

Enhancement of Loading of Radial Distribution Networks Using Optimal Conductor Size

Smarajit Ghosh, Uttamjit Singh Chhatwal

Abstract—In this paper, an attempt has been made to enhance the loading of radial distribution by selection of proper conductor. The critical values of total real power load (TPL) and total reactive power load (TQL) for constant power are derived out for the sub-station voltage of 1.0 pu. for 69-node radial distribution network. The proposed method will reduce the real and reactive power losses, improves voltage profile and enhances the loading capability of distribution network. The voltage deviation is reduced to $\pm 10\%$. The superiority of the proposed method has been established by $\pm 6\%$ from $\pm 10\%$ taking results iteratively. Using network reconfiguration, loading is further increased.

Index Terms—Load-flow, Optimal, Conductor, Network, Reconfiguration, Power load

I. INTRODUCTION

A fast algorithm to help the distribution engineer to select proper size of conductors for one's future expansion plan is utmost important because it increases the loading of the system. The optimal conductor type is determined for each feeder segment to maintain an acceptable voltage profile of the entire feeder, minimizing capital investment and the cost of feeder losses. An optimal model for configuring feeder networks to derive an overall expansion was discussed by Tram and Wall [1]. Although their algorithm was based on realistic assumptions and reliable optimization techniques, it was relatively complicated to handle for the engineer. A model to represent feeder cost, energy loss cost and voltage regulation as a function of conductor cross-section and an objective function for optimizing the conductor cross-section had been formulated by Ponnavaikkio and Prakasa Rao [2]. The method proposed in [2] had taken into account the non-uniform distribution of loads along with the length of feeder and load growth in the future years of the plan period. A direct solution procedure for conductor grading was proposed, thereby eliminating the complexity of the dynamic programming approach by Rao [3]. A new computational procedure for obtaining the optimal conductor grading policy using PPR model was proposed, which was extremely simple and require very little computation and needed very little computer storage. Methods [1] and [3] could solve problems accurately for small scale whereas these two methods could not guarantee for optimal solution for large scale problem.

In [4] a new technique of optimizing the feeder routing problem which minimized the total cost of feeder subject to a

set of specified constraints was discussed. Ponnavaikko and Rao [2] developed a mathematical model for the problem, and presented multi stage decision dynamic programming method. However, this method failed in handling the large problem and showed only approximate results. The approach discussed by Wang *et al.* [5] included an economical current density based method and a heuristic method, which together enabled a satisfactory solution that could be easily achieved. Miu and Chiang [6] proposed a solution algorithm to determine distribution loading capability. A solution algorithm suitable for large-scale unbalanced distribution networks with capacitor control actions was developed and tested. However, their model was suitable only for constant current load and for radial main feeder only.

Das [7] presented a simple algorithm for determining the maximum loading of the feeders without violating the maximum current capacity of branch conductor. A predetermined annual load growth was also considered to determine allowable load growth period without violating the minimum voltage limit of the feeder. A dynamic model for the development of primary and secondary circuits supplying a residential area had been proposed by Kirn and Adler [8]. Features of the model which support optimal conductor sizing were the evaluation of annual revenue requirements associated with capital requirement and energy losses as area load evolves. These revenue requirements were responsive to change in area load (positive or negative) arising with change in the number of residences and change in the load per residence year by year. Results of optimization trials explored the relative penalties incurred for optimal conductor policies based on incorrect projections of load growth, degree of load management expected, and costs of losses.

A method was proposed for selecting the optimal size of branch conductor for radial distribution network by Satyanarayana *et al.* [9]. In the proposed method [9], the conductor would not only maintain maximum current carrying capacity but also maintain the voltage level for the distribution network.

Two algorithms for the reconfiguration of feeders was presented by Ghosh and Das [10] with two heuristic rules. In the first heuristic rule closing of an open tie switch was based on the maximum voltage drop across it during iterative process and this drop should be greater than some specified value. In the first heuristic rule closing of an open switch is arbitrary, but the voltage drop across it must be greater than some specified value. The load-flow proposed by S. Ghosh *et al.* [10] is used in the present paper.

