A SIMPLE METHOD FOR LOAD FLOW SOLUTION OF RADIAL DISTRIBUTION SYSTEMS

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Abstract

In this paper a new and efficient method for the reliable load flow solution of radial distribution system is presented wherein an easy and fast load flow solution algorithm is used. It fully exploits the radial structure of the network and employs an effective data structure to identify the nodes beyond a particular branch. Using this concept, load current summations are calculated to obtain the load flow solution. Unlike other traditional methods, the proposed method considers the effective convergence approach which is simple and is capable of reducing execution time of the network.

Index Terms: Constant power load modeling, Load currents, Nodes beyond branch, Radial distribution systems.

I. INTRODUCTION

There are many solution techniques for load flow calculations. However, an acceptable load flow method should meet the requirements [1] such as high speed and low storage requirements, highly reliable, and accepted versatility and simplicity.

The operation and planning studies of a distribution system require a steady-state condition of the system for various load demands. Distribution networks have recently acquired a growing importance because their extension has quite increased and also because their management has become quite complex. Unfortunately the techniques widely known and used at High Voltage level cannot be straightforward applied to distribution systems. This is because the distribution systems are ill-conditioned systems i.e. the systems which show large oscillations in the results by small perturbations. Since Low Voltage lines have a high R/X ratio. This high R/X ratio [2-4] factor of the distribution systems makes them ill conditioned and so the need of new and efficient method for the analysis of distribution system arises. The analysis of distribution systems is an important area of activity as distribution systems is the final link between a bulk power system and consumers.

Kersting and Mendive [5] and Kersting [6] have developed a load-flow technique for solving radial distribution networks using ladder-network theory. They have developed the ladder technique from basic ladder-network theory into a working algorithm, applicable to the solution of radial load-flow problems. Stevens et al. [7] have shown that the ladder technique is found to be fastest but did not converge in five out of 12 cases studied. Shirmohammadi er al. [8] have proposed a method for solving radial distribution networks based on the direct application of Kirchhoff's voltage and current laws. They have developed a branch-numbering scheme to enhance the numerical performance of the solution method. They have also extended their method for solution of weakly meshed networks. Baran and Wu [9] have obtained the load-flow solution in a distribution system by the iterative solution of

three fundamental equations representing real power, reactive power and voltage magnitude. They have computed the system Jacobian matrix using a chain rule. In their method, the mismatches and the Jacobian matrix involve only the evaluation of simple algebraic expressions and no trigonometric functions. They have also proposed decoupled and fast decoupled distribution load-flow algorithms. Chiang [10] has also proposed three different algorithms for solving radial distribution networks based on the method proposed by Baran and Wu [9]. Renato [11] has proposed one method for obtaining a load-flow solution of
radial distribution networks. Jasmon and Lee [15, 16] have proposed a new load-flow method for obtaining the solution of radial distribution networks. They have used the three fundamental equations representing real power, reactive power and voltage magnitude derived in [9]. Das et al. [14] have proposed a load-flow technique for solving radial distribution networks by calculating the total real and reactive power fed through any node. They have proposed a unique node, branch and lateral numbering scheme which helps to evaluate exact real- and reactive power loads fed through any node and receiving-end voltages.

The aim of the paper is to propose a simple and fast load flow method for radial distribution systems. Here, a method is presented for identifying the total nodes beyond a particular node, which will improve the speed of the proposed method. Load flow solution is based on simple iterative method of receiving end voltage of radial distribution system. The convergence of the method is accelerated by a judicious choice of the initial voltages and
power losses are taken into consideration from the first iteration. The proposed method is tested on standard distribution systems. It is also observed that the proposed method has good and fast convergence characteristics. Loads in the present formulation have been presented as constant power.

II. ASSUMPTIONS

While implementing all the discussed methods it was assumed that:

1. Three-phase radial distribution networks were balanced and represented by their single-line diagrams.
2. Charging capacitances are neglected at the distribution voltage level (medium level).
3. The load flow solution has been computed for constant power load modeling.

