*	*Proposed method [LSF]*
Tie switches	33,35,34,37,36	7,9,14,37,32	7,9,14,37,32	7,9,14,37,36	7,10,14,37,36	28,14,32,11,7
Loss in kW	202.71	141.6	139.5	139.28	138.06	137.53
% loss reduction	-	30.15	31.20	31.29	31.89	32.15

5. CONCLUSIONS

A LSF based Network Reconfiguration algorithm has been proposed and found to have improved voltage profile, reduced system power losses in radial distribution system without any additional cost. Results are also compared with other techniques.

Table 2
Convergence Values Of Voltage Magnitude, Phase Angle and LSF Before Network Reconfiguration for 33-Bus RDS

Bus No.	*Voltage magnitude (p.u)*	*Phase angle (p.u)*	*Loss Sensitivity Factor*
1	1	0	0.0051951
2	0.99703	0.00025	0.00431478
3	0.98295	0.00167	0.01051783
4	0.97548	0.00282	0.01298182
5	0.96808	0.00398	0.0165552
6	0.9497	0.00233	0.00948952
7	0.94621	0.00168	0.00982601
8	0.94137	0.00105	0.00287008
9	0.93511	0.00233	4.3343E-05
10	0.9293	0.00342	0.00104288
11	0.92844	0.00329	0.00011932
12	0.92694	0.00309	0.0009799
13	0.92083	0.00469	0.00319683
14	0.91857	0.00606	0.00136568
15	0.91715	0.00672	0.0011611
16	0.91579	0.00712	0.00184411
17	0.91376	0.00847	0.00085005
18	0.91316	0.00864	0.00012771
19	0.99651	0.00006	0.00211302
20	0.99293	0.00111	0.00045087
21	0.99222	0.00144	0.00233601
22	0.99159	-0.0018	0.0040978
23	0.97936	0.00113	0.00474819
24	0.97269	0.00041	0.00370522
25	0.96937	0.00118	0.00827093

Bus No.	*Voltage magnitude (p.u)*	*Phase angle (p.u)*	*Loss Sensitivity Factor*
26	0.94777	0.00302	0.00311782
27	0.94521	0.004	0.00344163
28	0.93378	0.00545	0.00603113
29	0.92556	0.00681	0.00209428
30	0.92201	0.00864	0.00162933
31	0.91785	0.00717	0.0031726
32	0.91694	0.00677	0.00334036
33	0.91665	0.00664	0.00364528

Table 3
Convergence Values Of Voltage Magnitude, Phase Angle and LSF After Network Reconfiguration for 33-Bus RDS

Bus No	*Voltage magnitude (p.u)*	*Phase angle (p.u)*	*Loss sensitivity Factor*
1	1	0	0.003277878
2	0.99822	-0.00004	0.002676881
3	0.99031	-0.00022	0.002645253
4	0.98852	-0.00025	0.002828291
5	0.98704	-0.00033	0.003822708
6	0.9839	-0.00133	0.002220244
7	0.98327	-0.00201	0.001748261
8	0.9687	-0.00143	0.014794002
9	0.95739	0.00054	0.00766122
10	0.95608	0.00021	0.006055276
11	0.95595	0.00022	0.002373282
12	0.991	-0.00213	0.00830471
13	0.98849	-0.00238	0.009546032
14	0.98772	-0.00265	0.005821218
15	0.93559	0.00247	0.019315573
16	0.9295	0.00439	0.012122829
17	0.92339	0.0011	0.002601737
18	0.9215	0.00072	0.010899802
19	0.99775	-0.00021	0.004858679
20	0.99628	-0.00085	0.011567579
21	0.99607	-0.00098	0.012820466
22	0.99569	-0.00111	0.002717635
23	0.98528	-0.00098	0.001042075
24	0.97558	-0.00318	0.002858355
25	0.96662	-0.00518	0.000716731
26	0.98363	-0.00136	0.001123771
27	0.98337	-0.00139	0.002571052
28	0.98285	-0.00161	0.005778241
29	0.96166	-0.00696	0.001484544
30	0.9578	-0.00703	0.003288641
31	0.94988	-0.00991	0.009496276
32	0.94855	-0.01053	0.008721276
33	0.92117	0.00065	0.011346559

REFERENCES

[1] S. Civanlar, J.J. Grainger, H. Yin and *S. S.* H. Lee, "Distribution Feeder Reconfiguration for Loss Reduction", IEEE Trans. on Power Delivery, Vo1.3, No. 3, pp. 1217-1223, July 1988.