The aim of authors is to propose a method to pick up the optimal conductor to enhance the loading of the system. Further, the network reconfiguration [10] is applied to

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enhance the loading. 69–node radial distribution network [12] is selected to demonstrate this method.

VI. ASSUMPTION

The three phase radial distribution networks are assumed to be balanced and can be represented by their single line diagram. Load is assumed to be constant power load.

VII. NETWORK RECONFIGURATION

Radial distribution networks have some advantages over mesh distribution networks such as lower short circuit current and simpler switching and protecting equipment. On the other hand, the radial structure provides lower overall reliability. Therefore, to use the benefits of the radial structure and at the same time to overcome the difficulties, distribution systems are planned and built as weakly meshed networks, but operated as radial networks.

Distribution systems consist of group of interconnected radial circuits. Their configuration may varied with manual or automatic switching operations to transfer loads among the feeders. There are two kind of switching in the primary distribution systems, namely, normally closed switches that connect line sections and normally open switches on the tie lines that connect two primary feeders, two substations, or loop type laterals. The former is called sectionalizing switches and the latter is called tie–lines switch. Both of them are designed for fault isolation and network reconfiguration. The purpose of network reconfiguration is to produce the minimum loss possible under the circuit’s capacity constraint.

VIII. SOLUTION METHODOLOGY

69–node radial distribution network [12] is taken as example. Initially the network has 5 tie–lines switches and connecting the nodes (11, 43), (13, 21), (15, 46), (27, 65), (50, 59). At first load–flow is run to compute the branch currents and node voltages. The results of load–flow will give branch current using these branch currents conductor as per their maximum current carrying capability is being selected for their respective branch. In the present paper work, conductor is loaded 85% of its maximum value. The reason for not taking 100% loading of conductor is that during fault condition if conductor is 100% loaded then it will be burnt out.

Load–flow also gives voltages at every node, the percentage deviation of voltage w.r.t to p.u. voltage is calculated and it is derived that one has to operate on those nodes having minimum percentage voltage deviation. Then according to percentage voltage deviation the nodes are arranged in ascending order. The nodes having percentage deviation less than 1 are selected. According to voltage deviation the load is distributed on the branches.

Fig. 1 shows a sample radial distribution network. Table I shows the branch number, sending–end node, receiving–end node of Fig. 1.

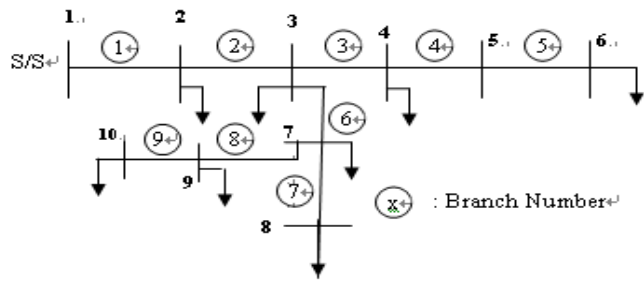


Fig. 1 Single-line diagram of a radial distribution network

TABLE I BRANCH NUMBER (JJ), SENDING END NODE (M1 = IS(JJ)), RECEIVING END NODE (M2 = IR(JJ)) AND NODES BEYOND BRANCHES 1, 2, 3, ..., 10 OF FIG. 1

Branch Number (jj)	Sending-end nodes	Receiving-end nodes
1	1	2
2	2	3
3	3	4
4	4	5
5	5	6
6	3	7
7	7	8
8	7	9
9	9	10

Table II shows the nodes beyond each branch of Fig. 1.