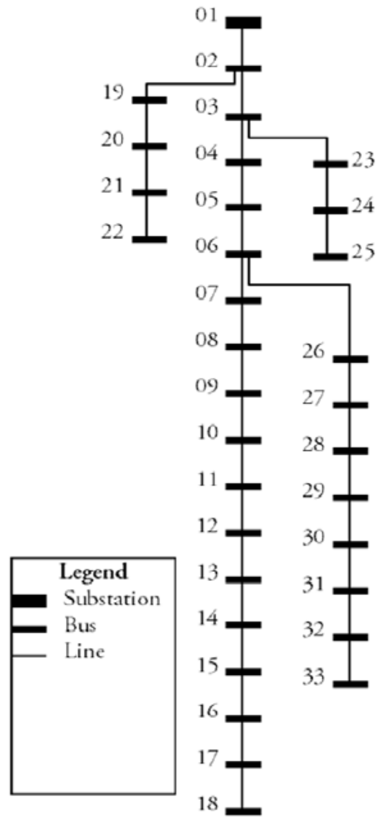

Fig.3. 33-bus radial distribution system

III. SOLUTION METHODOLOGY

A 33-bus radial distribution system Fig.3. was tested using the proposed method [12-13]. The branch number sending-end and receiving-end node of this feeder are given in Table 1. Table 1 also shows the results of nodes beyond a particular node. Consider branch 1. The receiving-end node voltage can be written as

$$V(2) = V(1) - I(1)\, Z(1)$$

Similarly for branch 2,

$$V(3) = V(2) - I(2)\, Z(2)$$

As the substation voltage V(1) is known, so if Z(1) is known, i.e. current of branch 1, it is easy to calculate V(2) from above eqn.

Once V(2) is known, it is easy to calculate V(3), if the current through branch 2 is known. Similarly, voltages of nodes 4, 5, ..., NB can easily be calculated if all the branch currents are known. Therefore, a generalised equation of receiving-end voltage, sending-end voltage, branch current and branch impedance is

$$V(m2) = V(m1) - I(jj)\, Z(jj) \quad \text{....(i)}$$

where j j is the branch number.

m2 = I R (j j)

m1 = I S (j j)

Eqn. (i) can be evaluated for jj = 1, 2, ..., LN1 (LN1 = NB - 1 = number of branches). Current through branch 1 is equal to the sum of the load currents of all the nodes beyond branch 1. Therefore, if it is possible to identify the nodes beyond all the branches, it is possible to compute all the branch currents. Identification of the nodes beyond all the branches is realised through an algorithm as explained in Section IV.

The load current of node *i* is

$$IL(i) = \frac{PL(i) - jQL(i)}{V^*(i)} \qquad i = 2, 3, \ldots, NB$$

....(ii)

Load currents are calculated iteratively. Initially, a flat voltage of all the nodes is assumed and load currents of all the nodes are computed. A detailed load flow calculation algorithm is described in Section V.