[2] M. E. Baran and F. F. Wu,'Network Reconfiguration in Distribution Systems for Loss Reduction and Load Balancing', IEEE Trans. on Power Delivery, Vo1.4, No. 2, pp. 1401-1407, April 1989.

[3] Merlin, H. Back, "Search for a Minimal-Loss Operating Spanning Tree Configuration for an Urban Power Distribution System", Proc. of the 5th Power System Conference pp. 1-18, Cambridge, 1975.

[4] D. Shirmohammadi and H. W. Hong, "Reconfiguration of Electric Distribution Networks for Resistive Line Losses Reduction", IEEE Trans. on Power Delivery, vo1.4, No. 2, pp. 1492-1498, April 1989.

[5] S. K. Goswami and *S.* K. Basy "A New Algorithm for the Reconfiguration of Distribution Feeders for Loss Minimization", IEEE Trans. on Power Delivery, Vo1.7, No. 3, pp. 1484-1491, July 1992.

[6] R. P. Broadwater, A. H. Khan, H. E. Shaalan and R. E. Lee, "Time Varying Load Analysis to Reduce Distribution Losses through Reconfiguration", IEEE Trans. on Power Delivery, Vo1.8, No. 1, pp. 294-300, January 1993.

[7] C. T. Huddleston, R. P. Broadwater and A. Chandrasekaran, "Reconfiguration Algorithm for Minimizing Losses in Radial Electric Distribution Systems", Electric Power System Research, Vol. 18, No. 1, pp. 57-67, 1990.

[8] G. P. Peponis, M. P. Papadopoulos and N. D. Hatziargyriou, "Distribution Network Reconfiguration to Minimize Resistive Line Losses", lEEE Trans. on Power Delivery, Vol. 10, No. 3, pp. 1338- 1342, July 1995.

[9] M. A. Kashem, V. Ganapathy, G. B. Jasmon, M. I. Buhari "A Novel Method for Loss Minimization in Distribution Networks", International Conference on Electric Utility Deregulation and Restructuring and Power Technologies 2000,City University, London, 4-7 April 2000.

[10] Elgerd I.O. 1971. "Electric energy system theory: an introduction", McGraw-Hill

[11] Kazemi A., Sadeghi M., 2009. "Sitting and sizing of distributed generation for loss reduction", Power and Energy Conference, APPEEC, pp. 1-4, Asia-Pacific, Wuhan.

[12] G. K.ViswanadhaRaju, P.R. Bijwe, "Efficient reconfiguration of balanced and unbalanced distribution systems for loss minimisation", IET Proceedings of Generation, Transmission, Distribution, Vol. 2, (1),2008,PP,7-12.

[13] R. SrinivasaRao, S V L Narasimham, M Ramalingaraju, A. SrinivasaRao, "Optimal Network Reconfiguration of Large Scale Distribution System using Harmony Search Algorithm", IEEE Trans. on Power Systems, Vol. 26, No. 3, Aug. 2011, pp. 1080-1088.

[14] A.Mohamed Imran, M. Kowsalya, "A New Power System Reconfiguration Scheme for Power Loss Minimization and Voltage Profile Enhancement Using Fireworks Algorithm", Electrical Power and Energy Systems, 2014, pp. 312-322

[15] Satish Kansal, B.B.R. Sai, BarjeevTyagi, Vishal Kumar "Optimal placement of distributed generation in distribution networks" International Journal of Engineering, Science and Technology Vol. 3, No. 3, 2011, pp. 47-55

[16] K. Nara, A. Shiose, M. Kitagawoa, and T. Ishihara, "Implementation of genetic algorithm for distribution systems loss minimum reconfiguration," IEEE Trans. Power Syst., Vol. 7, No. 3, pp. 1044–1051, Aug.1992

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

[18] D. Zhang, Z. Fu, and L. Zhang, "An improved TS algorithm for loss minimum reconfiguration in large-scale distribution systems", Elect. Power Syst. Res., Vol. 77, pp. 685–694, 2007.