TABLE II NODES BEYOND BRANCHES 1, 2, 3, ..., 10 OF FIG. 1

Branch Number (jj)	Nodes beyond each branch (jj)
1	2, 3, 4, 5, 6, 7, 8, 9, 10
2	3, 4, 5, 6, 7, 8, 9, 10
3	4, 5, 6
4	5, 6
5	6
6	7, 8, 9, 10
7	8
8	9, 10
9	10

The voltage at any receiving–end node (m2) of branch–jj is expressed by

$$V(m2) = V(m1) - I(jj)Z(jj) \tag{1}$$

$$\text{i.e., } V(m2) = V(m1) - I(jj) [R(jj) + j X(jj)] \tag{2}$$

$$\text{where, } m1 = IS(jj) \tag{3}$$

$$\text{and } m2 = IR(jj) \tag{4}$$

The load current of any receiving–end node m2 = IR(jj) of branch–jj is expressed by

$$IL(m2) = \frac{PL(m2) - jQL(m2)}{V^*(m2)} \quad (5)$$

The real and reactive power losses of branch-jj are expressed by

$$LP = |I(jj)|^2 R(jj) \quad (6)$$

$$\text{and } LQ = |I(jj)|^2 X(jj) \quad (7)$$

respectively.

The current through branch-jj is the sum of all load currents of all nodes beyond branch-jj i.e.,

$$I(jj) = \sum_{i=1}^{N(jj)} IL\{IE(jj, i)\} \quad (8)$$

where N(jj) is the total number of nodes beyond branch jj and IE(jj, i) is the receiving-end node beyond branch-jj. The algorithm for identification of nodes beyond each branch-jj is available in [11]. Table II shows the nodes beyond each branch of Fig. 1. Let CImax(jj) be the maximum current capacity of the conductor of branch-jj. After running the load-flow, current through the each branch and voltage of each node can be obtained. The difference $DI(jj) = 0.85 \times CImax(jj) - I(jj)$ can be computed. The percentage change in voltage of each node is arranged in ascending order. The node having the voltage less than 1.0000 pu are taken into account only. The load of this node is increased slowly until the DI(jj) remains positive. The network is reconfigured and the similar technique is applied. The complete algorithm is shown below.

- Step - 1 : Start
- Step - 2 : Read sending-end and receiving-end nodes and total number of nodes and branches
- Step - 3 : Set $V(i) = 1.0 + j 0.0$ for all $i = 1, 2, 3, \dots, NB$
- Step - 4 : Set $ISS(jj) = IS(jj)$ and $IRR(jj) = IR(jj)$ for $jj = 1, 2, 3, \dots, LN1$
- Step - 5 : Set iteration count $k = 1$.
- Step - 6 : Set $kMAX = 100$ (say)
- Step - 7 : Set $DVMAX = 0.0$ and $\epsilon = 0.00001$
- Step - 8 : Identify the nodes beyond each branch using IDENT software [11].
- Step - 9 : Compute load currents $IL(m2)$ for $m2 = 1, 2, 3, \dots, NB$ using Eq.[5]
- Step - 10 : Compute current through each branch i.e., $I(jj)$ for $jj = 1, 2, 3, \dots, LN1$ using Eq.[8]
- Step - 11 : Set $jj = 1$
- Step - 12 : Compute $\Delta I(jj) = 0.85 \times CImax(jj) - I(jj)$
- Step - 13 : Set $m1 = ISS(jj)$ and $m2 = IRR(jj)$. Compute

receiving-end voltage $V(m2)$ for all $m2$ using Eq. [2].

- Step - 14 : Compute the voltage deviation $VD(m2) = 1 - V(m2)$
- Step - 15 : $jj = jj + 1$
- Step - 16 : If $jj < LN1$, go to Step-13, otherwise go to next Step-17.
- Step - 17 : Find the percentage voltage deviation $VD(m2)$
- Step - 18 : Arrange percentage voltage deviation $VD(m2)$ in ascending order.
- Step - 19 : If all $VD(m2) > 1.000$, go to Step-25
- Step - 20 : Set $m2=0$
- Step - 21 : Calculated total number of nodes having $VD(m2) < 1.000$.
- Step - 22 : $m3=m2+1$
- Step - 23 : Increase pl & ql till $\Delta I(jj)$ is positive.
- Step - 24 : Print "Results"
- Step - 25 : Stop