Table 1: Calculation of Nodes beyond branch jj

jj	m1 = IS(jj)	m2 = IR(jj)	Nodes beyond branch jj	N(jj)
1	1	2	2,3,19,4,23,20,5,24,21,6,25,22,7,26,8,27,9,28,10,29,11,30,12,31,13,32,14,33,15,16,17,18	32
2	2	3	3,4,23,5,24,6,25,7,26,8,27,9,28,10,29,11,30,12,31,13,32,14,33,15,16,17,18	27
3	3	4	4,5,6,7,26,8,27,9,28,10,29,11,30,12,31,13,32,14,33,15,16,17,18	23
4	4	5	5,6,7,26,8,27,9,28,10,29,11,30,12,31,13,32,14,33,15,16,17,18	22
5	5	6	6,7,26,8,27,9,28,10,29,11,30,12,31,13,32,14,33,15,16,17,18	21
6	6	7	7,8,9,10,11,12,13,14,15,16,17,18	12
7	7	8	8,9,10,11,12,13,14,15,16,17,18	11
8	8	9	9,10,11,12,13,14,15,16,17,18	10
9	9	10	10,11,12,13,14,15,16,17,18	9
10	10	11	11,12,13,14,15,16,17,18	8
11	11	12	12,13,14,15,16,17,18	7
12	12	13	13,14,15,16,17,18	6
13	13	14	14,15,16,17,18	5
14	14	15	15,16,17,18	4
15	15	16	16,17,18	3
16	16	17	17,18	2
17	17	18	18	1
18	2	19	19,20,21,22	4
19	19	20	20,21,22	3
20	20	21	21,22	2
21	21	22	22	1
22	3	23	23,24,25	3
23	23	24	24,25	2
24	24	25	25	1
25	6	26	26,27,28,29,30,31,32,33	8
26	26	27	27,28,29,30,31,32,33	7
27	27	28	28,29,30,31,32,33	6
28	28	29	29,30,31,32,33	5
29	29	30	30,31,32,33	4
30	30	31	31,32,33	3
31	31	32	32,33	2
32	32	33	33	1

IV. IDENTIFICATION OF NODES BEYOND ALL THE BRANCHES

For jj = 1 (first branch of Fig. 1 , Table 1, IR(jj) = IR(1) = 2; check whether IR(1) = IS(i) or not for i = 2, 3, 4, ..., LN1. It is seen that IR(1) = IS(2) = 2, IR(1) = IS(18) = 2; the corresponding receiving-end nodes are IR(2) = 3 and IR(6) = 19.

Therefore, IE(1, 1) = 2, IE(1, 2) = 3 and IE(1, 3) = 19. Note that there should not be any repetition of any node while identifying nodes beyond a particular branch [17], and this logic has been incorporated in the proposed algorithm.

From the above discussion, it is seen that node 2 is connected to nodes 3 and 19. Similarly, the proposed logic will identify the nodes which are connected to nodes 3 and 19. Firstly, it will check whether node 3 appears in the left-hand column of Table 1 . It is seen that node 3 is connected to node 4. Therefore, IE(1, 4) = 4. Then it will check whether node 19 appears in the left-hand column of Table 1 . It is seen that the node 19 is connected to node 20. Therefore, IE(1, 5) = 20.

From the above discussion, it is again seen that node 3 is connected to node 4 and node 19 is connected to node 20. Similarly, the proposed logic will check whether nodes 4 and 20 are connected to any other nodes. This process will continue unless all nodes are identified beyond branch 1. Table 1 shows the result of the coding implemented in MATLAB 7 for the calculation of nodes beyond branch jj. This will help to obtain load flow solution by summation of load currents of all the nodes beyond a particular branch.

The total current flowing through branch 1 is equal to the sum of the load currents of all nodes beyond branch 1.

Note that, if the receiving-end node of any branch in Fig. 1 is an end node of a particular lateral, the total current of this branch is equal to the load current of this node itself.

V. ALGORITHM FOR LOAD FLOW COMPUTATION

The complete algorithm for load-flow computation is shown below:

Step 1 : Start

Step 2 : Read line data and load data of the system.

Step 3 : Read base values.

Step 4 : Set ITMAX = 100.

Step 5 : Set V(i,j) = 1.0 + j0.0 for i = 1,2,3……TFL and j = 1,2,3……..TN(i).

Step 6 : Set IT = 1.

Step 7 : Set PL1(i,j) = PL(i,j) and QL1(i,j) = QL(i,j) for i=1,2,3……TFL and j=1,2,3…..TN.

Step 8 : Using equation (ii) calculate IL(m2) for m2 = 2,3……..TN.