IX. EXAMPLE

A 69-node radial distribution network is shown in Fig. 2. Base values are 12.66 kV and 100 MVA. Load data and line data for 69-node radial distribution network are available in [12]. Initially the real and reactive power losses of radial network are 224.933kW and 102.129kVAr respectively. Node 65 has the lowest voltage level i.e 0.9091 pu. The total real and reactive power load on the system are 3801.89 kW and 2692.60 kVAr respectively. Table III shows the branch current, maximum current rating and allowable current rating and their difference for 69-node radial distribution network. Fig. 3 shows the 69-node radial distribution network after network reconfiguration using the method of [12]. Table IV shows branch current of 69-node radial distribution network [12] after network reconfiguration. Table V Branch Current of 69-node Radial Distribution Network after network reconfiguration. Table VI percentage voltage deviation w.r.t to p.u. voltage of 69-node radial distribution network after network reconfiguration in ascending order. Table VII percentage voltage deviation w.r.t pu voltage of 69-node radial distribution network [12] in ascending order for percentage deviation less than 1.000 after network reconfiguration. Table VIII shows increase in real power (PL) and reactive power (QL) load of 69 node radial distribution network [10] after network reconfiguration. Table IX shows comparison of real and reactive power losses. Table X shows comparison of minimum pu voltage level and respective node number. Table XI shows comparison of total real and reactive power load.

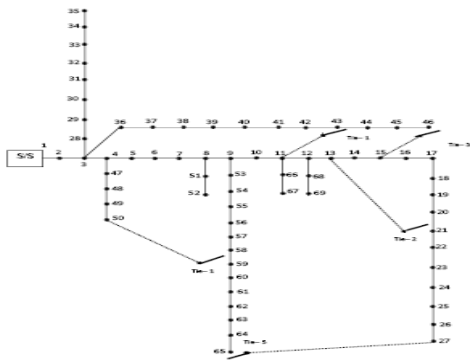


Fig. 2 69 node radial distribution network [12]

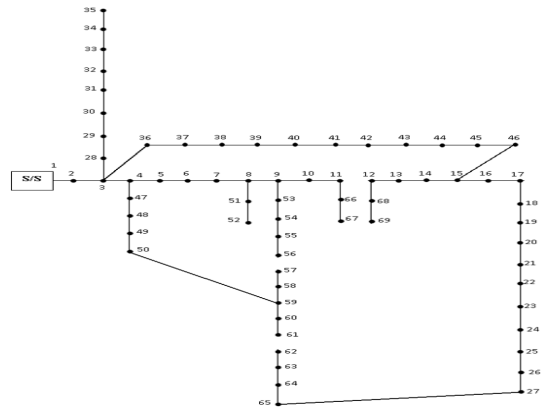


Fig. 3 Reconfigured 69 Node Radial Distribution Network [10]

TABLE III BRANCH CURRENT, MAXIMUM CURRENT RATING AND ALLOWABLE CURRENT RATING AND THEIR DIFFERENCE FOR 69-NODE RADIAL DISTRIBUTION NETWORK [12]