Step 9 : Calculate I(i,jj) for i=1,2,…….TFL and jj = 1,2,……TN-1 where

$$I(i,jj) = \sum_{i=1,jj=1}^{i=TFL,jj=TN-1} IL(i,j)$$

Step 10 : Compute V(i, j+1) = V(i, j) - I(i, jj)Z(i, jj) for i=1,2,3……TFL and j=1,2,3……..TN(i).

Step 11 : Compute $\Delta V^k(i, j) = V^{k-1}(i, j) - V^k(i, j)$.

Step 12 : Arrange ΔVk(i, j) in descending order.

Step 13 : Get the highest value of ΔVk(i, j).

Step 14 : If ΔVk(i, j) < 0.001 go to step 17 else go to step 15.

Step 15 : IT = IT+1.

Step 16 : If IT < ITMAX, go to step 7 else go to step 17.

Step 17 : Display 'SOLUTION CONVERGED'.

Step 18 : Stop.

VI. EXAMPLE

To demonstrate the effectiveness of the proposed method, a 33-node radial distribution system has been selected. Input data for this 33-node system is given in Table 2 [12]. Table 2 also shows the results of votage (p.u.) for each node of this 33-node radial distribution network.

VII. CONCLUSION

A simple and efficient load-flow technique has been proposed for solving radial distribution networks. Herein this work, it is observed that the values of absolute voltage at each node, obtained by the proposed method, are more precise and accurate. In future, the proposed method will be used for the evaluation of voltages for other load models, in a way which will be more convergent.

REFERENCES

[1] B. Scott, "Review of load flow calculation methods," Proc. IEEE, Vol.62, No.7, pp. 916-929, July 1974.

[2] RAJICIC, D., and TAMURA, Y.: 'A modification to fast decoupled power flow for networks with hgh R/X ratios', IEEE Tram., 1988, PWRS-3, pp. 743-746.

[3] IWAMOTO, S., and TAMURA, Y.: 'A load flow calculation method for ill-conditioned power systems', IEEE Trans., 1981, PAS-100, pp.1736-171 3.

[4] TRIPATHY, S.C., DURGAPRASAD, G., MALIK, O.P., and HOPE, G.S.: 'Load flow solutions for ill-conditioned power system by a Newton like method', ZEEE Tram., 1982, PAS-101, pp. 3684-3657.

[5] KERSTING, W.H., and MENDIVE, D.L.: 'An application of ladder network theory to the solution of three phase radial load flow problem'. IEEE PES winter meeting, New York, January 1976

[6] KERSTING, W.H.: 'A method to the design and operation of a distribution system', ZEEE Trans., 1984, PAS-103, pp. 1945-1952

[7] STEVENS, R.A., RIZY, D.T., and PURUCKER, S.L.: 'Performance of conventional power flow routines for real-time distribution automation application'. Proceedings of 18th south eastern symposium on System theory, 1986, (IEEE Computer Society), pp. 196-200

[8] SHIRMOHAMMADI. D.. HONG. H.W.. SEMLYEN. A.. and LUO, G.X.: 'A compensa6on-based power 'flow method for weakly meshed distribution and transmission networks', IEEE Trans., 1988, PWRS-3, pp. 753-743

[9] BARAN, M.E., and WU, F.F.: 'Optimal sling of capacitors placed on a radial distribution system', IEEE Trans., 1989, P-2, pp. 735- 743

[10]CHIANG, H.D.: 'A decoupled load flow method for distribution power network algorithms, analysis and convergence study', Electr. Power Energy Syst., 1991, 13, (3), pp. 130-138

[11]RENATO, C.G.: 'New method for the analysis of distribution networks', IEEE Trans., 1990, PWRD-5, (l), pp. 9-13

[12]A. Arunagiri , Suresh K, B.Venkatesh, R.Ramesh Kumar and Mustajab Ahmed Khan, "Artificial Neural Network Approach: An Application to Harmonic Load Flow for radial systems," Yanbu journal of engineering and science, Vol. 1, October 2010 (1431H).