Branch Number	Branch Current	Conductor Name	Maximum Current Rating	Allowable Current Rating	Difference
1	223.53	CAT	290	246.5	22.96
2	223.53	CAT	290	246.5	22.97
3	208.09	CAT	290	246.5	38.41
4	160.35	FERRET	175	148.75	9.65
5	160.35	FERRET	175	148.75	9.65
6	160.19	FERRET	175	148.75	9.81
7	157.85	FERRET	175	148.75	12.15
8	151.03	FERRET	175	148.75	18.97
9	44.06	MOLE	70	59.5	15.44
10	42.47	MOLE	70	59.5	17.03
11	32.01	MOLE	70	59.5	27.49
12	20.37	MOLE	70	59.5	39.13
13	19.93	MOLE	70	59.5	39.57
14	19.48	MOLE	70	59.5	40.02
15	19.48	MOLE	70	59.5	40.02
16	16.89	MOLE	70	59.5	42.61
17	13.59	MOLE	70	59.5	45.91
18	10.29	MOLE	70	59.5	49.21
19	10.29	MOLE	70	59.5	49.21
20	10.24	MOLE	70	59.5	49.26
21	3.57	SQUIRREL	120	102	55.93
22	3.28	SQUIRREL	120	102	56.22
23	3.28	SQUIRREL	120	102	56.22
24	1.64	SQUIRREL	120	102	57.86
25	1.64	SQUIRREL	120	102	57.86
26	0.82	SQUIRREL	120	102	8.68
27	5.13	SQUIRREL	120	102	4.37
28	3.67	SQUIRREL	120	102	55.83
29	2.21	SQUIRREL	120	102	57.29
30	2.21	SQUIRREL	120	102	57.29
31	2.21	SQUIRREL	120	102	57.29
32	2.21	SQUIRREL	120	102	57.29
33	1.42	MOLE	70	59.5	58.08
34	0.33	MOLE	70	59.5	59.17
35	10.32	MOLE	70	59.5	49.18
36	8.86	MOLE	70	59.5	50.64
37	7.41	MOLE	70	59.5	52.09
38	7.41	MOLE	70	59.5	52.09
39	6.06	MOLE	70	59.5	53.44
40	4.72	MOLE	70	59.5	54.78
41	4.65	MOLE	70	59.5	54.85
42	4.65	MOLE	70	59.5	54.85
43	4.31	MOLE	70	59.5	55.19
44	4.31	MOLE	70	59.5	55.19
45	2.16	MOLE	70	59.5	57.34
46	47.75	MOLE	70	59.5	11.75
47	47.75	MOLE	70	59.5	11.75
48	43.32	MOLE	70	59.5	16.18
49	21.67	MOLE	70	59.5	37.83
50	2.51	MOLE	70	59.5	56.99
51	0.21	MOLE	70	59.5	59.29

52	105.24	MOLE	70	59.5	5.26
53	104.98	MOLE	70	59.5	5.52
54	103.45	SQUIRREL	120	102	7.05
55	102.06	SQUIRREL	120	102	8.44
56	102.06	SQUIRREL	120	102	8.44
57	102.06	SQUIRREL	120	102	8.44
58	102.06	SQUIRREL	120	102	8.44
59	95.98	GOPHER	130	110.5	14.52
60	95.98	GOPHER	130	110.5	14.52
61	19.58	MOLE	70	59.5	39.92
62	17.61	SQUIRREL	70	59.5	41.89
63	17.61	MOLE	70	59.5	41.89
64	3.63	MOLE	70	59.5	55.87
65	2.09	MOLE	70	59.5	57.41
66	1.04	MOLE	70	59.5	58.46
67	3.24	MOLE	70	59.5	56.26
68	1.62	MOLE	70	59.5	57.88

TABLE IV BRANCH CURRENT, MAXIMUM CURRENT RATING AND ALLOWABLE CURRENT RATING AND THEIR DIFFERENCE FOR 69-NODE RADIAL DISTRIBUTION NETWORK AFTER NETWORK RECONFIGURATION

Branch Number	Branch Current	Conductor Name	Maximum Current Rating	Allowable Current Rating	Difference
1	219.0057	CAT	290	246.5	27.4943
2	219.0057	CAT	290	246.5	27.4943
3	153.1999	CAT	290	246.5	93.3001
4	25.7184	MOLE	70	59.5	33.7816
5	25.7184	MOLE	70	59.5	33.7816
6	25.5633	MOLE	70	59.5	33.9367
7	23.2614	MOLE	70	59.5	36.2386
8	16.5651	MOLE	70	59.5	42.9349
9	11.7665	MOLE	70	59.5	47.7335
10	10.2162	MOLE	70	59.5	49.2838
11	2.0359	MOLE	70	59.5	57.4641
12	1.0179	MOLE	70	59.5	58.4821
13	5.1261	MOLE	70	59.5	54.3739
14	3.6681	MOLE	70	59.5	55.8319
15	2.2100	MOLE	70	59.5	57.2900
16	2.2100	MOLE	70	59.5	57.2900
17	2.2100	MOLE	70	59.5	57.2900
18	2.2100	MOLE	70	59.5	57.2900
19	1.4249	MOLE	70	59.5	58.0751
20	0.3292	MOLE	70	59.5	59.1708
21	60.6870	SQUIRREL	120	102	41.3130
22	59.2304	MOLE	70	59.5	0.2696
23	57.7721	MOLE	70	59.5	1.7279
24	57.7721	MOLE	70	59.5	1.7279
25	56.4270	MOLE	70	59.5	3.0730
26	55.0819	MOLE	70	59.5	4.4181
27	55.0102	MOLE	70	59.5	4.4898
28	55.0102	MOLE	70	59.5	4.4898
29	54.6685	MOLE	70	59.5	4.8315
30	54.6685	MOLE	70	59.5	4.8315
31	52.4793	MOLE	70	59.5	7.0207
32	50.2901	MOLE	70	59.5	9.2099
33	37.7662	MOLE	70	59.5	21.7338
34	35.2174	MOLE	70	59.5	24.2826
35	31.9716	MOLE	70	59.5	27.5284
36	28.7278	MOLE	70	59.5	30.7722
37	28.7278	MOLE	70	59.5	30.7722
38	28.6732	MOLE	70	59.5	30.8268
39	22.0961	MOLE	70	59.5	37.4039
40	21.8090	MOLE	70	59.5	37.6910
41	21.8090	MOLE	70	59.5	37.6910
42	20.1881	MOLE	70	59.5	39.3119
43	20.1881	MOLE	70	59.5	39.3119
44	19.3752	MOLE	70	59.5	40.1248
45	18.5619	MOLE	70	59.5	40.9381
46	15.1283	MOLE	70	59.5	44.3717
47	1.8735	MOLE	70	59.5	57.6265
48	1.8735	MOLE	70	59.5	57.6265
49	12.5258	MOLE	70	59.5	46.9742
50	12.0714	MOLE	70	59.5	47.4286
51	11.6162	MOLE	70	59.5	47.8838

52	3.2339	MOLE	70	59.5	56.2661
53	1.6169	MOLE	70	59.5	57.8831
54	127.4816	FERRET	175	148.75	21.2684
55	127.4816	FERRET	175	148.75	21.2684
56	123.0390	FERRET	175	148.75	25.7110
57	101.1829	GOPHER	130	110.5	9.3171
58	79.2705	SQUIRREL	120	102	22.7295
59	110.5000	GOPHER	130	110.5	0.9590
60	110.5000	GOPHER	130	110.5	0.9590
61	73.4108	SQUIRREL	120	102	28.5892
62	73.4108	SQUIRREL	120	102	28.5892
63	2.4670	MOLE	70	59.5	57.0330
64	0.2059	MOLE	70	59.5	59.2941
65	3.0960	MOLE	70	59.5	56.4040
66	2.8407	MOLE	70	59.5	56.6593
67	1.3518	MOLE	70	59.5	58.1482
68	59.5000	MOLE	70	59.5	0.9961

TABLE V BRANCH CURRENT OF 69-NODE RADIAL DISTRIBUTION NETWORK AFTER NETWORK RECONFIGURATION.