[13]Vaishali Holkar, Dr. Deepika Masand, "Intelligent System for Radial Distribution Load Flow", International Journal of Engineering Innovation & Research Volume 1, Issue 5, ISSN: 2277 – 5668.

[14]DAS, D., NAGI, H.S., and KOTHARI, D.P.: 'Novel method for solving radial distribution networks', IEE Proc. C, 1994, 141, (4), pp. 291-298.

[15]JASMON, G.B., and LEE, L.H.C.C.: 'Distribution network reduction for voltage stability analysis and load flow calculations', Electr. Power Energy Syst., 1991, 13, (I) , pp. 9-13.

[16]JASMON. G.B.. and LEE. L.H.C.C.: 'Stabilitv of load flow techniques for distribution system voltage stability analysis', IEE Proc. C, 1991, 138, (6), pp. 479484.

[17]S. Ghosh and D. Das, 'Method for load-flow solution of radial distribution networks', IEE Proc.-Gener Transm. Distrib., Vol. 146, No. 6., Nov 1999.

APPENDIX.1. NOMENCLATURE

NB : Total number of the nodes
LN1 : Total number of the branch (LN1 = NB − 1)
jj : Branch number
m1 : Receiving end node
m2 : Sending end node
PL(i) : Real power load of ith node
QL(i) : Reactive power load of ith node
|V(i)| : Voltage magnitude of ith node
R(jj) : Resistance of the branch–jj
X(jj) : Reactance of the branch–jj
Z(jj) : Impedance of the branch–jj
I(jj) : Current flowing through branch–jj
IS(jj) : Sending end node of branch–jj
IR(jj) : Receiving end node of branch–jj
IL(i) : Load current of node-i
kV : Kilovolts
kW : Kilowatts
kVAr : Amount of reactive power

Table 2: 33-BUS RADIAL DISTRIBUTION SYSTEM UNDER STUDY

Branch no. (jj)	Sending End IS(jj)	Receiving End IR(jj)	R(Ω)	X(Ω)	PL(kW)	QL(kVAr)	V(p.u.)
1	1	2	0.0922	0.047	100	60	1
2	2	3	0.493	0.2511	90	40	0.9972
3	3	4	0.366	0.1864	120	80	0.9885
4	4	5	0.3811	0.1941	60	30	0.9923
5	5	6	0.819	0.707	60	20	0.9933
6	6	7	0.1872	0.6188	200	100	0.9866
7	7	8	1.7114	1.2351	200	100	0.9964
8	8	9	1.03	0.74	60	20	0.9852
9	9	10	1.044	0.74	60	20	0.9917
10	10	11	0.1966	0.065	45	30	0.9921
11	11	12	0.3744	0.1238	60	35	0.9988
12	12	13	1.468	1.155	60	35	0.9978
13	13	14	0.5416	0.7129	120	80	0.9906
14	14	15	0.591	0.526	60	10	0.9970
15	15	16	0.7463	0.545	60	20	0.9982
16	16	17	1.289	1.721	60	20	0.9982
17	17	18	0.732	0.574	90	40	0.9970
18	2	19	0.164	0.1565	90	40	0.9994
19	19	20	1.5042	1.3554	90	40	0.9995
20	20	21	0.4095	0.4784	90	40	0.9962
21	21	22	0.7089	0.9373	90	40	0.9991
22	3	23	0.4512	0.3083	90	50	0.9994
23	23	24	0.898	0.7091	420	200	0.9989
24	24	25	0.896	0.7011	420	200	0.9983
25	6	26	0.203	0.1034	60	25	0.9993
26	26	27	0.2842	0.1447	60	25	0.9986
27	27	28	1.059	0.9337	60	20	0.9982
28	28	29	0.8042	0.7006	120	70	0.9930
29	29	30	0.5075	0.2585	500	600	0.9962
30	30	31	0.9744	0.963	150	70	0.9987
31	31	32	0.3105	0.3619	210	100	0.9974
32	32	33	0.341	0.5302	60	40	0.9993