Branch Number	Branch Current	Conductor Name	Maximum Current Rating	Allowable Current Rating	Difference
1	219.006	CAT	290	246.5	27.494
2	219.006	CAT	290	246.5	27.494
3	153.200	CAT	290	246.5	93.300
4	25.718	MOLE	70	59.5	33.782
5	25.718	MOLE	70	59.5	33.782
6	25.563	MOLE	70	59.5	33.937
7	23.261	MOLE	70	59.5	36.239
8	16.565	MOLE	70	59.5	42.935
9	11.767	MOLE	70	59.5	47.733
10	10.216	MOLE	70	59.5	49.284
11	2.036	MOLE	70	59.5	57.464
12	1.018	MOLE	70	59.5	58.482
13	5.126	MOLE	70	59.5	54.374
14	3.668	MOLE	70	59.5	55.832
15	2.210	MOLE	70	59.5	57.290
16	2.210	MOLE	70	59.5	57.290
17	2.210	MOLE	70	59.5	57.290
18	2.210	MOLE	70	59.5	57.290
19	1.425	MOLE	70	59.5	58.075
20	0.329	MOLE	70	59.5	59.171
21	60.687	SQUIRREL	120	102	41.313
22	59.230	MOLE	70	59.5	0.270
23	57.772	MOLE	70	59.5	1.728
24	57.772	MOLE	70	59.5	1.728
25	56.427	MOLE	70	59.5	3.073
26	55.082	MOLE	70	59.5	4.418
27	55.010	MOLE	70	59.5	4.490
28	55.010	MOLE	70	59.5	4.490
29	54.668	MOLE	70	59.5	4.832
30	54.668	MOLE	70	59.5	4.832
31	52.479	MOLE	70	59.5	7.021
32	50.290	MOLE	70	59.5	9.210
33	37.766	MOLE	70	59.5	21.734
34	35.217	MOLE	70	59.5	24.283
35	31.972	MOLE	70	59.5	27.528
36	28.728	MOLE	70	59.5	30.772
37	28.728	MOLE	70	59.5	30.772
38	28.673	MOLE	70	59.5	30.827
39	22.096	MOLE	70	59.5	37.404
40	21.809	MOLE	70	59.5	37.691
41	21.809	MOLE	70	59.5	37.691
42	20.188	MOLE	70	59.5	39.312
43	20.188	MOLE	70	59.5	39.312
44	19.375	MOLE	70	59.5	40.125
45	18.562	MOLE	70	59.5	40.938
46	15.128	MOLE	70	59.5	44.372
47	1.874	MOLE	70	59.5	57.626
48	1.874	MOLE	70	59.5	57.626
49	12.526	MOLE	70	59.5	46.974
50	12.071	MOLE	70	59.5	47.429
51	11.616	MOLE	70	59.5	47.884

52	3.234	MOLE	70	59.5	107.266
53	1.617	MOLE	70	59.5	108.883
54	127.482	FERRET	175	148.75	21.268
55	127.482	FERRET	175	148.75	21.268
56	123.039	FERRET	175	148.75	25.711
57	101.183	GOPHER	130	110.5	9.317
58	79.270	GOPHER	130	110.5	31.230
59	0.000	GOPHER	130	110.5	110.500
60	0.000	GOPHER	130	110.5	110.500
61	73.411	SQUIRREL	120	102	28.589
62	73.411	SQUIRREL	120	102	28.589
63	2.467	MOLE	70	59.5	57.033
64	0.206	MOLE	70	59.5	59.294
65	3.096	MOLE	70	59.5	56.404
66	2.841	MOLE	70	59.5	56.659
67	1.352	MOLE	70	59.5	58.148
68	0.000	MOLE	70	59.5	59.500

TABLE VI % VOLTAGE DEVIATION W.R.T TO PU VOLTAGE OF 69-NODE RADIAL DISTRIBUTION NETWORK AFTER NETWORK RECONFIGURATION IN ASCENDING ORDER

Node Number	% Voltage Deviation	Node Number	% Voltage Deviation	Node Number	% Voltage Deviation
2	0.003696	55	0.879171	12	4.426449
3	0.007392	56	0.886056	68	4.458965
28	0.009448	49	0.956970	69	4.459141
4	0.013848	10	1.118716	20	4.536425
29	0.019095	50	1.163702	21	4.744587
36	0.022452	11	1.176740	22	4.752645
30	0.038472	66	1.200969	23	4.838912
5	0.044765	67	1.200999	57	4.923616
47	0.123415	41	1.709013	24	5.026785
31	0.135982	42	2.257031	25	5.435194
32	0.183106	43	2.327745	26	5.602879
33	0.188574	44	2.343712	27	5.697106
34	0.233401	45	2.533104	65	6.258768
35	0.258396	46	2.534721	64	6.811211
37	0.375555	59	3.728695	63	7.191548
6	0.380648	60	3.739175	62	7.250012
38	0.411558	61	3.739175		
39	0.428671	60	3.739175		
40	0.431815	61	3.739175		
7	0.542986	15	3.798987		
8	0.731318	16	3.938504		
51	0.811226	58	4.059528		
52	0.834372	17	4.194888		
48	0.836456	18	4.198091		
9	0.849895	14	4.264913		
53	0.852150	13	4.375873		
54	0.865271	19	4.408591		

TABLE VII % VOLTAGE DEVIATION W.R.T PU VOLTAGE OF 69 NODE RADIAL DISTRIBUTION NETWORK [12] IN ASCENDING ORDER FOR % DEVIATION LESS THAN 1.000 AFTER NETWORK RECONFIGURATION

Node Number	% Voltage Deviation	Node Number	% Voltage Deviation
2	0.003308	38	0.254089
3	0.006617	39	0.290011
28	0.007308	40	0.292091
4	0.013586	7	0.318519
29	0.014480	8	0.351306
36	0.014736	51	0.354811
30	0.026597	52	0.355754
5	0.026799	48	0.361241
47	0.026984	9	0.363792
31	0.028738	53	0.372024
32	0.039432	54	0.380840
33	0.065077	55	0.386709
34	0.098683	56	0.386709
35	0.105438	10	0.497600
37	0.129826	11	0.524161
6	0.169935	66	0.529762

TABLE VIII INCREASE IN REAL POWER (PL) AND REACTIVE POWER (QL) OF 69 NODE DISTRIBUTION NETWORK AFTER NETWORK RECONFIGURATION.

Node Number	Real Load(P) Increase (kW)	Reactive Load(Q) Increase(kVAR)
2	0.0000	0.0000
3	0.0000	0.0000
28	42.120	30.132
4	0.0000	0.0000
29	42.120	30.132
36	42.120	30.051
30	0.0000	0.0000
5	0.0000	0.0000
47	0.0000	0.0000
31	0.0000	0.0000
32	0.0000	0.0000
33	22.680	16.200
34	31.590	22.680
35	9.7200	6.4800
37	42.120	30.051
6	4.2120	3.5640
38	0.0000	0.0000
39	38.880	27.540
40	38.880	27.540
7	65.448	48.600
8	121.50	87.480
51	65.610	45.846
52	5.8320	4.3740
48	127.98	91.368
9	48.600	35.640
53	7.0470	5.6700
54	42.768	30.780
56	0.0000	0.0000
10	0.0000	0.0000
11	45.360	30.780
66	234.90	168.48

TABLE IX COMPARISON OF REAL AND REACTIVE POWER LOSSES

	Number of Iterations	Real Power Loss (kW)	Reactive Power Loss(kVAR)
Before Network Reconfiguration	5	224.933	102.129
After Network Reconfiguration	4	104.939	99.059

TABLE X COMPARISON OF MINIMUM PU VOLTAGE LEVEL AND RESPECTIVE NODE NUMBER

	Number of Iterations	Branch Number	Voltage Level (pu)
Before Network Reconfiguration	5	65	0.909191
After Network Reconfiguration	4	61	0.949483
	4	62	0.932401

TABLE XI COMPARISON OF TOTAL REAL AND REACTIVE POWER LOAD

	Number of Iterations	Real Power Load (TPL)	Reactive Power Load(TQL)
Before Network Reconfiguration	5	3801.890090	2692.599781
After Network Reconfiguration	4	3801.890090	2693.599649
	4	4226.186872	2997.647785

X. CONCLUSION

A formula for maximum loading of conductor for radial distribution network is proposed in the paper to compute the change in loading of the radial network. In this proposed method, the most sensitive node and the node having the minimum voltage deviation are found and operated in this paper, nodes having voltage deviation less than 1% are operated. The critical loadings of the 69-node radial distribution network [12] have been found out for constant power load modelling for substation voltage of 1.0 p.u. and the results are obtained by the proposed method. The comparison of various switching options will show that the critical loading by the proposed method is superior. The overall loss i.e., real and reactive power losses are reduced, voltage profile of the network is improved and total loading of network is increased.

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